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2WD	Two-wheel drive
4WD	Four-wheel drive
SAAMA	South African Agricultural Machinery Association
TFP	Total Factor Productivity
DAFF	Department of Agriculture Forestry and Fisheries
GDP	Gross Domestic Product
MSV	Machinery Sales Value
TSV	Tractor Sales Value
OECD	Organisation for Economic Cooperation and Development
FAO	Food and Agriculture Organisation of the United Nations
VBA	Visual Basic for Application
VEC	Vector Error Correction
ADF	Augmented Dickey Fuller
BFAP	Bureau of Food and Agricultural Policy
GPS	Global Positioning System
GFCF	Gross Fixed Capital Formation

CHAPTER 1:
INTRODUCTION

1.1 BACKGROUND AND CONTEXT

Capital makes up a significant portion of the investment series in agriculture, particularly because of its importance as an input in agricultural production. The relationship that exists between investment in capital and productivity growth has been explained in endogenous growth models which show capital investment as a growth catalyst. Capital formation is a factor, among others, which ultimately affects confidence in agricultural business (Purchase, 2015). Hence, capital formation has been discussed in various studies that evaluate agriculture sector performance and productivity (Thirtle, Von Bach & van Zyl, 1993; Gebrehiwet, 2012; Greyling, 2012 & Liebenberg, 2013). However, data limitations (data availability and/or quality) have compromised studies on the contribution of capital and its influence on productivity analysis (Butzer, Mundlak & Larson, 2010). This is not only limited to South Africa, and also applies in other countries, especially in Africa.

In South African agriculture, capital formation is classified by the Abstract of Agricultural Statistics ("Abstract") as consisting of fixed improvements, tractors, machinery, implements, vehicles and change in livestock inventory. Machinery and implements which include tractors make up the most of capital formation, with an average ratio to total gross capital formation of more than 60 percent over the period 1970 to 2012 (Abstract, 2013). Using the Abstract numbers, many studies have reported real capital formation in agriculture to have declined from 1970 to 2012 (Gebrehiwet, 2012; Greyling, 2012). Figure 1.1 below illustrates the general capital formation trend in South Africa, using both the Abstract and Census numbers, in a detailed comparison illustrated by Liebenberg (2013). The trend shows an increase in capital formation from 1945, peaking in 1981. The World Bank (cited in Gebrehiwet, 2012) suggests that the two most important variables that have influenced capital formation in the sector were real interest rates and the tax legislation. The support enjoyed by the agricultural sector at that time included the provision of subsidised credit and tax concessions which reduced the effective price of capital.

The trend was reversed by the end of 1983 when a series of droughts had occurred in the country, followed by the depreciation of the rand coupled with a decrease in the gold price and changes in credit and tax legislation (Thirtle, 1993). Major tax concessions in the treatment of certain capital purchases were reduced and the decline in capital formation as a result of this is illustrated in Figure 1.1. This trend declined and reached its lowest level in the early 1990s. From 1993, an upward trend was seen, with fluctuations up to 2010/2011.

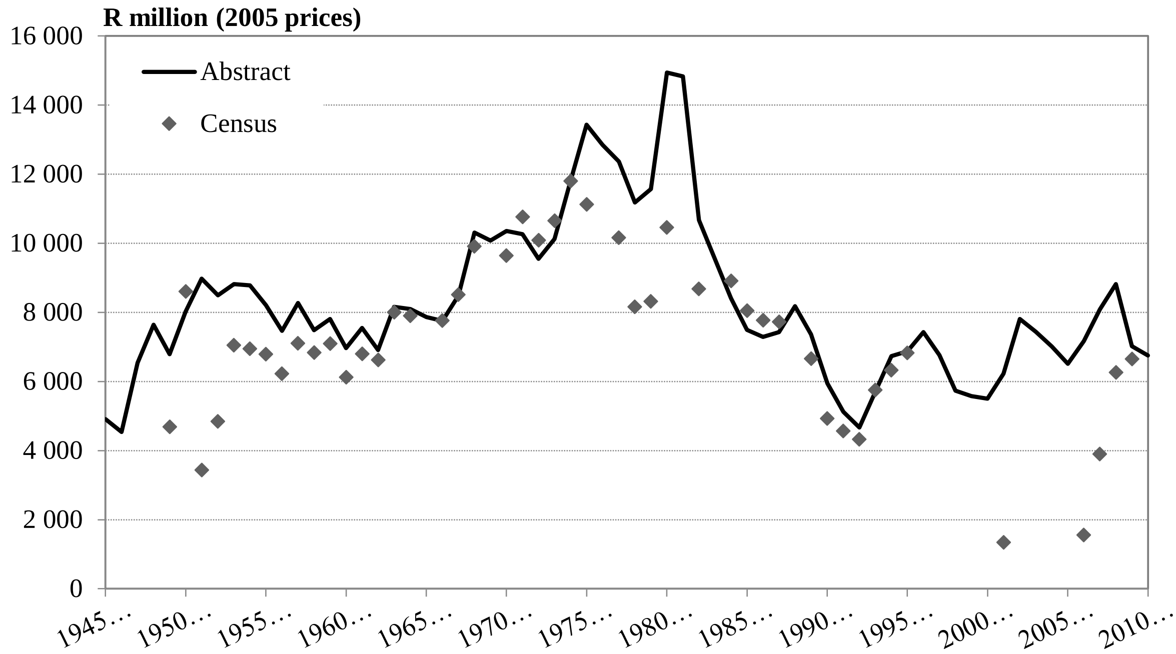

Figure 1.1: Capital formation trends in South Africa

Source: Liebenberg (2013)

As shown in the figure above, these trends were correlated for most of the time period from 1945 to 2010/2011. However, some noticeable differences can be seen in this trend between census and Abstract numbers in the early 1950s, which might be attributed to the fact that the census did not always capture a full range of capital inputs (Liebenberg, 2013). Another significant difference is also noted from the mid-1970s into the early 1980s. Liebenberg (2013) attributes these differences to the fact that the Department of Agriculture began using the Survey of Agricultural Mechanisation as their basis for estimating machinery and equipment expenditures. However, the Survey of Agricultural Machinery Sales did not include the former homelands that is those parts of South Africa which were dealt with under the apartheid era legislation as though they were independent or self-governing territories. In an attempt to incorporate the former homelands, the Abstract overestimated the capital expenditure projections. This was then corrected and the trend is almost correlated until after the year 2000 where the census became a survey, only tracing a selected tax-paying sector of the commercial farmers. Other differences in this trend are attributed to the differences in financial year-ends and accounting methods, and sampling strategies in census surveys (Liebenberg, 2013). Capital formation includes machinery and implements, fixed improvements and changes in livestock inventory

1.2 PROBLEM STATEMENT

Different studies have endeavoured to measure the performance of the agriculture sector in South Africa but the consensus is that data scarcity has limited the analytical basis to provide sufficient understanding of investment agriculture. Thirtle *et al.* (1993) used the aggregates from the national accounts to derive the capital index. This presents an analytical limitation and results in the invalid assumption that on-farm assets are homogeneous in terms of age and unit value (Liebenberg, 2013). Although Liebenberg (2013) improved the capital index by disaggregating the data into classes, further disaggregation of the data within a class is conceivable to improve the estimates of service flow in estimating the capital use index. An understanding of capital as an input in agriculture is necessary. How capital is measured and defined is important because it has been defined and measured differently across different disciplines.

Liebenberg (2013) outlines the problems with the presented capital formation trend including failure to include the full range of inputs by the census and surveys. This calls into question the basis for machinery and implements estimation in the series because it remains unclear how estimates of the investment in farm machinery and equipment was developed by the department. To arrive at an accurate measure of capital, understanding of the nature of the flow of services is required. For this, the detail on on-farm stock is required at a disaggregated level. Pardey (2013) states that measure of capital inputs estimation involves aggregating over different vintages, types and classes of capital. Different classes are defined by the different service profiles (Alston, Andersen, James & Pardey, 2010), such as combines, ploughs, and tractors. Types are defined by the differing productive attributes (Alston *et al.*, 2010) such as 20kw tractors versus 300kw tractors. Each capital class would then consist of differing types within the class. The type and class differs from the vintage where vintage concerns the version of the capital input, whether it is newer or older. This level of detail is lacking in the current capital formation account and defines the problem being addressed in this study.

Since 1994, the estimates of investment in machinery and implements were based on a value imputed from the value of tractor sales and not actual observations (Liebenberg, 2013). It is shown in this study that the value of tractor sales is an estimate itself, not the actual sales value, based on underlying sales and price data. The tractor sales value is then used to input the overall sales value of machinery and implements. However, the proportional basis for imputing the overall sales value of machinery is based on a constant cost share value that prevailed in the mid-1990s. This proportion has never been adjusted to factor in changes that have taken place as the nature of tractorisation evolved since then.

In the face of innovation and changes in the quality of capital inputs, it is important that a quality adjustment is incorporated in the valuations of capital input accounts. Griliches (1961) showed that failure to adjust for quality change would lead to undercounting in the measurement of capital input use. This necessitates the revision of the national capital input series to address the known caveats in its measurement to improve our understanding of the evolution of tractorisation in South African agriculture, and to better address the policy questions associated with it, for example the effect of tractorisation on labour input use. Policy questions also arise in relation to innovations in tractorisation and its use, and how this may affect labour use and lead to farm consolidation (Sunding & Zilberman, 2001). It is necessary to evaluate tractorisation in South Africa in the context of a more precise national capital formation account to answer these questions. In addition, an accurate understanding of the relationship between farm income and the tractorisation market, businesses can make better decisions about investing in the future.

1.3 CONCEPTUAL FRAMEWORK

Butzer, Mundlak and Larson (2010) explain that measures of agricultural capital are important in two related empirical fields namely, determinants of agricultural productivity and growth and also structural transformation in developing countries. However, data limitations have led to analytical restrictions in studies that measure the importance of capital and its role on productivity analysis (Butzer, Mundlak & Larson, 2010). Measurement inaccuracies in the valuation of capital can result in the use of invalid assumptions and mis-measurement of capital as a production input. This results in imprecise estimation and conclusions of agricultural productivity. This process is explained by the illustration below in Figure 1.2:

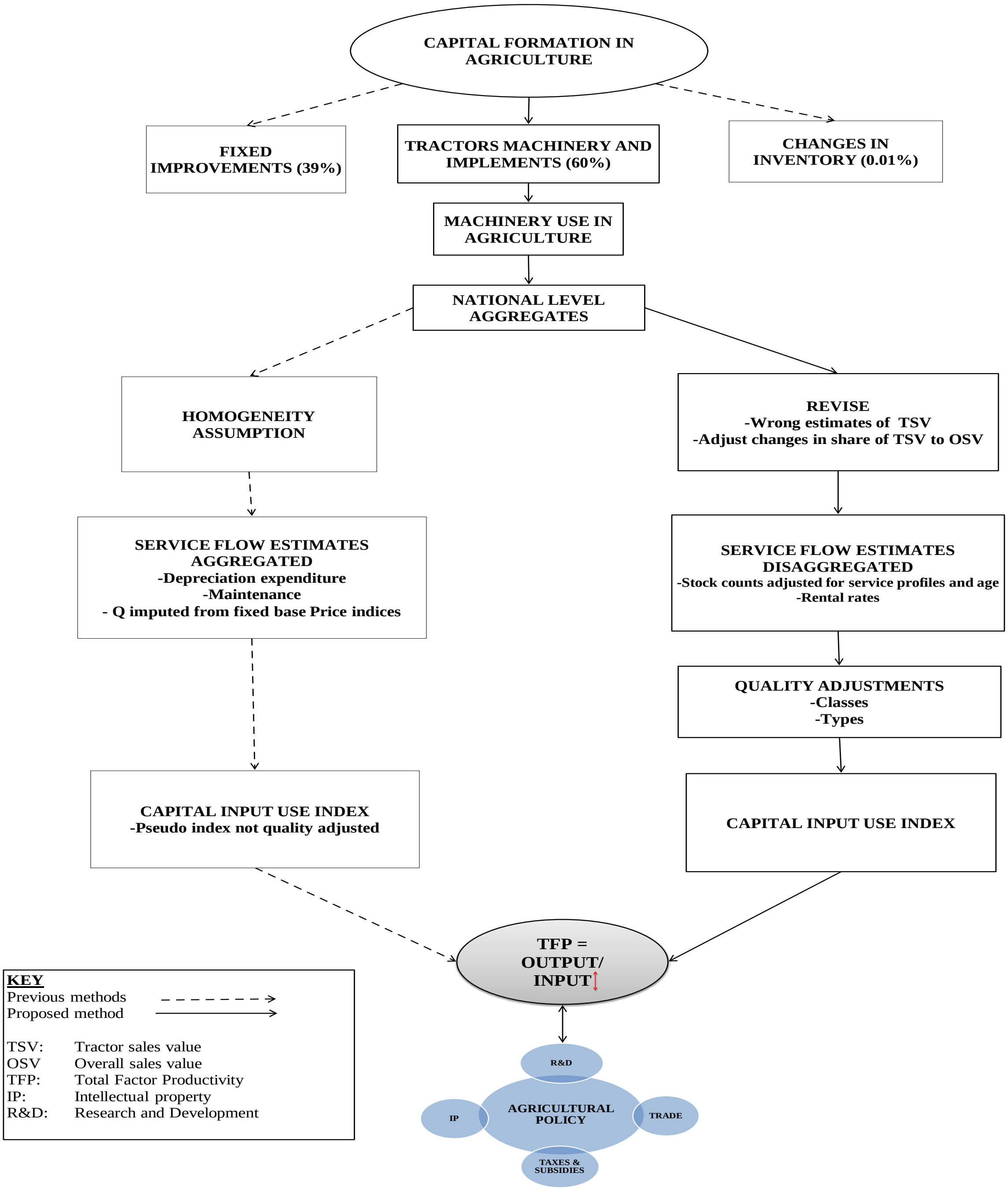

Figure 1.2: Conceptual Framework

Source: Author

As shown in Figure 1.2 above, the essence of this study is to contribute to precise productivity analysis and ultimately all other analyses for which productivity contributes. The production function expressed as $Q_t = X_{it}, i = 1 \ldots. n \; and \; t = i \ldots.. m$ illustrates the relationship between aggregate outputs Q_t Where Q is a share weighted aggregate of all outputs and the Xi are various inputs such as labour land, raw materials, capital, time and technology that can be aggregated using shares in total cost (or prices) as weights. The concept of a production function is a useful abstraction from the practical complexities with two computable aspects of the function as returns to scale and elasticity of substitution. Firstly, returns to scale explains how output increases in response to an increase in all inputs. Secondly, elasticity of substitution explains how one input for example labour, can be replaced by another input such as capital, while maintaining the same output level (Snyder & Nicholson, 2012). Technological improvements can also be reflected in the production function. The production function is a technical relationship that shows the technical transformation of inputs into outputs. Thus, by studying production functions, it is of interest to identify those inputs that are economically scarce and over which some control can be exercised in the sense of choosing how much to employ.

To extend this relationship further, in productivity analysis; productivity is defined as a ratio of a quantity measure of output obtained to a quantity measure of input use. In TFP analysis, capital, weighted appropriately with other inputs, makes up the input denominator of the TFP formula. The residual measures of productivity growth are not only viewed as measures of technical change but changes in the quantities and qualities of inputs and economies of scale (Griliches, 1963). The increase in productivity might actually be a result of increase in input quality. Thus (Griliches, 1961) proposes that the discrepancy that is referred to as productivity requires further investigation to establish whether it is returns to scale, changing quality of inputs or pure technical change.

A number of economic models have been used to explain the changes and directions of technical change, such as the Hick's Induced Innovation Hypothesis. Various other improvements and developments of this hypothesis are presented by Kennedy (1964) with the Innovation Possibility Function, Samuelson (1965) with the Factor-Augmenting Model, and others. However, in agriculture, the Induced Innovation model is mostly used to explain biased technical change. Binswanger (1974) and Olmstead and Rhode (1993) criticised the model for its lack of microeconomic foundation. The above conceptual framework illustrates that although the measured impact of this study will be directly related to productivity analysis, this study will have agricultural policy implications related to agricultural inputs such as agricultural mechanisation policy and influence the private sector led investments.

1.4 RESEARCH OBJECTIVES

The main objective of this study is to formulate a new capital investment account for agriculture in South Africa in order to fill the knowledge gap caused by the changing nature of the agricultural tractorisation process. In addition the study also endeavours to improve the measurement of capital use in South African agriculture. Although this study does not attempt to measure TFP, the improvement of capital measurement will result in improved productivity analysis in South Africa. The study is guided by the following specific research objectives:

1. To re-estimate the tractor price index in SA agriculture;

2. To re-evaluate the machinery and implements input accounts in SA agriculture;

3. To re-visit the estimates of capital service flows in SA agriculture;

4. To measure the effect of quality adjustments on the value of capital inputs.

1.5 HYPOTHESES

The following hypotheses guide the study:

1. *Estimates of the tractor price index are mismeasured due to the use of a standard numeraire to calculate the value of tractor sales*

Prices play a key role in neoclassical economics as they drive resource allocation and output mix decisions by economic actors. This instrumental role that price plays draws attention to the precision and accuracy of estimation methods of price indices in relation to economic theory. Using both consumption and investment theory, tractor prices should relate to exchange rate and net farm income as an increase in purchasing power leads to an increase in demand for tractors and influence prices. The value of tractor sales are estimated using a shortcut numeraire methodology. This leaves a number of unanswered questions in terms of accuracy and reliability of the current tractor price index. The question that remains unanswered is: Does the current tractor price index in South Africa relate to changes in the agriculture sector?

2. *Estimates of the capital formation account are understated due to the use of fixed ratios in the estimation technique*

Identified measurement problems in the capital formation account call into question the state of the South African national capital input accounts. Data limitations result in assumptions being made in valuation which might compromise the precision of the accounts. An example of this is the overemphasis on tractors as a capital input, to the extent of making conclusions about the rest of the capital inputs based on tractor trends without investigating the other capital inputs. In addition to the overemphasis on tractors, an investigation into the precision of methods used in the valuation of tractor inputs remains outstanding. Therefore, questions remain on the validity of the methods that have been used to measure capital following Andersen, Alston and Pardey (2009) who reveal some of the problems in capital measurement that result in differences in the measurement of capital. The measurement and current state of the national capital investment account are therefore problematic and need to be corrected.

3. *Estimates of capital service flows based on re-calibrated proportions of implement sales will show a higher level of capital input use since 1994 than previous estimates*

The flawed estimates of capital input use bring about an inherent problem related to service flow estimations – critical in the measuring of productivity change. The proportional basis for imputing the overall sales value of machinery is based on a constant cost share value that prevailed in the mid-1990s and has never been adjusted as the nature of tractorisation which has evolved since then. However, a much greater use of capital equipment is expected as a result of the switch to more productive farming inputs such as 4WD tractors for example compared to what the current reported numbers of the use of capital equipment. It is argued that the changing nature of capital inputs is not reflected in the trends of capital formation in South Africa from 1994. This means the input mix would have changed the composition as well as the quality of inputs. A question that remains unanswered is: what is the evolution process of the machinery and implements component of the capital formation account in South Africa?

4. *Estimated rates of productivity growth are overstated due to failure to incorporate input quality changes*

One of the most limiting factors of past TFP studies in South Africa is the failure to adjust for input quality changes. Capital investment is part of the input variable which is the denominator of the TFP index. As noted in previous studies, ignoring quality adjustments in capital inputs can lead to undercounting. This agrees with past studies that suggest that measures of productivity are biased, as their construction does not fully account for quality change (Bosworth, Massimi & Nakayama, 2003). Quality bias in price indexes occurs when an index does not factor in the changes in the quality of goods being measured. With recent technological advancements such as tractorisation, many quality changes in capital inputs have taken place which should be taken into account in productivity analysis. Griliches (1961) defines the notion of quality and quality change as wide and incorporating many technological changes. Quality change is not only limited to numerical measures as some qualities cannot be measured and are unobservable. However Griliches (1961) defines "size" and "capacity" as very important quality attributes. Quality in this study refers to tractor size in kilowatts and capability in terms of the tractor drive. Quality encapsulates more than just kilowatt size and capability, however data availability on the available models in South Africa made these two quality attributes to be more feasible for this study. Quality changes over time include factoring changes in vintage, durability and size of machines used in farms. The shift to the use of more 4WD machines is an example of the changes in quality which have an impact on productivity analysis. This study will therefore answer the question on the effect of incorporating quality changes in the capital index on productivity estimates.

1.6 RESEARCH METHODOLOGY

This section outlines the methodology used in this study, specifying the methods for each objective of the study. The methodology used in this study builds on the capital formation estimates by Liebenberg (2013). To extend the analysis, data that was more detailed was used in the form of class and type of tractors in estimating the value of machinery and implements in South African agriculture.

1.6.1 Revision of the tractor price index

A series of steps were taken in this study to revise the tractor price index, revise the machinery and implements series, and to re-estimate the tractor service flows. The Laspeyres index methodology was used in this study to revise the tractor price index. The Laspeyres index formula is expressed as follows:

$$P_L = \frac{\sum_{i=1}^{N} p_{i,t} q_{i,0}}{\sum_{i=1}^{N} p_{i,0} q_{i,0}} \quad \text{Equation 1.1}$$

Equation 1 shows that the Laspeyres index fixes the base period quantities represented by q_{io} while it measures the relative price changes p_{it} price in in the current year and p_{io} price in the base year. The Laspeyres index is known for its upward bias but it is used in this study to enable comparison with the current methods used to estimate the tractor price index.

To further test the usefulness of the estimated tractor price index, econometric modelling of the tractor price index and net farm income was done in the form of cointegration analysis. The Johansen multivariate cointegration is a superior analysis because it proposes calculating two tests to determine the number of cointegrating vectors using maximum likelihood estimation procedure namely, the Maximum eigenvalue (**λ**-Max) and the Trace (**λ**-Trace) statistic tests. The tests are important procedures to determine the number of cointegrating relations among variables (Enders, 1995). The Maximum eigenvalue test statistic evaluates the null hypothesis of r (is the rank of the matrix of cointegrating relationships) cointegrating relations against the alternative of r + 1 cointegrating relations for r = 0, 1, 2…. n – 1. The test statistic is calculated as:

$$LR_{max}(r \,/\, (n+1)) = -T * log(1 - \hat{\lambda}) \quad \text{Equation 1.2}$$

where **λ** is the Maximum eigenvalue and T is the sample size. While the Trace statistic tests the null hypothesis of r cointegrating relations against the alternative of n cointegrating relations. In this case n is the number of variables in the equation for r = 1, 2 …n – 1. The Trace statistic equation takes the following form:

$$LR_{tr}(r/n) = -T * \sum_{i=r+1}^{K} log(1 - \hat{\lambda}) \quad \text{Equation 1.3}$$

In most cases, Trace and Maximum eigenvalue statistics yield similar results. In scenarios where the results of the test are different, the Trace statistic test is more superior and preferred (Enders, 1995). In addition, Johansen tests according to Equations (1.2) and (1.3) could test both the unrestricted model (with a trend) and restricted model (without a trend). Thus, the test for a cointegrating relationship between the tractor prices, exchange rates and net farm income, where $n = 2$, becomes the test for the null hypothesis: $r = 0$ and $r = 1$ with and without a trend, starting without trend. The model formulated in this study is a two-variable model, which hypothesises that farm income is a function of tractor prices.

$TractorPrices_t = f(Exchange\ rates_t + Net\ Farm\ Income_t)$……………………………Equation 1.4

where net farm income is in billion rands, exchange rate is the rand dollar exchange rate and a tractor price index is used for tractor prices. The *t* denotes the time trend and takes an individual year (from 1995 to 2015). After determining the existence of a long-run relationship, the VEC model can be used to generate the long-run and short-run relationships between the price series, and also determine the error of adjustment to the equilibrium (Lütkepohl, 2005).

1.6.2 Revision of the tractor sales value, machinery investment series and service flows

Building on the recalculated tractor price index as mentioned above, the price and quantity data with tracked model change history is used to revise the tractor sales value. The recalculated tractor sales value and the revised tractor price index are then used to derive a new machinery and implements investment series. To revise the machinery and implements investment series, time series descriptive statistics was used to measure the difference between estimation of investment in machinery and implements using a constant ratio, as compared with using a varying ratio of tractors to overall machinery and implements. Historical ratios are also presented in order to show the actual changes of tractor ratios to different combinations of machinery and implements. Cumulative ratio analysis was made for different input baskets to determine how the 60 percent ratio was derived, as well as to test if it remains constant over time. The perpetual inventory method was used to estimate the tractor stocks which were then converted to service flows from the net stocks. All data used in this study was disaggregated in terms of class and type of tractors.

The great advantage of disaggregated data is that quality changes are transformed into quantity changes (Star, 1974). In the context of this study, changing prices per type of input was used to measure quality changes. This in essence, is the reason why this study focuses on disaggregated data to type level: to mitigate the risk of bias brought about by assuming homogeneity of inputs. The decision to disaggregate data as finely as possible is based on the work of Star (1974) who showed that pre-aggregated data may be used only if all of the inputs in the class are growing at the same rate or are perfect substitutes for one another, that is if they are homogenous. Star (1974) argues that aggregation is only possible if each unit is a perfect substitute for any other unit that is the marginal rate of substitution is constant and the units of measurement are chosen such that the marginal products of every unit are equal.

If, for example, the rate of growth of the higher-priced inputs exceeds the rate of growth of the lower-priced inputs the estimated rate of growth of the group will be biased downwards when pre-aggregated data is used. In the South African context, it has been established by Liebenberg (2013) that, in principle, it is possible to further disaggregate the machinery and implements category of the capital account into types within each category to then allow for quality changes adjustments. By disaggregating data to types and estimating the service flows at type level, this study ensures that a different quality adjusted capital series will be derived. The quality-adjusted index will then be compared with the existing capital input series, which is unadjusted for quality changes, to measure the impact of the quality adjustments in inputs. This method was also used by Alston *et al*. (2010) in their analysis of productivity patterns in US agriculture.

It is noted that there is no consensus or defined method in the treatment of quality changes from which it can be argued that focus should be on the use of reliable underlying data. The route to decision making on quality changes can be summarised as shown in Figure 1.3 below.

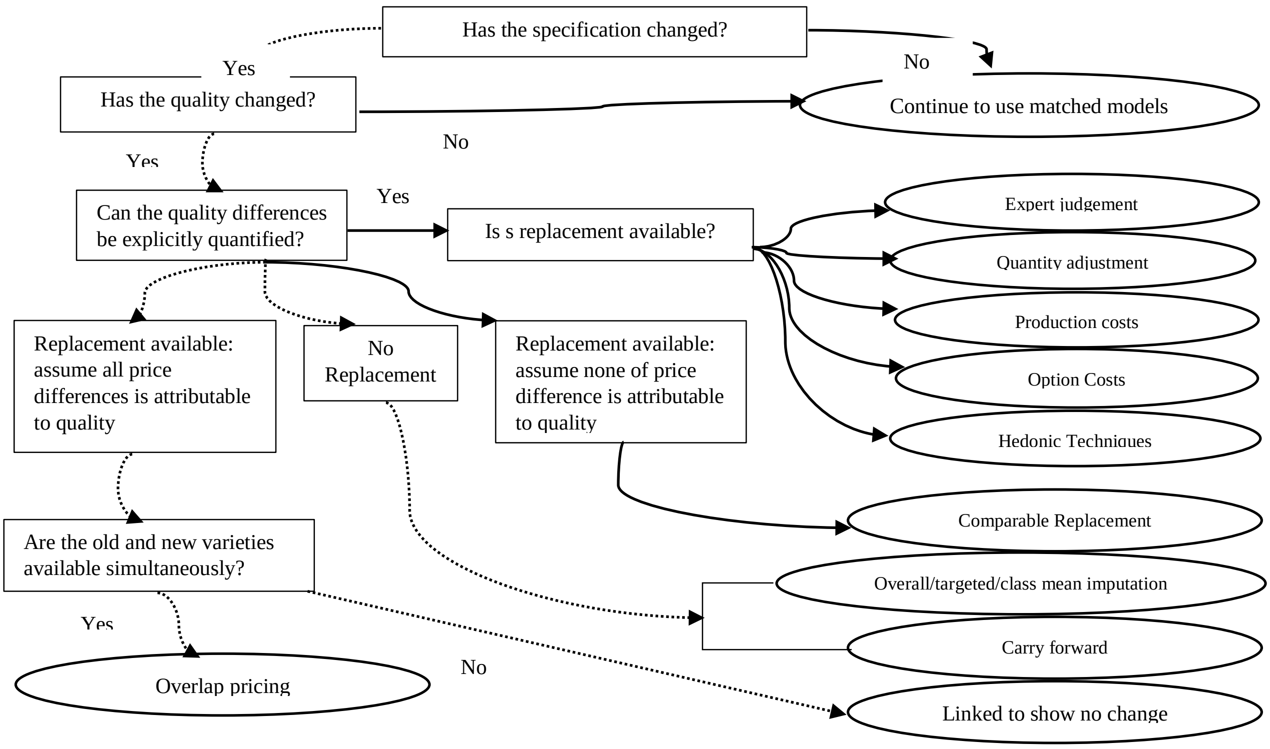

Figure 1.3: Quality adjustments decision flow chart

Source: Triplett (2004)

The figure above shows that the route to quality adjustments is not well defined and it depends on a number of factors, with most factors hinging upon the availability of data. The methodology used in this study follows the dotted arrows on the illustration above which results in three possible outcomes: overlap pricing, linked to show no change and lastly imputations where there are no model replacements. Tractorisation has changed over time, therefore the route to follow is shown by establishing the availability of quantification of quality differences (Figure 1.3). In the case of tractors specific data that quantifies quality differences is not available so all quality changes are assumed to be incorporated in the price. Therefore in the case where the tractor replacement is available then the price differences are attributed to quality. If replacements are not available, then imputations per class are done. If the old and new tractor models are available simultaneously, then prices are overlapped. In essence, quality adjustments are made in tractor inputs by using underlying data for tractor inputs, disaggregated by class and type. This results in different outcomes to achieve the incorporation of quality adjustments in the price series.

1.7 JUSTIFICATION OF THE STUDY

This study revises the national capital input account in South Africa, with specific emphasis being placed on machinery and implements by cleaning the tractor series. Therefore, this study corrects the current series to provide precise evidence to make conclusions about the relationships that exists between tractors and other inputs in South African agriculture using a new and revised machinery investment series. This study enables future work in estimation of the marginal rate of technical substitution between labour and capital. It will inform resource allocation in terms of agricultural inputs and agricultural labour policies in South Africa.

This study refines the current national capital series for machinery and implements and creates a detailed database on the national capital account, with a level of detail that does not exist elsewhere in the country, to enable a step towards refining earlier studies that improve productivity measures. By rectifying this imprecision problem, estimates of returns to research begin to get closer to the truth by correcting the national capital input account. A precise capital input account informs studies that estimate returns to investment in research an objective that remains unfulfilled in most research institutions, as well as most research analysis in agricultural research performance in South Africa. Policy on capital formation is important to assess capital requirements, formulation of principles that govern savings, and mobilisation of capital for productive investments, and also to ensure the maximisation of productivity.

The changing quality of capital inputs such as tractors has not been investigated in South African agriculture, yet this constitutes the basis for future policy in agricultural innovation. Price data exists and needs to be well documented for future studies in the areas of productivity and other evaluation studies of the sector. Hence, this study establishes a comprehensive capital accounts data set which takes into account the quality changes of tractor inputs. This study contributes to the correction of the problems associated with an imprecise total factor productivity estimation based on flawed capital input accounts. In essence, total inputs are understated and productivity growth is overstated. With this hypothesis in mind, this study provides evidence of the impact of the failure to incorporate quality changes in productivity studies in a South African context. The study contributes to illustrating the importance of input quality adjustment as a source of productivity growth.

By evaluating quality adjustments, a distinction can be made between embodied and disembodied technical change in trying to trace the sources of productivity growth. Disembodied technical change is “costless”, for example spillovers, thus the making of a distinction between embodied and disembodied technical change is important for policy and analysis (OECD, 2001). The optimal mix of public and private efforts is important in the design of technology policies in agriculture. The generation of new technologies and their adoption are affected by intentional public policies unintended policies and the private sector activities. Sunding and Zilberman (2001) explain that disembodied innovations are an area for public action because of the difficulty to sell them, while private investment in the generation of embodied innovations requires appropriate institutions for intellectual rights protection.

1.8 OUTLINE OF THE THESIS

This thesis consists of six chapters. These chapters will address the four objectives of the study, organised as follows:

Chapter 2 discusses the changes that have taken place in the machinery and implements industry, with a specific focus being placed on tractors. It gives context of the changes that are taking place in the tractor industry which justifies the existence of a measurement problem which does not factor in the changes taking place in machinery and implements. It uses two tractor attributes (drive and power) to explain the changing nature and quality of tractorisation. It seeks to answer the question; what is the current state of machinery in South Africa and how has it evolved? Data and measurement problems for agricultural machinery in South Africa are presented, showing how the monitoring and recording of agricultural machinery and implements in South Africa ignores the changes that have taken place. This chapter seeks to give an overall context of the changes that have taken place in tractorisation and describe how these changes have been ignored in the measurement of machinery and implements as part of the capital formation series in South Africa.

Chapter 3 discusses tractor prices in South Africa. Changes that have taken place in the machinery and implements sector can be reflected by changes in the tractor prices. By comparing prices reported by the Abstract of Agricultural Statistics to the revised tractor price index, this chapter shows the importance of using underlying price and quantity data (tractor sales data) in comparison with the use of assumptions. This chapter answers questions on how tractor prices have been measured in South African agriculture, and if they are a true reflection of the economic cycles that have taken place in South Africa. This chapter uses econometric techniques to compare the current tractor price index and the revised tractor price index. The existence of long-term relationships between the net farm income and tractor price index is tested in this chapter.

Chapter 4 presents a revision of the investment series. This chapter revises the machinery investment series of South Africa, following the revised tractor price index and observed missing knowledge that exists resulting from measurement problems in the current capital formation account in South African agriculture. The main contribution of this chapter is to correct the capital formation account of South Africa, which is currently flawed. This study proposes that the current methodology used to determine the total sales value of machinery is flawed and will result in an underestimation of the machinery and implements value. Underlying price and quantity data is used to arrive at a revised investment series. Contrary to the use of a fixed proportion of tractors to the overall machinery and implements profile, an adjusted ratio is used to recalculate the total sales value of machinery and implements.

Chapter 5 revises the stocks and service flow estimates of machinery use in South African agriculture. Using the perpetual inventory method the capital stock for tractors is estimated and service flows are estimated from net capital stocks. This chapter compares service flows from the current tractor investment series to the revised series. The main contribution of this chapter is to illustrate the impact of the use of assumptions in the estimation of service flows, as this will result in understated capital use and resultantly impacts on productivity analysis. By illustrating the difference between current estimation methods and the methods used in this study, this chapter shows the impact of quality adjusted estimates, as compared with the use of aggregates.

Chapter 6 summarises and concludes on the findings of this study. Implications of the revision of the capital formation account on productivity analysis are explored. The revised capital formation account was hypothesised to have implications on previous productivity analyses. In summarising the findings, this chapter therefore explores the possibilities of the measured impact of imprecision in capital estimation. It shows how current productivity analysis would be impacted by comparing results of the new capital series derived in this study to analysis made using the existing capital formation series for productivity analysis. This chapter evaluates the implications of this effect by measuring the quantified effect of incorporating quality changes by disaggregation in the valuation of capital.

CHAPTER 2:
EVOLUTION OF THE USE OF AGRICULTURAL MACHINERY IN SOUTH AFRICA

2.1 INTRODUCTION

Mechanisation is one of the innovations that was introduced in African agriculture in the 1940s. Mechanisation has evolved, in both its nature and composition, resulting in changes in its use on the farm. These changes are various and have different impacts on the use of inputs such as labour. Of particular interest in the recent past, is the labour debate in South Africa, specifically the effect of tractorisation on labour input use. Policy questions arise in relation to innovations in mechanisation, its use, and how this may negatively affect labour use, leading to farm consolidation (Sunding & Zilberman, 2001). To answer these sometimes politically charged questions, an investigation into the evolution of agricultural machinery is required. Among other factors, mechanisation is linked to a number of topical issues in agriculture, such as technical change, factor proportions or intensity, research and development, trade, and climate change. Tracing the evolution of agricultural machinery will therefore enable informed policy decisions to be made in terms of mechanical input use. The changes in agricultural machinery need to be quantifiable over time to inform future policies. These changes include the use of bigger machines in terms of power and the switch from 2WD to 4WD tractors.

