Towards a new capital formation series for machinery in agriculture: A way to improve agricultural productivity measurements

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Abstract

In most developing countries data limitations lead to the use of assumptions that compromise studies on the measurement of capital and its impact on productivity analysis. A possible approach is to use the ratio of the value of tractor sales to overall expenditure to impute overall machinery sales. The use of a constant ratio over an extended period results in increasingly incorrect estimates and fails to reveal the changing nature of mechanisation. In this paper, the probems with such an approach are highlighted through an analysis of the historic share of tractor sales to overall machinery sales in South Africa. This paper establishes that the current methods lead to underestimation in the overall value of machinery and implements sales in South Africa by approximately a $100 million per annum in recent years. An alternative method is suggested and the implications of a new capital formation series are discussed.

Keywords: Machinery and implements, capital formation, measurement problems

1 Introduction

The measurement of capital inputs is valuable for policy makers and researchers who are interested in production and productivity analysis (Andersen Alston & Pardey, 2011). Measurement errors in the valuation of capital can lead to mis-measurement of capital as a production input and ultimately lead to imprecise of agricultural productivity measurement. The link between investment in capital and productivity growth is articulated in endogenous growth models which show capital investment as a growth catalyst. Total Factor Productivity (TFP) growth is a measure of performance and provides a guide to efficiency of the sector. Because of this important role played by TFP growth, it is important to accurately measure both the inputs used and the output produced that form this ratio. The input index, the denominator of the total factor productivity index, includes the service flows from capital inputs which should be precise enough for accurate productivity measurement. The main problem associated with capital measures is the errors resulting from the scarcity of data and the assumptions made in the construction of a capital input index.

The measurement of capital is generally accepted as a difficult process, thus Solow (1957) suggests that "the capital time series is one that would really drive a purist mad". Capital statistics are however, an important component of the national account. The importance of precision in the measurement thereof is crucial. This is the reason why frameworks for measuring national accounts such as the System of National Accounts (SNA, 1993 & 2008) have been developed including the OECD Manual (2009) on Measuring Capital. Although the System of National Accounts is an internationally agreed, standard, macroeconomic framework for the measurement of economic activity, compliance to these guidelines differs among countries. One of the reasons for this variation between countries is the unavailability of data which often compromises the implementation of proper systems of national accounts. As such, it is difficult to compare capital measures between different countries. Wallmar and Evinger (2007) point out that data availability of reasonable accuracy, both in scope and frequency is the most important impediment to implementation of the 1993 System of National Account in developing countries particularly in Africa.

This situation differs in developed countries where national statistics are adequately collected monitored and accounted for. The use of assumptions cannot be under estimated in economic modelling, however the choice of assumptions still remains questionable in the valuation of capital inputs. Andersen (2005) presents the typical measures of capital input that are constructed by assuming that the annual flow of capital services is proportional to the stock of capital in the USA. Andersen (2005) demonstrates the measurement error in the capital variable when estimates of the capital stock are taken as a proxy for the flow of services from the capital stock. In addition, questions remain on the validity of the methods that have been used to measure capital following Andersen, Alston & Pardey (2009) who reveal some of the problems in capital measurement that result in differences in the measurement of capital.

The questionable use of assumptions is also tested by Butzer, Mundlac & Larson (2010) where they show that although economists tend to use FAO data on the number of tractors as a proxy of agricultural fixed capital in the absence of cross country data sets, it is not adequate. Data from thirty countries including developing countries such as Tanzania, Kenya, India, Malawi, Peru, Sri Lanka and Mauritius, was used to illustrate the inadequacy of this assumption. The use of the assumptions is aggravated by the absence of data and this leads to overemphasis on a single input for example tractors, to impute the value of the rest of the value of other inputs as is the case in South African agriculture. In South Africa capital formation in agriculture has been a subject of discussion in studies that assess agriculture performance and productivity (Thirtle, Von Bach & van Zyl, 1993; Gebrehiwet, 2012; Greyling, 2012; Liebenberg, 2013). As established by these studies, data limitations have compromised most studies on the role of capital and its impact on productivity analysis (Butzer, Mundlac & Larson, 2010).

Capital formation in South African agriculture is reported in the *Abstract of Agricultural Statistics* and consists of three aggregate categories; namely fixed improvements, machinery and implements, and the change in livestock inventory. Tractors machinery and implements represent about 60 per cent of investment in capital formation over the period 1970 to 2012 (DAFF, 2013). Machinery and implements form one of the three primary factors of production in economic theory, others being land and labour. Physical capital is defined by Kataria, Curtiss

and Balmann (2012) as an asset that is used in production which is manufactured by humans. In the production process capital is both an asset and an input.