Agricultural machinery use in South Africa has evolved because of the technological changes that have taken place over time. However, in the monitoring and reporting of the national agricultural machinery and implements, these changes are ignored. In fact, the reporting style has also deteriorated, from disaggregated statistics to aggregates, thus leaving a number of questions unanswered in terms of how machinery and implements have evolved over time. In tracking the changing structure of agriculture, the Agricultural Censuses/Surveys serve as a valuable source of information. This is particularly true if the method remains consistent in terms of its basis of elicitation (and reporting), particularly the level of detail. In the early years before the first round of the World Agricultural Census of 1930, detailed attention was given the development of a uniform basis to conduct the census in terms of methodology to elicit information and to report the results in an effort to provide internationally comparable data on the structure of agriculture (International Institute of Agriculture, 1939). The decennial rounds of the World Agricultural Census provide guidance to countries in collecting structural data using standard concepts, definitions and classification (FAO, 2010).

Agricultural surveys were based on a sample of the frame for the census were conducted for the inter-census years in many of the member countries of the United Nations (before that the League of Nations). South Africa participated in this endeavour since 1918 and complied to these guidelines in both the variable coverage and the detailed level of reporting, albeit with the primary focus on commercial agriculture. On the other hand, Censuses and Surveys systematically excluded black farmers in the homeland areas and self-governing territories after 1975. The detailed scope in terms variables covered and the level of aggregation in reporting began to deviate from the norms provided by the FAO since 1983 and more pertinently so, since 1993 (Liebenberg, 2013).

The sampling frame of the agricultural census/survey changed to include commercial farms only registered for tax from 1994. Statistics South Africa defines a commercial farm as a farm producing agricultural products intended for the market usually registered for both value added tax and income tax (Statistics South Africa, 2010). Information is sourced in an increasingly aggregated form that varies from year-to-year in terms of composition. With specific reference to capital expenditure, Table 2.1 below shows that very little, to no, information is provided on the composition of the different capital items included within each aggregated capital category, for instance the survey for 2005 (Statistics South Africa, 2006).

Table 2.1: Machinery expenditure aggregates in the *Agricultural Census/Survey*

New machinery categories	1993	1994	1995	1996	2002	2005[1a]	2006[2a]	2007	2008	2009	2010	2011[b]	2012[b]
Tractors	C	S	S	S	C	unknown		C	X			X	X
Combines	C	S	S	S									
Motor vehicles	C	S	S	S	C			C	X			X	X
Trucks	C								X			X	X
Machinery	C	S	S	S	C			C	X			X	X
Tools and implements								C	X			X	X
Aggregates reported in surveys since 2005													
Capital expenditure						S	S						
Motor vehicles, tractors and other transport equipment									S	S			
Motor vehicles and other transport equipment													S
Motor vehicles, tractors and other office equipment											S		
Motor vehicles, plant, tractors, machinery and other transport												S	
Plant, machinery and implements									S	S			
Plant machinery and other office equipment											S		
Plant, machinery, tractors and implements													S
Plantations											S		
Computers and other IT equipment											S	S	
Computers, IT, furniture and other office equipment													S
Other new assets									S	S	S	S	S

Source: *Various Agricultural Census and Agricultural Survey Reports*

Notes:
"c" reported separately in census,
"s" reported separately in survey
"x" assumed to be included in the aggregate reported
[a] *Composition of capital expenditure in terms of classes of inputs not clearly specified. Includes expenditure on pre-owned assets which must not be included in the capital formation account of the sector*
[b] *Expenditure on pre-owned assets not separately specified; assumed to be included in reported statistics*

Table 2.1 shows the evolving nature of the categories against which the data elicited from farmers was reported on capital expenditure on new machinery. The data reported in census and survey reports are indicated with a "C" or "S", respectively, against the aggregate reported for the category. The changing nature of reporting in the *Agricultural Census/Survey* reports from 2005 through to 2012 is immediately clear. The proportional ratio of tractors to the total expenditure on new machinery and equipment through to 2007 can be used to better reflect the changing nature of tractorisation when using the annual AGFACTS estimates on new tractor

[1] Composition of capital expenditure in terms of classes of inputs not clearly specified. Includes expenditure on pre-owned assets which must not be included in the capital formation account of the sector.
[2] Expenditure on pre-owned assets not separately specified; assumed to be included in reported statistics

sales. However, from 2008 the varying nature of reporting severely compromises the usefulness of the agricultural survey as a source of information on structural change in capital investment.

Expenditure on tractors now forms part of the aggregate of other capital items, such as motor vehicles and office equipment, from 2008 to 2010, and from 2011 it was aggregated with plant, machinery and implements. This restricts this analysis in that the exact amount of expenditure on tractors is not computable but is required to form the basis for estimating overall expenditure of machinery and implements. Data available from the overlapping years of each survey report proved useful to form a rough estimate of the share of tractors to overall machinery sales for the years since 2007. Using tractors as the main mechanical input on most farms in South Africa, the next section explains how tractorisation has evolved over time in South Africa.

2.2 EVOLUTION OF TRACTORISATION IN SOUTH AFRICA

South Africa is a net importer of agricultural machinery and the evolution of tractorisation should therefore be viewed in the light of the changes that take place globally, as South Africa imports from various countries around the world. The tractor is the most recognisable farm input in most commercial farms in South Africa. Tractors in South Africa also make up the greater part of the machinery and implements component of the capital formation account (Abstract, 2013). Figure 2.1 below shows the importance of the tractor on the farm processes. At every stage in the farming process, from seedbed preparation, sowing and planting, weeding, inter cultivation, plant protection, harvesting and threshing until the last stage in post-harvest and agro-processing, the tractor plays an important role.

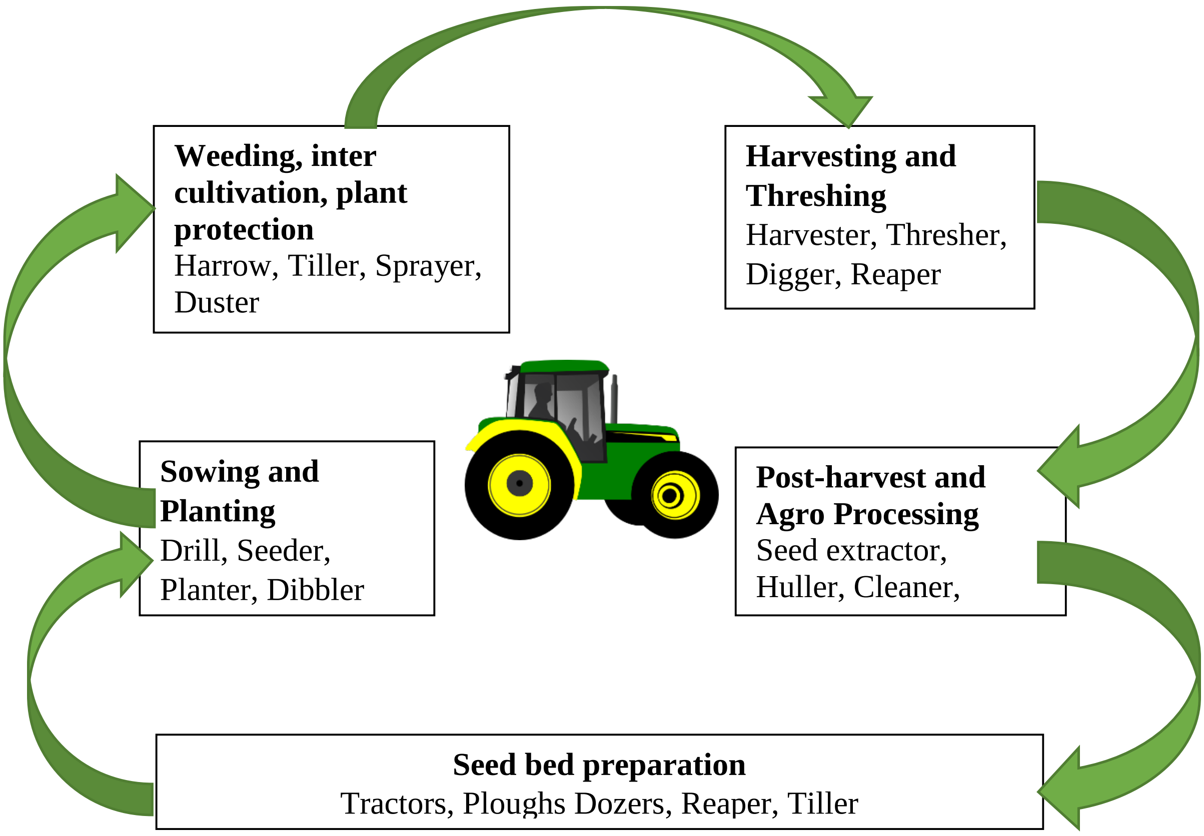

Figure 2.1: The role of the tractor on the farm

Source: Sims and Kienzle (2016)

Figure 2.1 above illustrates the importance of the tractor, which is the reason why estimates of tractor values in South Africa are used as a proxy to estimate the value of the rest of the machinery and implements. The tractor is an important farm implement, compared with other machinery and implements. As a result, this necessitates an understanding of the history of the tractor and how it has evolved over time, because tractor trends ultimately affect the valuation of the rest of the machinery and implements in capital formation.

The quality of tractors has undoubtedly changed from the steam engine-powered tractors in the early 1800s to the gasoline-powered tractors used today. The tractors today offer more comfort, as farmers operate in a tractor cabin that is equipped with air conditioning and complex computer systems. As such, farmers are able to easily monitor a number of processes in farming, such as power take off, digital hour, fuel and temperature gauge, tractor working hours, programmable service times and power supply voltage. One of the most recent innovations in the tractor market is the self-driving tractor, launched by the Autonomous

Tractor Company in 2012. This tractor allows 24-hour operations on a farm that are programmable from a portable-computer tablet. This follows other innovations, such as two tractors operated by a single driver where the tractors are connected to one unit via satellite navigation and radio communication. One of the tractors would be unmanned, but would perform the same procedures as the manned vehicle.

Other tractor innovations were seen in the early 1990s with the advent of precision farming. Tractor tractorisation in South African agriculture has also evolved over time with the advent of precision farming. Farming practices have evolved and precision farming is one of the farming practices that have become common since the early 1990s in South Africa for achieving efficiency and sustainable farming. With its origins in Europe, precision farming is a management strategy that employs detailed, site-specific information to precisely manage production inputs (Rusch, 2001). Machinery and implements manufacturers tailor their products to meet precision farming solutions, thus changing the nature of the composition of machinery and implements in agriculture. To increase agricultural productivity, technology is changing the way that humans operate the machines for example the use of computer monitoring systems, GPS locators, and self-steer programs allow the most advanced tractors and implements to be more precise and less wasteful in the use of fuel, seed, or fertilizer.

With improvements in technology, tractors vary in quality, as well as in power size. The dynamism and speed of technological changes that have taken place in tractorisation has led to manufacturing companies, such as John Deere, changing their name and numbering system to allow for a more consistent approach to naming equipment around the world. The John Deere 6115D tractor, for example, is a 6-series tractor with a 115-horse power engine in the D capacity and price levels. The updated systems are envisaged to enable customers to quickly and easily identify the engine size of a tractor and its capability by looking at the hood decal (Robisky, 2008). These updates are necessitated by the evolution of the tractors, both in size and quality.

Understanding the evolution for tractorisation in South Africa informs machinery investment valuation methodologies that are important for policy development and performance measures of the sector. In order to measure the changes that have taken place in the tractor market, the quantified power used by tractors in kilowatts can be investigated. Tractor trends indicate greater use of bigger kilowatt tractors, rather than smaller machines. This will be discussed further in this chapter, describing both the power and drive attributes of the tractor. This chapter seeks to show how tractorisation has changed over time in South Africa, using the tractor as the main mechanical input on most farms in South Africa. The changes that have taken place in agricultural machinery imply a change in the monitoring and valuation of machinery and implements in agricultural censuses, but this is not the case in South Africa. The changing nature and quality of machinery in South Africa has been ignored in the measurement of input use, resulting in flawed estimates of capital use.

2.3 THE CHANGING NATURE OF TRACTORISATION IN THE CONTEXT OF TRACTOR DRIVE TRAIN 2WD AND 4WD

One of the attributes of tractors that can be used to trace the changing nature and quality of tractor inputs used in agriculture is the tractor drive train. A four-wheel drive tractor has a transmission system that delivers power to the four wheels of the tractor, while in a two-wheel drive tractor, the transmission system delivers power only to the two rear wheels. The tractor drive train relates to the tractive force in a tractor. The process of investing in a tractor involves a number of considerations for the farmer, such as the brand, power, drive and price, which all play an important role in that decision. Tractors can be classified in different ways, depending on the brand, the purpose, the size and other attributes. In this study, size and drive are used as the main attributes for classifying tractors. Figure 2.2 below gives a general view of the different types and classes of tractors in South Africa.

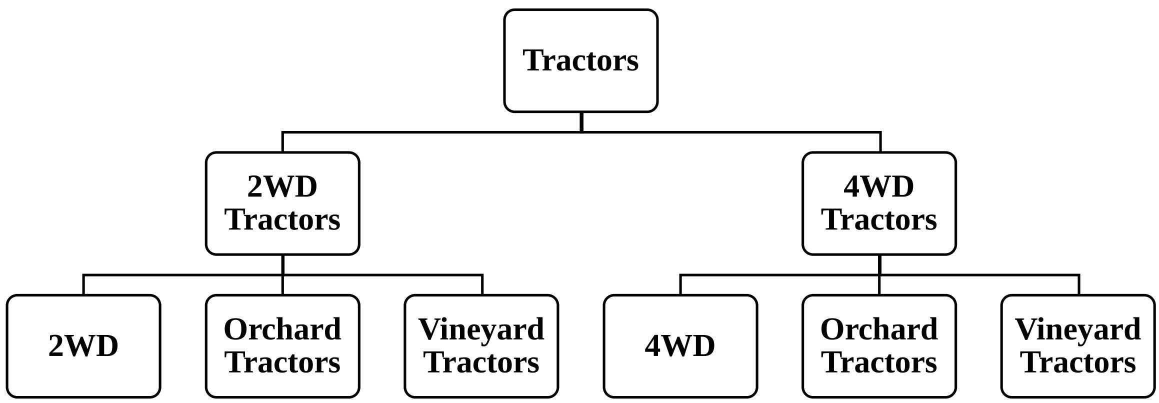

Figure 2.2: Types of tractors

Source: Author

Tractors consist of two main categories, 2WD tractors and 4WD tractors. Under these two main categories, a further categorisation can be made for normal tractors, orchard tractors and vineyard tractors. Given Figure 2.2 above, the first level of analysis of the evolution is the split between the 4WD tractors and 2WD tractors, which is illustrated in Figure 2.3 below.

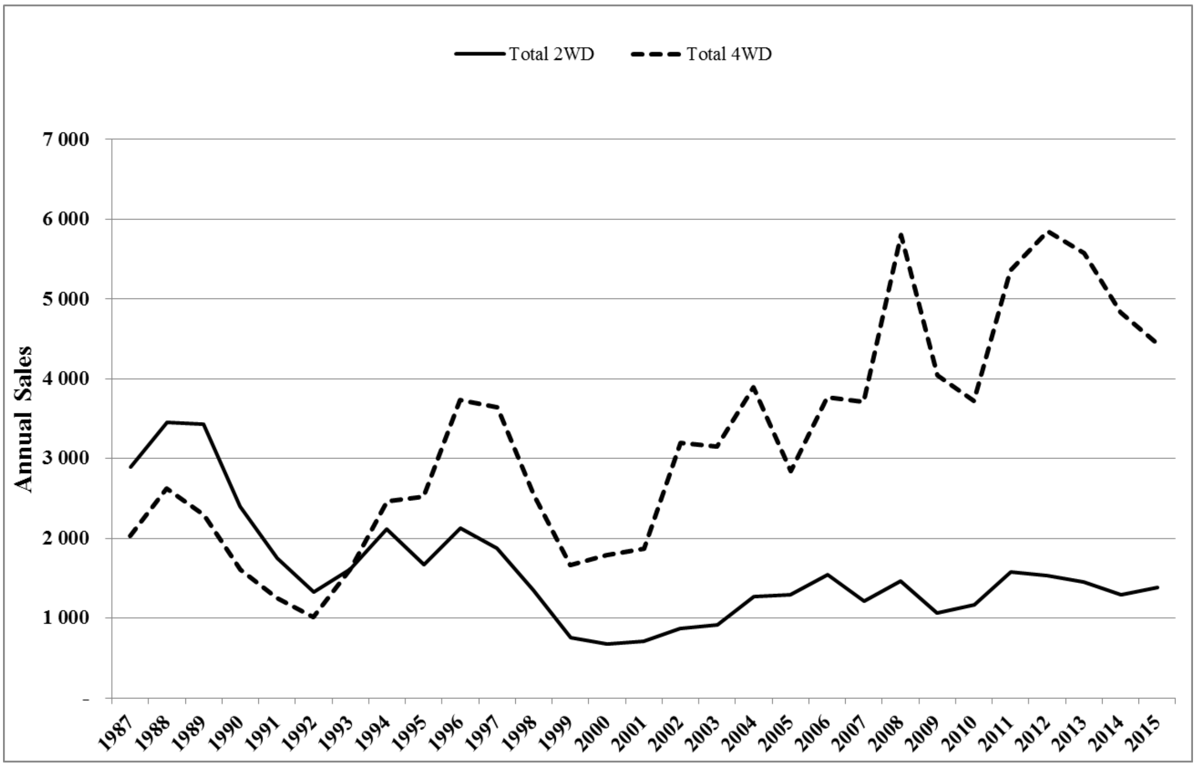

Figure 2.3: Annual total number of tractors sold, 1987-2015

Source: AGFACTS (2015)

Figure 2.3 shows that 2WD machines dominated the tractor market from 1987 to 1994. From 1987 to 1992, tractor sales declined at an annual average rate of -11.97 percent. From 1992 to 1996, tractor sales increased at an annual average growth rate of 27.95 percent, with 4WD tractors becoming dominant in the market from 1994. A significant decline in the tractor market is shown from 1997 to 1999 for both 2WD and 4WD tractors, at an annual average rate of -24.39 percent. The main cause of the drop was the impact of the climate. Over this period, much less rain was received and the maize crop production declined in these years, resulting in a negative impact on farming income. Furthermore, this period was also associated with a level of uncertainty in the marketplace due to the deregulation of the commodity markets. Farmers had to make a rapid shift from a single-channel marketing system for most of the agricultural produce to a free-market environment where commodity prices are determined by market forces. From 1999 to 2015, tractor sales grew by an annual average rate of 8.23 percent due to a general increase in the 4WD tractor market, estimated at an annual average growth rate of 9.63 percent , while the 2WD tractor market experienced a 5.45 percent annual average growth rate. The year-on-year growth rates are illustrated in Figure 2.4 below.

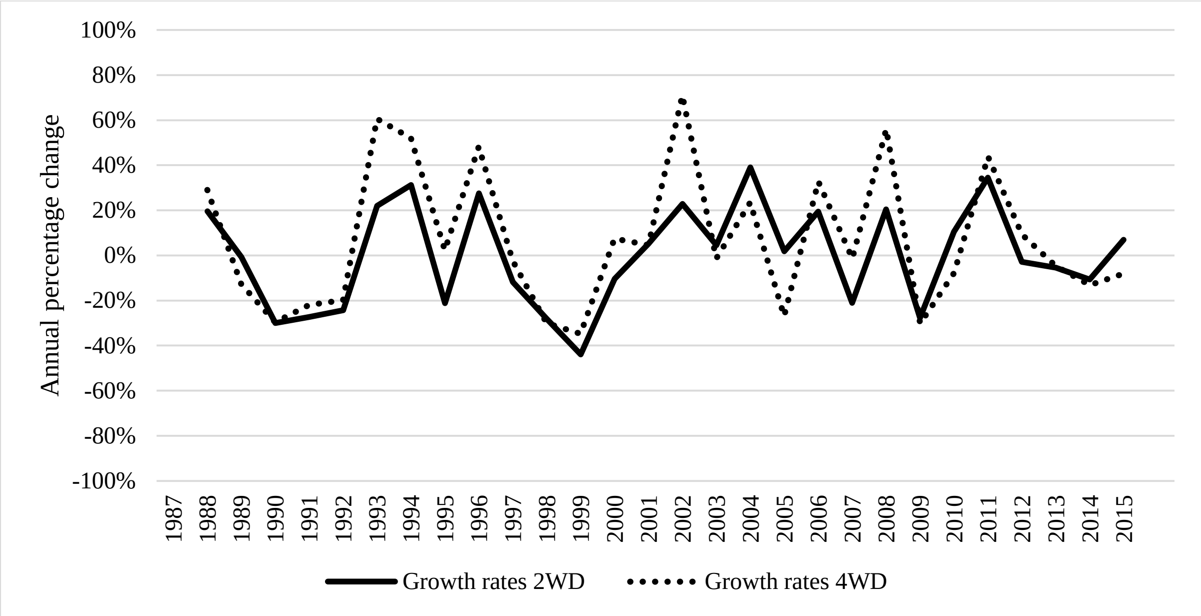

Figure 2.4: Annual growth rates in tractors sold, 1987-2015

Source: Author's own calculations from AGFACTS database

The highest growth rates in the 4WD tractor market were from 2001 to 2002 (70.96 percent) and 2007 to 2008 (56.01 percent). Farming was a viable business during that time, as there was a sharp increase in real commodity prices. In these two specific periods real price spikes were experienced. The first price spike was due to the low value of the Rand currency in 2001/2, which caused real agricultural prices to increase sharply. The 2008/07 spike in real commodity prices was mainly caused by a sharp rise in global commodity prices due to the introduction of biofuel policies. Over a very short period of time, the production of ethanol from maize added a further demand of approximately 100 million tons to global maize demand. Using maize prices as an example, the increase in prices experienced within the specific periods in 2001/2 and 2007/8 resulted in net farm income increases and the ability of farmers to finance and invest in agricultural machinery. Figure 2.5 below illustrates the white maize real and nominal prices in South Africa from 1979 to 2017.

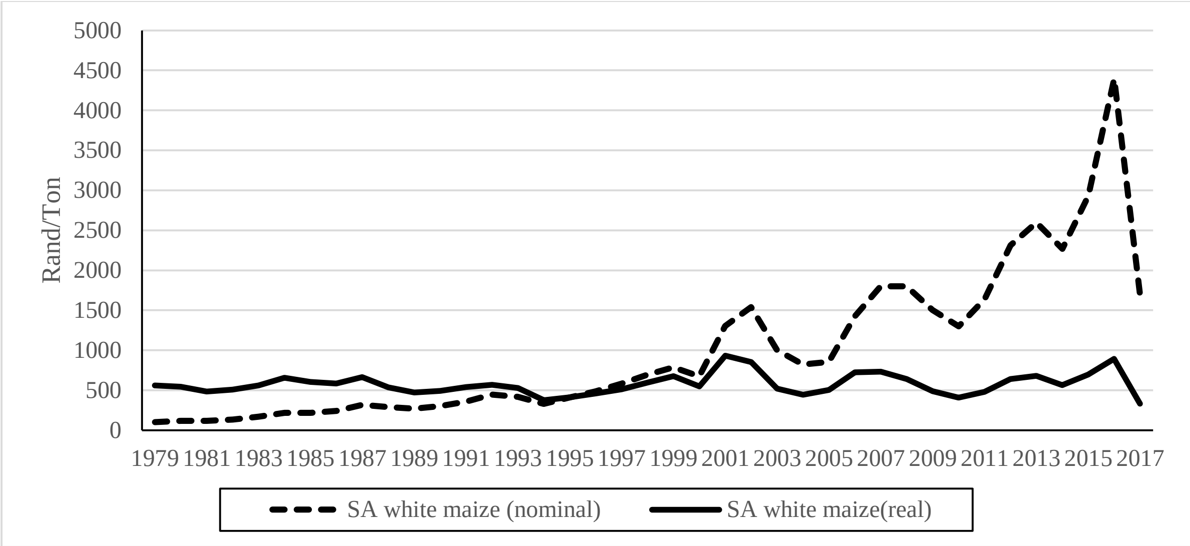

Figure 2.5: White maize prices

Source: BFAP (2017)

Figure 2.5 shows the cycles in the maize prices, which can clearly be linked with the changes in the tractor market, particularly the increase in demand for 4WD tractors. A sharp increase in real agricultural prices results in the ability for farmers to make investment in machinery and equipment. Over the 29 years from 1987 to 2015, tractor sales grew by 18 percent, from 4 925 units to 5 380 units per annum. It is, however, interesting to note that this increase in tractor sales is attributed to 4WD tractors that grew by 118 percent over this period. Sales of 2WD tractors declined by -52 percent from 1987 to 2015. The growth in the 4WD tractors coincides with changes in farming systems, such as precision farming introduced in the early 1990s. Precision farming is acknowledged by equipment manufacturers (John Deere, 2016) as being a solution that will shape the future of agriculture, thus indicating how changes in farming systems for sustainable farming influence the evolution of tractorisation.

The trend shown in Figure 2.3 above can be related to the realities in the evolution of the South African agricultural sector in the 21st century. The deregulation of the markets in the early 1990s saw most import and export controls being dropped, resulting in increased international trade. The lifting of the protection of the local engine of production, including all protective tariffs, led to the entry of new manufacturers into the tractor market (AGFACTS, 1997). With reference to Figure 2.3 above, other policy changes can be associated with the trend shown. The Agricultural Labour Act (No. 147of 1993) imposed further administrative pressures for farmers to comply with, such that by the time the minimum wages were set in 2003, the demand in tractors was already high. As such, Cochet, Anseeuw and Fréguin-Gresh (2015) suggest that the changes in land and labour legislation and minimum conditions for workers have led to significant job losses as farmers mechanised their activities to limit the number of workers on farms.

This section has illustrated a shift in demand from 2WD tractors to 4WD tractors. The following section will take this further in terms of the different provinces to determine if the nature of production has had an impact on tractorisation trends. Trends analysed at disaggregated levels ensure the relevance of focus and detail in policy decision making.

2.3.1 2WD tractors sold in South African provinces from 1995 to 2015

For both 2WD and 4WD tractors in South Africa, three main categories can be defined as the normal 4WD or 2WD tractors, the orchard tractors, and the vineyard tractors (Figure 2.2). The orchard and vineyard tractors are ideal for working with specialty crops, where there is little distance between rows, such as in orchards and vineyards. The distinction between the 4WD and 2WD tractors is also based on the tractive power of the machine. It is, therefore, expected that the 2WD tractors are more prominent in the South African provinces where the traction power requirements on the farm are minimal depending on the farming system. To confirm this proposition, Figure 2.6 below shows the distribution of the total units sold of 2WD tractors in South Africa from 1995 to 2015.

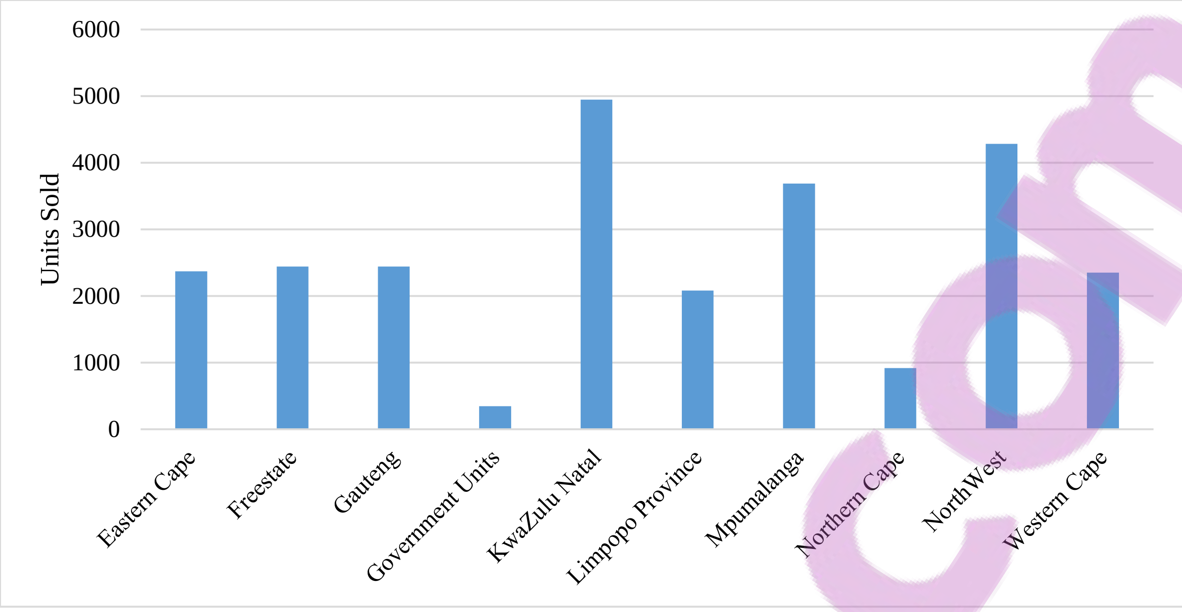

Figure 2.6: 2WD tractor units sold by provinces, 1995-2015

Source: Author’s own calculations from AGFACTS database

Figure 2.6 above shows that the most 2WD tractors were sold in KwaZulu-Natal, North West and Mpumalanga provinces for the period 1995–2015. The above illustration shows the total units sold over the entire period. However, to understand the changes that took place on a yearly basis, Annexure A provides the annual figures of the units sold per year. As illustrated above, less than 5000 units of 2WD tractors were sold during the whole period. The units sold of orchard and vineyard tractors sold for the period 1995–2015 are also shown in Figure 2.7 below.

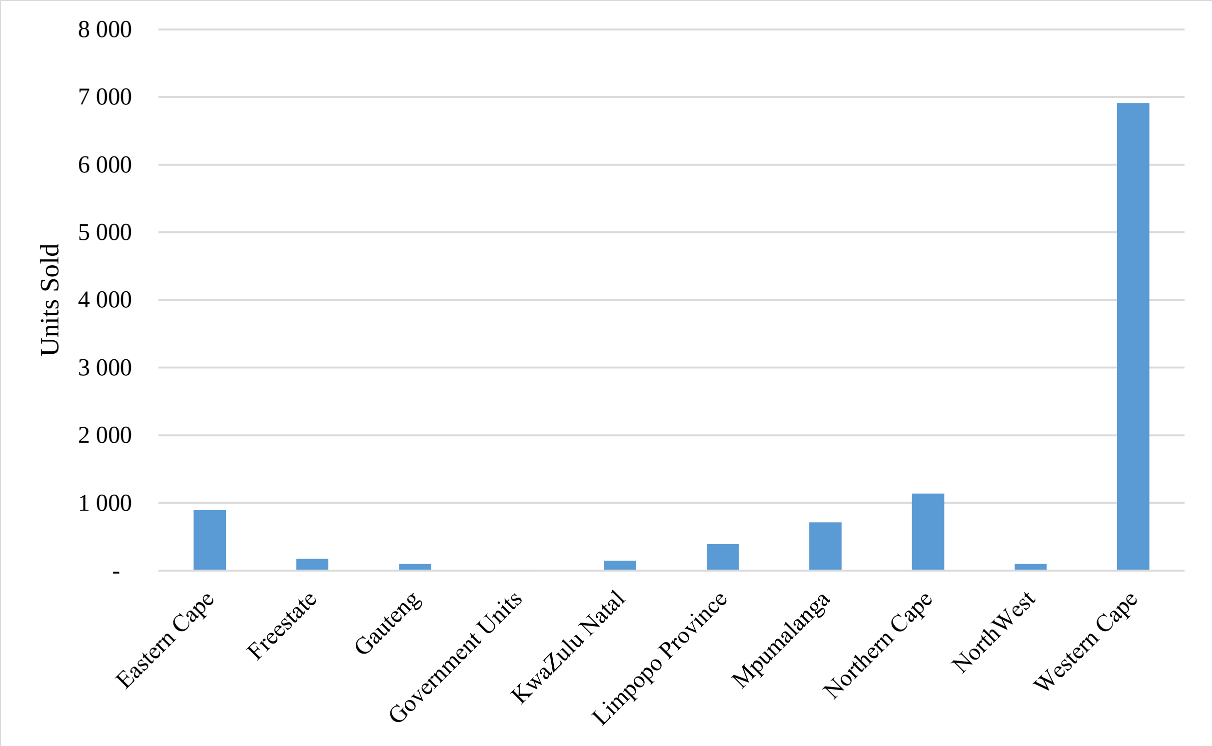

Figure 2.7: Orchard and vineyard tractor units sold by province, 1995–2015

Source: Author's own calculations from AGFACTS database

The above illustration shows that orchard and vineyard tractors are very few in numbers and are almost extinct in most South African provinces, except for the Western Cape province. The Western Cape province is known for its fruit, wine, and viticulture products, among others. These products do not require as much tractor power as does the grain market, for example, hence the dominance of the market by 2WD tractors. A different picture is shown in the distribution of the 4WD tractors in the other provinces in South Africa.

2.3.2 4WD Tractor tractorisation in South African provinces from 1995 to 2015

The same analysis as above is performed for 4WD tractors in order to compare trends in the different provinces of South Africa. Figure 2.8 below shows the distribution of the total units of 2WD tractors sold in South Africa from 1995 to 2015. The Free State province has the highest number of 4WD tractors sold in the provinces and is consistently higher than all the other provinces throughout the series. This is because the Free State is one of the main producers of field crops, such as maize, soybeans, wheat, sorghum, sunflowers and groundnuts, in South Africa. From a technical perspective, as the kilowatt requirements per tractor are increasing, a 4WD system becomes essential to bring all the kilowatt to effective use.

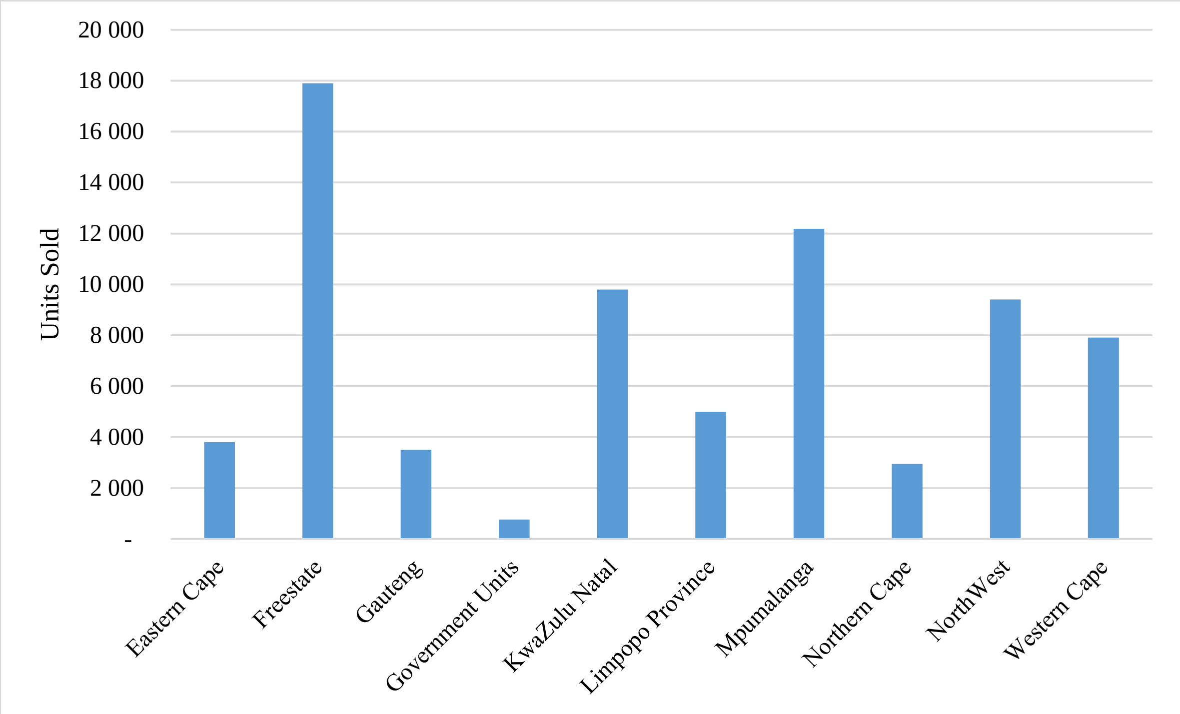

Figure 2.8: Total number 4WD orchard and vineyard tractors sold by province, 1995-2015

Source: Author's own calculations from AGFACTS database

Figure 2.8 above shows that farmers in the dominant grain-producing provinces of Mpumalanga, Free State, North West and KwaZulu-Natal bought the largest numbers of 4WD tractor units in the 20-year period between the years 1995 and 2015. The Free State, North West and Mpumalanga are the leading provinces in South Africa in terms of commercial agriculture, particularly in the production of field crops such as maize and wheat (Abstract, 2013).

2.4 FARM PROFITABILITY AND TRACTOR EVOLUTION

Investment in capital, such as tractors, is important for growth in output and agricultural productivity. One of the measures of growth in agriculture is net farm income. The relationship between net farm income and tractor prices is based on both consumption theory (derived demand) and investment theory. Tractors constitute the largest portion of the machinery and implements component of capital formation in agriculture and have an important role to play at every stage of the farming process. Based on the basic Keynes' theory of consumption, higher income implies higher consumption. Using the same analogy as Keynes, the higher the incomes farmers have, the higher the purchasing power and investment demand for tractors will be. However, a tractor is both an input and an asset, such that it is a factor that contributes to the generation of net farm income. Tractor evolution trends are discussed below in relation to net farm income and farming system to give context of how capital input use has changed in South Africa and how they influence our understanding of capital formation in agriculture.

2.4.1 Field crops and tractor evolution

The agricultural environment plays an important role in influencing the demand for farm tractors. This means that any trend that affects the sector will influence the tractor prices and sales, for example droughts, producer profitability and other macro-economic factors that affect the economy in general. This is because tractors are a source of power and an agricultural production performance determinant, particularly for grain crops. As pointed out by AGFACTS (2010), maize, wheat and more recently soyabeans are the most significant drivers of the tractorisation in agriculture. This is because maize and wheat are the main food crops whose production is dependent upon mechanical power. Figure 2.9 below uses total area under field and total tractors sales and net farming income to explain evolution of tractorisation in South Africa.

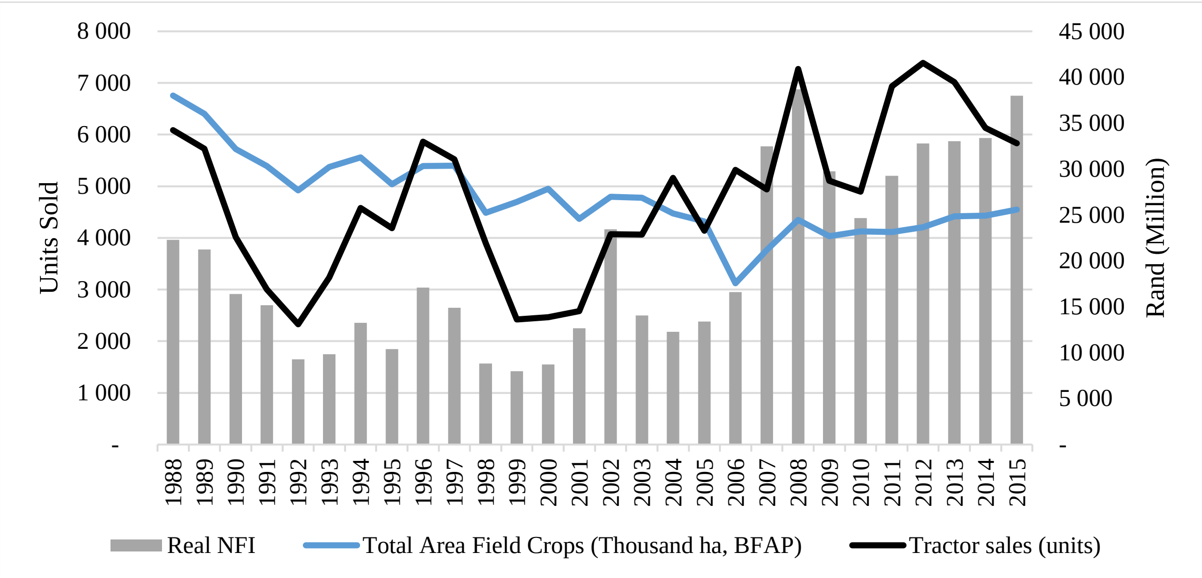

Figure 2.9: Farm profitability and tractor evolution in field crops, 1988–2015

Source: Author's own calculations from various sources

Figure 2.9 illustrates the co-movement existing between yearly tractor sales and net farm income in South Africa. As indicated above, net farming income is an indicator of farm profitability. While area planted to field crops has declined, higher net farm income can be related to the use of more efficient tractors, such as 4WD tractors. This is further defined in Figure 2.10 below, which clearly shows the correlation between net farm income and 4WD tractors.

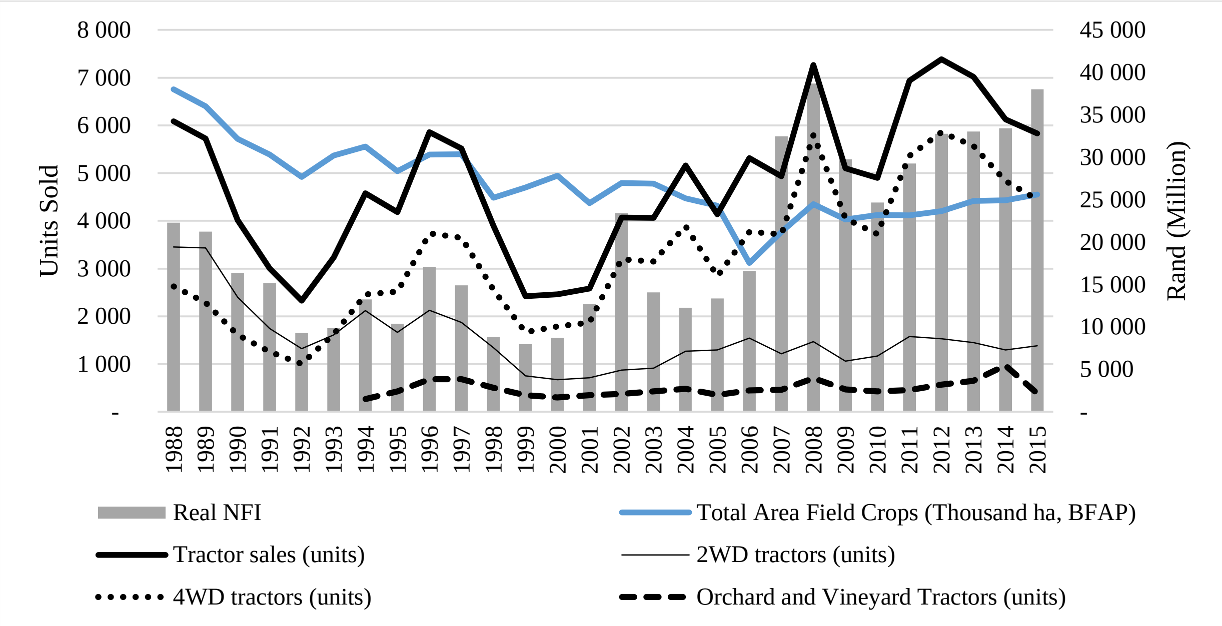

Figure 2.10: Farm profitability and tractor evolution by tractor type in field crops, 1988–2015

Source: Author's own calculations from various sources

Figure 2.10 illustrates the high correlation (with a correlation coefficient of 0.81, Annexure B) existing between yearly 4WD tractor sales and net farm income in South Africa; however, a different relationship exists with 2WD and orchard and vineyard tractors with a correlation coefficient of 0.05 illustrated in Annexure B. The lower coefficient is due to the shift from the use of 2WD to 4WD tractors illustrated in Figure 2.3 above. There is a question around capital formation measurement and Figure 2.10 above shows a strong correlation coefficient for 4WD tractors units sold and net farm income. Further analysis on this will be conducted in Chapter 3 where net farm income and tractor prices will be investigated. This shows that the tractor market is driven by more efficient tractors in the form of 4WD tractors, particularly for the field crops. This same analysis can be done for horticultural crops in South Africa.

2.4.2 Horticultural crops

The horticultural industry, including fruits and vegetables, such as oranges, potatoes, apples, pineapples, lemons, cabbage, tomatoes and pears contributes 30 percent to the South African gross value of agricultural production (Abstract, 2016). Figure 2.11 depicts the area under orchards and vineyards in South Africa in relation to the sales of 2WD tractors and Orchard and Vineyard tractors.

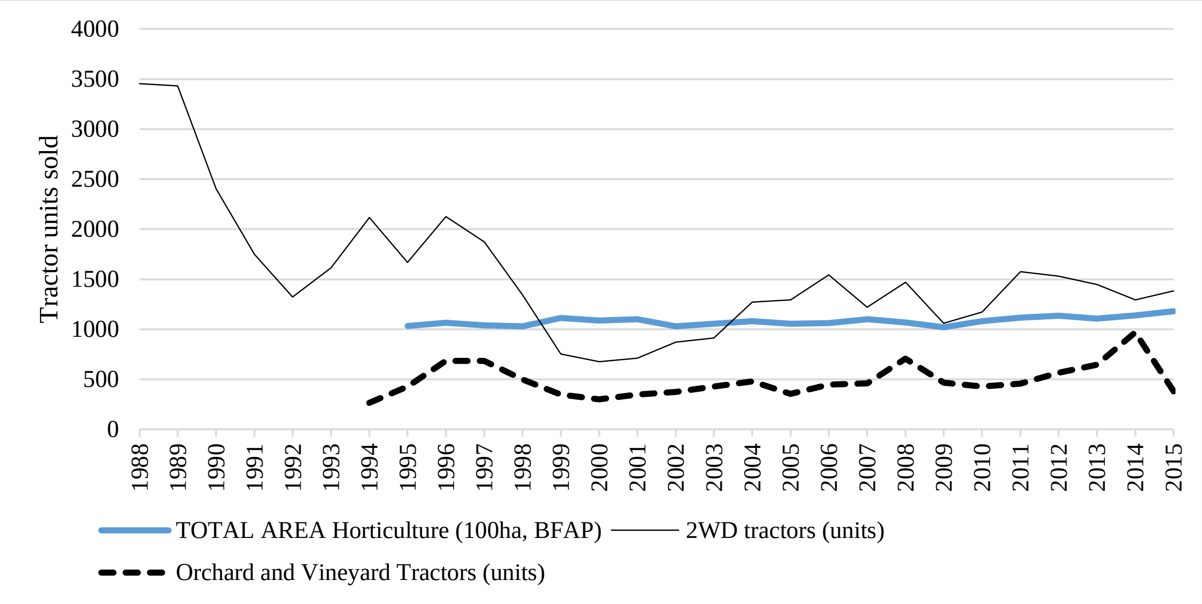

Figure 2.11: Farm profitability and tractor evolution by tractor type in horticulture, 1988–2015

Source: Author's own calculations from various sources

Area under horticulture has not significantly increased from 1995 to 2015. This is a similar trend with the 2WD, orchard and vineyard tractors sold over the same period. This is in line with figure 2.7 which shows that orchard and vineyard tractors are dominant in specific horticultural areas and almost extinct in other provinces. Given the section above where tractor evolution is explained by the attributes of tractors such as the drive train, the evolution of tractorisation can also be explained using the change in power in kilowatts. This will be explained in the following section.

2.5 SHIFTS IN TRACTOR SALES ACCORDING TO POWER (KW) CATEGORIES

In the South African tractor market, tractor power sizes range from below 20 kilowatts to over 200 kilowatts for normal 4WD and 2WD tractors. Table 2.2 below gives a snapshot of estimated market shares (units sold) of 2WD tractors and 4WD tractors in 1995 and 2015. As expected, 2WD tractors have fewer categories sold on the market, as compared with 4WD tractors.

Table 2.2: Estimated share of 4WD and 2WD tractors to total sales by kilowatts in 1995 and 2015

Category	Kilowatt size	Estimated share of total 2WD sales (%)		Estimated share of total 4WD sales (%)	
		1995	2015	1995	2015
1	<20			0.27	1.14
2	20.1-30		1.20		0.24
3	30.1-40	9.73	32.56	1.76	1.16
4	40.1-50	3.63	17.28	0.09	4.54
5	50.1-55	40.88	22.32	11.31	9.90
6	55.1-60	11.88	8.24	8.61	7.01
7	60.1-70	14.54	17.52	6.26	25.46
8	70.1-80	18.88	0.16	43.85	12.02
9	80.1-90	0.26	0.48	7.66	10.05
10	90.1-100			3.70	8.38
11	100.1-110			2.34	3.28
12	110.1-120		0.16	1.53	1.38
13	120.1-150	0.19		4.82	5.79
14	150.1-200			5.05	3.16
15	>200			2.75	6.44
		100	100	100	100

Source: Author's own calculations from AGFACTS database

Historically, 2WD tractors rated between 50 and 80 kilowatts dominated the tractor market, with a total share of the market of more than 85 percent, (as shown by market shares of units sold in categories 5–8) in 1995. However, in 2015, market shares increased in the power categories below 55 kilowatts, with a market share of about 70 percent for 2WD tractors. This illustrates the need for 2WD tractors for the minor jobs on the farm that do not require much traction power, such as cutting grass, pulling light-weight trailers, hammer mills and equipment, scrapping roads, and other light-weight jobs on the farm.

Table 2.2 also shows that market shares of 4WD tractors have also changed over time. In 1995, Category 8 for tractor power sizes between 70.1 and 80kw had the highest market share of 43.85 percent, followed by Category 6 for 50.1–55kw tractors with a market share of 11.31 percent. In 2015 however, the estimated market share percentage was highest for tractors between 60 and 70kw in size, with a market share of 25.46 percent. The largest share of the market was constituted by categories 7, 8 and 9 tractor power sizes between 60 and 80kw in 2015. The shift to higher kilowatt tractors is shown by the increase in market share of tractors above 100kw, from about 16.4 percent in 1995 to above 20.1 percent in 2015. This is explained by the higher demand for bigger kilowatt tractors to achieve productivity in farming operations. Table 2.3 below is a snapshot of the orchard and vineyard tractors, which are categorised by tractors below 50 kilowatts and category 2 above 50 kilowatts.

Table 2.3: Estimated share of 4WD and 2WD vineyard and orchard tractors to total sales by kilowatts in 1995 and 2015

Category	Kilowatt size	Estimated share of total 2WD Orchards and Vineyards sales (%)		Estimated share of total 4WD Orchards and Vineyards sales (%)	
Category	**Kilowatts**	**1995**	**2015**	**1995**	**2015**
1	<50	69.84	14.18	40.67	5.96
2	>50	30.16	85.82	59.33	94.04

Source: Author's own calculations from AGFACTS database

The shift towards bigger machines in the orchard and vineyard categories for both 2WD and 4WD tractors is shown in Table 2.3 above. In 1995, vineyard and orchard tractors below 50 kilowatts made up a bigger share of the market – 69.84 percent in 1995 for 2WD and 40.67 percent for 4WD in 1995. In 2015, 2WD and 4WD orchard tractors made up 85.82 percent and 94.04 percent, respectively. This is a clear illustration of the change towards higher power machines, as evidenced by the trends in tractorisation evolution explained in this chapter. In order to understand the sales patterns shown above in the context of prices, Table 2.4 below shows the average price comparisons between all tractor categories in both the 2WD and 4WD tractor markets in 1995 and 2015.

Table 2.4: Average price per tractor category in Rand, 1995 and 2015

Category	Kilowatt size	Average price per category 2WD		Average price per category 4WD	
		1995	2015	1995	2015
1	<20			34 045	137 088
2	20.1-30		153 460	94 520	217 100
3	30.1-40	85 825	223 246	114 790	299 192
4	40.1-50	104 854	244 485	128 282	304 337
5	50.1-55	99 550	309 178	137 992	354 393
6	55.1-60	116 729	414 780	151 642	464 112
7	60.1-70	137 168	326 879	154 980	514 802
8	70.1-80	136 520	601 028	242 378	679 385
9	80.1-90	179 170	278 645	239 553	882 180
10	90.1-100	293 912		243 818	1 095 618
11	100.1-110			311 896	1 284 217
12	110.1-120		302 100	324 457	1 310 127
13	120.1-150			395 824	1 531 118
14	150.1-200			506 363	2 246 339
15	>200				3 981 280

Source: Author's own calculations from AGFACTS database

Table 2.4 above shows the price differences between the different tractor categories in both the 2WD and 4WD tractor markets. As expected, there is variability between tractor prices in the different categories, with the price increasing with the tractor size in kilowatts for 4WD and 2WD tractors. In 2015, average prices for 4WD tractors sold ranged from R137 088 in category 1 to R3 981 280 in category 15. Using the market shares given above, most 4WD tractors sold are between 70 and 80 kilowatts, while the 2WD tractors are between 30 and 55 kilowatts, for both 1995 and 2015. The expensive tractors are 4WD tractors over 100 kilowatts in size. In comparison to 1995 where only 20 percent of the market share by units sold was for tractors above 100 kilowatts, in 2015, 28 percent of market share was constituted by tractors above 100 kilowatts in size. This relates to the move towards bigger and more efficient tractors in South African agriculture.

2.5.1 Average kilowatts per tractor sold

The composition of farm power has evolved, with most changes taking place in the principal power source associated with the preparation of land. Farm power typologies were defined by Clarke and Bishop (2002) as human power, draught power, and motorised power. One of the main constraints in increasing agricultural production is the shortage of farm power. Tractors are the most prominent source of power in South Africa, and this analysis uses power in kilowatts to show how tractorisation has evolved over time in the context of power.

Figure 2.12 below shows the trends in terms of kilowatt-rated tractors sold from 1995 to 2015. In order to determine the total power sold in a year, the number of tractor units sold is multiplied by the kilowatts per model, and the sum of all the kilowatts in a year for all models is then the kilowatts sold illustrated in Figure 2.12 below. As such, from 1996, the kilowatts sold per year declined and reached the lowest in 1999, mostly because of changes in legislation as well as the weaker rand–dollar exchange rate. The year 1998 had a record number of makes and models entering the market, resulting in higher competition (AGFACTS, 1999) and thus reduces sales and effectively power on farms. The illustration related to the 2WD and 4WD units sold is depicted in Figure 2.12.

Figure 2.12: Total kilowatts bought by farmers annually, 1995-2015.

Source: Author's own calculations from AGFACTS database

Figure 2.12 above shows that the total tractor kilowatts per year bought by farmers has increased from a low point of 176 064kw in 1999 to over 600 000kw in 2012. Average kilowatts sold per year is 318 692kw which implies that tractor kilowatts sales in the years since 2006 exceeded the 20 year average. The contribution of 4WD tractors to the total kilowatts sales increased from an average of 77 percent between 1995 and 2005 to an average of 85 percent in the period 2006 and 2015. This corresponds well with the changes in labour legislation in

2002/2003 and the changes in farming practices resulting from this. This trend is in line with the increase of the number 4WD tractors sold from about 2002 to 2015 (Figure 2.3). The changes in the use tractor power on South African farms can also be illustrated by trends relating to average power sold and units sold, as shown in Figure 2.13 below.

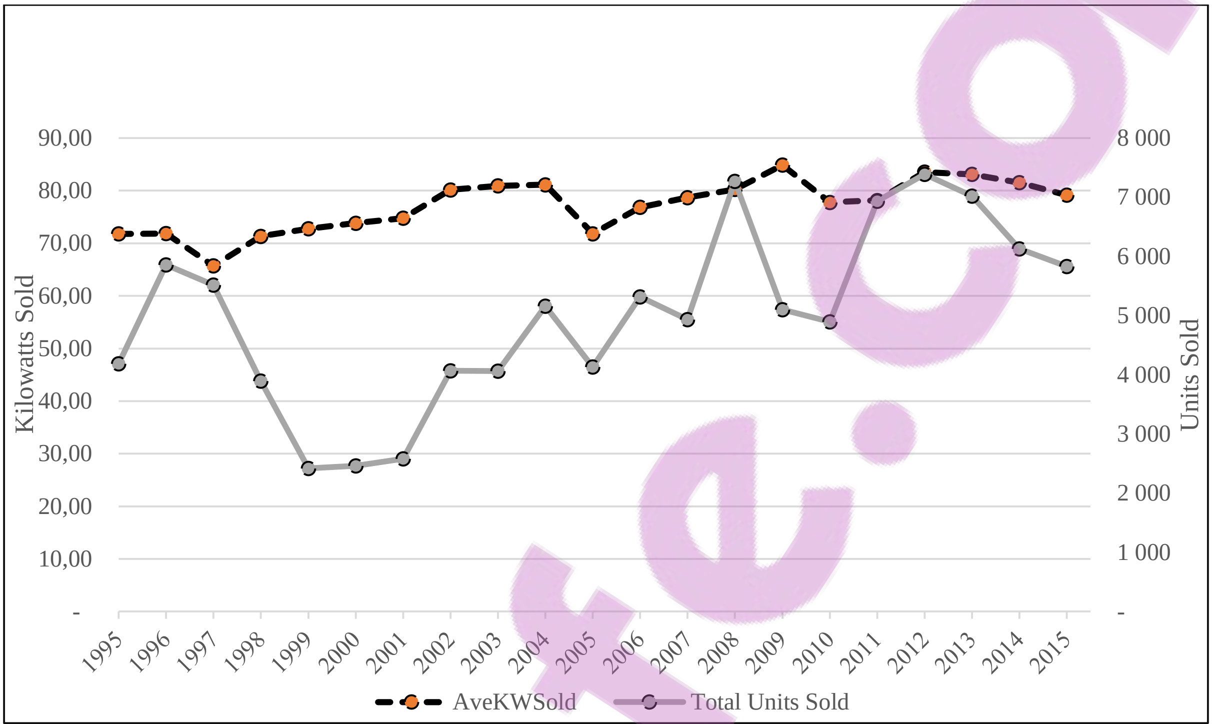

Figure 2.13: Average kilowatts per unit sold and total units sold in South Africa

Source: Author's own calculations from AGFACTS database

Figure 2.13 shows the annual average kilowatts sold and total units sold of tractors on the same plane to illustrate the state of tractor power, as opposed to the units of tractors sold on the farms. Average kilowatts sold increased in periods when grain farming (field crops) increased in 2005/6, 2008/9 and 2010/11. Units sold increased average increase in kilowatts. Bigger machines that came with minimum tillage practices such as, rippers, tined implements that work deeper were introduced. Furthermore, operations have become more intense with respect to the period of time that an operation has to be completed. In other words, more kilowatts are required per hectare so complete the operation in a shorter period of time. There are two main drivers for this phenomenon; first, precision farming is leading to a more exact science of when a specific operation or application has to be completed. This has a direct impact on the efficiency of an operation, for example the correct timing of applying a pesticide.

The second driver that is reducing the period of time that an operation can be completed relates variability in weather. The variability in weather patterns is increasing with a less equal spread in rainfall, but rather more erratic events of high downfalls and then longer dry spells. This implies that the window for completing an operation, like soil preparation or planting is much shorter and bigger tractors are required to complete the operation. For the period 1995–2015, the average annual kilowatts sold per tractor increased by 10 percent, from 71,8 kilowatts sold per tractor per year to 79.2 kilowatts sold per tractor per year. The units sold grew by 39 percent from 4186 in 1995 to 5840 units in 2015. Figure 2.13 above shows that, at an aggregate level, the units sold are growing faster than the kilowatts sold. This means that more machines are being sold in comparison to the tractor power sold in kilowatts. This finding is also in line with the dominance of tractors in categories between 60 and 80 kilowatts. However, a disaggregated analysis is done for 4WD and 2WD machines below, which shows a similar trend in the 4WD market.

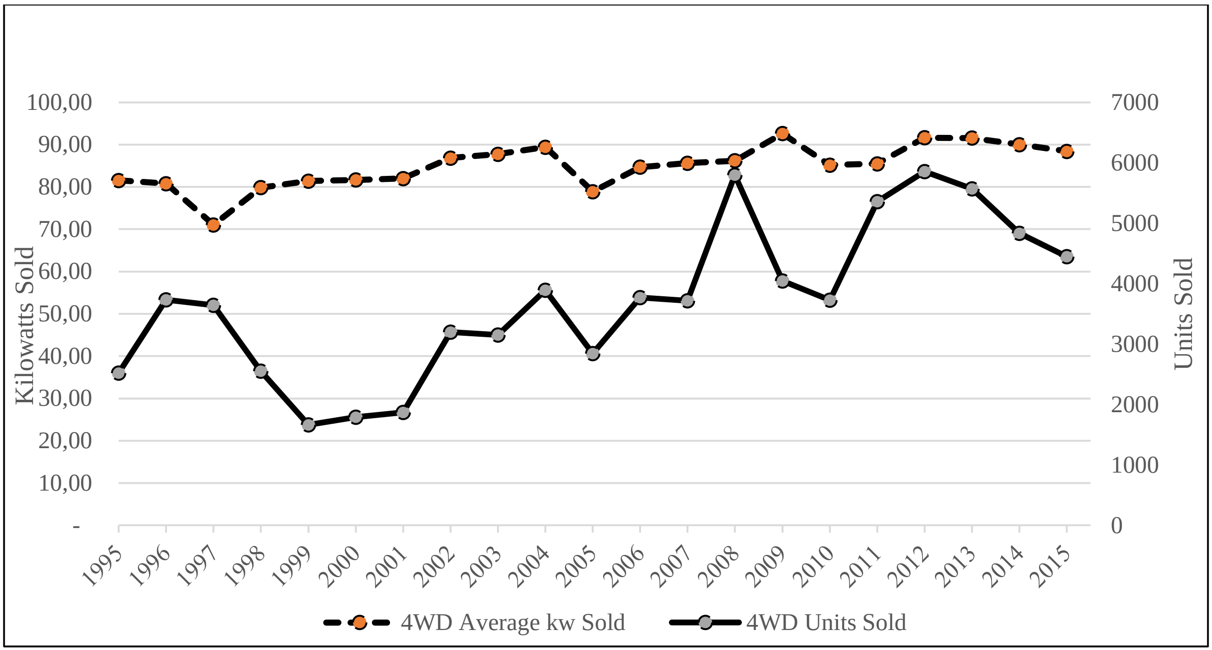

Figure 2.14: Average kilowatts per 4WD tractor sold and units sold in South Africa

Source: Author's own calculations from AGFACTS database

Figure 2.14 above shows that while the units sold increased for the whole period with fluctuations in between the years, the average kilowatts per tractor sold did not follow the same trend. This affirms the observed trend for most of the 4WD tractor market share being in tractor categories between 60-90 kilowatts, as shown in Table 2.2. This is different from the 2WD scenario, which shows the average kilowatts sold per tractor declining from 57 kilowatts per tractor to 49 kilowatts per tractor sold per annum.

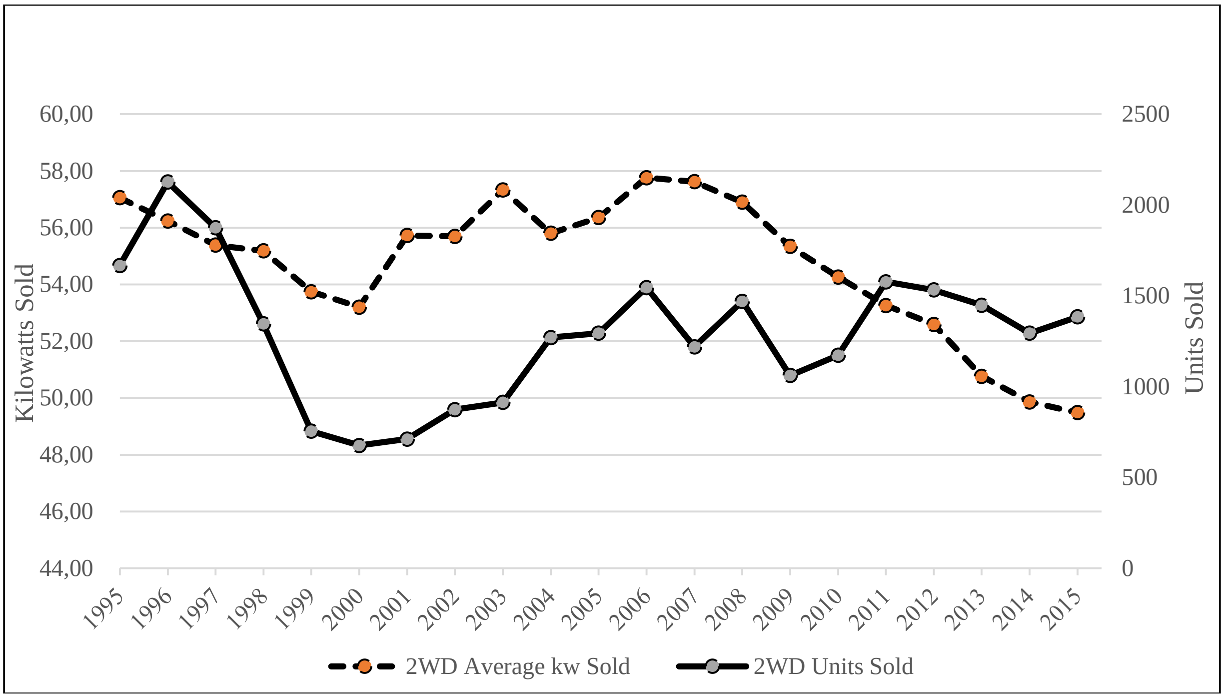

Figure 2.15: 2WD Average kilowatts sold and units sold in South Africa

Source: Author's own calculations from AGFACTS database

Figure 2.15 illustrates trends that are in line with the reduced use of 2WD tractors in South Africa and a shift towards the more powerful 4WD tractors. This illustration shows that the 2WD market depicts a less efficient power use, as compared with the 4WD tractor market. This can be attributed to the average kilowatts sold per tractor declining, while more 2WD tractors are being sold annually, particularly from 2010. Figure 2.15 shows a move towards less efficient power use, in that more units were sold from 2010 to 2015 with fewer kilowatts sold for the same period. This can be explained by the sharp decline in kilowatts sold on the 2WD tractor market that persisted from 2008 to 2015, as shown in Figure 2.16 below.

2.5.2 Tractor power and area planted for select field crops

In order to gain insights into the power used per hectare in South Africa, the area planted to a number of major field crops was calculated. The area planted to maize, wheat, grain sorghum, groundnuts, sunflower, canola, soybeans, barley, dry beans, sugar cane, cotton and tobacco was used to derive the total area under field crops. The derived kilowatts per hectare show very little use of tractor power in kilowatts per hectare, with an average of 0.07 kilowatts per hectare over the years 1995–2015. This use of tractor power in kilowatts per hectare is lower than in other countries where tractor adoption rates are higher.

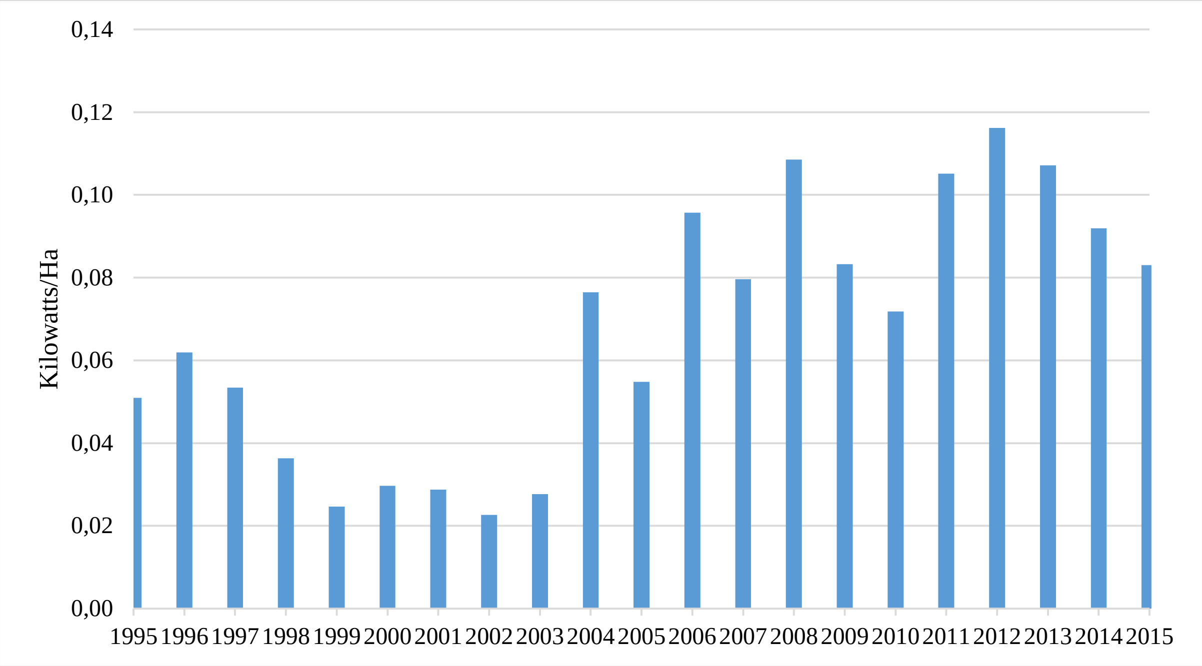

Figure 2.16: Annual kilowatts sold per hectare

Source: Author's own calculations from the Abstract and AGFACTS databases

Figure 2.16 shows that power efficiency, measured by kilowatts per hectare, is generally linked to the 4WD tractor market as the trend follows the 4WD tractors sold in South Africa. Tractor power use on the farms is a function of the 4WD tractor trends, among other factors such as the choice of input mix on the farm. The power efficiency has not significantly risen, and ranges between 0.02 and 0.12 kilowatts per hectare. However, this finding should be interpreted with caution since the analysis is not inclusive of the total agricultural area planted. Only field crops were used to derive the kilowatt per hectare in South African agriculture.

2.6 CHAPTER SUMMARY

In conclusion, this chapter provides evidence of the current state of tractor tractorisation in South Africa and of the changes that have taken place in tractorisation. This chapter also shows the deterioration in the monitoring and reporting style of machinery and implements used in agriculture, which affects the valuation of machinery and implements amidst the evolution in the use of agricultural machinery. Evidence presented above shows that the tractor inputs have grown in terms of efficiency, with reference to the power and type of drivetrain used on South African farms. The use of 4WD tractor models, compared with the use of 2WD tractors, is an indicator of growth towards more efficiency in farming.

The analysis presented above is also in line with the practical realities on South African farms in terms of the technology in use and its distribution in the various provinces in South Africa. However, current methods used to value investment in machinery and implements in the form of capital formation ignore these changes that have taken place in tractor tractorisation in South African agriculture. The implication of such an approach to the valuation of machinery and implements is an underestimation of the true value of machinery and implements on South African farms, which will be illustrated in the following chapters. In order to develop a comprehensive understanding of the evolution of tractorisation in South Africa, a thorough assessment of the South African national capital accounts has to be made. The understanding of the tractorisation process provides a further perspective on the national capital accounts in South Africa.

Having discussed the evolution of tractor tractorisation in South Africa using the drivetrain and power attributes of tractors in South Africa, the next chapter will discuss the price of tractors in South Africa. It will show how the price changes in the tractor market have been tracked and how they can be used to explain the changes that have taken place in the agricultural machinery sector. The importance of tracing the evolution of tractor tractorisation in terms of the model change history of tractors is also discussed in more detail in the next chapter. The reliability of the revised tractor price index is tested in relation to exchange rate and net farm income in explaining the evolution of tractor prices in the tractor market in South Africa.

CHAPTER 3:
THE REVISED TRACTOR PRICE INDEX

3.1 INTRODUCTION

The discussion in Chapter 2 clearly illustrated that there has been substantive changes in the South African tractor market over the last two decades. There is a more diverse set of tractor types being sold, with a general trend towards more powerful and predominantly 4WD tractors, which are more expensive. As illustrated in Chapter 2, there is a much greater variation in prices of the different tractors sold (Table 2.4). This reality therefore brings to the fore a major question concerning the manner in which tractor prices and values are published in South Africa. It is clear from the use of assumptions, for example when there is a change in a tractor model, that the Department of Agriculture Forestry and Fisheries (DAFF) assumes a constant price from the previous models, instead of tracking the model change history (Liebenberg, 2013). By definition, this is problematic and adds to the fact that the tractor market in South Africa is characterised by a wide range of manufacturers, as well as by differentiated tractors in terms of quality and power size, and thus prices will vary considerably. This presents a problem in the construction of the tractor price index in terms of the choice of basket of tractors to include in the construction of the index.