Since 1994 total expenditure on agricultural machinery is imputed from the value of tractor sales using a constant ratio of 60 per cent as the relative share of tractor sales to the total machinery sales. This is questionable in that the ratio of tractor sales to the value of machinery does not necessarily remain constant over time. Very few studies in South Africa have focussed on the basis of estimation of expenditure on machinery and implements in agriculture. Liebenberg (2013) illustrated that the *Agricultural Census/Survey* reports since 1984 indicate that the share of tractor sales to the total machinery sales could vary between 38 per cent and 80 per cent. This means that the current constant ratio to impute overall machinery sales is highly questionable. He also outlined the problems in the measurement of the capital formation series of South Africa and highlighted the need to revise this account. Liebenberg (2013) lamented about the lack of a comprehensive *Agricultural Census* to aid the South African Department of Agriculture in developing its annual estimates of investment in farm machinery and implements. This paper will discuss this problem in detail to establish solutions to develop detailed estimates of investment in farm machinery and implements.

2 Past studies on agricultural capital measurement in South Africa

A number of studies have attempted to measure the performance of the South African agriculture sector but they concur that data scarcity has limited the analytical basis to provide sufficient understanding of investment agriculture. In order to derive the capital index, Thirtle *et al,* (1993) used the aggregates from the national accounts. This limits analysis 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, he noted that a further disaggregation of the data is possible and would improve the service flow estimates in formulating the capital use index. This presents the need to understand capital as an input in agriculture; how it is measured and defined because capital has been defined and measured in different ways across different disciplines.

Liebenberg (2013) outlined the problems associated with the capital formation series including failure to include the full range of inputs in the census and calls into question the basis for machinery and implements estimation in the series. He further notes that it remains unclear how estimates of the investment in farm machinery and equipment was developed by the Department of Agriculture. In order to arrive at an accurate measure of capital, the nature of the flow of services needs to be understood. For this, details on on-farm stock is required in terms of type and class. Forming a measure of capital inputs involves aggregating over different vintages, types and classes of capital (Pardey, 2013). Different classes refer the different service profiles (Alston, Andersen, James & Pardey, 2009), such as combines, ploughs, and tractors. Types refer to a given type of differing productive attributes (Alston *et al*, 2009) such as 50kw tractors versus 200kw tractors. Therefore, each capital class would 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 detail concerns the main problem in the current capital formation accounts which lack this type of detail in measurement.

Among the concerns Liebenberg (2013) raised was the fact that 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. The latter being an estimate itself. The proportional basis for imputing the overall sales value of machinery is also based on a constant cost share value that prevailed in the mid-1990s and has never been adjusted as the nature of on-farm mechanisation process evolved since then. Figure 1 highlights the problem discussed here.

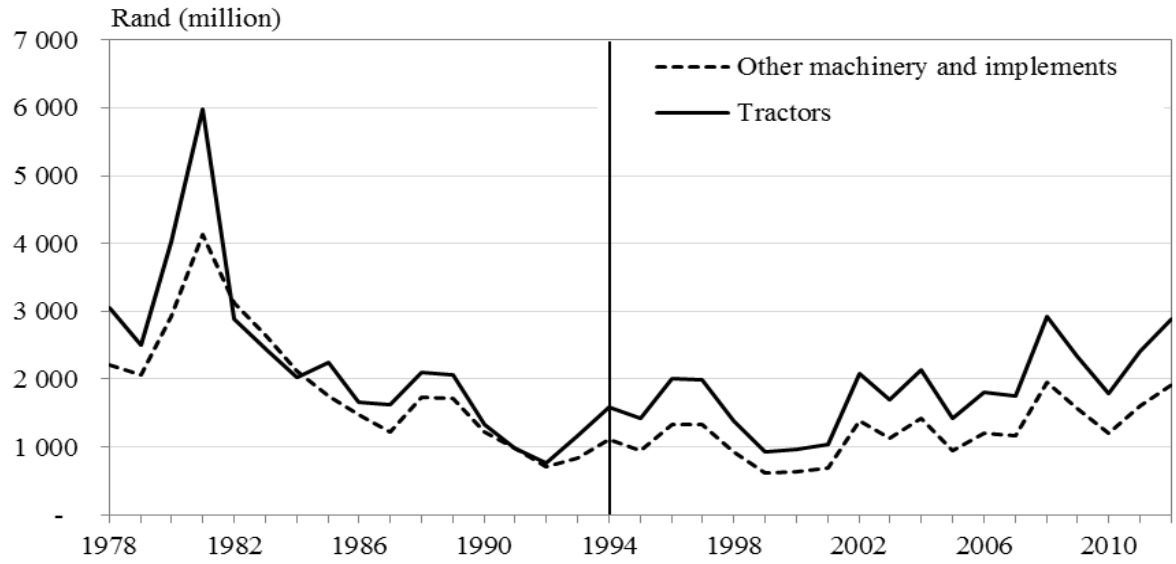

Figure 1: Sales value trends for machinery inputs in (R) million

Source: Liebenberg (2013), Agfacts (2013)