The tractor price index in South Africa needs to be reconstructed, given the fact that assumptions, instead of underlying price and quantity data, are used, as shown in Table 2.1 where the census data has deteriorated in its reporting style. The agricultural sector in South Africa relies heavily on import markets for agricultural inputs. Among other inputs that are imported into the South African agricultural sector, are machinery and capital equipment, with tractors in particular being imported the most (Trade Research Niche Area, 2013). As such, tractor prices in South Africa are mainly a function of the exchange rate because South Africa is a net importer of tractors. The current tractor price trends are not reflective of for example the influence of the exchange rate on tractor prices. Furthermore, tractor prices could also be affected by improved technology and the demand for tractors (tractor sales). There is a strong correlation between tractor sales and net farm income. In other words NFI can influence tractor prices through the derived demand for tractor prices. This chapter will compare the results of a cointegration analysis between the revised tractor prices, exchange rate and NFI and the current tractor prices to determine if the revised TPI will provide a higher level of cointegration.

Net farm income is calculated as gross farm income from production minus depreciation, salaries, wages, interest and rent. Net farm income is of interest to different economic agents because it provides the basis for assessing the state of the agricultural industry and aids in the formulation of different policy options for the sector. Literature argues that net farm income can be used as a measure of profitability and thus the neo-classical investment theory starts with the optimisation problem of the firm. Assuming a Cobb-Douglas production function as follows:

$Y(t) = f\big(K(t), L(t)\big) = AK^{\propto} L^{1-\propto}$……………………………………………….Equation 3.1

Where $Y(t)$ is output, A is the level of technology, K is capital, α is a parameter that measures capital's share of output and L denotes labour all in period t. Assuming the above production function satisfies neo classical properties including constant returns to scale, under conditions of perfect competition, the firm is expected to employ a factor to the point where marginal costs will be equal to marginal revenue. Taking the first difference of the above production function (Equation 3.1) with respect to labour would result in:

$MPK = \frac{\propto Y}{K}$……………………………………..…………………………..Equation 3.2

To maximise profits such a firm would be equate the marginal productivity of capital to the rental price of capital:

$\frac{\propto Y}{K} = \frac{r}{P}$…………………………………………………………………......Equation 3.3

Where $\frac{r}{p}$ is the real rental price (user cost) of capital. The desired capital stock is therefore expressed as:

$K* = \frac{\propto PY}{r}$……………………………………………………………………Equation 3.4

Equation 3.4 shows that the higher the rental cost of capital (r), the lower will be the desired capital stock by the firm and vice versa. The equation 3.4 further illustrates that the greater the expected output (Yt) the greater the desired capital stock. Eklund (2013) states that from investment theory, investment in any period will depend on growth in output as explained in the following Equation 3.5.

$I = \propto Y$…………………………………………….. ………………………………...…Equation 3.5

From the above, it is expected that net farming income and tractor prices should be cointegrated over time because capital formation is a function of tractor prices. The relationship between net farm income and capital formation should, therefore, be highly correlated. However, in recent years (Figure 3.1), the relationship between net farm income and capital formation in South Africa has not been upheld. There is a poor correlation between net farm income and capital formation and this leads to the need for further investigation of the variables used to measure capital formation.

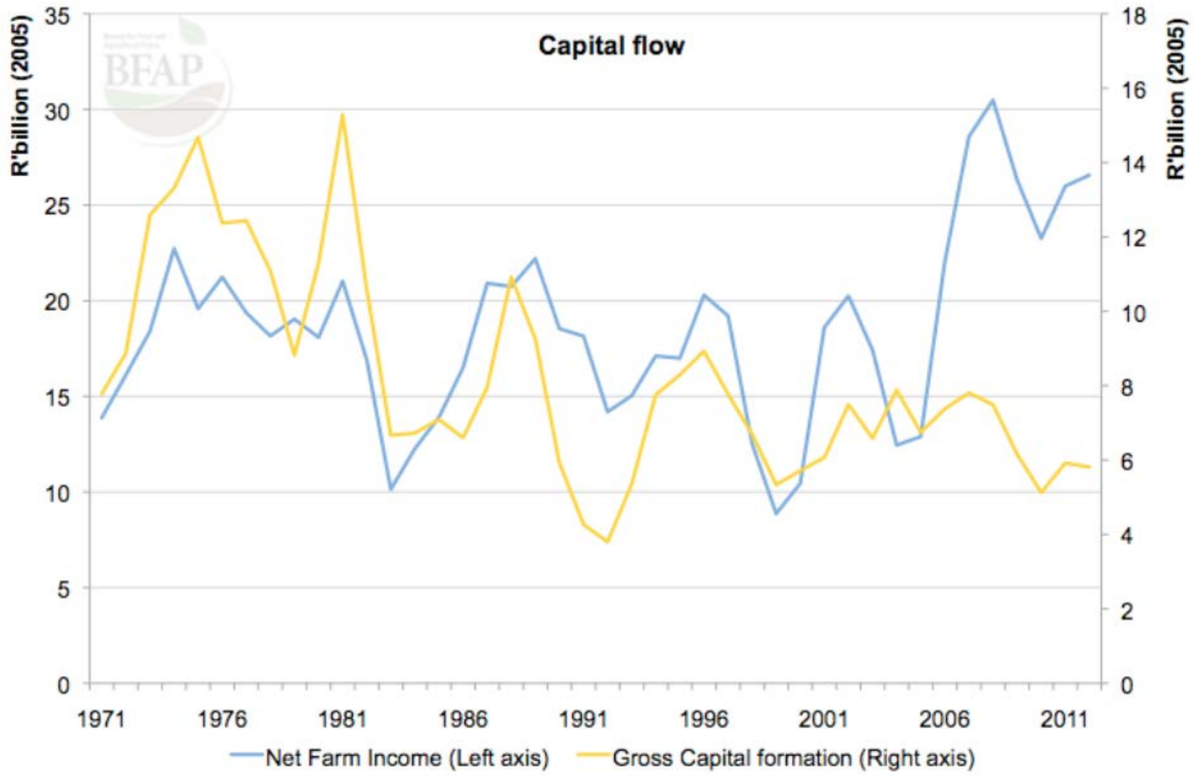

Figure 3.1: Gross capital formation and net farm income of the agricultural sector, 1970-2012

Source: BFAP (2014)

Figure 3.1 above shows a high level of co-movement between net farm income and capital formation trends since 1970. However, this relationship changes from 2005 where net farm income increases sharply and gross capital formation does not follow the same trend. This disparity raises questions and potential factors such as lack of confidence due to policy changes, the increase in capital intensity and other off-farm investments (BFAP, 2014) need to be investigated. The actual factors that may have led to this difference in previously co-moving trends are not clear. However, one of the factors that this study would like to bring to the body of literature is how capital formation, more specifically how investment in machinery and implements has been measured using tractors. If tractor sales within the measurement of capital formation are not measured correctly, this could be the reason for this disparity. This chapter addresses this issue by investigating the relationship between net farm income and tractor prices.

The need for precision in documenting tractor prices and calculating the capital investment by farmers in tractors is confirmed by the fact that investment in tractors is used as a proxy for the investment in all machinery and implements in South African agriculture. Improving the identification of the value of tractor investment by farmers will go a long way in gaining a much better understanding of total investment of machinery and implements by South African farmers. Precision is achievable by minimising the use of assumptions in measurement. It is evident from the arguments above that there have been technological advancements in physical inputs such as tractors and that price trends should be analysed much more carefully to enhance the understanding of the evolution process, with a specific focus on tractors. That will provide insight into future trends and policy recommendations in the tractor market. It is in this context that this chapter aims to explore the current methods used to calculate the current tractor price index from 1995 to 2015.

In this chapter, an index of tractor prices is constructed by using underlying price and quantity data. Current methods used in the Abstract of Agricultural Statistics to measure and track the tractor price index in South Africa are tested in order to validate the current methods. A new Laspeyres index of tractor prices is presented which is based upon underlying price data of the tracked tractor model change history and disaggregated tractor prices by size of tractors in terms of power in kilowatts. This chapter shows that by using disaggregated data, a different tractor price index is constructed which shows an underestimation in the tractor price changes from 1995 to 2010. Ultimately, such imprecision has implications for the valuation of input use and productivity analysis.

This chapter is organised as follows: the next section discusses index number problem and the current methods of tractor price estimation. Section 3.2 discusses the index number problem. Section 3.3 discusses the different applications of index numbers economic measurement. In this section, the different index numbers that have been used in an agricultural context are discussed. Section 3.4 discusses the steps taken in revising the Laspeyres tractor price index, followed by a presentation of the revised tractor price index in section 3.5. Section 3.6 explains cointegration analysis and its relevance. Section 3.7 will outline the tests for stationarity of the findings. Section 3.8 outlines regression results. Lastly, section 3.9 presents a summary and conclusion of the findings. The recommendations for policy analysis are discussed in this section.

3.2 THE INDEX NUMBER PROBLEM AND CURRENT METHODS OF TRACTOR PRICE INDEX ESTIMATION

The construction of an index number presents difficult choices relating to the base year, the aggregation problems, and how weights should be allocated to the commodities. Therefore, Milana (2009) summarises the index number problem as that of aggregating across different heterogeneous elements. In many instances, data limitations result in assumptions that increase the risk of mismeasurement in the calculation of the indexes. In addition to the lack of clarity in the methods used to calculate the price indexes, the use of assumptions, for example when a tractor model changes, the DAFF assumes a constant price from the previous models, instead of tracking the model change history (Liebenberg, 2013).

This lack of precision in measurement has far-reaching effects, resulting in the short cut method of using mid-point (based on price per kilowatt) values by power category, instead of the underlying price and quantity data on tractor models that are available in the calculation of the investment series. The mean values assume a normal distribution of the data, which may be an oversight in terms of tractor price data. Price quotations also present a problem in the measurement of an index. In addition to the problem of unavailability of data, which is very prevalent in Africa, price quotations should be kept relevant to the purpose of the measurement. Price quotations can also be widely different, for example price quotations given in different currencies. A decision has to be made and defined to avoid the inherent ambiguity associated with the differences in price quotations. The rule of thumb would be to standardise in money price per unit of the commodity.

One of the major sources of bias in price indexes is the lack of quality adjustments. Triplett (2004) suggests that quality change has long been recognised as being perhaps the most serious measurement problem in estimating price indexes. In the face of technological changes in the world, particularly in agricultural inputs such as physical capital, quality changes occur with a higher impact on the price level, except that the quality adjustment is not accounted for in the price index. Understatement of quality change in inputs implies an understatement of real inputs and an overstatement of productivity growth (OECD, 2001). As identified by Thirtle *et al.* (1993), work has needed to be done on the capital account of South African agriculture, particularly with regard to incorporating quality changes in the price indexes. Price indexes allow for analysis of the general price level, as well as calculating real output and incomes using deflators.

Besides the lack of quality adjustments being a major source of bias in input measures, a big debate is presented in the literature on the measurement of quality changes whether it is a user-value criterion or a production-cost criterion that quality changes evaluation should be based on. Triplett (1982) suggests that, in equilibrium, these two criteria yield the same numbers and therefore the distinction between them is inoperative. Most proposals use the market price information, suggesting that prices reflect both value and cost. Some of the methods that have been used are discussed below.

The matched method is one of the methods used to capture quality changes where a sample is confined to models whose characteristics do not change from one period to the next. A modification of the matched method is the overlapping method where two different models are observed in a given period. The ratio in the prices on the overlapping period is then used as a measure of quality adjustment (Triplett, 2006). Bover and Izquierdo (2003) point to the price of the change in the product as being one of the most satisfactory traditional methods in taking quality changes into account where the value of the additional quality change is estimated using different sources of information such as the manufacturer or published prices. In most cases, it has been observed that these methods are not feasible (Bover & Izquierdo, 2003), as information on prices may not be available and also because all these methods assume that an increase in production costs is a necessary condition for quality change to occur, which is not always true in the case of high technology products.

Another common method used in literature, and which is adopted by most public statistics offices, is the hedonic methodology. This method breaks down the product into characteristics, and measures the pure change in the prices as that which would take place under given characteristics (Bover & Izquierdo, 2003). This methodology has become a standard tool for quality change measurement in the national statistical systems of many OECD countries, following Court (1939) and Griliches (1961), who both estimated the hedonic price indexes for automobiles. This method has been applied to many durable goods and is therefore relied upon for measuring quality adjustments in capital inputs such as machinery and implements. Hedonic pricing is based on the premise that each characteristic has its own implicit price and therefore requires the specification of a market for such a characteristic. Although this method is quite commonly used due to its feasibility, it fails to capture shifts in totally new products. The data requirements for the implementation of this methodology present another limitation of this methodology, specifically the breakdown of product characteristics. This level of detail is not always available and this therefore limits the level of analysis that can be done with the data.

The choice of a base period presents another measurement problem in index calculations. Any period within the coverage of the index series can be used as the base period. It is, however, critical to understand the underlying reasons for the calculation of a particular index, in that when a special purpose index is being calculated to measure changes occurring in a particular period, that period would then be taken as the base period. The base period should involve relatively normally standard conditions because many index users assume that the base period represents such conditions. This also ensures that there are no overstatement or understatement biases in the calculation of the index. Sancheti and Kapoor (2005) argue that the base period should not be too distant from the given period in order to ensure that the index number remains relevant for short-period comparisons, as changes take place in time. A compromise solution for the above problem may be the decision to use a chained base, as opposed to a fixed base. If the period is a fixed base, the comparisons are kept fixed for all the current years.

3.3 APPLICATIONS OF INDEX NUMBERS

Index numbers are sometimes referred to as the barometers of economic change. This means that they can be used to measure the level of economic behaviour. The level of economic behaviour is related to economic outcomes, thus index numbers comprise a useful tool in estimating production functions. An index number can be defined as a statistical measure designed to show changes in variables or a group of related variables with respect to time, geographic location or other relevant characteristics. Index numbers will therefore serve the same purpose in the context of tractors. According to the OECD (2009), an index is a measure reflecting the average of the proportionate changes in the quantities of a specified set of goods and services between two periods of time. Usually a quantity index is assigned a value of 100 in some selected base period and the values of the index for other periods are intended to indicate the average percentage change in quantities compared with the base period.

The index number approach to calculating productivity involves dividing an output quantity index by an input quantity index. Aggregate input-output data is commonly used to capture changes in production. Within a production stage, the input–output process is encapsulated in a production function. It is important to acknowledge that the usefulness of index numbers in analytical or predictive purposes will depend on the precision exercised in the choice of the method and the manner in which it was compiled. Tractors are an input in productivity analysis and therefore precision in their valuation is significant for policy analysis. A number of index methodologies can be used to track price changes, and a discussion is set out below describing the particular weighted index numbers that have been used in an agricultural context.

Weighted indexes assign rational weights to all the items or commodities in an explicit manner. The weights indicate the relative importance of the items or commodities included in the calculation of an index. The weights can be quantity weights or value weights. In a weighted aggregate price index, each item in the basket of items chosen for calculation is assigned a weight according to its importance. Weights may be assigned to the various commodities as deemed appropriate, with the main purpose being to bring out their economic importance. Below is a brief discussion of the different commonly used weighted indexes (Laspeyres index, Paasche index and Fisher index) in the context of agriculture. Price indices are used to monitor the changes in price levels over time.

3.3.1 Laspeyres Index

This is one of the most widely used price and quantity index methodologies. In South Africa, the official CPI is based on a Laspeyres index as well as the tractor price index. In the calculation of the Laspeyres price index, the quantities of the base time period are taken as weights, which is why this methodology is usually called the base year quantity weight method. The Laspeyres index is an aggregate index with specific weights which are prices of the base year. In production theory, the quantity indexes are of interest, therefore the prices are fixed and quantities are varied. Therefore, without having a constant weight or price, the clear effect of change in quantity will not be affected in the two periods by a change in quantity. The constant weight helps in excluding the effect of price elasticity of demand. Although the Laspeyres index is generally known for its upward bias, it is a more commonly used method than the Paasche because of its simplicity and the practicability of the use of base year weights, which do not change from one period to the next (Sancheti & Kapoor, 2005).

The Laspeyres index usually overstates the growth in real output as the current period moves further away from the base period. This occurs because of the disparity between price and quantity and price particularly in relative terms. The commodities that increase the most in quantity tend not to increase significantly in price over time. Resultantly the use of prices from an earlier period as weights exaggerates the relative significance of the fast-growing commodities over time. The second limitation of Laspeyres index is that it does not accommodate the effects of substitutions by fixing weights over time, "substitution bias" of fixed–weighted indexes. From economic theory, it is expected that as the relative prices of commodities change over time, consumers may reach the same standard of living by substituting the commodities whose prices decreased relatively for commodities whose prices increased relatively.

3.3.2 Paasche Index

Under this method, the weights are equal to the quantities or prices of the given current year, and not of the base year as in the Laspeyres index method. Under this method, new weights (price and quantity) have to be generated for each year. As such, this index continuously updates the weights to the current values that is why it is referred to as a current weighted index. This method imposes limitations in the data requirements to update weights to current values on a regular basis which may be difficult and expensive resulting in statistical bodies preferring the Laspeyres methodology to the Paasche methodology (Falzo & Lanzon, 2011). The Paasche index is generally accepted to have a downward bias.

3.3.3 Fisher index

The Fisher index is an alternative that can be used in the measurement of price and quantity indexes. The Fisher index is the geometric mean of the Laspeyres and the Paasche index. This index uses the base period prices when computing the price index. However, when computing the quantity index, base period quantities are used. The Fisher index is known to have the following merits, firstly is free from bias, it is based on geometric mean and it confirms to certain tests of consistency (Sancheti & Kapoor, 2005). The Fisher ideal index has the capacity to accommodate substitution effects and it also takes into account the weights of both the base and current periods. This is compared to fixed-weighted Laspeyres or Paasche indexes which are unable to do so. Another major benefit of Fisher ideal index over other superlative indexes, such as the Tornqvist index, is its "dual' property, i.e. a Fisher ideal price index implies a Fisher ideal quantity index, and vice versa. In other words, the product of a Fisher ideal price index between two periods and a Fisher ideal quantity index between the same two periods is equal to the total change in value.

3.4 REVISION OF THE LASPEYRES TRACTOR PRICE INDEX

A systematic process was followed to clean up the tractor price series, in which data was firstly sourced from mainly AGFACTS and other sources. The price data was obtainable in PDF format, which was then transformed into a usable format for Microsoft Excel. Data in Excel was analysed using Visual Basic for Application (VBA) and Eviews software for econometric analysis. Figure 3.2 below summarises the data processing steps.

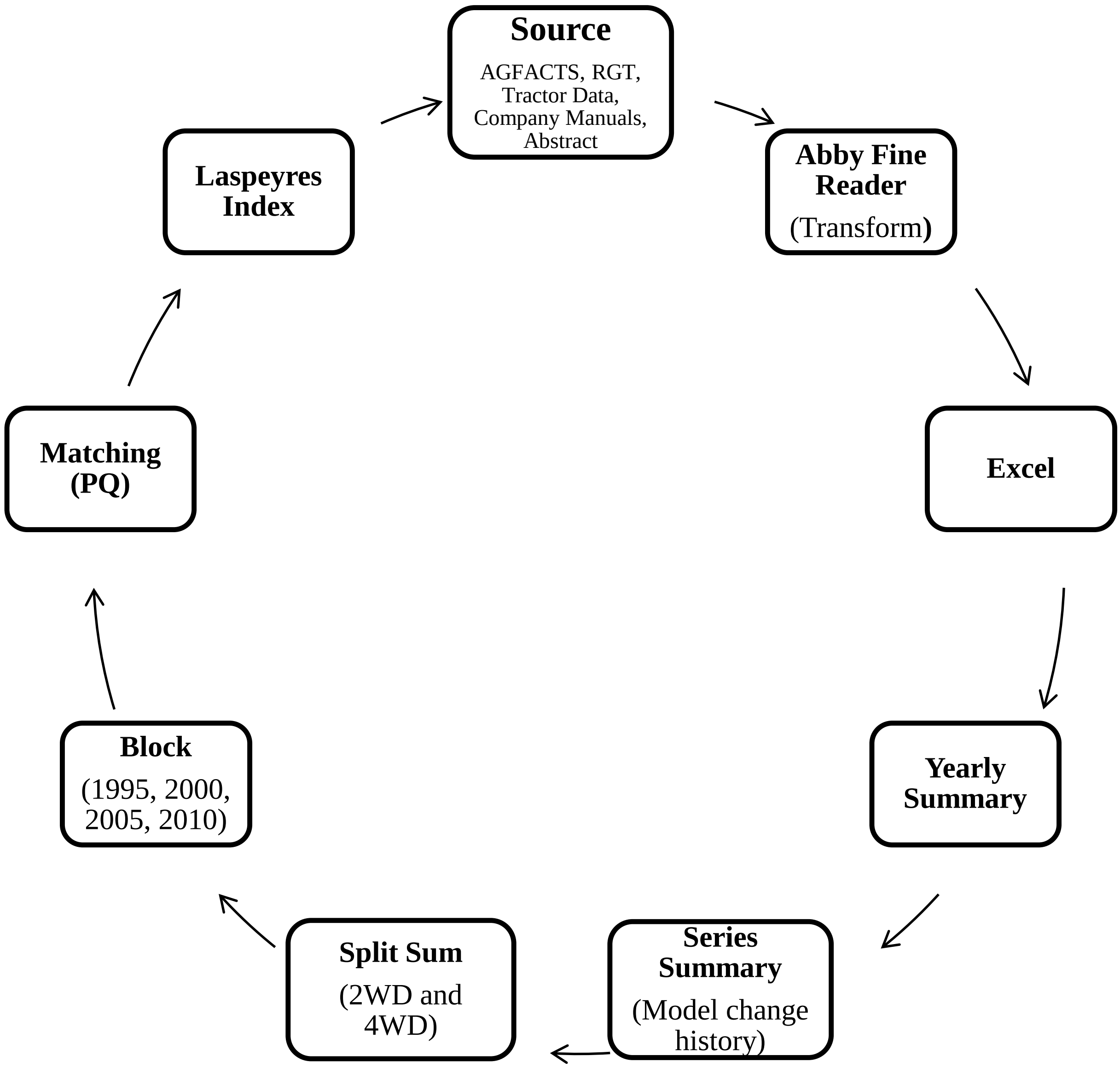

Figure 3.2: Data Processing flow chart

Source: Author

Figure 3.2 summarises the process described above to process data from the source until an index was derived. This was a repetitive process that heavily relied on industry information and updates on the data. Figure 3.2 shows the process of disaggregation on the "split sum" stage where data was summarised separately for two-wheel drive (2WD) tractors and four-wheel drive tractors (4WD). This means that all series summaries including the model change history were disaggregated by drive resulting in two separate series for the 2WD and 4WD tractors. VBA in Excel was used to analyse the data, particularly in stringing the prices for the series from 1995 to 2015, as well as splitting the analysis from 2WD to 4WD tractors.

3.4.1 Tracking model change history

In order to track price changes resulting from model changes, the model change histories in the tractor market were monitored and recorded from 1995 to 2015. An example of this change is Landini 7860 DT that changed to Landini 7865 DT in 2010. A distinction was made between a model change and a manufacturing discontinuation. In the case of a manufacturing discontinuation, a model in the same category in terms of the brand and power size was used as a replacement. This is done mainly to minimise missing prices as a result of a model discontinuation or change. Tracking the model change history is important for identifying models discontinued or lost, thus resulting in minimising assumptions. A log of the model change history was kept and consulted each time data on a model could not be traced in each year. This minimised assumptions on the price movements or replacing missing prices with the prices for models that did not necessarily replace them. This was done consistently to avoid assumptions that lead to the underestimation or the overestimation of the price index. Quantity data was obtained from RGT through AGFACTS. RGT monitors tractor sales quantities in the tractor market. The quantity data records the units sold per tractor model in each quarter of the year.

3.4.2 Reconciling price and quantity data

The tractor sales data consisted of price data collected from and quantity data from RTG. The two sources of tractor sales data had fundamental differences in terms of recording formats of the monitored models. Although both sources reported the same quarters, differences were noted in the naming of the models, for example '2WD ADE' would be 'ADE 2WD' and this happened inconsistently across amost models. RTG data did not have specific power details for each model, thus the models had to be matched with AGFACTS price data which had the power per model specified. Therefore, in order to use data from these two sources (AGFACTS and RTG), these formats had to be synchronised so that the underlying quantity data could then be matched with underlying price data. In addition to the inconsistent naming of models, some of the models sold did not have a matching price, and so the prices of the replacement model were used, although consistently sticking to the same power category in the same brand. The size of the tractors was an important variable for this analysis. As such, the following procedures were used to match the underlying price and quantity data:

i. The use of other years to obtain more information on the specifications of a model. If a price could not be found in one year, then that model would be searched for in other years. If it was found, then this would inform the power size of a tractor model. If it could not be found in other years, then details available at www.TractorData.com were used.

ii. Details at TractorData.com were triangulated with those for available models and the website showed approximately the same power categories, and therefore it was heavily relied upon for the missing models. TractorData.com is a free online data source of information on specifications of a wide range of agricultural tractors. Again, this would inform the power category so as to stick to the correct power category.

iii. An appropriate model with the same power and in the same brand would then be chosen to replace the missing match. The price of that particular model would then be used for analysis.

iv. In some cases, no matches were found at all for the price and the quantity where a model was discontinued without any further replacement. In such a case, a price trend for the same model was used to impute the missing price. The assumption used was that models from the same manufacturer would follow the same trend in terms of price changes.

Other sources of data were also consulted, for example company websites where manuals on the different models were published, and these were useful in cases where TractorData.com did not provide sufficient information.

3.4.3 Estimation of the Laspeyres index

The Laspeyres index was used to enable comparisons with the current methods used to estimate the tractor price index. Replication of this index methodology would then enable the building upon of the current methods of estimation. The year 2010 was chosen as the base period to enable comparison with current reported tractor price indexes in the Abstract. Firstly, the value of tractors sold in each base year was determined using quantity sold and the prices. In the construction of the Laspeyres index, the values of the weights were calculated as a percentage of total expenditure of the tractor basket. Only models with a share of the total basket more than 10 percent were chosen to be part of the basket in the calculation of the index. The assumption used here is that a tractor model is not preferred in the market where it is based on the expenditure of less than 10 percent of the total basket. Value-based weights were calculated across kilowatt categories, which range from Category 1 (below 20 kilowatts) to Category 15 (above 200 kilowatts). The orchards and vineyard tractors were categorised into only 2 categories, below 50 kilowatts and above 50 kilowatts. The same categorisation was made for both two-wheel drive (2WD) and four-wheel drive (4WD) tractors. Table 3.1 below summarises the different categories of tractors used to construct the tractor price index.

Table 3.1: Weighting tractor categories by kilowatts

Category	Kilowatt size	2WD Weight per category (%)	2WD Weight per category (%)
1	<20	0.3	0.0
2	20.1-30	0.6	0.4
3	30.1-40	0.8	7.8
4	40.1-50	0.5	8.5
5	50.1-55	3.9	23.6
6	55.1-60	5.5	17.3
7	60.1-70	13.6	20.5
8	70.1-80	10.0	4.2
9	80.1-90	12.6	1.0
10	90.1-100	14.1	0.0
11	100.1-110	8.9	0.0
12	110.1-120	3.7	0.0
13	120.1-150	5.6	
14	150.1-200	5.7	
15	>200	9.6	
Orchards			
0-50	1	0.4	1.9
50-100	2	4.0	14.6

Source: Author's own calculations using AGFACTS database

Using the categorisation in Table 3.1 above, the weights across categories were used to estimate the Laspeyres index for both 2WD and 2WD tractors separately. An aggregate index was constructed for agricultural tractors from 1995 to 2015 and this was compared with the Laspeyres index that is reported by the Abstract of Agricultural Statistics in 2016, using descriptive graphical illustrations as well as econometric analysis discussed in the following section.

3.5 THE REVISED TRACTOR PRICE INDEX

This section discusses the results of the re-estimated Laspeyres index of tractor prices from 1995 to 2015. Firstly, the two-wheel drive index is presented and discussed, together with the four-wheel drive index. This spilt in analysis is important for gaining insight into the different tractor markets, according to drivetrain. Lastly, an aggregate tractor price index is presented and compared with the Abstract index.

3.5.1 Two-wheel drive and four-wheel drive tractor price index 1995–2015

Figure 3.3 below shows the price index for the four-wheel drive and two-wheel drive tractors in South Africa. The rate of change in the price of two-wheel drive tractors is high from 1995 to 2010, as compared to the four-wheel drive tractors. This is consistent with the idea that the demand for two-wheel drive tractors has been low for most of the period. However, the four-wheel drive tractors' rate of price change is higher from 2010 to 2015.

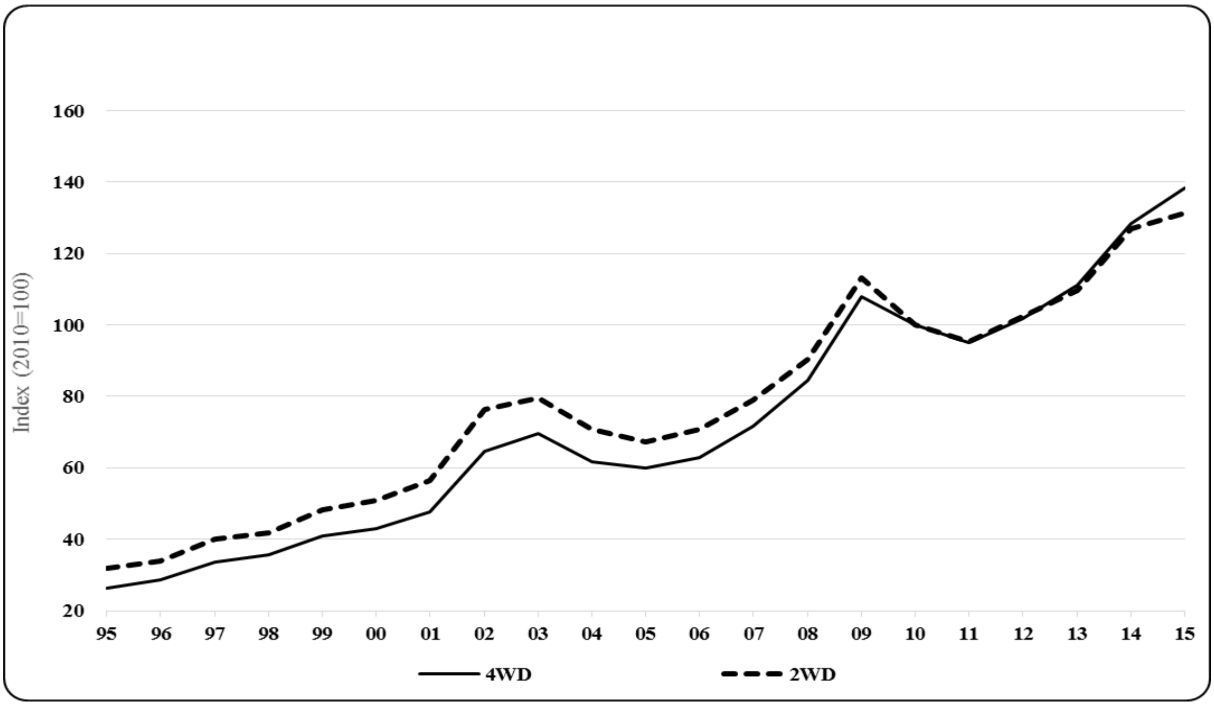

Figure 3.3: Revised Tractor Price Index 2WD and 4WD

Source: Author's own calculations using AGFACTS database

The illustration above shows the difference in price changes of four-wheel drive and two-wheel drive tractors, which is only possible to identify by disaggregating the tractors by drivetrain.

Therefore, the trends specific to four-wheel drive are separated from the two-wheel drive tractor trends, and forecasts on future price trends can be based on this disaggregated analysis.

3.5.2 Tractor price index compared with the Abstract of Agricultural Statistics

Figure 3.4 below presents the revised index of tractor prices in South Africa from 1995 to 2015, which shows a generally similar upward trend with the index reported in the Abstract, with differences which will be discussed below.

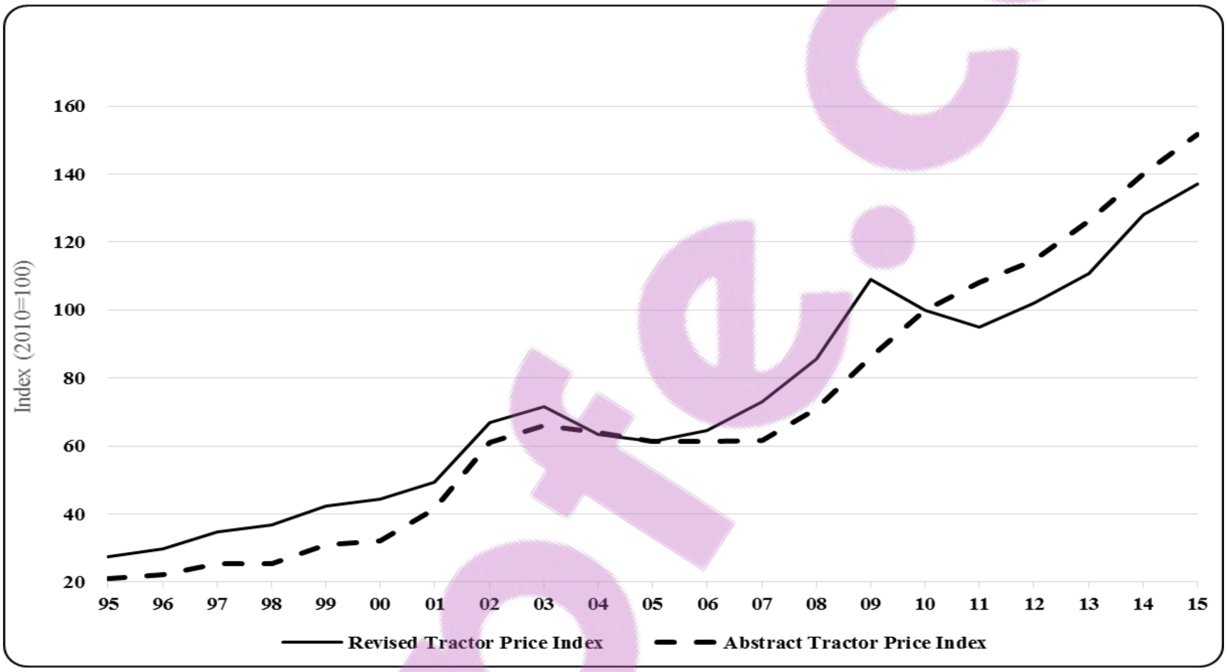

Figure 3.4: Revised Tractor Price Index

Source: Author's own calculations using AGFACTS database and Abstract

The results shown above indicate the revised Laspeyres tractor price index. However, as discussed in the various indexing methodologies in section 3.3 above, the Fischer ideal index is the most appropriate method to use, as it is free from bias. Figure 3.5 below shows the Fisher ideal index which is a geometric mean of the Laspeyres and Paasche index.

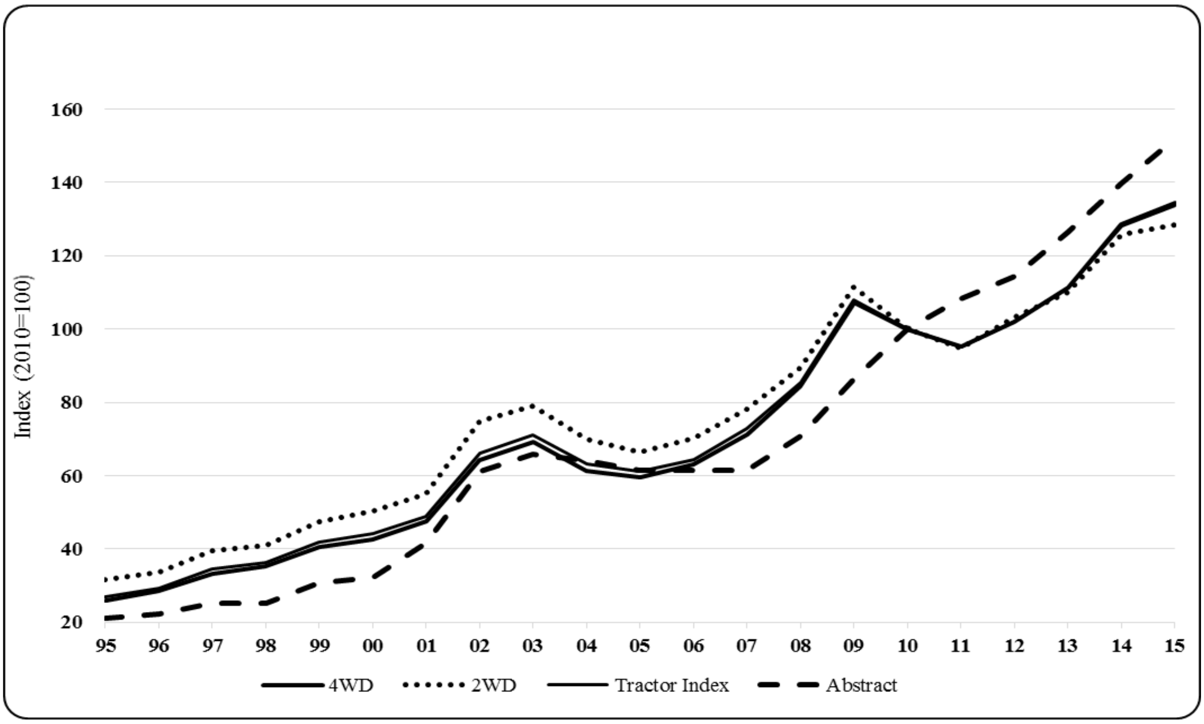

Figure 3.5: Fisher price index

Source: Author's own calculations using AGFACTS database and Abstract

The Fisher index presented above shows a similar trend to the Laspeyres index previously illustrated in Figure 3.4 above. As the Fisher index shows a similar trend with the re-estimated Laspeyres index, the analysis of the Laspeyres index in comparison with the Abstract index is discussed further. The tractor price index as reported by the Abstract 2016 starts at an index number 21, which is a lower price index in 1995 than the index number 27 estimated in this study. The trends meet in 2004 and 2005, but deviate from each other again until 2010, where the Abstract reports a higher index than the re-estimated index reported in this study. Two sets of notable price increases are observed, from 2001 to 2003 and from 2008 to 2009. These price increases are associated with movements in the exchange rate. Most items of agricultural machinery, particularly the bigger machines that AGFACTS monitors the prices of, have a very high import component, thus the prices of such items of equipment are highly dependent on the relative value of the rand against the value of the trading partners (AGFACTS, 2016).

The sharp increase in prices in 2009 is associated with the depreciation of the rand. This is because import-based manufacturers, such as John Deere, New Holland and Kubota, increased their prices due to increases in import costs. As such, prices of tractors and other equipment increased sharply, by as much as 45 percent (AGFACTS, 2016). The 2009 tractor price index differs to what is reported in the Abstract and the decline in tractor prices after 2009 is also under-played in the Abstract. Since April 2009 the rand and currencies of other prominent developing markets started to recover and slowly progressed to its current stronger trading levels. Prices of tractors and other agricultural equipment progressively reduced through this period to approximate pricing levels prior to the sharp weakening of the rand. The trend described here can be graphically illustrated as follows:

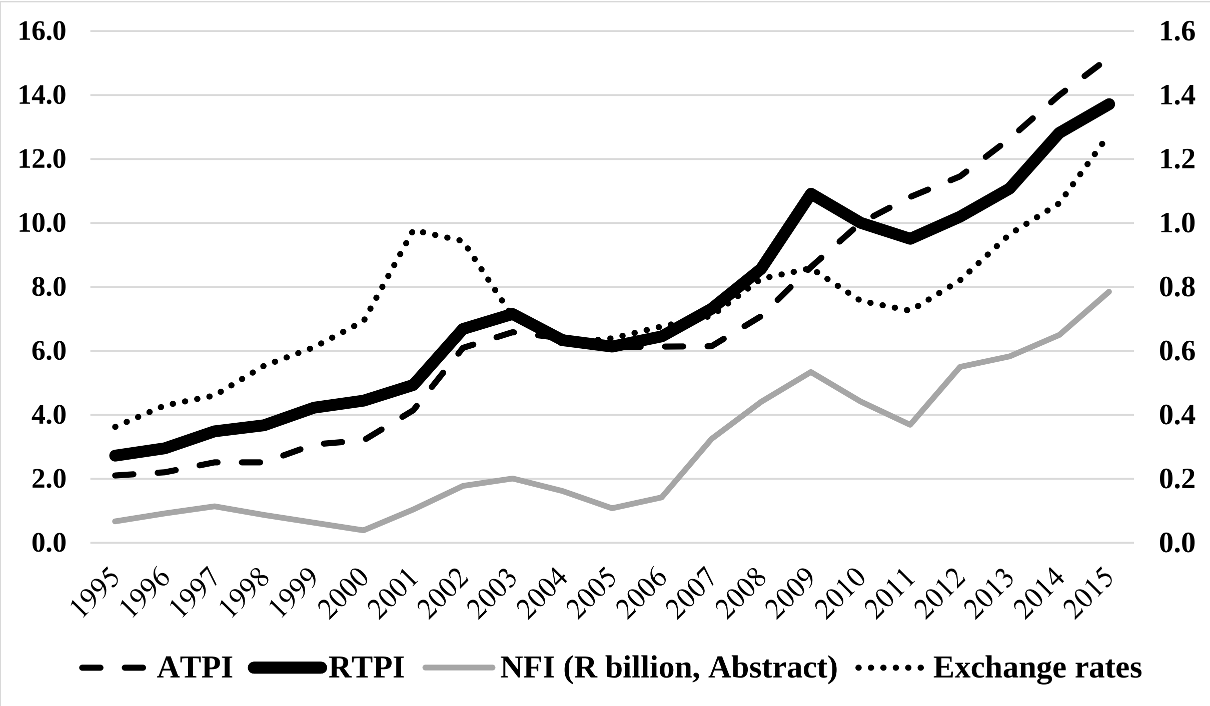

Figure 3.6: Revised Tractor Price Index and other variables

Source: Authors own calculations from various sources

Given the above, the revised tractor price index is more responsive to changes in the market than the Abstract tractor price index is. Figure 3.6 illustrates the appropriate movements in the tractor price index following exchange rate fluctuations in 2009 and the movements in net farm income. This trend is not reflected in the Abstract tractor price index which smoothed out the effect of other variables such as exchange rate and net farm income. To further test the findings of a similar but different tractor price index after revision with refined methods, a cointegration test is done between farm income and the tractor price index below.

3.6 COINTEGRATION ANALYSIS BETWEEN TRACTOR PRICES EXCHANGE RATE AND NET FARM INCOME

The previous section illustrated the difference made by an improved tractor price index. The improved tractor price series will be tested using cointegration analysis. Even though the time series used in this study is very limited annual data from 1995 to 2015 which amounts to 20 observations, time series analysis was used to test the usefulness of the revised tractor price index. Establishing long-term relationships in different economic variables through cointegration provides insight into the long-run relationship between the variables. Cointegration is a time series concept that is used to measure long-term relationships between economic variables (Ahmed, Islam & Sukar, 2009). Cointegration analysis has been used in different economic applications, as well as in finance. For example, in the permanent income model, cointegration implies long term relationships between income and consumption. Similarly, in economic growth theories, cointegration explains relationships between money, income, prices and interest rates while in growth theory models cointegration between relationships income, consumption and investments (Zakrajsek, 2009).

The equilibrium relationships established in these economic theories are referred to as long-run equilibrium relationships. On the other hand, in finance, cointegration is used in as a high frequency or low frequency relationship where in high frequency, cointegration is motivated by arbitrage arguments. The economic theory in question is, therefore, the law of one price which states that in an efficient market there must be, in effect, only one price of such commodities regardless of where they are traded. It relates to the impact of market arbitrage and trade on the prices of identical commodities that are exchanged in two or more markets. Similar arbitrage arguments imply that there exist cointegration between spot and future prices, spot and forward prices, bid and ask prices.

Cointegration has been mainly applied to variables that are fundamentally related, for example, cointegration tests have been applied to determine the existence of long-run relationship between oil prices and energy sector equity indices (Constantin & Cernat-Gruici, 2001) or oil price and US inflation by Ahmed, Islam and Sukar (2009). While Florkowski and Lai (1997) test for the existence of cointegration among pecan nuts prices and other edible nuts. In testing market integration and convergence in the European Union (EU) machinery and equipment industry, Jorgensen and Persson (2013) tested the law of one price in different countries in the EU, with a specific focus on agricultural tractors.

In South Africa, there have been various applications of cointegration analysis in agriculture, particularly in assessing equilibrium relationships that are useful for policy formulation in South African agriculture. Abidoye and Labuschagne (2013) explain the relationship between domestic maize price in South Africa and world maize prices to establish co-movement and transmission of world prices in sub-Saharan African countries. Chisasa and Makina (2015) investigated the relationship between bank credit and agricultural output. Among other results, they found that in the short term, capital formation has a positive and significant influence on agricultural output, with a rapid adjustment to equilibrium. As such, this necessitates an investigation into farm income and agricultural tractor prices because farm income is positively related to agricultural output, while tractor prices are related to capital formation. The validation of the tractor price index measurement methodologies is therefore necessary because of the problems associated with the estimation of indexes.

The unit root testing for stationarity, the Johansen multivariate cointegration in order to test the existence of a long-term relationship between the tractor price indexes and net faming income are performed in this study. The Augmented Dickey-Fuller (ADF) is performed to test for unit roots (Dickey & Fuller, 1979) in the tractor price index as published in the Abstract of Agricultural statistics, the revised tractor price index, exchange rate and the net farm income in agriculture. The Johansen cointegration test (Johansen, 1988; 1992) is used to determine the rank of the cointegrating matrix in the price series. Cointegration describes a long-run, or equilibrium relationship between the variables (Lütkepohl, 2005). This definition makes cointegration an ideal analysis technique to ascertain the existence of a long-term relationship between the tractor price index and net farm income.

3.7 TESTING FOR STATIONARITY SERIES

Table 3.2 shows the Augmented Dickey-Fuller (ADF) tests for a unit root. The test is done to test stationarity of the price series, in level as well as in differences. The null hypothesis for this test was that there is a unit root process. The result of the test showed that all the variables, namely net farm income, the tractor price index reported by the Abstract, and the revised tractor price index, have a unit root process in level (i.e. accepting the null hypothesis). However, after differencing the data, exchange rate, farm income and the revised tractor price index were stationary, that is, they are of order one (I(1)), while the Abstract tractor price index became stationary after differencing it for the second time, meaning it is integrated of order two (I (2)). Testing for stationarity among data series is a precondition for evaluating the existence of a long-run relationship among variables. The consequence of differencing is a loss of data and effective explanation about the long-run relationships among series; however, the loss of data and effective explanation of the long-run relationship can be handled by estimating the error correction model.

Table 3.2: ADF Unit root test including trend and intercept

Variables	At Level		First Difference	
	t-statistic	Critical values	t-statistic	Critical values
Real Net Farm income (Real NFI)	-1.46	-4.66	-4.46***	-3.85
	(0.79)	-3.73	(0.002)	-3.04
		-3.31		-2.66
Abstract Tractor Price Index (ATPI)	-1.84	-4.53	-3.16	-4.57
	(0.64)	-3.67	(0.12)	-3.69
		-3.27		-3.28
Revised Tractor Price Index (RTPI)	-3.05	-4.35	-4.27**	-4.66
	(0.06)	-3.67	(0.01)	-3.73
		-3.27		-3.31
Exchange Rate (ExRate)	-1.02	-3.83	-2.31	-2.69
	(0.72)	-3.03	(0.02)**	-1.96
		-2.65		-1.61

*** t-stat significantly different from 0 at 1 %, ** t-stat significantly different from 0 at 5 %, * t-stat significantly different from 0 at 10 %

Source: Eviews output

Given the results shown in Table 3.2 above (detailed in Annexure G), exchange rates (Exrate), net farm income (NFI) and the revised tractor price index are (RTPI) stationary at first differences, meaning that they are integrated of the same order and therefore a cointegration test can be conducted to test the existence of a long-run relationship between exchange rates, farm income and the revised tractor price index. However, a cointegration test cannot be performed on exchange rates, net farm income and the Abstract tractor price index (ATPI) because, by definition, an I(1) process and I(2) process do not have a cointegrating relationship.

A Johansen cointegration test was conducted for exchange rate, net farm income and the revised tractor price index, with results as follows:

Table 3.3: Johansen cointegration test using Trace Statistic

Eigen Value	Trace statistic	5% Critical value	Prob	Hypothesised No of CE(s)
0.92	63.02	29.82	0.0000	None
0.67	19.03	15.49	0.01	At most 1
0.01	0.17	3.84	0.68	At most 2

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

Source: Eviews output

Table 3.4: Johansen cointegration test using Max-Eigen Statistic

Eigen Value	Max-eigenvalue statistic	5% Critical value	Prob	Hypothesised No of CE(s)
0.92	43.98	21.13	0.000	None
0.67	18.86	14.26	0.008	At most 1
0.01	0.17	3.84	0.68	At most 2

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level

Source: Eviews output

The Trace statistic and Max-Eigen statistic indicates 2 cointegrating equations between exchange rates, net farm income and tractor prices series. Therefore, the null hypothesis of no cointegration at $r = 0$ is rejected and accept that there is $r = 2$, where H_A: $r = 0$ ($0.17 < 3.84$) for both Trace and Max-Eigen statistics, at 5 percent level of significance. Given that the Abstract tractor price index, exchange rates and net farm income did not have a cointegrating relationship, cointegration tests were sufficient to show the limitations in measurement of the Abstract tractor price index in comparison with the revised tractor price index.

3.8 GRANGER CAUSALITY TESTS

In order to establish the direction of causality, a pairwise granger causality test was performed on the variables exchange rate, net farm income and revised tractor price index. The granger causality test is important in showing the direction of causality and the results of this test are shown on Table 3.5.

Table 3.5: Granger Causality Test Results

Dependent Variable	D(RTPI)		
	Chi-square	**df**	**Probability**
D(NFI)	8.95	2	0.01
D(EXRATE)	5.33	2	0.06
All	11.98	4	0.01

Source: Eviews output

Table 3.5 shows that both net farm income and exchange rate Granger cause the revised tractor price index as we reject the null hypothesis that exchange rate and net farm income do not Granger Cause the revised tractor price index with a p-value of 0.01 for net farm income and 0.06 p-value for exchange rate. This confirms the theoretical expectations that net farm income and exchange rates drive tractor prices in South Africa and can therefore be used as leading indicators in the tractor market. In addition to the Granger causality tests, the variables were also tested for multicollinerity, one of the classical linear regression model assumptions which ensures independence of the individual regressors included in the model. This means that net farm income and exchange rate have unique and independent influence on tractor prices and that they are not highly correlated. Using the variance inflation factor (VIF) there was no multicollinearity between the regressors as the VIF statistic was less than 10.

3.9 CHAPTER SUMMARY

In summary, this chapter tests the validity of the current tractor price index by estimating the Laspeyres index, using underlying quantity data as far as possible. This process minimises the use of assumptions in estimation. Thus, although the two aggregate tractor index graphs show the same upward trend in the price changes, the details of the extent of the price changes are ignored in the index of the Abstract of Agricultural Statistics, for example the effect of the exchange rate in 2009. Cointegration analysis is used to evaluate the existence of long-run relationship between the exchange rate, net farm income and the tractor price index in South Africa. Contrary to practical expectation, the tractor price reported in the Abstract does not show a cointegrating relationship with exchange rates and net farm income and tractor prices. The fact that the Abstract tractor price index is an I(2) process, and is therefore not cointegrated with exchange rate and net farm income, affects analysis with other variables that inform policy recommendations on the dynamics of the tractor market in South Africa.

In South Africa, a significant amount of resources has been invested in collecting data on the tractor market. No effort has, however, been invested in validating the current methods of constructing a precise tractor index in South Africa and exploring the existence of any long-term relationships between tractor prices and net farm income. This analysis provides evidence of the difference that exists when underlying price data is used to construct a tractor price index using disaggregated data by drivetrain and power categories, and by tracking the model change history of tractors. Differences are seen in the estimation of the price index to that used in the Abstract and that estimated in this analysis. This study recommends that resources be allocated to monitoring the changes that take place in the tractor market, particularly the model change history. Tracking the model change history enhances the use of underlying price and quantity data and ultimately minimises assumptions made in estimation of the value of machinery and implements.

The tractor price index is relevant to the prices of agricultural tractors that are sold on the market. The importance of a tractor price index is then to forewarn the farmers of the changes taking place in the tractor market. This implies that any imprecision in the measurement of tractor price index misleads farmers and other stakeholders that analyse movements in the tractor market. In the Mechanisation Support Policy framework of DAFF, mechanisation support in the form of inputs such as tractors and implements would be provided by the government to farmers. Despite the problems that are known to exist with this policy, the initial budgets for the implementation of such a policy are based on appropriate indicators, such as the tractor price index, to inform decision-making on input costs. Imprecision in the measurement of the tractor price index results in wrong conclusions being made in capital input use analysis in the valuation of inputs, and ultimately in productivity analysis.

The existence of a cointegrating relationship between the revised tractor price index and net farm income is useful for managerial purposes. The revised tractor price index provides business intelligence the tractor market. Given the Granger causality test results, exchange rate and net farm income can be used as leading indicators of the tractor prices. This is important for forecasting as these are measurable indicators of future trends in the market. The noted imprecision in the measurement of the tractor price index therefore means that the valuation of machinery investment is also flawed. This is because investment is a product of price and quantity. This will be further investigated in the next chapter.

CHAPTER 4[3]:
THE REVISED MACHINERY INVESTMENT SERIES

4.1 INTRODUCTION

Given the flaws in the evaluation of tractor prices and the failure to incorporate the evolution of tractorisation in reporting and monitoring of machinery and implements discussed above, the estimations of the capital investment series for South African commercial agriculture remain questionable. The valuation of the capital investment series is derived from price and quantity data, and if they are not well documented to reflected reality, then the resulting imprecise capital valuation will have a direct impact on productivity analysis, which is a measure of performance in the sector. Productivity is defined as a ratio of output to input. It can be calculated using total quantity or total value of output and input. Capital is part of the other production inputs that form part of the input denominator of the Total Factor Productivity (TFP) formula:

$$TFP = {}^{Y}/_{X} \quad \text{……………………………………………………………Equation (4.1)}$$

Equation 4.1 above shows a simplified TFP ratio where Y is a share-weighted average of all outputs, and X is a share-weighted average of all inputs. This representation shows that in the estimation of productivity, if X is underestimated, it results in the overestimation of TFP, and if X is overestimated, TFP is underestimated. Where data is unavailable, precision in estimation remains questionable and thus the use of assumptions results in mismeasurement of the capital input account. To minimise the incidence of this mismeasurement, precision is required in capital measurement. Accurate measurement of the capital input account will inform studies that estimate returns to research, an objective that remains unfulfilled in most research institutions, as well as in most research analysis in agricultural research performance in South Africa. Policy on capital formation is important for assessing capital requirements, the formulation of principles that govern savings, tax policies and the mobilisation of capital for productive investments, and also for ensuring the optimisation of productivity.

[3] This chapter was published in an accredited journal: Colleta Gandidzanwa and Frikkie Liebenberg, 2016. Towards a new capital formation series for machinery in South African agriculture. *Agrekon* 55(3): 216-23

Capital investment is also an important statistic in the national accounts in the derivation of net farm income and net agricultural value added. The effect of the increasingly invalid estimates of capital formation in machinery and equipment can be clearly seen in the poor correlation between net farm income and capital formation in South African agriculture. Theory suggests that net farm income from capital gains should be correlated with the investment in capital, which impacts capital formation. In addition, net value added, defined as the value of output less the values of both intermediate consumption and consumption of fixed capital, is also underestimated owing to capital mismeasurement. The value of consumption of fixed capital is an important item in GDP and in gross value added by sector or industry. It is also referred to, in the literature, as depreciation or capital consumption allowance (OECD, 2009). Net value added is a more accurate and broader indicator of the farm sector's total output, since it reflects the contribution of all factors of production, regardless of the form of ownership. It reflects agriculture's contribution to national economic product. In the system of national accounts, net value added represents agricultural contribution to the overall economic activity (Erickson, Blank, Moss & Mishra, 2004). For the reasons outlined above, it is important to evaluate and correct the measurement of capital in South African agriculture.

Attempts to measure capital in South Africa have been seen in productivity measurement studies, but they have their limitations. The national aggregates used by Thirtle *et al.* (1993) limits analysis and results in the invalid assumption that on-farm assets are homogeneous in terms of age and unit value (Liebenberg, 2013). Star (1974) shows that pre-aggregated data may be used only if all of the inputs in the class are growing at the same rate or are perfect substitutes for one another, that is, if they are homogenous. Homogeneity implies that marginal rate of substitution is constant and the units of measurement are chosen in a manner that meets equi-marginal principle of production (marginal products of every unit are equal). To minimise these shortcomings of pre-aggregated data, disaggregated data should be used.

One of the data problems outlined by Liebenberg (2013) is that the full ranges of inputs were not included in the censuses. It therefore remains unclear how estimates of the investment in farm machinery and equipment was developed by the Department of Agriculture. Representativeness of agricultural census since 1993 is non-existent. Both the Department of Agriculture and statistical services, such as the South African Reserve Bank and Statistics SA, have resorted to using the estimates computed by AGFACTS. Liebenberg (2013) observes that estimates of investment in machinery and implements were based on a value imputed from the value of tractor sales since 1994. The value of tractor sales is not based on actual observations. Confounding the matter is the fact that the value of tractor sales is also an estimate. Moreover, given the changes that have taken place in on farm tractorisation, the proportional basis for imputing the overall sales value of machinery requires revision as it is outdated.

The fixed rate for imputing the overall sales value of machinery used since the mid-1990s has led to current data on capital formation in agriculture being increasingly imprecise. Up to 1994, the total value of tractor, machinery and implement sales exhibited a similar, but not perfectly correlated, trend. The perfect correlation between tractor sales and other machinery and implements sales is clear from 1994, but fails to reflect, for example, the change to minimum till and precision agriculture, as is so often reported on. Figure 4.1 below highlights the problem discussed here.

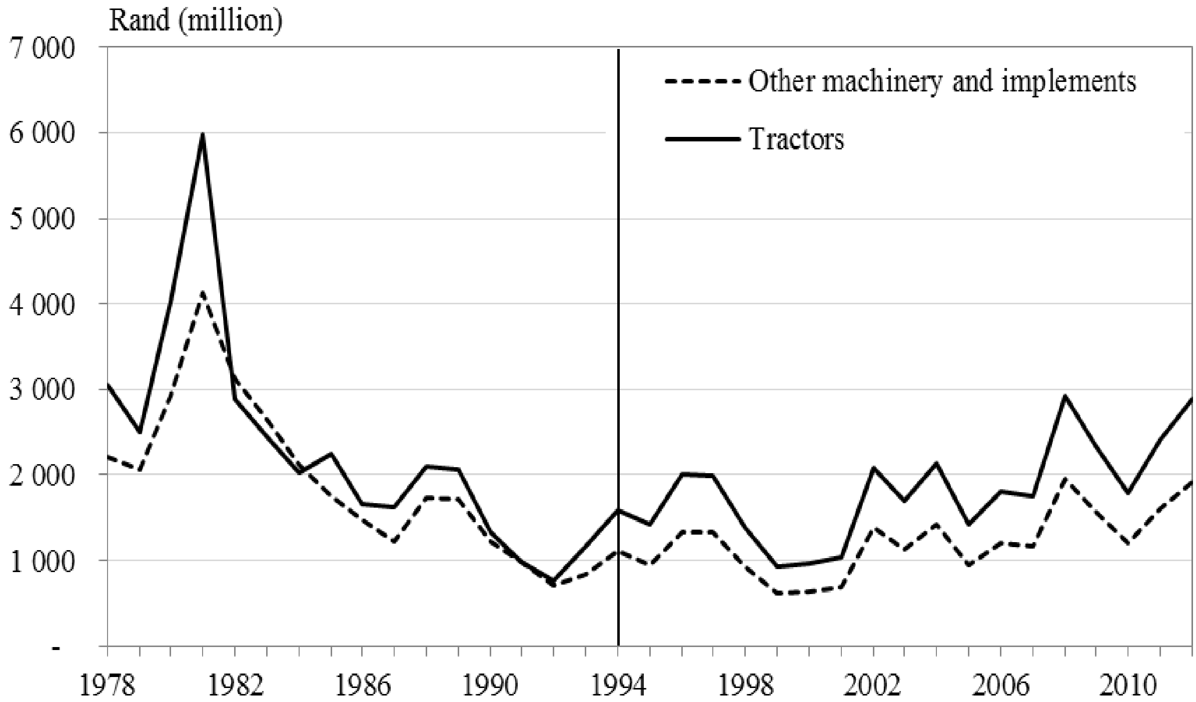

Figure 4.1: Real sales value for machinery inputs in South African agriculture, 1978 - 2015

Source: Liebenberg (2013); AGFACTS (2013)

Figure 4.1 shows a perfectly correlated trend of tractor sales to the rest of the machinery and implements sales since 1994, which in effect ignores the actual evolution of tractorisation. This undermines the validity of the estimates of investment in machinery that national agricultural statistics has reported in the capital formation account, and subsequently affects all analysis based on that. The problem originates from the lack of information on the changing nature of tractorisation in South African agriculture since 1994 when the Survey of Machinery Sales ceased and AGFACTS started monitoring this. Liebenberg (2013) used the proportions that prevailed on "implement sales shares" in 1994, which effectively fixed the nature of tractorisation to what it was in the 1990s. By sourcing data on the units sold (monitored by AGFACTS, but not reported) and using this in the analysis, it is possible to better reflect the nature of tractorisation in the estimated flow of services from capital equipment. Even though the sampling basis of the agricultural censuses qualifies them as surveys, the structural information can be used to approximate the changing nature of tractorisation in the machinery sales estimates. As discussed, the changing nature of collecting both survey and census data is increasingly becoming an aggregate basis of reporting.

4.2 RE-ESTIMATING THE TRACTOR SALES VALUE

The tractor sales value is used to estimate the overall machinery sales value. However, the tractor sales value itself is an estimate, in that a numeraire midpoint in kilowatts per category is multiplied by the price per kilowatt to derive the value of tractor sales. This study tests the use of underlying price and quantity data instead of a standard numeraire to get to the value of machinery and implements sales. This study hypothesises that the current methodology used to determine the total sales value of machinery is flawed. Building on the work of Liebenberg (2013), data was disaggregated by drive and then by power size (Chapter 2 and Chapter 3), instead of using totals per class. From 1995, the basis for estimating the value of tractor sales (TSV) was revisited as a first step towards revisiting the machinery and implements value. Instead of calculating the value of aggregate unit sales per size category, this study hypothesises that it would be more accurate to do this by doing the analysis for 2WD and 4WD tractors separately. The revision of the national capital series was estimated from 1995 to 2015, the years in which disaggregated data was available.

Since the value of tractor sales is used as a proxy to estimate the value of overall machinery sales, the revision of the machinery and implements estimation starts by firstly disaggregating tractors by drive and then by power size. The value of tractor sales was determined through the use of underlying price and quantity data, instead of numeraire price, and the results of that estimation are presented in Table 4.1 below.

Table 4.1: Nominal value of tractor sales in million Rand per year

Year	2WD	4WD	Revised Tractor Sales Value	AGFACTS Tractor Sales Value	Difference	%Difference
1995	188.5	466.0	654.6	687.0	32.4	4.7
1996	252.6	751.0	1 003.6	1 048.8	45.2	4.3
1997	240.0	839.8	1 079.8	1 124.0	44.2	3.9
1998	185.2	634.9	820.2	844.0	23.8	2.8
1999	113.7	460.4	574.1	618.0	43.9	7.1
2000	106.4	519.2	625.7	678.0	52.3	7.7
2001	127.0	596.2	723.2	793.0	69.8	8.8
2002	204.7	1 467.2	1 671.9	1 764.0	92.1	5.2
2003	212.9	1 480.5	1 693.5	1 520.0	-173.5	-11.4
2004	263.4	1 681.2	1 944.6	2 026.0	81.4	4.02
2005	253.3	968.5	1 221.8	1 426.0	204.2	14.3
2006	320.5	1 488.2	1 808.7	1 933.0	124.3	6.43
2007	292.5	1 708.6	1 744.7	2 014.0	269.3	13.3
2008	384.9	3 269.2	3 654.2	3 655.7	1.6	0.04
2009	317.0	3 035.5	3 352.5	3 147.7	-204.8	-6.51
2010	300.0	2 179.3	2 479.3	2 594.3	115.1	4.43
2011	380.7	3 078.2	3 458.9	3 780.7	321.8	8.51
2012	447.3	4 231.9	4 679.3	4 538.8	-140.4	-3.1
2013	383.6	4 413.8	4 797.5	4 846.3	48.9	1.0
2014	382.9	4 337.7	4 720.6	5 341.9	621.4	11.6
2015	406.9	4 157.7	4 564.6	5 180.3	615.7	11.9

Source: AGFACTS (2015) and Author's own calculations

Table 4.1 above shows the revised value of tractor sales, compared with the AGFACTS estimations. These two methods do not differ significantly, as is shown in the table above. However, the variation in the different estimations is between -11.9 percent and 14.3 percent , where -11.4 percent represents a year in which AGFACTS understates the value of sales, and 14.3 percent indicates an overestimation in the value of tractor sales, which shows inconsistency in the measurement tool.

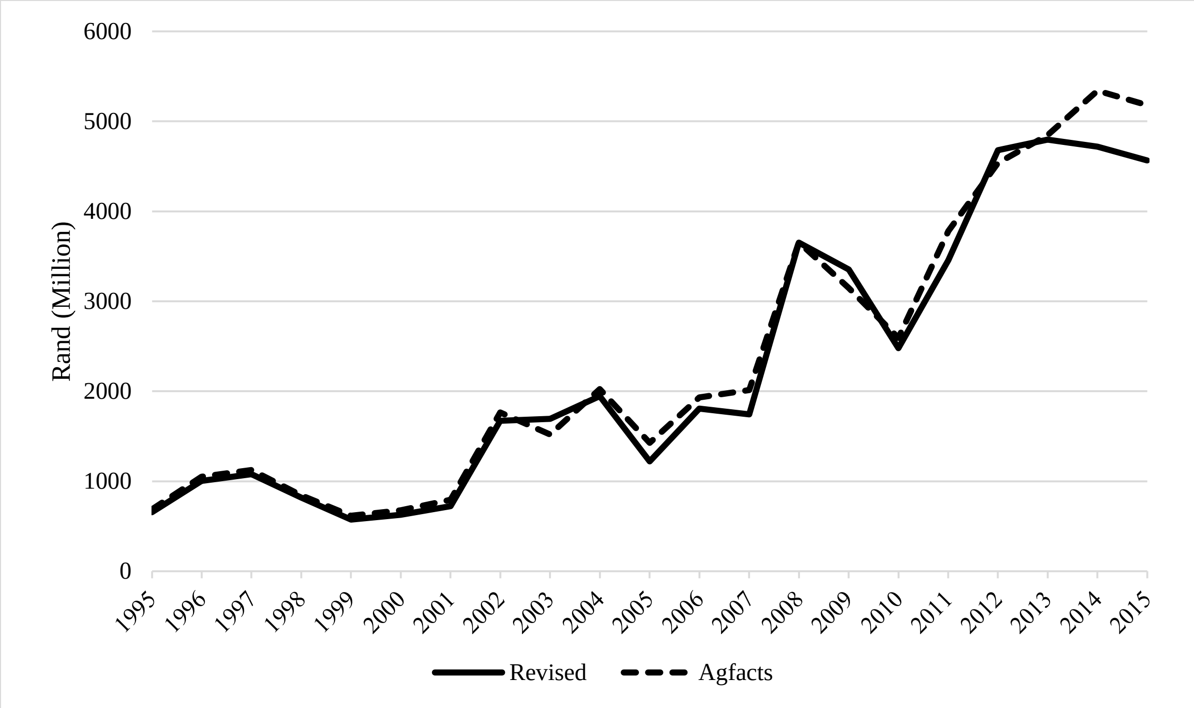

Figure 4.2: Revised and current overall tractor sales value in nominal terms

Source: AGFACTS (2015) and Author's own calculations

The differences shown above are an indication of the flaws that exist in the measurement of tractor sales value that result from a failure to use underlying price and quantity data. Flaws in the estimation of the value of tractor sales affect the overall machinery sales, since tractors are used as a proxy to estimate the rest of machinery and inputs in South Africa. As such, the second flaw in the measurement of machinery sales value would result from the use of the share of the tractors to overall machinery sales value which is questionable. The cumulative effects of these measurement differences are discussed below.

4.3 REVISITING THE BASIS FOR CALCULATING MACHINERY AND IMPLEMENTS VALUE

Given the revised value of tractor sales above, this section investigates the use of the tractor sales value to estimate the value of machinery and implements. As discussed in the problem statement, the total expenditure on agricultural machinery is imputed using the relative share of tractor sales at a constant rate of 60 percent to the total machinery sales. This methodology is problematic in that the ratio of tractor sales to the value of machinery does not necessarily remain constant over a given time period. Liebenberg (2013) illustrates that the Census reports since 1984 indicate that the share of tractor sales to the total sales could vary between 38 percent and 80 percent. This means that the basis for calculating overall sales of machinery requires amendment.

In order to trace the changes in the proportion of tractors to overall machinery sales, data on capital expenditure and machinery sales was sourced from the Survey of Agricultural Mechanisation Sales reports from 1978 to 1994. This survey was first conducted in 1968, but the scope of the sample made use of is only valid since the mid-70s. The Agricultural Census/Survey capital expenditure data from 1978 to 2012 was also used for comparison purposes. The analysis intentionally begins in 1978, the year in which the sample and data collection methods of the Survey of Agricultural Mechanisation Sales began to stabilise (Liebenberg, 2013). AGFACTS Agricultural Machinery sales data from 1994 to 2012 was used.

The analysis starts by establishing how the 60 percent ratio of tractors to overall machinery sales was computed, using different baskets of machinery sales statistics from the Survey of Agricultural Mechanisation Sales of 1994. This is then compared with the Agricultural Census/Survey data for the same time period to evaluate the nature of change of this ratio. Using sales data available from AGFACTS, the effects of varied ratios to form a new investment series from 1995 to 2012 are measured. Therefore, instead of using a fixed ratio of tractors to the rest of the machinery basket, a varied ratio calibrated against the Agricultural Census/Survey statistics on capital expenditure. This was used to re-estimate the total value of machinery sales, and the difference was evaluated.

Having revised the sales value of tractors, the ratio used to impute the overall machinery sales (MSV) was adjusted, only using information available from successive Agricultural Census and Survey Reports. The Residual of the MSV minus TSV would then form the basis upon which estimation of the trend in implement sales would be done. The process envisaged was to construct a sales value series for each of the implement categories AGFACTS monitors. This objective seeks to answer questions on the methodology used to value the machinery and implements series. Therefore, instead of using a constant ratio of tractors to the rest of machinery and implements from 1994, a varying ratio is used to impute the value of other machinery and implements.

4.4 COMPOSITION OF MACHINERY AND EQUIPMENT

This section determines the exact composition of the basket of machinery and equipment that resulted in 60 percent share of tractors to total machinery sales, using the Survey of Agricultural Mechanisation Sales report of 1994. The historic trend in the share of tractor sales is then reviewed, using information of earlier Survey of Agricultural Mechanisation Sales reports since 1978. Comparisons of the ratios based on the Agricultural Census/Survey to the ratios based on the Survey of Agricultural Mechanisation Sales reports are then presented and the measurable impact is derived.

4.4.1 Spending on tractors as a share of the basket of machinery inputs monitored by the Survey of Agricultural Mechanisation Sales, 1978-1994

Table 4.2 below lists the types of machinery, in addition to tractors, that were monitored in the Survey of Agricultural Mechanisation Sales reports, ranked by the value of sales in 1994. The four categories that are currently still monitored by AGFACTS are tractors, harvesting equipment, planters, hay and silage equipment. The remainder of the categories represent input type categories that used to be either consistently included in the survey or categories that were periodically included in the survey. To test which input categories were included in the basket with tractors to arrive at the 60 percent share of tractors, the share of tractors was calculated against a cumulative profile of inputs. Starting from the top of Table 4.2, the changing ratio of tractors to a particular profile of machinery and implements is shown with additional input until all inputs are included in the profile. For example, the ratio of tractors in a profile that consists of agricultural tractors, harvesting equipment, hay and silage machinery and planters is 75 percent.

Table 4.2: Spending on tractors as a percentage share of the expanding profile of machinery inputs, 1978-1994

Machinery and implements	**1994**
	Share of tractors in expanded machinery profile (%)
Rotavator	58.7
+Sugar equipment	58.8
+Equipment not classified but sold & figures not available	59.5
+Forestry equipment	60.7
+Grain dryers grain handling equipment	64.8
+ Potato equipment	65.0
+ Diverse equipment for animal handling	65.3
+ Earth moving equipment loaders	65.7
+Trailers	66.1
+Tine implements cultivators	66.8
+ Mouldboard plough, disk plough, disk harrows	68.2
+ Feed mixers	69.6
+ Plant nutrition and pest control equipment	72.2
+ Planters	75.0
+ Hay and silage machinery	79.2
+ Harvesting equipment	84.7
+ Tractors	100
+Tobacco equipment	N/A
+Milking machine systems	N/A
+Refrigerated farm milk tanks	N/A
+Peanut & edible bean harvesting machinery	N/A
+Stationary diesel engines	N/A
+Hammermills	N/A
+Animal waste handling equipment	N/A

Source: *Compiled from the Survey of Agricultural Mechanisation Sales Reports (1978-1994)*

Notes: N/A = machinery and implements figures not available/not monitored in 1994

Table 4.2 shows that 60 percent is more or less reached when all types of equipment are added to the profile. However, it is possible that the 60 percent ratio used by AGFACTS is based on the proportion of tractors in the whole basket (58.7 percent), but rounded up to 60 percent for ease of use. Information on how this ratio was derived was never recorded, and therefore it is uncertain what combination of machinery and implements resulted in the exact 60 percent ratio.

4.4.2 Comparing the Survey of Agricultural Mechanisation Sales and Agricultural Census/Surveys

A comparison of the trend in the share of tractors to overall machinery sales was done using data from both the Agricultural Census/Survey reports and the Survey of Agricultural Mechanisation Sales to evaluate the validity of the use of a constant ratio, as has been done since 1994. Figure 4.3 below illustrates the different trends in the share of tractor sales to the total machinery sales for the period 1978 to 2015.

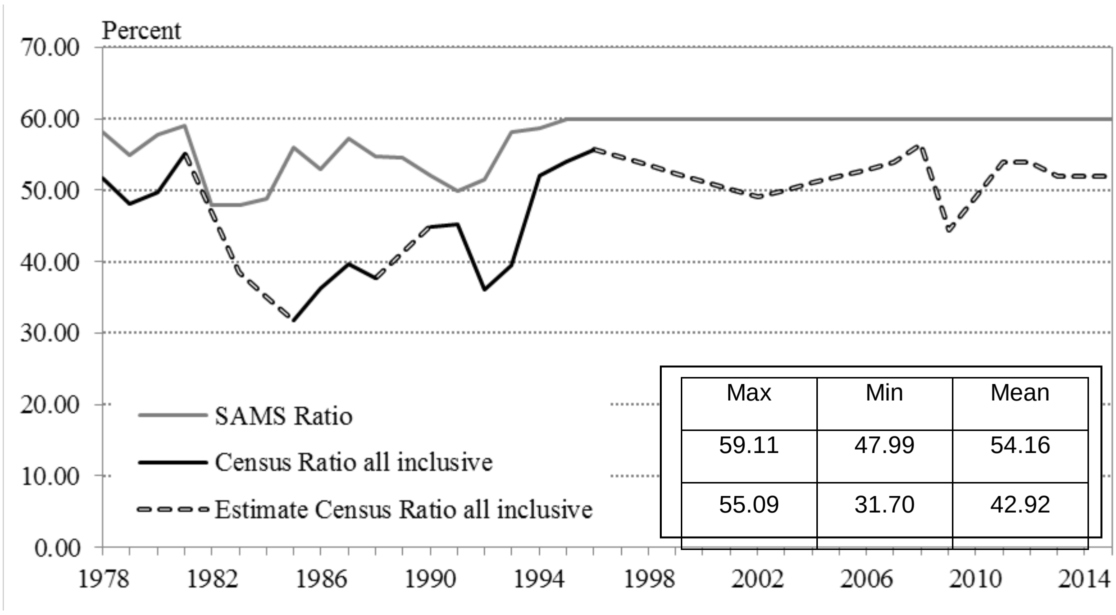

Figure 4.3: Comparative share of tractors to a different basket of machinery inputs

Source: *Survey of Agricultural Mechanisation Sales and Agricultural Census/Survey data (1978-1994)*

Notes: SAMS Ratio: Share of tractors to total machinery sales monitored by SAMS
Census Ratio all inclusive: share of tractors to expenditure on all new machinery

Figure 4.3 shows that, on average, the census-based share of expenditure on tractors to overall machinery expenditure is about ten percent lower than the share derived from the data of the *Survey of Agricultural Mechanisation Sales.* The ranges between the observed minimum and maximum values of the two series also differ substantially. Using the sales data, the share varied between a maximum of 59.1 percent (1981) and a minimum of 47.9 percent (1983). The shares, based on census data, also show a maximum of 55.1 percent in 1981, but it reached a minimum of 31.7 percent in 1985. Three observations can be made from the trends presented in Figure 4.3. Firstly, there are loose relations between the shares estimated using the two sources. Secondly, estimates derived from sales data are less variable, compared to estimates from the census data. Lastly, the composition of the aggregate of capital expenditure on machinery may be variant and require further analysis. Though it is assumed that a constant share of tractors to machinery and implements is 60 percent, the ratio of tractors to overall machinery sales is not constant, as shown by the estimates from the census ratios since 1995.

4.5 REVISED MACHINERY INVESTMENT SERIES 1995-2015

Using the AGFACTS sales data from 1995 to 2015, the revised tractor price index to deflate the investment series and projecting the trend in the variant ratios from the census and survey reports to impute the value of overall machinery sales, yields a different level of investment in machinery when compared with the fixed ratio estimates of AGFACTS. The results are shown in Figure 4.4 below and Table 4.3 below.

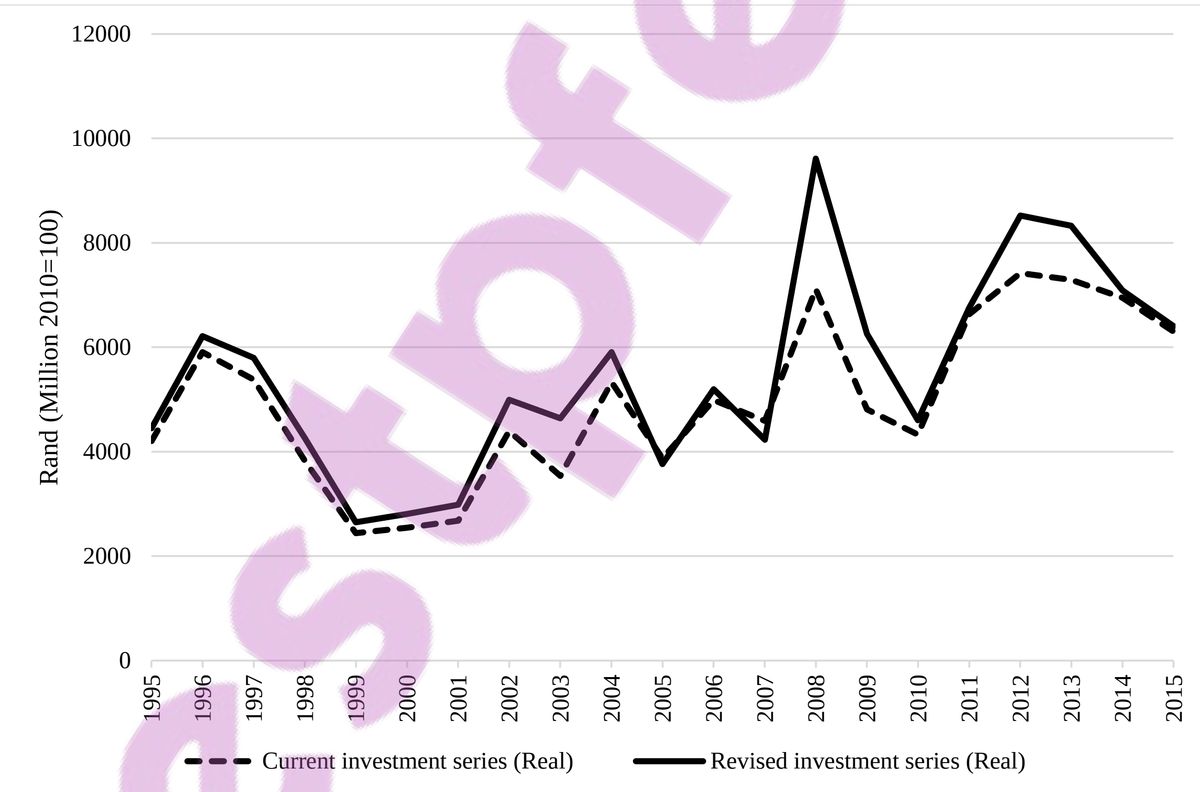

Figure 4.4: Current and revised overall machinery investment series in real terms (R million)

Source: AGFACTS (2013) and own calculations

Figure 4.4 shows that the use of a constant ratio leads to an underestimation of the overall value machinery sales throughout the period. The difference fluctuates over time and mostly higher than the results reported by AGFACTS, which uses a constant ratio of tractor sales to overall sales. The detailed results of this analysis are shown in Table 4.3 below, together with the difference between the two methods of estimation for the period since 1995. The differences in underestimation between the two series vary between a minimum of -1.7 percent and a maximum of over 30 percent in 2008/9.

Table 4.3: Implications of a revised investment series in real terms (R million)

Year	**Annual Machinery Sales**	**Current investment series**	**Revised investment series**	**Difference**	**%Difference**
1995	654.6	4 202.0	4 446.3	-244.3	-5.8
1996	1 003.6	5 908.4	6 213.3	-304.9	-5.2
1997	1 079.8	5 379.2	5 796.3	-417.1	-7.8
1998	820.2	3 826.9	4 258.9	-432.1	-11.3
1999	574.1	2 439.1	2 650.4	-211.3	-8.7
2000	625.7	2 542.2	2 804.4	-262.3	-10.3
2001	723.2	2 675.3	2 982.3	-306.9	-11.5
2002	1 671.9	4 396.0	4 995.5	-599.4	-13.6
2003	1 693.5	3 538.5	4 638.1	-1 099.5	-31.1
2004	1 944.6	5 329.1	5 907.3	-578.1	-10.8
2005	1 221.8	3 873.5	3 763.7	109.8	2.8
2006	1 808.7	4 987.3	5 198.2	-211.0	-4.2
2007	1 744.7	4 588.1	4 225.7	362.4	7.9
2008	3 654.2	7 114.8	9 612.0	-2 497.2	-35.1
2009	3 352.5	4 808.2	6 254.2	-1 446.1	-30.1
2010	2 479.3	4 323.9	4 602.9	-279.0	-6.5
2011	3 458.9	6 628.5	6 755.1	-126.7	-1.9
2012	4 679.3	7 421.4	8 522.7	-1 101.2	-14.8
2013	4 797.5	7 290.7	8 327.5	-1 036.7	-14.2
2014	4 720.6	6 950.3	7 086.8	-136.5	-2.0
2015	4 564.6	6 296.1	6 401.2	-105.1	-1.7

Source: Compiled from AGFACTS Sales data (1995- 2015), Agricultural Survey/Census (1995- 2015)

The general observation from the revised series is that it reflects a marginally higher rate of tractorisation expenditure represented by the negative signs for most of the series, with a few exceptions in 2005 and 2007. Although the differences may be regarded as minor (less than 10 percent difference), the value of this underestimation is over a R100 million in 2011, for example. The major differences are noted in years where the ratio of machinery and implements to tractor sales is less than 60 percent by a big margin. For example, in 2008 and 2009, the varying ratios of machinery and implements to machinery were estimated at 44 percent and 49 percent, respectively. This is indicative of the lack of precision in the estimation methods of the investment series. An underestimation in the actual investment in machinery has bigger implications, over time.

As noted concerning the evolution of the reporting style of machinery and implements in agricultural censuses, of late tractors are not monitored as an individual item of the expenditure. Therefore, the big differences come about as a result of the census including more items under capital investment in machinery, such as pumping equipment, tools and lately security equipment, as well as office equipment, which traditionally were not included in this category of capital investment (United Nations, 2009). In 2010 and 2011, for example, plantations were included in this category (normally accounted for under fixed improvements and excluded in deriving the ratios here). It is these shifts in the composition of the aggregate reported on expenditure of capital that yield outliers, such as the ones observed in 2009 and 2010.

Another factor that has an influence on the validity of the estimates made for total investment in machinery and implements is the accuracy of the estimated value of tractor sales itself, both through the basis at which unit sales is valued and in terms of the comprehensiveness of the affiliated members of SAAMA of the total sales of tractors. Both of these are areas of further investigation, but an underestimate of the units sold and incorrect valuation of the price at which tractors are sold will lead to a further underestimation of the total value of machinery investment imputed from the value of tractor sales.

4.6 CHAPTER SUMMARY

The use of a constant ratio of tractors to overall machinery and implements sales leads to an underestimation of the overall machinery sales in South Africa from 1995. This underestimation is in line with the reality that the tractorisation process has evolved in South Africa. Therefore, by fixing this ratio, an underestimation of the expenditure in the industry arises in the analysis. It is clear that the nature of agricultural tractorisation has evolved over the years; for example, from the use of tractor-trailed combines to self-propelled combines.

Demand for precision farming to increase agricultural productivity has resulted in changes in the composition and structure of the machinery and implements sector. Besides the nature of the inputs evolving, the quality of the implements has also evolved and this does have an impact on the composition of the inputs, which translates to the share of tractors to overall machinery sales.

The results presented above also present a number of analytical limitations in using tractors as a share of the total machinery sales. If this method is to be used, it is recommended that the allocation of resources in monitoring capital investment series components is made at a disaggregated level. In the absence of comprehensive censuses, the use of tractor sales to impute overall machinery sales is an inadequate method. However, this method serves as a basis to estimate the value of agricultural machinery, if the appropriate details exist in the census and survey data at a disaggregated level, because the use of national aggregates limits analysis of the evolution of the different components that make up the series. Aggregated data has policy implications in terms of assessment of penetration of a new technology and thus the associated returns on investment. Spending on machinery and equipment used in agricultural production provides building blocks for capital stock, which can be used to measure rate of return on capital in multifactor productivity analysis.

A number of challenges still remain outstanding in terms of rectifying the problems associated with the measurement of machinery and implements, and ultimately capital formation in South African agriculture, for example the analysis of individual capital inputs making up machinery and implements besides tractors. This estimation would result in the use of underlying data and departing from using the tractor as a proxy. In that case, there would be no question about the appropriateness of the ratio used to estimate the value of overall machinery sales.

A revision of the capital account enables measurement of the rates of substitution between labour and capital inputs. Policy recommendations that are backed by quantified analysis are only possible given the availability of precise data in the valuation of inputs, which this chapter mainly contributes to. This study will, therefore, contribute to correcting the current series to provide precise evidence upon which to make conclusions about the relationship that exists between capital and other inputs in South African agriculture, using a new and revised capital formation series. This analysis will enable a further step in refining earlier studies that improve on the precision of measures of productivity.

CHAPTER 5:
REVISION OF CAPITAL SERVICE FLOWS IN SOUTH AFRICA

5.1 INTRODUCTION

Following the revision of the tractor price index and the investment series in machinery and implements, tractor service flow estimates cannot be ignored. The durability of capital such as tractor necessitates the measurements of its service flows. Because of its nature, capital is productive for more than one period, and as such, a distinction should be made between the value of owning capital in a particular year, versus using or renting it (Hulten, 1991). One way of solving this measurement problem is to estimate service flows. It has been widely discussed in literature that service flows, as opposed to capital stocks, constitute a better measure of capital contribution to production (OECD, 2009). The concepts of a flow and stock are closely related in that stocks build up as a result of the accumulation of the relevant flows. Service flows are therefore an important element of capital use indexes, as well as productivity estimates.

In South Africa, previous studies that have estimated service flows used information on operating costs, interest on investment and reported depreciation on capital assets obtained from the aggregate agricultural statistics to estimate service flows. Information on expenditure incurred in the year of purchase was not used (Thirtle *et al.*, 1993). Therefore, this necessitates the revision of the service flow estimates of machinery and implements. Following the revision of the tractor sales value in Chapter 4, the service flow estimates will also be revisited, with a greater level of detail in the data in terms of the degree of disaggregation, to improve current service flow estimates. Liebenberg (2013) revisited the service flow estimates of South Africa. The limitation of Liebenberg (2013) lies in the level of detail of the data available for the estimation of the service flow of tractor use.

The revision of the value of tractor sales by disaggregating the tractors by drive, and using underlying price and quantity data, resulted in changes to the overall machinery sales series reported in the earlier chapters. The machinery sales value influences capital input use in agriculture, which is measured by service flows. The revised service flow estimations for tractors are outlined and discussed in this chapter. The following section discusses the estimation of service stocks. Section 5.3 discusses the estimation of service flows and 5.4 presents the revised service flow estimates and discusses the measured impact of quality adjusted service flow estimates. The final section, 5.5, concludes and summarises the findings of this chapter.

5.2 SERVICE STOCK ESTIMATION

The capital service stocks can be measured either by the physical inventory or by the perpetual inventory method. The physical inventory method is a more direct measurement of capital, where physical units of capital are counted as they are in place or as they are purchased (Anderson, Alston & Pardey, 2011). This method is less popular because of its achievability in terms of data and resource requirements. With the deterioration of the reporting and monitoring of capital inputs in the agricultural censuses and surveys, the use of the physical inventory method would not be possible in South Africa. As a result, the perpetual inventory method is the most appropriate method used to estimate capital service flows. The perpetual inventory method rests upon the idea that stocks constitute cumulated flows of investment, corrected for retirement and efficiency loss (OECD, 2009).

A number of variants for the estimation of the perpetual inventory method are described in literature, requiring different data sets. According to the OECD (2009), much data is required in order for the perpetual inventory method to be applicable, such as the average asset lives; length of time they are used in production; retirement distribution as in the extent to which the assets are retired on, or after the average asset life for that asset; the age–price function of the assets; the age–efficiency function of the assets; the gross fixed capital formation ("GFCF") for the period for which the capital stock estimate is required and for prior periods up to the maximum life of the assets; and the price indexes for the entire life span of the GFCF. However, in this study, the following estimation method illustrated in equation 5.1 is used. Anderson *et al.* (2011) define the current stock of capital through the following capital accumulation equation:

$$K_t = I_t + (1-\delta)I_{t-1} + (1-\delta)^2 I_{t-2} + \ldots + (1-\delta)^L I_{t-L} \qquad \text{Equation(5.1)}$$

where I denotes the stock of capital in each period using a time series on investment in real dollars, the service life of assets denoted by L and the capital rate of depreciation is denoted by δ. Equation (5.1) computes the moving sum of the depreciated value of current and past investments adjusted for the assumed service life of the asset and assists in developing the annual estimates of the stock of capital for each class. The equation shows that the most important variables for the estimation of the perpetual inventory method are the rate of depreciation, the service life, and the initial investment of capital in each period. There is a big debate in literature with regards to the estimates and assumptions on these three parameters because they affect the useful life of the tractors and thus influence investment behaviour. Accurate estimates of depreciation are important for investment behaviour because tax policies relate to allowances made on depreciation which influence investment behaviour.

The replacement age of a tractor is based on its economic life-useful life. The useful life of a machine is usually shorter that the machines life depending mainly on the repair and maintenance costs of the machine (Chenarbon, Afsar and Ebrahimzadeh, 2014). Depreciation costs are part of the fixed costs in the life of the machine. Different depreciation profiles have been used and there is very little evidence to discriminate among different depreciation profiles that are used to estimate capital stock (Baldwin, Gellatly, Tanguay & Patry, 2005). The South African Revenue Services uses a depreciation rate of 25% per year for tractors which amounts to 4 years write off period. Liebenberg (2013) used a depreciation rate of 17% per year. Some of the parameter values used in the calculation of stocks and services are listed below:

Table 5.1: Parameter values for calculating stocks and service flows

Category and Class	Depreciation (δ)	Service Life (L)	Age (k)
Machinery			
Tractors	0.17	12	9.1
Combines: Trailed	0.15	14	10.5
Combines Self Propelled	0.15	14	10.5
Mowers	0.15	14	10.5
Balers	0.21	10	7.5
Ploughs	0.21	10	7.5
Planters: Maize	0.21	10	7.5
Planters: Wheat	0.21	10	7.5
Crop Sprayers	0.21	10	7.5

Source: Liebenberg (2013)

In this study we use 10% depreciation rate which is in line with Anderson *et al.* (2009) and the long useful lives used by South African farmers in South Africa, who generally retain their tractors longer than the useful life. This is because the process of replacing farm machinery is a complex decision resulting from a dynamic and interactive process of different variables. Replacement policies of different farms will therefore vary depending on factors such as tax planning considerations, farming systems, the age of the tractor- the hours 'on the clock', the size of tractors in kilowatts, level of technological improvement required, timeliness, availability of capital, total mechanisation plan on the farm and new cultivation methods (Louw, 2018).

It is also evident that a second hand market for tractors also exists in South Africa especially with the number of small holder farmers who are mostly credit constrained and would opt for a second hand market. A lot of transactions take place between farmers and trading agents in this market. However, information on this market is scanty as there is no record the various sub agents, agents, dealers and general traders who have expertise in the purchase and sale of tractors. It is therefore very difficult to make any precise estimate of the transactions made in these markets because there are no regular records of sale of tractors in the second hand market. This study only focussed on the new tractor market in South Africa where tractor sales could be used to estimate investments in machinery and implements.

Although statistics on investment may be available, statistics on the service lives and age of physical assets is not available; therefore, the parameters used in this study are based on literature. Where sufficient data lacks on the annual capital vintages needed to estimate equation 5.1 above, an average age is assumed for all machines used on farms then gross stock can be adjusted for the average age of tractors to form the net stock of the assets using a constant rate of depreciation as follows:

Net Stock = Gross Stock x $(1 - \delta)^\wedge(k)(2)$……………………………………….Equation (5.2)

The equation for δ is:

$\delta = 1 - 0.1^\wedge(1/L)$ ……………………………………………………………Equation (5.3) where δ also includes the assumption that the asset is retired when 10 percent of the original asset remains. Equations 5.1 to 5.3 above yield net capital stock.

Determining the depreciation value is a well-debated issue in the literature, although Anderson *et al.* (2011) suggest that InSTePP researchers set the threshold at 10 percent and calculated the service lives using the formula given in equation 5.2 above. As explained above, there is no consensus in the literature as to what the appropriate rate of depreciation should be used but the nature of the product must direct the choice of a depreciation method. A geometric rate of depreciation will be used in this study because it provides a good approximation to physical deterioration when working with measures of the aggregate stock of assets (Anderson *et al.*, 2009). It is based on a constant annual rate of capital consumption over the life of an asset, which is a constant proportion. The usage of the input is considered in this method which is more appropriate compared to the straight-line depreciation which considers that an asset loses value over its life by a constant amount each period. The Hoss-Shay pattern on the other hand considers that an asset does not lose value until the end of its useful life (Anderson *et al.*, 2009), which will not be relevant in this case.

5.3 SERVICE FLOW ESTIMATION

Following the application of Equation 5.1 above resulting in derivation of the stocks, the rental rates are used to estimate the capital service flows. Liebenberg (2013), following Andersen *et al.* (2011) suggests that rental rates are calculated using the following formula:

$$\rho t = Pt(rt + \sigma)$$

Where the rental rate is equal to the opportunity cost of the funds invested *($P_t r$)* plus the cost of physical wear and tear and other sources of economic depreciation of the asset as it depreciates represented by *($P_t\ \sigma$)*. The service flows are then estimated by multiplying the productive capital stock by the applicable rental rate. TFP estimations require further costs to be taken into account in the estimation of service flows such as running costs of labour and intermediate inputs among other costs (Thirtle *et al.*, 1993).

δ

5.4 REVISED CAPITAL SERVICE FLOWS

Using equation 5.1, the capital service flows in South Africa were re-estimated using a reestimated tractor sales value and compared with the current tractor sales series. The differences between the results from the two estimation methods are shown in Table 5.2 below.

Table 5.2: Current and revised annual service flows in real terms (R million)

Year	Current Annual Service flows (R million)	Revised Annual Service flows	Difference	%Difference
1995	1 172.2	1 240.3	-68.2	-5.5
1996	2 860.6	3 015.5	-154.9	-5.1
1997	4 230.1	4 496.9	-266.8	-5.9
1998	5 251.1	5 642.9	-391.9	-6.9
1999	4 845.3	5 215.1	-369.8	-7.1
2000	4 438.5	4 793.9	-355.5	-7.4
2001	4 511.7	4 895.0	-383.4	-7.8
2002	5 530.6	6 058.7	-528.1	-8.7
2003	5 707.7	6 442.8	-735.1	-11.4
2004	5 516.9	6 204.4	-687.5	-11.1
2005	5 608.6	6 185.4	-576.7	-9.3
2006	6 236.0	6 813.3	-577.3	-8.5
2007	7 205.6	7 690.3	-484.7	-6.3
2008	8 820.8	9 921.4	-1 100.6	-11.1
2009	7 903.0	9 072.7	-1 169.7	-12.9
2010	7 355.9	8 373.0	-1 017.1	-12.1
2011	7 601.5	8 502.6	-901.0	-10.6
2012	8 142.9	9 149.6	-1 006.7	-11.0
2013	8 579.7	9 665.5	-1 085.8	-11.2
2014	9 311.8	10 348.1	-1 036.3	-10.0
2015	9 730.9	10 698.3	-967.33	-9.0

Source: Author's own calculations from AGFACTS database

As shown in Equation 5.1, capital accumulation is a sum of investments in previous years, adjusted for depreciation and service life. The depreciation rate is assumed to be 10 percent, and a service life of 10 years is assumed. These assumptions are based on the Department of Agriculture estimates to enable a comparison between current service flow estimates and revised estimates. Table 5.2 shows that capital service flow estimates are being underestimated by a range of 5.4 percent to 12.9 percent in productivity analysis.

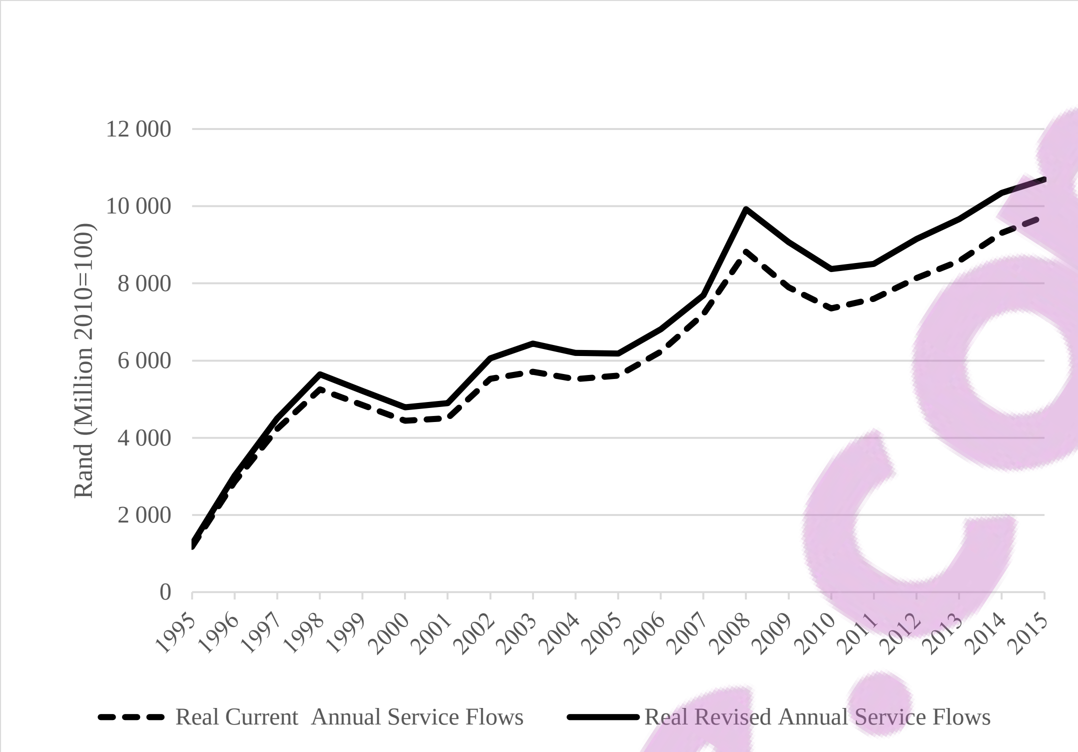

Figure 5.1: Real capital service flow estimates (R million) for machinery and implements using different methods

Source: Author's own calculations from AGFACTS database

Figure 5.1 shows an increasing service flow accumulation, annually from 1995 to 2015. This means that services flowing from capital use in tractors in South Africa are increasing, for both the varying ratio and the fixed ratio. However, the underestimation that results from mismeasurement of the investment series translates to an underestimation in the service flows, as shown by the higher service flows estimated for the revised series. Statistically, there is no significant difference between the two series and therefore no significance on the capital use indexes because only one input in the form of tractors has been quality adjusted by disaggregation among other machinery and implements. Therefore, all the components of machinery and implements have to be disaggregated in order to influence the capital input use in agriculture. Accordingly, although the tractor constitutes the largest portion of machinery and implements in agriculture, the flows of services from other machinery and implements, such as combines, hay and forage machinery and other implements, have to be measured.

5.5 CHAPTER SUMMARY

Utilising the revised investment series, this chapter used quality-adjusted investment estimates to revise the capital service flows in machinery and implements. As expected, higher estimates of capital input use are derived for the period 1995–2015, with a maximum percentage difference of 12.9 percent in 2009, and a minimum of 5.5 percent difference in 1995. This means that the failure to capture quality change and improved level of mechanisation in all the other inputs that make up the machinery and implements component will result in an underestimation of the service flows. However, the differences between the two series are not statistically significant because, as with the investment series, only one capital input has been disaggregated and then used as a proxy to measure the overall machinery investment. This means that quality adjustments for all other machinery and implements are required before valuing inputs for productivity analysis.

A number of data limitations have been identified in the estimation of precise service flows in this study. Service lives of the capital inputs are not readily available in South Africa, and one way of collecting this information would be by way of a national statistics survey. This is because it is not clear what replacement patterns or service lives South African farmers use for their machinery and implements, and whether they differ according to the type of capital input. Though service lives are important in the estimation of the service stocks using the perpetual inventory method, the availability of estimates of service lives based on statistical information is scarce, which presents a limitation in the estimation of the perpetual inventory method. Given these limitations, this chapter provides a basis for arguing a case of underestimation in productivity analysis, if quality adjustments are not incorporated in capital valuation estimates. The cumulative effect of using aggregates and proxies is shown by the higher estimates of service flows, as compared with the current service flow estimates.

CHAPTER 6:
SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

6.1 SUMMARY AND CONCLUSIONS

The uses and composition of agricultural machinery and implements in South Africa have evolved over time. This evolution is reflected, for example, in the switch from using 2WD to 4WD tractors, as shown in this study. However, the evolution of tractorisation is not reflected in the agricultural censuses or other sources of agricultural machinery data, and in fact, reporting and monitoring has deteriorated to the extent of using highly aggregated capital statistics. The purpose of this study was to revisit the national capital input account for agriculture, with a specific focus being placed on machinery and implements in order to fill the knowledge gap in the changing nature of the tractorisation process and to improve the capital use measurement for productivity analysis in South Africa. This thesis pursued four objectives and hypotheses, which were addressed with the overall main objective to formulate a new capital investment account by tracing the changing nature and quality of capital inputs in South African agriculture.

The thesis begins by exploring in Chapter 2 how tractorisation has changed, using trends and descriptive statistics to contextualise the evolution of tractorisation. In this chapter, both the drivetrain and power attributes of tractors were analysed to illustrate the changes in quality and composition of machinery and implements in South Africa. The tractor attributes were used, as the tractor constitutes the largest portion of machinery and implements in South Africa. Tractor units sold are related to area harvested for field crops and horticultural crops so as to give the context of the current state of tractorisation in South Africa. In addition to the drive and power attributes of tractors, this study in Chapter 3 assessed the price of tractors and how the prices have changed over time. The evolution of tractorisation in South Africa had not previously been traced, over time. This study, therefore, illustrates the evolution of tractorisation using tractor attributes (drive, power in kilowatts, and price) to show how tractorisation has changed over time.

This study shows that the evolution of tractorisation is more evident when the actual attributes of the tractors are used to analyse the changes in quality of the tractors, such as power, price, and drive. The analysis of the power attributes of the tractors shows a much higher use of power per hectare in recent years as power requirements are increasing per hectare planted of field crops. On the other hand, this finding could be explained by the fact that farming operations are becoming more intense over a shorter period of time. With precision farming, and also because of the more erratic climate, farmers want to respond much quicker to changing weather patterns in order to execute farming operations optimally, for example planting time is crucial, depending on soil moisture content. Heavy high-tech planters and strip-tillers are all part of the move to minimum till, and these require more power. There has been a general shift to four-wheel drive tractors over the years, particularly in grain producing provinces. The orchard and vineyard tractors, both the 4WD and 2WD, are dominant in the Western Cape Province. This is in line with expectations and a particular focus in those provinces where the most units are sold also reflects an increase in use of 4WD over 2WD tractors. Relating tractor evolution to farming systems such as field crops, horticulture and net farming income, shows that the 4WD tractor market is related to net farming income, as trends are highly correlated. On the other hand, horticultural crop trends are related to annual sales trends for the 2WD and vineyard and orchard tractors because the types of operations they are used for are less intense than those field crops are, and therefore the requirements for 4WD are not as critical as they are for the field crop operations.

The first specific objective concerns the re-estimation of the tractor price index, necessitated by the mismeasurements of the value of tractors arising from the use of a standard numeraire to estimate the Laspeyres index. Given the deterioration of the reporting style, the tractor price index is revised in Chapter 3 and compared with the Abstract tractor price index. Econometric estimations using cointegration techniques are carried out in this chapter to test the validity of the revised tractor price index. It is evident from this study that the use of underlying price and quantity data leads to better estimates being made of the tractor price index, which better reflect theoretical and practical expectations on the behaviour of tractor prices in response to factors such as net farm income and exchange rates. The revised tractor price index clearly shows the effect of the rand–dollar exchange rate depreciation in 2009, while the Abstract tractor index ignores this. This is, however, important for managerial purposes, as it provides business intelligence that ultimately translates into market share. Due to the long lead-time that arises when stock is ordered in the anticipation of future sales, tractor companies depend heavily on accurate estimates and projections of future net farm income. More robust estimates of the relationship between farm-level income and tractor prices, which influence the revenue of tractor companies, will support the business decisions that have to be made. Using the Abstract tractor price index would mislead investment decisions by tractor manufacturers and farmers because it ignores the influence of the rand dollar exchange rate which is a factor as South Africa is a net importer of tractors.

The second objective deals with the measurement of capital formation, using a fixed proportion of tractors to overall machinery and implements. Since tractors make up the greater part of machinery and implements, the value for tractors is used as a proxy to estimate the overall machinery and implements value, fixed at a 60 percent proportion to overall machinery and implements value. This study investigates the validity of this assumption, as discussed in Chapter 4 of the thesis. Firstly, the 60 percent assumption is investigated in detail to establish whether it is a constant ratio or not. This study illustrated that the 60 percent ratio is not fixed, but varies over time, with a minimum of 44 percent in 2002 for the analysis period. To confirm this finding, a historical analysis of this ratio using the survey of agricultural machinery showed that the ratio can be as low as 31 percent, as it was in the year 1985. This proves the underestimation that takes place in the valuation of machinery and implements when tractors are used as a proxy to estimate overall machinery and implements, using a fixed ratio as opposed to a varying ratio. The use of underlying price and quantity data that is based on tracked model change history enabled a clear reflection of the actual changes that took place in the tractor market, for example through the link between the tractor prices and the rand–dollar exchange rate in the revised tractor price index.

The third objective aims to revisit service flow estimates, following changes to the investment series observed in objective two. This third objective is related to the last objective, which is aimed at illustrating the implications of the changes made to capital series, for example in capital use and investment in South Africa. This study shows that service flow estimations are understated by a range of 5 percent to 13 percent in difference for the period 1995–2015. As such, a quality-adjusted series was compared with the previous series where disaggregation was not factored into the estimation of investment in machinery and implements. Although a statistically insignificant difference was established, differences were seen between the investment series based on disaggregated data, as compared with the use of national aggregates, which illustrate the underestimation of capital use. This shows that the current estimates of productivity analysis cannot be relied upon, given the questionable labour input numbers and other inputs, such as infrastructure and other fixed improvements.

What sets this study apart from the others is the use of disaggregated underlying data and tracking model change history in tractor prices. In addition, this study analyses the drive and power attribute of tractors to establish changes in tractorisation in South Africa. This study also uses econometric techniques to test the relationship between current estimation methods and the revised methods presented in this thesis. This study quantifies the magnitude of underestimation that occurs when the evolution of tractorisation is ignored in the valuation of capital inputs such as tractors.

6.2 MANAGERIAL IMPLICATIONS

The revised tractor price index has important managerial implications for farmers and investors in the tractor market. The existence of a cointegrating relationship between the revised tractor price index, exchange rates and net farm income is useful for managerial purposes. The revised tractor price index provides business intelligence in the tractor market. This means that changes in exchange rates and net farm income can be used to predict the changes that will take place in tractor prices. By measuring the relationship between exchange rates, farm income and tractor prices, this study provides a reliable and theoretically relevant relationship between exchange rate, net income and the tractor price index.

6.3 POLICY IMPLICATIONS

Numerous policy implications can be drawn from this study, particularly through the provision of the basis upon which data can be measured to provide precise trends that explain changes in the market. Tractors form the greater proportion of machinery and implements in South African agriculture. Machinery and implements constitute a large proportion of capital formation in South Africa. This study has refined the methods used to measure capital formation in South Africa so as to be more reflective of related trends that have taken place in the tractorisation sector. This study provides evidence of the implications of the mismeasurement in capital formation, such as a failure to reflect trends in the machinery and implements market. Using estimations for 2012 as an example, a 14,8 percent underestimation of the value of machinery and implements translates to close to a billion rand in real terms of the value of capital investments. In addition, the disaggregation of 2WD and 4WD tractors clarifies the main drivers of the market value of capital inputs. The policy implications of this study hinge upon the idea that it is very difficult to monitor and evaluate what is not measurable. This affects investments in the agriculture sector.

One of main issues of national importance and debate is the understanding of the evolution of tractorisation in terms of the capital resource and its relationship with labour. The higher capital input use estimations derived in this study provide insights into how the higher use of capital might have an impact on labour. Using the results of this study, capital and labour may now be analysed at a disaggregated level. This study provides the quantitative evidence of the actual changes that have taken place in the machinery and implements sector by analysing the drive and power attributes of the tractor input. Ultimately, this data can effectively be used to measure the marginal rate of technical substitution between labour and capital, holding other inputs constant. Tractorisation has been argued to displace labour, but the quantified extent of this displacement is not known.

The main contribution of this analysis is in providing empirical evidence of the changes taking place in the power attributes of South African tractors. A number of policy questions remain unanswered on the substitutability of one power type for another, for example for labour and capital, because of the lack of understanding on a tractor's power attributes. This study provides the basis for such an analysis by providing evidence of the actual power in use in the South African market. Secondly, there are environmental questions regarding the use of power on farms and the sustainability of the power in use. By quantifying the power sold on farms on an annual basis in South Africa, this study provides measured evidence of the power in question, enabling a start to be made in determining the sustainability of power systems on South African farms. The understanding of the power attribute of tractors is instrumental in the efficiency and performance measurement of the sector.

The tractor price index is relevant to the prices of agricultural tractors that are sold on the market. The importance of a tractor price index is then to forewarn the farmers of the changes taking place in the tractor market. This implies that any imprecision in the measurement of tractor price index misleads farmers and other stakeholders that analyse movements in the tractor market. In the Mechanisation Support Policy Framework of DAFF, mechanisation support in the form of inputs such as tractors and implements would be given to farmers. Despite the problems that are known to exist with this policy, the initial budgets for the implementation of such a policy are based on appropriate indicators, such as the tractor price index, to inform on input costs. Imprecision in the measurement of the tractor price index results in wrong conclusions being made in capital input use analysis in the valuation of inputs, and ultimately in productivity analysis.

The Department of Agriculture and Rural Development has a mechanisation programme that assists the farming sector in different provinces, and this study contributes to the mechanisation policy by providing a tool that is useful for monitoring the mechanisation programmes. The revised tractor price index, for example, is a more accurate tool that relates to economic theory, and is thus useful as an economic barometer for the tractor market. This study gives insights into how the monitoring and evaluation of tractor schemes can be evaluated through using tractor attributes such as the drive and power attributes. Trends indicate a move towards high-performance tractors, such as 4WD tractors. The government programmes should therefore target such tractors in policy development designed for increasing productivity and performance of farmers.

6.4 AREAS OF FURTHER INVESTIGATION

This study provides a deeper understanding of the evolution of mechanisation by focusing on the valuation of tractors only. It tests the use of a fixed ratio versus a varying ratio by using the tractor as a proxy for estimating other machinery and implements. However, there are other machinery and implements which need to be individually investigated to estimate their unique value and contribution to the basket of machinery and implements in South Africa, including combines, mowers, bailers and ploughs. Each of these implements can be investigated in detail to depart from the use the tractors as a proxy for estimating the value of overall machinery and implements in South African agriculture.

This study focuses on the tractor input, which makes up 60 percent of machinery and implements. Machinery and implements themselves make up 60 percent of capital formation in South Africa. In effect, this study only analyses the effect of tractors, which constitute 36 percent of the capital formation account. Although this is important, it is not entirely sufficient for gauging the influence of cleaning up the tractor series on the whole of the capital formation account. In other words, other machinery and implements should be analysed and their data cleaned up to avoid the use of assumptions. Combines, hay and forage machinery, and implements should be tracked more carefully to analyse the changes that have taken place in the evolution of mechanisation.

Although this study has provided evidence of the underestimation in the valuation of tractors and ultimately overall machinery sales, a number of other routes could be taken to determine the value of underestimation of the machinery and implements in South Africa, for example by conducting a survey of the non-members of SAAMA. Although SAAMA monitors and reports the prices of its members, other manufacturers are not monitored by SAAMA. A survey of the non-members to SAAMA could be conducted to establish the value of machinery and implements that are not monitored by SAAMA. In other words, further investigations into the value of the underestimation of capital input use and into other far-reaching impacts on productivity analysis need to be undertaken. This study has focused on valuing capital inputs, based on the revision of new tractors, yet there is also a second-hand market for tractors that exists in South Africa. Within the limits of available resources, this study only focused on the new tractor market, and not the second-hand market, which would require further resources for investigating the assumptions of the values of used tractors. The only way that this can be captured is by means of an agricultural survey undertaken by Statistics South Africa. Although the model used for valuing service flows factored in a service life of 10 years, it is known that some tractors in South Africa serve for more than 10 years on the farms.

In understanding the evolution of tractorisation, the changing sources of tractorisation play a role, particularly in the context of globalisation and associated technological innovations. It is important to understand spillovers when technologies such as tractorisation spread across borders, as this may reveal reasons for underinvestment in both public and private research. It has been established that interstate and international spillovers from agricultural R&D investments account for a significant share of agricultural productivity. Alston (2002) suggests that studies of aggregate state or national agricultural productivity, interstate or international R&D spillovers might account for half or more of the total measured productivity. As such, and in order to understand the sources of tractorisation, an investigation into the spillover potential for mechanical innovations is required, based on geopolitical boundaries.

In putting together the first South African agricultural productivity series Thirtle *et al.* (1993) mentions that “The data series are at present quite crude and there is at least one PhD in quality adjusting inputs like land and labour as well as intermediate items like fertilizer and capital inputs such as machinery as well as sophisticated modelling of the capital series.” This study provides the first step to cleaning the capital series and providing data that is useful in evaluating capital use in South Africa. This study also uses econometric modelling in substantiating the relationship between net farm income and tractor prices in South Africa. More work remains in cleaning data on other inputs such as labour, land, intermediate inputs and other capital inputs.

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ANNEXURE A: Units sold by province 1995-2015

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Grand Total
2WD	**2073**	**1616**	**1982**	**1758**	**1289**	**720**	**612**	**702**	**993**	**867**	**1091**	**1398**	**1484**	**1124**	**1349**	**1022**	**1103**	**1543**	**1600**	**1484**	**1228**	**1574**	**28612**
Eastern Cape	97	88	102	116	70	29	29	26	39	70	90	160	188	141	137	131	89	145	191	113	126	192	2369
Freestate	391	229	227	204	126	82	48	66	53	40	48	102	109	87	122	62	113	130	63	68	47	27	2444
Gauteng	146	121	157	134	75	65	65	152	105	48	61	111	138	94	116	44	86	194	157	153	78	143	2443
Government Units	23	24	15	2	8	1	3	19	13	27	82	2	25		4	19	67	3	2	5	1		345
KwaZulu Natal	354	357	374	355	286	113	137	128	140	165	242	319	337	212	198	199	190	229	231	176	102	104	4948
Limpopo Province	60	57	126	93	82	76	47	31	62	64	75	68	109	78	123	116	121	152	103	148	140	151	2082
Mpumalanga	307	203	263	204	165	78	86	80	122	121	168	186	184	166	173	145	134	230	185	191	110	185	3686
Northern Cape	37	37	41	39	29	31	18	13	29	27	38	32	33	29	34	19	44	42	64	111	80	90	917
NorthWest	495	282	435	405	255	113	89	65	158	119	163	84	157	153	211	139	111	164	266	161	130	126	4281
Western Cape	106	142	153	126	116	54	50	30	53	110	68	117	122	99	122	55	63	118	81	142	194	232	2353

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Grand To
4WD	2318	2246	3343	3259	2205	1496	1684	1679	2998	2862	3571	2676	3535	3462	5394	3847	3542	5216	5632	5235	4325	4400	74925
Eastern Cape	68	113	99	86	92	53	42	36	43	102	206	237	227	192	241	158	221	335	257	314	289	393	3804
Freestate	883	661	1138	1072	768	462	458	474	1013	737	812	390	723	835	1361	842	643	1060	1149	925	768	719	17893
Gauteng	117	63	140	159	123	90	94	67	133	133	127	108	175	178	228	170	179	224	269	254	213	255	3499
Government Units	4	5	12	4		1	1	2		14	23	4	11	3	77	10	168	1	333	82	3		758
KwaZulu Natal	230	314	292	357	265	163	248	241	311	401	451	491	581	465	518	478	482	772	766	875	540	550	9791
Limpopo Province	77	110	129	174	141	95	97	121	150	180	252	198	211	174	345	329	283	355	366	386	393	435	5001
Mpumalanga	404	304	527	532	378	300	310	308	457	461	617	390	568	559	757	647	582	827	876	935	759	687	12185
Northern Cape	46	62	103	109	39	37	57	66	130	127	124	58	105	163	255	176	144	204	262	230	225	232	2954
NorthWest	187	147	350	292	210	139	170	234	493	302	508	316	504	519	911	610	452	886	754	535	526	365	9410
Western Cape	281	440	494	371	168	92	122	113	192	388	427	407	364	330	634	312	303	408	447	573	458	584	7908

ANNEXURE B: Correlation Tests

	Net Farm income	2WD Tractor units Sold	4WD Tractor units sold
Net Farm income	1		
2WD Tractor units Sold	0.05305	1	
4WD Tractor units sold	0.812247	-0.09265	1

ANNEXURE C: Ratio of Tractors in the machinery and implements profile

MACHINERY AND IMPLEMENTS	RATIOS																
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
HARVESTING EQUIPMENT	85.15	83.04	87.43	83.13	75.94	78.82	82.62	82.11	81.69	86.73	81.76	84.45	83.83	87.31	90.82	89.46	84.66
HAY AND SILAGE MACHINERY	80.51	77.25	82.53	78.42	68.68	69.18	70.34	75.36	72.29	76.88	73.13	75.15	73.71	76.02	79.19	79.48	79.23
PLANTERS	74.48	71.47	76.78	73.77	63.44	64.88	65.04	69.88	66.61	72.65	70.17	72.00	70.60	72.57	76.21	75.77	75.05
PLANT NUTRITION AND PEST CONTROL EQUIPMENT	72.16	69.38	74.49	71.77	61.46	63.19	62.97	67.98	63.89	69.34	67.15	69.08	67.13	68.60	71.02	72.41	72.22
FEED MIXERS	72.01	69.11	74.34	71.56	60.94	62.70	62.64	67.77	63.64	67.97	65.94	67.24	65.27	66.19	67.54	69.67	69.64
MOULDBOARD PLOUGH, DISK PLOUGH, DISK HARROWS	67.21	64.37	69.23	67.48	57.19	58.94	59.93	65.61	61.69	65.66	63.53	64.61	63.24	64.06	65.58	67.94	68.17
TINE IMPLEMENTS CULTIVATORS	64.60	61.08	65.97	65.02	54.64	56.01	56.37	61.64	58.42	63.06	61.61	63.21	62.18	62.98	64.43	66.51	66.82
TRAILERS	63.62	60.02	64.46	63.82	53.23	55.10	55.37	60.81	57.12	61.55	60.22	61.59	61.12	61.83	63.40	65.78	66.14
EARTH MOVING EQUIPMENT LOADERS	63.25	59.64	64.05	63.38	52.64	54.46	54.40	60.14	56.43	60.85	59.23	60.76	60.27	60.89	62.55	65.21	65.66
DIVERSE EQUIPMENT FOR ANIMAL HANDLING	63.13	59.52	63.89	63.18	52.40	53.91	53.96	59.88	56.20	60.38	58.53	59.97	59.42	60.10	61.75	64.82	65.28
POTATO EQUIPMENT	62.95	59.42	63.66	62.96	52.14	53.60	53.64	59.61	55.76	59.64	57.89	59.00	59.06	59.76	61.15	64.35	64.96
GRAIN DRYERS GRAIN HANDLING EQUIPMENT	62.84	59.32	63.54	62.89	52.03	53.32	53.43	59.25	55.55	59.20	57.53	58.62	58.75	59.48	60.87	64.15	64.75
FORESTRY EQUIPMENT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56.57	54.62	55.48	59.70	60.74
NOT CLASSIFIED BUT SOLD & FIGURES NOT AVAILABLE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	56.41	56.39	54.79	50.41	52.45	58.60	59.45
SUGAR EQUIPMENT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55.85	54.16	50.01	51.70	58.22	58.84
ROTAVATOR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	58.75	56.15	55.64	53.92	49.82	51.50	58.06	58.72
TOBACCO EQUIPMENT	62.07	59.02	63.38	62.69	51.36	52.75	52.68	58.76	55.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MILKING MACHINE SYSTEMS	61.64	58.40	62.73	62.30	50.79	52.14	52.10	58.44	55.06	57.40	54.94	54.72	52.16	N/A	N/A	N/A	N/A
REFRIGERATED FARM MILK TANKS	60.84	56.95	61.66	61.72	49.86	51.28	51.34	58.10	54.81	57.22	54.80	54.61	52.04	N/A	N/A	N/A	N/A
PEANUT & EDIBLE BEAN HARVESTING MACHINERY	60.34	56.63	61.46	61.52	49.78	51.24	51.29	58.00	54.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
STATIONARY DIESEL ENGINES	58.52	55.32	58.32	59.50	48.34	48.44	49.25	56.39	53.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HAMMERMILLS	58.21	54.92	57.86	59.12	47.96	47.99	48.89	56.07	52.94	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ANIMAL WASTE HANDLING EQUIPMENT	58.14	54.87	57.83	59.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ratio including all monitored implements for the period	58.14	54.87	57.83	59.11	47.96	47.99	48.89	56.07	52.94	57.22	54.80	54.61	52.04	49.82	51.50	58.06	58.72

ANNEXURE D: Laspeyres Tractor index estimations

Categories	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	57.52	59.32	66.50	70.86	105.25	100.00	96.73	100.99	108.74	122.80	129.54
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	70.46	70.60	76.62	82.02	114.75	100.00	95.29	104.29	111.43	133.04	142.43
Cat 3	39.28	42.18	46.52	48.66	57.98	59.41	65.61	87.58	90.93	82.44	78.72	77.91	81.75	80.21	104.94	100.00	94.99	100.31	105.45	122.74	131.23
Cat 4	60.49	60.49	60.49	60.49	60.49	60.49	64.16	92.82	96.56	83.95	81.04	78.04	85.33	91.39	108.69	100.00	93.56	93.27	97.08	110.20	117.45
Cat 5	38.55	39.31	45.38	47.07	50.81	55.79	60.26	80.88	85.87	77.07	73.42	72.53	76.52	89.14	110.26	100.00	95.73	101.55	108.49	128.08	137.31
Cat 6	30.75	32.56	37.86	38.86	42.83	45.06	48.73	65.28	67.87	59.33	60.11	61.44	68.96	80.34	103.95	100.00	99.48	102.54	110.02	127.82	137.17
Cat 7	31.84	34.89	40.29	42.95	49.34	48.99	51.97	67.19	74.04	65.93	63.77	66.39	74.70	87.67	108.91	100.00	95.04	98.99	105.50	126.90	138.36
Cat 8	26.25	29.03	34.97	37.34	44.86	46.36	51.19	70.27	75.20	65.99	64.35	66.17	74.17	89.58	107.46	100.00	98.04	103.60	112.52	129.26	134.39
Cat 9	26.32	29.68	33.85	34.18	38.05	40.87	44.48	58.80	62.45	57.70	57.12	59.29	68.37	77.13	107.67	100.00	96.25	106.64	120.14	136.75	148.66
Cat 10	24.47	27.59	31.94	33.82	36.13	38.37	41.43	55.71	62.38	58.88	58.74	62.62	71.65	88.66	109.65	100.00	93.35	99.57	106.73	116.13	127.55
Cat 11	22.15	24.51	30.44	31.90	35.97	37.53	42.44	54.37	57.36	53.46	52.55	55.78	66.10	75.88	105.82	100.00	93.32	96.23	104.58	118.89	126.39
Cat 12	27.20	27.94	32.63	32.93	36.96	41.01	45.75	62.29	66.01	59.21	56.65	64.23	73.07	95.71	111.92	100.00	79.76	86.79	95.64	117.00	125.12
Cat 13	24.14	26.62	31.25	34.30	38.35	40.48	46.34	60.66	67.89	59.76	56.93	58.83	70.45	80.40	106.12	100.00	96.25	107.65	120.19	146.68	163.16
Cat 14	22.82	25.41	29.97	33.21	38.60	40.35	46.95	66.72	72.40	64.09	58.95	63.17	72.88	82.34	110.75	100.00	100.17	109.11	120.97	141.73	150.88
Cat 15	21.04	24.31	27.80	31.29	34.84	39.81	47.18	68.51	73.63	58.19	53.64	61.66	70.98	81.00	110.40	100.00	94.96	104.57	115.08	131.23	137.92
CATO1	32.59	32.23	35.23	38.05	46.67	45.24	50.55	66.89	69.71	63.48	66.08	66.40	73.75	84.07	104.42	100.00	93.81	106.07	117.13	136.38	144.50
CATO2	31.30	31.79	36.75	35.62	38.88	39.57	45.79	61.18	64.19	56.37	55.51	59.71	68.07	79.83	104.79	100.00	91.98	101.67	109.12	129.76	142.56
4WD	26	29	34	36	41	43	48	65	70	62	60	63	72	84	108	100	95	102	111	128	138
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	100.00	98.69	109.12	130.84	146.50	158.02
Cat 3	41.22	43.49	48.29	47.61	56.61	57.30	64.26	88.24	91.90	76.53	70.91	73.59	79.79	90.40	117.28	100.00	88.88	93.25	95.84	105.18	113.18
Cat 4	47.06	48.44	50.73	50.35	59.05	60.81	67.65	88.43	95.53	87.99	80.34	81.87	90.10	100.96	116.59	100.00	97.96	104.63	114.56	127.16	139.77
Cat 5	31.92	34.63	42.47	44.04	50.65	52.70	57.54	75.82	79.48	71.91	69.42	68.18	74.94	89.09	109.18	100.00	96.45	101.18	108.47	128.48	137.43
Cat 6	36.16	35.47	40.00	42.28	45.73	53.87	59.16	83.00	86.22	77.81	72.55	74.70	83.43	88.97	125.01	100.00	98.32	106.44	115.70	134.83	128.45
Cat 7	32.29	34.99	41.25	44.31	50.34	49.22	52.86	66.29	74.30	63.43	60.69	68.19	77.58	91.01	107.86	100.00	92.51	101.33	108.07	123.28	124.48
Cat 8	26.96	30.22	37.08	38.17	46.00	50.54	63.34	89.98	83.40	73.33	67.72	73.33	84.37	93.20	126.32	100.00	99.46	115.28	125.80	141.79	141.09
Cat 9	28.28	29.71	34.86	35.75	44.39	52.04	65.23	92.65	85.88	75.52	69.73	73.22	83.68	88.73	105.26	100.00	94.74	111.59	120.89	132.57	147.87
Cat 10	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cat 11	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 12	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!											
CATO1	29.58	30.00	34.20	35.41	40.83	43.11	47.36	63.35	69.14	64.69	62.94	67.88	74.13	79.12	109.21	100.00	104.24	123.73	144.92	166.53	176.88
CATO2	40.01	40.08	45.83	45.06	51.36	51.99	56.95	83.83	84.25	76.83	73.03	74.92	82.98	88.28	113.89	100.00	92.65	96.65	100.96	120.66	128.41

ANNEXURE E: Paasche Tractor index estimations

Categories	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	58.9	61.7	67.8	70.5	109.1	100.0	98.0	102.9	107.5	122.7	130.4
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	69.6	69.6	75.7	79.5	112.9	100.0	95.1	104.3	110.3	133.0	142.5
Cat 3	40.0	41.7	47.3	48.8	59.3	59.6	66.9	90.0	90.9	82.6	78.2	81.6	81.6	75.8	104.7	100.0	91.4	99.9	104.7	120.0	121.7
Cat 4	61.4	61.4	61.4	61.4	61.4	61.4	67.6	94.7	98.9	86.0	82.9	82.1	87.3	94.8	113.0	100.0	94.0	94.3	97.5	111.7	118.7
Cat 5	37.5	38.1	44.2	46.1	49.4	54.7	61.1	82.2	85.1	77.2	73.3	73.5	76.5	84.7	110.3	100.0	95.7	102.5	108.4	127.2	139.2
Cat 6	30.0	32.2	37.4	37.7	41.7	44.0	45.9	66.0	66.7	58.3	59.3	60.5	68.5	82.0	101.6	100.0	100.8	102.8	112.4	125.9	137.3
Cat 7	32.8	36.8	41.6	43.5	50.5	49.6	52.2	65.1	75.4	67.7	64.7	67.1	77.0	88.4	107.6	100.0	93.1	98.1	105.8	126.2	139.4
Cat 8	26.2	29.6	35.0	37.3	45.4	46.5	52.9	70.1	75.7	68.3	64.9	67.5	75.5	90.4	108.4	100.0	99.1	105.0	111.8	134.5	131.7
Cat 9	25.6	28.8	32.8	32.4	36.3	40.7	42.7	59.7	62.3	57.2	57.0	60.1	66.6	78.1	106.5	100.0	96.2	103.8	120.0	134.8	114.6
Cat 10	24.2	28.5	32.0	34.3	35.2	38.1	41.7	55.5	61.7	58.6	57.9	61.9	69.3	89.9	104.2	100.0	92.2	99.7	107.3	116.0	129.3
Cat 11	21.1	23.1	28.7	29.1	33.9	35.4	41.4	50.6	54.3	50.7	50.3	51.7	63.6	70.2	102.3	100.0	94.9	97.9	105.1	121.2	128.8
Cat 12	24.4	26.2	30.0	29.4	33.0	37.1	43.0	50.6	60.1	54.0	51.5	59.9	65.7	87.5	102.0	100.0	80.6	87.0	96.9	117.6	116.6
Cat 13	23.9	26.5	30.6	33.7	37.7	41.0	46.7	56.6	68.5	63.7	57.6	60.6	71.4	82.6	107.5	100.0	97.3	111.2	120.4	152.7	139.1
Cat 14	21.1	22.6	27.7	30.2	35.3	37.7	44.2	63.2	69.8	63.1	59.4	64.4	73.3	77.6	111.4	100.0	106.9	111.6	126.7	144.0	143.2
Cat 15	21.2	24.9	27.4	30.5	35.8	39.4	46.7	70.0	73.8	55.6	53.6	62.8	71.3	82.6	110.4	100.0	93.8	104.1	113.7	130.4	126.6
CATO1	31.9	31.4	34.5	37.8	46.0	44.8	49.9	68.4	69.7	63.6	66.1	69.4	75.5	83.8	104.5	100.0	91.5	103.5	110.6	133.0	142.9
CATO2	30.3	30.4	35.2	33.9	38.3	38.3	43.8	54.2	61.8	54.6	53.3	59.2	66.0	76.9	101.1	100.0	92.1	101.8	115.6	128.1	142.2
FWD	**25.6**	**28.3**	**32.9**	**34.7**	**40.2**	**42.4**	**47.2**	**63.7**	**68.9**	**61.3**	**59.3**	**62.9**	**71.0**	**84.1**	**106.1**	**100.0**	**95.2**	**102.0**	**111.7**	**128.9**	**131.0**
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	100.0	100.7	110.5	146.8	150.1	119.1
Cat 3	38.4	40.7	44.7	43.4	53.3	53.5	59.7	85.4	86.0	74.9	70.3	73.6	81.8	89.4	114.6	100.0	89.9	93.2	95.9	103.5	112.6
Cat 4	47.3	48.4	50.8	53.1	58.9	61.0	67.4	87.2	94.3	87.0	80.1	81.5	92.5	105.9	116.6	100.0	97.2	103.9	115.1	125.8	135.4
Cat 5	32.2	34.8	43.8	44.0	51.7	53.3	58.7	73.6	81.0	72.6	70.3	69.9	76.1	92.5	110.7	100.0	96.7	102.8	108.4	129.2	137.8
Cat 6	33.3	33.3	37.5	39.0	42.8	50.7	53.1	76.6	82.2	74.2	67.7	67.5	77.1	83.7	116.0	100.0	98.9	106.9	115.7	133.9	122.1
Cat 7	32.2	35.6	41.6	44.3	50.6	49.3	52.2	66.7	74.4	62.0	60.7	67.7	76.0	89.6	106.4	100.0	85.3	105.1	105.7	116.2	106.1
Cat 8	24.2	26.3	30.3	31.1	38.2	43.2	45.5	78.1	74.8	62.0	57.2	61.5	71.4	78.8	102.7	100.0	110.5	125.8	136.2	141.8	147.8
Cat 9	31.5	34.2	39.4	40.5	49.7	56.3	56.3	84.9	88.2	82.0	69.7	71.3	83.7	88.2	105.3	100.0	98.2	115.2	124.6	141.4	100.0
Cat 10	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-	-	-	-	-	-
Cat 11	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 12	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
CATO1	28.2	28.0	33.3	34.4	39.9	41.8	46.1	64.0	68.5	62.8	61.5	68.1	70.5	77.6	106.3	100.0	103.2	127.1	143.1	169.9	169.9
CATO2	37.4	37.1	43.0	40.5	48.8	48.0	53.2	76.4	78.0	71.0	67.1	70.6	75.7	76.6	104.4	100.0	93.6	97.6	103.1	115.0	126.7
TWD	**31.2**	**33.2**	**39.1**	**40.1**	**46.9**	**49.6**	**53.8**	**73.7**	**78.4**	**69.3**	**65.8**	**69.3**	**77.3**	**88.5**	**109.9**	**100.0**	**94.5**	**104.2**	**110.1**	**124.5**	**125.4**
Tractor Ind	26.7	29.2	34.1	35.7	41.4	43.7	48.5	65.6	70.8	62.9	60.7	64.3	72.3	85.1	106.9	100.0	95.1	102.4	111.4	128.2	130.2
Abstract	21.1	22.1	25.2	25.2	30.8	32.1	41.5	61.0	65.9	64.0	61.3	61.4	61.5	70.9	86.3	100.0	108.1	114.5	126.3	139.9	151.7

ANNEXURE F: Fischer Tractor Index estimations

Categories	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	58.2	60.5	67.2	70.7	107.2	100.0	97.4	101.9	108.1	122.7	130.0
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	70.1	70.1	76.2	80.7	113.8	100.0	95.2	104.3	110.9	133.0	142.5
Cat 3	39.6	42.0	46.9	48.7	58.6	59.5	66.2	88.8	90.9	82.5	78.5	79.7	81.7	78.0	104.8	100.0	93.2	100.1	105.1	121.3	126.4
Cat 4	60.9	60.9	60.9	60.9	60.9	60.9	65.8	93.8	97.7	85.0	82.0	80.1	86.3	93.1	110.8	100.0	93.8	93.8	97.3	111.0	118.1
Cat 5	38.0	38.7	44.8	46.6	50.1	55.2	60.7	81.6	85.5	77.1	73.3	73.0	76.5	86.9	110.3	100.0	95.7	102.0	108.5	127.6	138.3
Cat 6	30.4	32.4	37.6	38.3	42.3	44.5	47.3	65.6	67.3	58.8	59.7	61.0	68.7	81.2	102.7	100.0	100.1	102.7	111.2	126.9	137.2
Cat 7	32.3	35.8	40.9	43.2	49.9	49.3	52.1	66.1	74.7	66.8	64.2	66.7	75.8	88.1	108.2	100.0	94.1	98.6	105.6	126.5	138.9
Cat 8	26.2	29.3	35.0	37.3	45.1	46.4	52.0	70.2	75.4	67.1	64.6	66.9	74.8	90.0	107.9	100.0	98.6	104.3	112.2	131.8	133.0
Cat 9	26.0	29.2	33.3	33.3	37.1	40.8	43.6	59.2	62.4	57.5	57.1	59.7	67.5	77.6	107.1	100.0	96.2	105.2	120.1	135.8	130.5
Cat 10	24.3	28.1	32.0	34.1	35.7	38.2	41.5	55.6	62.0	58.8	58.3	62.3	70.5	89.3	106.9	100.0	92.8	99.6	107.0	116.1	128.4
Cat 11	21.6	23.8	29.5	30.5	34.9	36.5	41.9	52.4	55.8	52.1	51.4	53.7	64.8	73.0	104.0	100.0	94.1	97.1	104.8	120.1	127.6
Cat 12	25.8	27.1	31.3	31.1	34.9	39.0	44.4	56.2	63.0	56.6	54.0	62.0	69.3	91.5	106.9	100.0	80.2	86.9	96.2	117.3	120.8
Cat 13	24.0	26.6	30.9	34.0	38.0	40.7	46.5	58.6	68.2	61.7	57.2	59.7	70.9	81.5	106.8	100.0	96.8	109.4	120.3	149.6	150.7
Cat 14	22.0	24.0	28.8	31.6	36.9	39.0	45.5	64.9	71.1	63.6	59.2	63.8	73.1	80.0	111.1	100.0	103.5	110.4	123.8	142.9	147.0
Cat 15	21.1	24.6	27.6	30.9	35.3	39.6	46.9	69.2	73.7	56.9	53.6	62.2	71.2	81.8	110.4	100.0	94.4	104.3	114.4	130.8	132.1
CATO1	32.2	31.8	34.9	37.9	46.3	45.0	50.2	67.7	69.7	63.5	66.1	67.9	74.6	83.9	104.4	100.0	92.6	104.8	113.8	134.7	143.7
CATO2	30.8	31.1	35.9	34.7	38.6	38.9	44.8	57.6	63.0	55.5	54.4	59.5	67.0	78.4	102.9	100.0	92.0	101.7	112.3	128.9	142.4
4WD	**26**	**28**	**33**	**35**	**41**	**43**	**47**	**64**	**69**	**61**	**60**	**63**	**71**	**84**	**107**	**100**	**95**	**102**	**111**	**129**	**135**
Cat 1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	100.0	99.7	109.8	138.6	148.3	137.2
Cat 3	39.8	42.1	46.5	45.4	54.9	55.4	61.9	86.8	88.9	75.7	70.6	73.6	80.8	89.9	115.9	100.0	89.4	93.2	95.9	104.3	112.9
Cat 4	47.2	48.4	50.8	51.7	59.0	60.9	67.5	87.8	94.9	87.5	80.2	81.7	91.3	103.4	116.6	100.0	97.6	104.2	114.8	126.5	137.6
Cat 5	32.1	34.7	43.1	44.0	51.2	53.0	58.1	74.7	80.2	72.2	69.9	69.0	75.5	90.8	109.9	100.0	96.6	102.0	108.4	128.8	137.6
Cat 6	34.7	34.3	38.7	40.6	44.2	52.3	56.0	79.7	84.2	76.0	70.1	71.0	80.2	86.3	120.4	100.0	98.6	106.6	115.7	134.4	125.2
Cat 7	32.2	35.3	41.4	44.3	50.5	49.3	52.5	66.5	74.3	62.7	60.7	68.0	76.8	90.3	107.1	100.0	88.8	103.2	106.9	119.7	114.9
Cat 8	25.6	28.2	33.5	34.5	41.9	46.7	53.7	83.8	79.0	67.4	62.2	67.2	77.6	85.7	113.9	100.0	104.8	120.4	130.9	141.8	144.4
Cat 9	29.9	31.9	37.1	38.1	47.0	54.1	60.6	88.7	87.0	78.7	69.7	72.2	83.7	88.5	105.3	100.0	96.4	113.4	122.7	136.9	121.6
Cat 10	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-	-	-	-	-	-
Cat 11	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
Cat 12	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	-	-	-	-	-	-
CATO1	28.9	29.0	33.8	34.9	40.3	42.5	46.7	63.7	68.8	63.7	62.2	68.0	72.3	78.3	107.8	100.0	103.7	125.4	144.0	168.2	173.4
CATO2	38.7	38.6	44.4	42.7	50.1	50.0	55.0	80.1	81.1	73.9	70.0	72.7	79.3	82.2	109.0	100.0	93.1	97.1	102.0	117.8	127.5
2WD	**32**	**34**	**40**	**41**	**47**	**50**	**55**	**75**	**79**	**70**	**67**	**70**	**78**	**89**	**112**	**100**	**95**	**103**	**110**	**126**	**128**
Tractor In	**27**	**29**	**34**	**36**	**42**	**44**	**49**	**66**	**71**	**63**	**61**	**64**	**73**	**85**	**108**	**100**	**95**	**102**	**111**	**128**	**134**
Abstract	**21**	**22**	**25**	**25**	**31**	**32**	**42**	**61**	**66**	**64**	**61**	**61**	**62**	**71**	**86**	**100**	**108**	**115**	**126**	**140**	**152**

ANNEXURE G: Eviews output: Cointegration tests

Null Hypothesis: ABSTRACT has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		1.152037	0.9962
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 18

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ABSTRACT)
Method: Least Squares
Date: 08/20/17 Time: 15:21
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ABSTRACT(-1)	0.054658	0.047445	1.152037	0.2686
D(ABSTRACT(-1))	0.615763	0.252969	2.434141	0.0289
D(ABSTRACT(-2))	-0.458047	0.262966	-1.741851	0.1035
C	1.800626	3.018095	0.596610	0.5603

R-squared	0.416920	Mean dependent var	7.027778
Adjusted R-squared	0.291974	S.D. dependent var	6.556524
S.E. of regression	5.516939	Akaike info criterion	6.446653
Sum squared resid	426.1126	Schwarz criterion	6.644514
Log likelihood	-54.01988	Hannan-Quinn criter.	6.473936
F-statistic	3.336809	Durbin-Watson stat	2.057894
Prob(F-statistic)	0.050287		

Null Hypothesis: ABSTRACT has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.840460	0.6447
Test critical values:	1% level	-4.532598	
	5% level	-3.673616	
	10% level	-3.277364	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 19

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ABSTRACT)
Method: Least Squares
Date: 08/20/17 Time: 15:23
Sample (adjusted): 1997 2015
Included observations: 19 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ABSTRACT(-1)	-0.259598	0.141050	-1.840460	0.0856
D(ABSTRACT(-1))	0.603089	0.231861	2.601081	0.0201
C	1.098073	2.663197	0.412314	0.6859
@TREND("1995")	1.789701	0.850759	2.103653	0.0527

R-squared	0.462899	Mean dependent var	6.821053
Adjusted R-squared	0.355478	S.D. dependent var	6.435197
S.E. of regression	5.166311	Akaike info criterion	6.306859
Sum squared resid	400.3615	Schwarz criterion	6.505688
Log likelihood	-55.91516	Hannan-Quinn criter.	6.340508
F-statistic	4.309231	Durbin-Watson stat	1.709747
Prob(F-statistic)	0.022190		

Null Hypothesis: D(ABSTRACT) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.655880	0.1008
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 18

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ABSTRACT,2)
Method: Least Squares
Date: 08/20/17 Time: 15:27
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ABSTRACT(-1))	-0.640715	0.241244	-2.655880	0.0180
D(ABSTRACT(-1),2)	0.347937	0.247638	1.405020	0.1804
C	4.432903	1.993237	2.223971	0.0419

R-squared	0.319984	Mean dependent var	0.483333
Adjusted R-squared	0.229316	S.D. dependent var	6.352512
S.E. of regression	5.576784	Akaike info criterion	6.426113
Sum squared resid	466.5078	Schwarz criterion	6.574509
Log likelihood	-54.83502	Hannan-Quinn criter.	6.446575
F-statistic	3.529157	Durbin-Watson stat	1.941346
Prob(F-statistic)	0.055449		

Null Hypothesis: D(ABSTRACT) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.158116	0.1236
Test critical values:	1% level	-4.571559	
	5% level	-3.690814	
	10% level	-3.286909	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 18

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ABSTRACT,2)
Method: Least Squares
Date: 08/20/17 Time: 15:24
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ABSTRACT(-1))	-0.819746	0.259568	-3.158116	0.0070
D(ABSTRACT(-1),2)	0.429013	0.243378	1.762745	0.0997
C	0.777587	3.070989	0.253204	0.8038
@TREND("1995")	0.414802	0.272767	1.520718	0.1506

R-squared	0.416388	Mean dependent var	0.483333
Adjusted R-squared	0.291328	S.D. dependent var	6.352512
S.E. of regression	5.347713	Akaike info criterion	6.384345
Sum squared resid	400.3724	Schwarz criterion	6.582205
Log likelihood	-53.45910	Hannan-Quinn criter.	6.411627
F-statistic	3.329514	Durbin-Watson stat	2.051605
Prob(F-statistic)	0.050585		

Null Hypothesis: D(ABSTRACT,2) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.795133	0.0120
Test critical values:	1% level	-3.886751	
	5% level	-3.052169	
	10% level	-2.666593	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 17

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(ABSTRACT,3)
Method: Least Squares
Date: 08/20/17 Time: 15:27
Sample (adjusted): 1999 2015
Included observations: 17 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ABSTRACT(-1),2)	-1.321452	0.348196	-3.795133	0.0020
D(ABSTRACT(-1),3)	0.350270	0.248442	1.409864	0.1804
C	0.898842	1.587579	0.566172	0.5802

R-squared	0.554990	Mean dependent var	0.076471
Adjusted R-squared	0.491418	S.D. dependent var	9.091585
S.E. of regression	6.483661	Akaike info criterion	6.735233
Sum squared resid	588.5300	Schwarz criterion	6.882270
Log likelihood	-54.24948	Hannan-Quinn criter.	6.749849
F-statistic	8.729996	Durbin-Watson stat	1.969557
Prob(F-statistic)	0.003456		

Null Hypothesis: REVISED_TRACTOR_SERIES has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.787302	0.9901
Test critical values:	1% level	-3.920350	
	5% level	-3.065585	
	10% level	-2.673459	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REVISED_TRACTOR_SERIES)
Method: Least Squares
Date: 08/20/17 Time: 15:35
Sample (adjusted): 2000 2015
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REVISED_TRACTOR_SERIES(-1)	0.067849	0.086179	0.787302	0.4494
D(REVISED_TRACTOR_SERIES(-1))	-0.169699	0.277556	-0.611404	0.5546
D(REVISED_TRACTOR_SERIES(-2))	-0.662702	0.267826	-2.474373	0.0329
D(REVISED_TRACTOR_SERIES(-3))	-0.358328	0.261163	-1.372050	0.2000
D(REVISED_TRACTOR_SERIES(-4))	-0.642421	0.281612	-2.281225	0.0457
C	9.014000	6.657042	1.354055	0.2055

R-squared	0.529111	Mean dependent var	5.931470
Adjusted R-squared	0.293666	S.D. dependent var	9.203850
S.E. of regression	7.735255	Akaike info criterion	7.209450
Sum squared resid	598.3416	Schwarz criterion	7.499171
Log likelihood	-51.67560	Hannan-Quinn criter.	7.224286
F-statistic	2.247282	Durbin-Watson stat	2.403625
Prob(F-statistic)	0.129190		

Null Hypothesis: REVISED_TRACTOR_SERIES has a unit root
Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.055476	0.0681
Test critical values:	1% level	-4.532598	
	5% level	-3.673616	
	10% level	-3.277364	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 19

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REVISED_TRACTOR_SERIES)
Method: Least Squares
Date: 08/20/17 Time: 15:35
Sample (adjusted): 1997 2015
Included observations: 19 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REVISED_TRACTOR_SERIES(-1)	-0.914610	0.247495	-3.695476	0.0022
D(REVISED_TRACTOR_SERIES(-1))	0.652196	0.230793	2.825888	0.0128
C	16.74895	5.182099	3.232079	0.0056
@TREND("1995")	4.667397	1.228827	3.798255	0.0017

R-squared	0.505301	Mean dependent var	5.660386
Adjusted R-squared	0.406361	S.D. dependent var	8.452313
S.E. of regression	6.512334	Akaike info criterion	6.769937
Sum squared resid	636.1575	Schwarz criterion	6.968766
Log likelihood	-60.31440	Hannan-Quinn criter.	6.803587
F-statistic	5.107156	Durbin-Watson stat	2.185664
Prob(F-statistic)	0.012398		

Null Hypothesis: D(REVISED_TRACTOR_SERIES) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.213269	0.0057
Test critical values:	1% level	-3.920350	
	5% level	-3.065585	
	10% level	-2.673459	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REVISED_TRACTOR_SERIES,2)
Method: Least Squares
Date: 08/20/17 Time: 15:35
Sample (adjusted): 2000 2015
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

D(REVISED_TRACTOR_SERIES(-1))	-2.637768	0.626062	-4.213269	0.0015
D(REVISED_TRACTOR_SERIES(-1),2)	1.549175	0.486633	3.183456	0.0087
D(REVISED_TRACTOR_SERIES(-2),2)	0.935127	0.369720	2.529281	0.0280
D(REVISED_TRACTOR_SERIES(-3),2)	0.611973	0.274082	2.232815	0.0473
C	13.40748	3.566461	3.759324	0.0032

R-squared	0.697076	Mean dependent var	0.222602
Adjusted R-squared	0.586922	S.D. dependent var	11.82554
S.E. of regression	7.600416	Akaike info criterion	7.144589
Sum squared resid	635.4295	Schwarz criterion	7.386023
Log likelihood	-52.15672	Hannan-Quinn criter.	7.156953
F-statistic	6.328178	Durbin-Watson stat	2.275223
Prob(F-statistic)	0.006786		

Null Hypothesis: D(REVISED_TRACTOR_SERIES) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.272410	0.0199
Test critical values:	1% level	-4.667883	
	5% level	-3.733200	
	10% level	-3.310349	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REVISED_TRACTOR_SERIES,2)
Method: Least Squares
Date: 08/20/17 Time: 15:36
Sample (adjusted): 2000 2015
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(REVISED_TRACTOR_SERIES(-1))	-2.705439	0.633235	-4.272410	0.0016
D(REVISED_TRACTOR_SERIES(-1),2)	1.579292	0.490085	3.222484	0.0091
D(REVISED_TRACTOR_SERIES(-2),2)	0.957264	0.372293	2.571267	0.0278
D(REVISED_TRACTOR_SERIES(-3),2)	0.624961	0.275784	2.266125	0.0469
C	8.801199	6.053167	1.453983	0.1766
@TREND("1995")	0.396398	0.419779	0.944301	0.3673

R-squared	0.721876	Mean dependent var	0.222602
Adjusted R-squared	0.582814	S.D. dependent var	11.82554
S.E. of regression	7.638107	Akaike info criterion	7.184173
Sum squared resid	583.4068	Schwarz criterion	7.473894
Log likelihood	-51.47338	Hannan-Quinn criter.	7.199009
F-statistic	5.191043	Durbin-Watson stat	2.402344
Prob(F-statistic)	0.013157		

Null Hypothesis: REAL_NFI___R_BILLION__AB has a unit root

Exogenous: Constant
Lag Length: 4 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		2.114226	0.9997
Test critical values:	1% level	-3.920350	
	5% level	-3.065585	
	10% level	-2.673459	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REAL_NFI___R_BILLION__AB)
Method: Least Squares
Date: 08/20/17 Time: 15:40
Sample (adjusted): 2000 2015
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REAL_NFI___R_BILLION__AB(-1)	0.267146	0.126356	2.114226	0.0606
D(REAL_NFI___R_BILLION__AB(-1))	-0.437545	0.330164	-1.325234	0.2146
D(REAL_NFI___R_BILLION__AB(-2))	-0.866538	0.270894	-3.198812	0.0095
D(REAL_NFI___R_BILLION__AB(-3))	-0.478957	0.247206	-1.937476	0.0814
D(REAL_NFI___R_BILLION__AB(-4))	-0.715121	0.310756	-2.301231	0.0442
C	-20.13935	13.93983	-1.444734	0.1791

R-squared	0.642319	Mean dependent var	4.737755
Adjusted R-squared	0.463479	S.D. dependent var	10.45665
S.E. of regression	7.659249	Akaike info criterion	7.189701
Sum squared resid	586.6410	Schwarz criterion	7.479422
Log likelihood	-51.51761	Hannan-Quinn criter.	7.204537
F-statistic	3.591578	Durbin-Watson stat	1.922648
Prob(F-statistic)	0.040464		

Null Hypothesis: REAL_NFI___R_BILLION__AB has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.462136	0.7994
Test critical values:	1% level	-4.667883	
	5% level	-3.733200	
	10% level	-3.310349	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REAL_NFI___R_BILLION__AB)
Method: Least Squares
Date: 08/20/17 Time: 15:40
Sample (adjusted): 2000 2015

Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REAL_NFI___R_BILLION__AB(-1)	-0.522744	0.357521	-1.462136	0.1777
D(REAL_NFI___R_BILLION__AB(-1))	0.007475	0.336186	0.022235	0.9827
D(REAL_NFI___R_BILLION__AB(-2))	-0.509841	0.273763	-1.862343	0.0955
D(REAL_NFI___R_BILLION__AB(-3))	-0.208335	0.237262	-0.878081	0.4027
D(REAL_NFI___R_BILLION__AB(-4))	-0.650351	0.260951	-2.492232	0.0343
C	32.77705	25.67401	1.276663	0.2337
@TREND("1995")	3.147576	1.361230	2.312303	0.0461

R-squared	0.775620	Mean dependent var	4.737755
Adjusted R-squared	0.626033	S.D. dependent var	10.45665
S.E. of regression	6.394543	Akaike info criterion	6.848403
Sum squared resid	368.0116	Schwarz criterion	7.186410
Log likelihood	-47.78722	Hannan-Quinn criter.	6.865712
F-statistic	5.185078	Durbin-Watson stat	2.112813
Prob(F-statistic)	0.014330		

Null Hypothesis: D(REAL_NFI___R_BILLION__AB) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.463301	0.0029
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 18

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REAL_NFI___R_BILLION__AB,2)
Method: Least Squares
Date: 08/20/17 Time: 15:41
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(REAL_NFI___R_BILLION__AB(-1))	-1.189702	0.266552	-4.463301	0.0005
D(REAL_NFI___R_BILLION__AB(-1),2)	0.544362	0.215198	2.529588	0.0231
C	4.338077	2.347999	1.847563	0.0845

R-squared	0.571304	Mean dependent var	-0.008487
Adjusted R-squared	0.514144	S.D. dependent var	12.99537
S.E. of regression	9.058208	Akaike info criterion	7.396231
Sum squared resid	1230.767	Schwarz criterion	7.544627
Log likelihood	-63.56608	Hannan-Quinn criter.	7.416693
F-statistic	9.994901	Durbin-Watson stat	2.118121
Prob(F-statistic)	0.001742		

Null Hypothesis: D(REAL_NFI___R_BILLION__AB) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.164855	0.0043
Test critical values:	1% level	-4.667883	
	5% level	-3.733200	
	10% level	-3.310349	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 16

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(REAL_NFI___R_BILLION__AB,2)
Method: Least Squares
Date: 08/20/17 Time: 15:41
Sample (adjusted): 2000 2015
Included observations: 16 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(REAL_NFI___R_BILLION__AB(-1))	-3.237669	0.626865	-5.164855	0.0004
D(REAL_NFI___R_BILLION__AB(-1),2)	1.907605	0.441665	4.319121	0.0015
D(REAL_NFI___R_BILLION__AB(-2),2)	1.136249	0.333212	3.409985	0.0067
D(REAL_NFI___R_BILLION__AB(-3),2)	0.726842	0.269807	2.693939	0.0225
C	-4.116843	5.001179	-0.823174	0.4296
@TREND("1995")	1.245887	0.423887	2.939195	0.0148

R-squared	0.822421	Mean dependent var	1.025465
Adjusted R-squared	0.733632	S.D. dependent var	13.07582
S.E. of regression	6.748543	Akaike info criterion	6.936527
Sum squared resid	455.4283	Schwarz criterion	7.226247
Log likelihood	-49.49221	Hannan-Quinn criter.	6.951363
F-statistic	9.262612	Durbin-Watson stat	2.077381
Prob(F-statistic)	0.001630		

Null Hypothesis: EXRATE has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.023147	0.7228
Test critical values:	1% level	-3.831511	
	5% level	-3.029970	
	10% level	-2.655194	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 19

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(EXRATE)
Method: Least Squares
Date: 01/31/18 Time: 22:03
Sample (adjusted): 1997 2015
Included observations: 19 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EXRATE(-1)	-0.162502	0.158825	-1.023147	0.3215
D(EXRATE(-1))	0.452633	0.253633	1.784595	0.0933
C	1.480393	1.177681	1.257041	0.2268

R-squared	0.177573	Mean dependent var	0.445789
Adjusted R-squared	0.074770	S.D. dependent var	1.157163
S.E. of regression	1.113062	Akaike info criterion	3.196046
Sum squared resid	19.82252	Schwarz criterion	3.345168
Log likelihood	-27.36244	Hannan-Quinn criter.	3.221283
F-statistic	1.727307	Durbin-Watson stat	1.542391
Prob(F-statistic)	0.209305		

Null Hypothesis: D(EXRATE) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.308528	0.0238
Test critical values:	1% level	-2.692358	
	5% level	-1.960171	
	10% level	-1.607051	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations
and may not be accurate for a sample size of 19

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(EXRATE,2)
Method: Least Squares
Date: 01/31/18 Time: 22:07
Sample (adjusted): 1997 2015
Included observations: 19 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(EXRATE(-1))	-0.533223	0.230979	-2.308528	0.0331

R-squared	0.225365	Mean dependent var	0.078421
Adjusted R-squared	0.225365	S.D. dependent var	1.276576
S.E. of regression	1.123558	Akaike info criterion	3.122074
Sum squared resid	22.72288	Schwarz criterion	3.171781
Log likelihood	-28.65970	Hannan-Quinn criter.	3.130486
Durbin-Watson stat	1.605183		

Cointegration

Date: 01/31/18 Time: 13:06
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: RTPI NFI__R_BILLION__ABSTRACT EXRATE
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.8273731294042109	58.87774868429707	42.91524702950814	0.0006411697980674045
At most 1 *	0.6065486694941347	27.25853772395461	25.87210792599721	0.0334346980376471
At most 2	0.4409773593100454	10.46817548133312	12.5179828950518	0.1074660289616139

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.8273731294042109	31.61921096034247	25.82321074815056	0.007653006317678123
At most 1	0.6065486694941347	16.79036224262149	19.38704005619111	0.1145971683454619
At most 2	0.4409773593100454	10.46817548133312	12.5179828950518	0.1074660289616139

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE	@TREND(96)
1.284756736168285	-0.7321929872713622	-3.52532137584528	-3.40942341444593
-0.2170377390422575	0.2580493615099753	1.259635624675579	-0.1385604066292288
0.3400793051684602	-0.2731372184976601	0.01970279708008782	-0.8134057550677523

Unrestricted Adjustment Coefficients (alpha):

D(RTPI)	-3.422562997751827	-0.4150316717481582	0.578100490826555
D(NFI__R_BILLION__ABSTRACT)	-4.428305596600424	-3.244893498490079	0.7622767028694835
D(EXRATE)	-0.3986773081968038	-0.19662036255981	-0.5446656199213555

1 Cointegrating Equation(s):	Log likelihood	-105.6500727433621

Normalized cointegrating coefficients (standard error in parentheses)

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE	@TREND(96)
1	-0.5699078795687666	-2.743960219550533	-2.653750175783746
	0.02391932344607692	0.151728328339163	0.09570390576458146

Adjustment coefficients (standard error in parentheses)

D(RTPI)	-4.3971608663215
	0.7585394880556398
D(NFI__R_BILLION__ABSTRACT)	-5.689295445043556
	1.938603598832086
D(EXRATE)	-0.5122033357631758
	0.3564208029397155

2 Cointegrating Equation(s):	Log likelihood	-97.2548916220514

Normalized cointegrating coefficients (standard error in parentheses)

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE	@TREND(96)
1	0	0.07293273650721211	-5.68455985914708
		1.339503522452024	0.3405390705681275
0	1	4.94271628283014	-5.318069449498861
		2.315350630479344	0.5886265609062658

Adjustment coefficients (standard error in parentheses)

D(RTPI)	-4.307083330652976	2.398877967546201
	0.7500396087806867	0.4468916322769533
D(NFI__R_BILLION__ABSTRACT)	-4.985031096695887	2.405031607870326
	1.441480389060845	0.8588686736289149
D(EXRATE)	-0.4695293183236038	0.2411709702274871
	0.352275352958109	0.2098941251253595

Date: 01/31/18 Time: 13:29
Sample (adjusted): 1999 2015

Included observations: 17 after adjustments
Trend assumption: Linear deterministic trend
Series: RTPI NFI__R_BILLION__ABSTRACT EXRATE
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.924787	63.02220	29.79707	0.0000
At most 1 *	0.670319	19.03588	15.49471	0.0140
At most 2	0.010075	0.172150	3.841466	0.6782

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.924787	43.98631	21.13162	0.0000
At most 1 *	0.670319	18.86373	14.26460	0.0087
At most 2	0.010075	0.172150	3.841466	0.6782

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE
0.399082	-0.474865	-1.428823
0.135346	-0.061405	-1.689097
0.166348	-0.217076	-1.586387

Unrestricted Adjustment Coefficients (alpha):

D(RTPI)	1.067382	-0.849687	-0.161165
D(NFI__R_BILLION__ABSTRACT)	4.190632	0.112912	-0.149299
D(EXRATE)	0.072223	0.489001	-0.065546

1 Cointegrating Equation(s): Log likelihood -81.15114

Normalized cointegrating coefficients (standard error in parentheses)

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE
1.000000	-1.189893	-3.580276
	(0.02885)	(0.40307)

Adjustment coefficients (standard error in parentheses)

D(RTPI)	0.425973
	(0.31540)

D(NFI__R_BILLION__ABSTRACT)	1.672405
	(0.31168)
D(EXRATE)	0.028823
	(0.14422)

2 Cointegrating Equation(s): Log likelihood -71.71928

Normalized cointegrating coefficients (standard error in parentheses)

RTPI	NFI__R_BILLION__ABSTRACT	EXRATE
1.000000	0.000000	-17.96433
		(3.71422)
0.000000	1.000000	-12.08852
		(3.14667)

Adjustment coefficients (standard error in parentheses)

D(RTPI)	0.310971	-0.454687
	(0.29926)	(0.34002)
D(NFI__R_BILLION__ABSTRACT)	1.687687	-1.996916
	(0.32854)	(0.37330)
D(EXRATE)	0.095007	-0.064323
	(0.12694)	(0.14423)

Vector Error Correction Estimates
Date: 01/31/18 Time: 13:31
Sample (adjusted): 1998 2015
Included observations: 18 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
RTPI(-1)	1.000000
NFI__R_BILLION__ABSTRACT(-1)	-1.066538
	(0.07303)
	[-14.6047]
EXRATE(-1)	-5.270002
	(0.97561)
	[-5.40175]
C	-4.361194

Error Correction:	D(RTPI)	D(NFI__R_BILLION__ABSTRACT)	D(EXRATE)
CointEq1	0.067817	0.815852	0.050126
	(0.33120)	(0.49047)	(0.08049)
	[0.20476]	[1.66340]	[0.62277]
D(RTPI(-1))	-0.769706	-0.581178	-0.012340
	(0.34896)	(0.51677)	(0.08480)
	[-2.20569]	[-1.12463]	[-0.14551]

D(RTPI(-2))	-0.608941	-0.469893	0.036072
	(0.26761)	(0.39630)	(0.06503)
	[-2.27549]	[-1.18571]	[0.55467]
D(NFI__R_BILLION__ABSTRACT(-1))	0.564657	0.643233	0.019376
	(0.28998)	(0.42942)	(0.07047)
	[1.94725]	[1.49792]	[0.27496]
D(NFI__R_BILLION__ABSTRACT(-2))	0.700335	0.210224	-0.040948
	(0.26817)	(0.39713)	(0.06517)
	[2.61153]	[0.52936]	[-0.62833]
D(EXRATE(-1))	4.436308	4.554087	0.794376
	(2.11239)	(3.12820)	(0.51335)
	[2.10013]	[1.45582]	[1.54745]
D(EXRATE(-2))	2.748540	4.464528	-0.236999
	(2.28530)	(3.38424)	(0.55536)
	[1.20271]	[1.31921]	[-0.42674]
C	6.491844	3.401563	0.211456
	(2.15314)	(3.18854)	(0.52325)
	[3.01506]	[1.06681]	[0.40412]
R-squared	0.788099	0.494339	0.331880
Adj. R-squared	0.639768	0.140376	-0.135804
Sum sq. resids	272.4547	597.4932	16.09034
S.E. equation	5.219720	7.729768	1.268477
F-statistic	5.313110	1.396585	0.709624
Log likelihood	-49.99480	-57.06223	-24.53152
Akaike AIC	6.443867	7.229137	3.614613
Schwarz SC	6.839587	7.624858	4.010334
Mean dependent	5.683736	3.725700	0.453333
S.D. dependent	8.696727	8.337048	1.190230

Determinant resid covariance (dof adj.)	334.0939
Determinant resid covariance	57.28633
Log likelihood	-113.0552
Akaike information criterion	15.56169
Schwarz criterion	16.89725

ANNEXURE H: Granger Causality Test

VEC Granger Causality/Block Exogeneity Wald Tests

Date: 01/31/18 Time: 13:32

Sample: 1995 2015

Included observations: 18

Dependent variable: D(RTPI)

Excluded	Chi-sq	df	Prob.

D(NFI__R_BILLION__ABSTRACT)	8.951131	2	0.0114
D(EXRATE)	5.333967	2	0.0695
All	11.98771	4	0.0174

Dependent variable: D(NFI__R_BILLION__ABSTRACT)

Excluded	Chi-sq	df	Prob.
D(RTPI)	2.225587	2	0.3286
D(EXRATE)	3.453556	2	0.1779
All	6.137502	4	0.1891

Dependent variable: D(EXRATE)

Excluded	Chi-sq	df	Prob.
D(RTPI)	0.376295	2	0.8285
D(NFI__R_BILLION__ABSTRACT)	0.560612	2	0.7556
All	0.625425	4	0.9602

ANNEXURE I: Service flow Estimations

								Depreciation=0,10															
								0.9															
		(1-sigma)	(1-sigma)^2	(1-sigma)^3	(1-sigma)^4	(1-sigma)^5	(1-sigma)^6	(1-sigma)^7	(1-sigma)^8	(1-sigma)^9	(1-sigma)^10	(1-sigma)^11	(1-sigma)^12	(1-sigma)^13	(1-sigma)^14	(1-sigma)^15	(1-sigma)^16	(1-sigma)^17	(1-sigma)^18	(1-sigma)^19	(1-sigma)^20	Kt (Real)	
		0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.25	0.23	0.21	0.19	0.17	0.15	0.14	0.12		
t	Investment (It)																						
	Revised																						
1995	4446311813																					**4 446 311 813**	4 446
1996	6213295283	4001680632	3601512569	3241361312	2917225181	2625502663	2362952396	2126657157	1913991441	1722592297	1550333067	1395299761	1255769784	1130192806	1017173525	915456172.9	823910555.6	741519500	667367550	600630795	540567715.5	**10 214 975 915**	10 215
1997	5796329429	5591965755	5032769179	4529492261	4076543035	3668888732	3301999859	2971799873	2674619885	2407157897	2166442107	1949797896	1754818107	1579336296	1421402667	1279262400	1151336160	1036202544	932582289.5	839324060.6	755391654.5	**14 989 807 752**	14 990
1998	4258927597	5216696486	4695026837	4225524154	3802971738	3422674564	3080407108	2772366397	2495129757	2245616782	2021055104	1818949593	1637054634	1473349170	1326014253	1193412828	1074071545	966664390.8	869997951.7	782998156.5	704698340.9	**17 749 754 574**	17 750
1999	2650426201	3833034837	3449731353	3104758218	2794282396	2514854157	2263368741	2037031867	1833328680	1649995812	1484996231	1336496608	1202846947	1082562252	974306027.1	876875424.4	789187882	710269093.8	639242184.4	575317965.9	517786169.4	**18 625 205 318**	18 625
2000	2804429541	2385383581	2146845223	1932160701	1738944631	1565050168	1408545151	1267690636	1140921572	1026829415	924146473.5	831731826.1	748558643.5	673702779.2	606332501.3	545699251.1	491129326	442016393.4	397814754.1	358033278.7	322229950.8	**19 567 114 327**	19 567
2001	2982253224	2523986587	2271587929	2044429136	1839986222	1655987600	1490388840	1341349956	1207214960	1086493464	977844117.9	880059706.1	792053735.5	712848361.9	641563525.7	577407173.2	519666455.8	467699810.3	420929829.2	378836846.3	340953161.7	**20 592 656 119**	20 593
2002	4995461806	2684027902	2415625112	2174062600	1956656340	1760990706	1584891636	1426402472	1283762225	1155386002	1039847402	935862662	842276395.8	758048756.2	682243880.6	614019492.5	552617543.3	497355789	447620210.1	402858189.1	362572370.1	**23 528 852 314**	23 529
2003	4638065758	4495915626	4046324063	3641691657	3277522491	2949770242	2654793218	2389313896	2150382506	1935344256	1741809830	1567628847	1410865962	1269779366	1142801430	1028521287	925669158	833102242.2	749792018	674812816.2	607331534.6	**25 814 032 841**	25 814
2004	5907274950	4174259183	3756833264	3381149938	3043034944	2738731450	2464858305	2218372474	1996535227	1796881704	1617193534	1455474180	1309926762	1178934086	1061040677	954936609.7	859442948.7	773498653.9	696148788.5	626533909.6	563880518.7	**29 139 904 507**	29 140
2005	3763746572	5316547455	4784892710	4306403439	3875763095	3488186785	3139368107	2825431296	2542888167	2288599350	2059739415	1853765473	1668388926	1501550033	1351395030	1216255527	1094629974	985166977	886650279.3	797985251.3	718186726.2	**29 989 660 628**	29 990
2006	5198231581	3387371915	3048634723	2743771251	2469394126	2222454713	2000209242	1800188318	1620169486	1458152537	1312337284	1181103555	1062993200	956693879.7	861024491.8	774922042.6	697429838.3	627686854.5	564918169	508426352.1	457583716.9	**32 188 926 146**	32 189
2007	4225657005	4678408423	4210567581	3789510823	3410559740	3069503766	2762553390	2486298051	2237668246	2013901421	1812511279	1631260151	1468134136	1321320722	1189188650	1070269785	963242806.6	866918525.9	780226673.3	702204006	631983605.4	**33 195 690 536**	33 196
2008	9611960587	3803091304	3422782174	3080503956	2772453561	2495208205	2245687384	2021118646	1819006781	1637106103	1473395493	1326055944	1193450349	1074105314	966694782.8	870025304.5	783022774.1	704720496.7	634248447	570823602.3	513741242.1	**39 488 082 070**	39 488
2009	6254226975	8650764528	7785688075	7007119268	6306407341	5675766607	5108189946	4597370952	4137633856	3723870471	3351483424	3016335081	2714701573	2443231416	2198908274	1979017447	1781115702	1603004132	1442703719	1298433347	1168590012	**41 793 500 838**	41 794
2010	4602860929	5628804278	5065923850	4559331465	4103398319	3693058487	3323752638	2991377374	2692239637	2423015673	2180714106	1962642695	1766378426	1589740583	1430766525	1287689872	1158920885	1043028797	938725916.9	844853325.2	760367992.7	**42 217 011 683**	42 217
2011	6755116304	4142574836	3728317352	3355485617	3019937056	2717943350	2446149015	2201534113	1981380702	1783242632	1604918369	1444426532	1299983879	1169985491	1052986942	947688247.5	852919422.8	767627480.5	690864732.5	621778259.2	559600433.3	**44 750 426 819**	44 750
2012	8522690755	6079604674	5471644206	4924479786	4432031807	3988828626	3589945764	3230951187	2907856069	2617070462	2355363416	2119827074	1907844367	1717059930	1545353937	1390818543	1251736689	1126563020	1013906718	912516046.2	821264441.6	**48 798 074 892**	48 798
2013	8327451926	7670421679	6903379511	6213041560	5591737404	5032563664	4529307297	4076376568	3668738911	3301865020	2971678518	2674510666	2407059599	2166353640	1949718276	1754746448	1579271803	1421344623	1279210161	1151289145	1036160230	**52 245 719 328**	52 246
2014	7086753353	7494706733	6745236060	6070712454	5463641208	4917277088	4425549379	3982994441	3584694997	3226225497	2903602947	2613242653	2351918387	2116726549	1905053894	1714548504	1543093654	1388784289	1249905860	1124915274	1012423746	**54 107 900 748**	54 108
2015	6401224749	6378078017	5740270216	5166243194	4649618875	4184656987	3766191288	3389572160	3050614944	2745553449	2470998104	2223898294	2001508465	1801357618	1621221856	1459099671	1313189704	1181870733	1063683660	957315293.9	861583764.5	**55 098 335 422**	55 098
																							-
	Fixed ratio																						-
1995	4201963550																					**4 201 963 550**	4 202
1996	5908362454	3781767195	3403590475	3063231428	2756908285	2481217456	2233095711	2009786140	1808807526	1627926773	1465134096	1318620686	1186758618	1068082756	961274480.3	865147032.3	778632329	700769096.1	630692186.5	567622967.9	510860671.1	**9 690 129 648**	9 690
1997	5379234824	5317526208	4785773587	4307196229	3876476606	3488828945	3139946051	2825951446	2543356301	2289020671	2060118604	1854106743	1668696069	1501826462	1351643816	1216479434	1094831491	985348341.9	886813507.7	798132156.9	718318941.2	**14 100 351 507**	14 100
1998	3826861495	4841311341	4357180207	3921462186	3529315968	3176384371	2858745934	2572871340	2315584206	2084025786	1875623207	1688060886	1519254798	1367329318	1230596386	1107536748	996783072.9	897104765.6	807394289	726654860.1	653989374.1	**16 517 177 851**	16 517
1999	2439082245	3444175345	3099757811	2789782030	2510803827	2259723444	2033751100	1830375990	1647338391	1482604552	1334344097	1200909687	1080818718	972736846.4	875463161.7	787916845.6	709125161	638212644.9	574391380.4	516952242.4	465257018.1	**17 304 542 312**	17 305
2000	2542155970	2195174021	1975656619	1778090957	1600281861	1440253675	1296228308	1166605477	1049944929	944950436.2	850455392.6	765409853.3	688868868	619981981.2	557983783.1	502185404.8	451966864.3	406770177.9	366093160.1	329483844.1	296535459.7	**18 116 244 050**	18 116
2001	2675324043	2287940373	2059146336	1853231702	1667908532	1501117679	1351005911	1215905320	1094314788	984883309.1	886394978.2	797755480.3	717979932.3	646181939.1	581563745.2	523407370.6	471066633.6	423959970.2	381563973.2	343407575.9	309066818.3	**18 979 943 689**	18 980
2002	4396046923	2407791639	2167012475	1950311228	1755280105	1579752094	1421776885	1279599196	1151639277	1036475349	932827814.2	839545032.7	755590529.5	680031476.5	612028328.9	550825496	495742946.4	446168651.7	401551786.6	361396607.9	325256947.1	**21 477 996 243**	21 478
2003	3538535727	3956442231	3560798008	3204718207	2884246386	2595821748	2336239573	2102615616	1892354054	1703118649	1532806784	1379526105	1241573495	1117416145	1005674531	905107077.8	814596370	733136733	659823059.7	593840753.8	534456678.4	**22 868 732 346**	22 869
2004	5329133015	3184682154	2866213939	2579592545	2321633290	2089469961	1880522965	1692470669	1523223602	1370901242	1233811117	1110430006	999387005.2	899448304.6	809503474.2	728553126.8	655697814.1	590128032.7	531115229.4	478003706.5	430203335.8	**25 910 992 126**	25 911
2005	3873543754	4796219714	4316597742	3884937968	3496444171	3146799754	2832119779	2548907801	2294017021	2064615319	1858153787	1672338408	1505104567	1354594111	1219134700	1097221230	987499106.6	888749195.9	799874276.4	719886848.7	647898163.8	**27 193 436 668**	27 193
2006	4987253796	3486189379	3137570441	2823813397	2541432057	2287288851	2058559966	1852703970	1667433573	1500690215	1350621194	1215559074	1094003167	984602850.3	886142565.3	797528308.7	717775477.9	645997930.1	581398137.1	523258323.4	470932491	**29 461 346 797**	29 461
2007	4588104763	4488528417	4039675575	3635708017	3272137216	2944923494	2650431145	2385388030	2146849227	1932164304	1738947874	1565053087	1408547778	1267693000	1140923700	1026831330	924148197.1	831733377.4	748560039.7	673704035.7	606333632.1	**31 103 316 880**	31 103
2008	7114776001	4129294287	3716364858	3344728372	3010255535	2709229982	2438306983	2194476285	1975028657	1777525791	1599773212	1439795891	1295816302	1166234671	1049611204	944650083.8	850185075.5	765166567.9	688649911.1	619784920	557806428	**35 107 761 194**	35 108
2009	4808176929	6403298401	5762968561	5186671705	4668004534	4201204081	3781083673	3402975306	3062677775	2756409998	2480768998	2232692098	2009422888	1808480599	1627632539	1464869286	1318382357	1186544121	1067889709	961100738.2	864990664.4	**36 405 162 004**	36 405
2010	4323878957	4327359236	3894623313	3505160981	3154644883	2839180395	2555262355	2299736120	2069762508	1862786257	1676507631	1508856868	1357971181	1222174063	1099956657	989960991.3	890964892.1	801868402.9	721681562.6	649513406.4	584562065.7	**37 088 524 760**	37 089
2011	6628454542	3891491061	3502341955	3152107759	2836896983	2553207285	2297886557	2068097901	1861288111	1675159300	1507643370	1356879033	1221191130	1099072017	989164814.9	890248333.4	801223500.1	721101150.1	648991035.1	584091931.6	525682738.4	**40 008 126 825**	40 008
2012	7421442100	5965609087	5369048179	4832143361	4348929025	3914036122	3522632510	3170369259	2853332333	2567999100	2311199190	2080079271	1872071344	1684864209	1516377788	1364740010	1228266009	1105439408	994895467	895405920.3	805865328.3	**43 428 756 243**	43 429
2013	7290721225	6679297890	6011368101	5410231291	4869208162	4382287346	3944058611	3549652750	3194687475	2875218728	2587696855	2328927169	2096034452	1886431007	1697787906	1528009116	1375208204	1237687384	1113918645	1002526781	902274102.8	**46 376 601 844**	46 377
2014	6950294441	6561649103	5905484193	5314935773	4783442196	4305097976	3874588179	3487129361	3138416425	2824574782	2542117304	2287905574	2059115016	1853203515	1667883163	1501094847	1350985362	1215886826	1094298143	984868329	886381496.1	**48 689 236 100**	48 689
2015	6296084584	6255264997	5629738497	5066764647	4560088182	4104079364	3693671428	3324304285	2991873857	2692686471	2423417824	2181076041	1962968437	1766671594	1590004434	1431003991	1287903592	1159113233	1043201909	938881718.3	844993546.5	**50 116 397 074**	50 116