Figure 1 shows a perfectly correlated trend of tractor sales to the rest of the machinery and implements sales since 1994, which freezes the actual evolution of the nature mechanisation. This undermines the validity of the estimates of investment in machinery that national agricultural statistics reported in the capital formation account and subsequently affects all analysis based on that. The problem is compounded as a result of a lack of information on the changing nature of mechanization in South African agriculture since 1994 when the Survey of Machinery Sales ceased and AGFACTS started the monitoring of this. Liebenberg (2013) used the proportions that prevailed on "implement sales shares" in 1994, which effectively fixed the nature of mechanization to what it was in the 1990's. By sourcing data on the unit sales (monitored by AGFACTS, but not reported) and using this in the analysis it is possible to better reflect the nature of mechanization in the estimated flow of services from capital equipment.

The fixed proportional basis for imputing the overall sales value of machinery used since mid-1990s has never been adjusted to reflect the changing nature of on-farm mechanisation since then. This has led to existing data on capital formation in agriculture being increasingly inaccurate. Up to 1994 the total value of tractor, machinery and implement sales exhibited a similar but not perfectly correlated trend. Absent is the availability of a representative

agricultural census since 1993. Both the Department of Agriculture and statistical services such as the South African Reserve Bank and Statistics SA have resorted to using the estimates made by AGFACTS. The perfect correlation between tractor sales and other machinery and implements sales is clear from 1994 and fails to reflect, for example, the change to minimum till and precision agriculture as is so often reported on.

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 mechanisation in the machinery sales estimates. As will be shown, the changing nature of eliciting information and the increasingly aggregate basis of reporting of the results also poses a challenge.

3 Data and Methods

Data on capital expenditure and machinery sales was sourced from the following sources:

a) *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 it only valid since the mid-70s.
b) *Agricultural Census/Survey* capital expenditure data from 1978 to 2012;
c) AGFACTS Agricultural Machinery sales data from 1994 to 2012.

The analysis starts by establishing how the 60 per cent ratio of tractors to overall machinery sales was derived using different baskets of machinery sales statistics from the *Survey of Agricultural Mechanisation Sales* of 1994. 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). 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 was used to re-estimate the total value of machinery sales and the difference is evaluated.

4 Results and discussion

This section determines the exact composition of the basket of machinery and equipment that was included to arrive at a 60 per cent 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.

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

Table 1 below lists the types of machinery other than tractors that were monitored in the *Survey of Agricultural Mechanisation Sales* reports, ranked by the value of sales in 1994. The top four categories are inputs currently still monitored by Agfacts and the remainder up to forestry equipment represent input type categories that used to be consistently included in the survey. The last nine input categories represent inputs that were periodically included in the survey. To test which input categories were included in the basket with tractors to arrive at the 60 per cent share of tractors, the share of tractors were calculated against a cumulative basket of inputs. Starting from the top of Table 1, the changing ratio of tractors to a particular basket of machinery and implements is shown with additional input until all inputs are included in the basket.

Table 1: Spending on tractors as a percentage share of the expanding basket of machinery inputs 1978-1994

Machinery and implements	1994
	Share of expanded basket
Agricultural tractors	100.0
+Harvesting equipment	84.7
+Hay and silage machinery	79.2
+Planters	75.0
+Plant nutrition and pest control equipment	72.2
+Feed mixers	69.6
+Mouldboard plough, disk plough, disk harrows	68.2
+Tine implements cultivators	66.8
+Trailers	66.1
+Earth moving equipment loaders	65.7
+Diverse equipment for animal handling	65.3
+Potato equipment	65.0
+Grain dryers grain handling equipment	64.8
+Forestry equipment	60.7
+Not classified but sold & figures not available	59.5
+Sugar equipment	58.8
+Rotavator	58.7
+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 1 shows that the 60 per cent is more or less reached when all equipment are added to the basket. This basket represents 96 per cent of the total value of sales of machinery monitored in 1994. However, it is possible that the 60 per cent ratio used by AGFACTS is based on the proportion of tractors in the whole basket (58.7 per cent), but rounded up to 60 per cent for ease of use. Information on how this ratio was derived were never recorded therefore it is uncertain what combination of machinery and implements resulted in the exact 60 per cent ratio.

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 is done since 1994. Figure 2 illustrates the different trends in the share of tractor sales to the total machinery sales for the period 1978 to 1994.

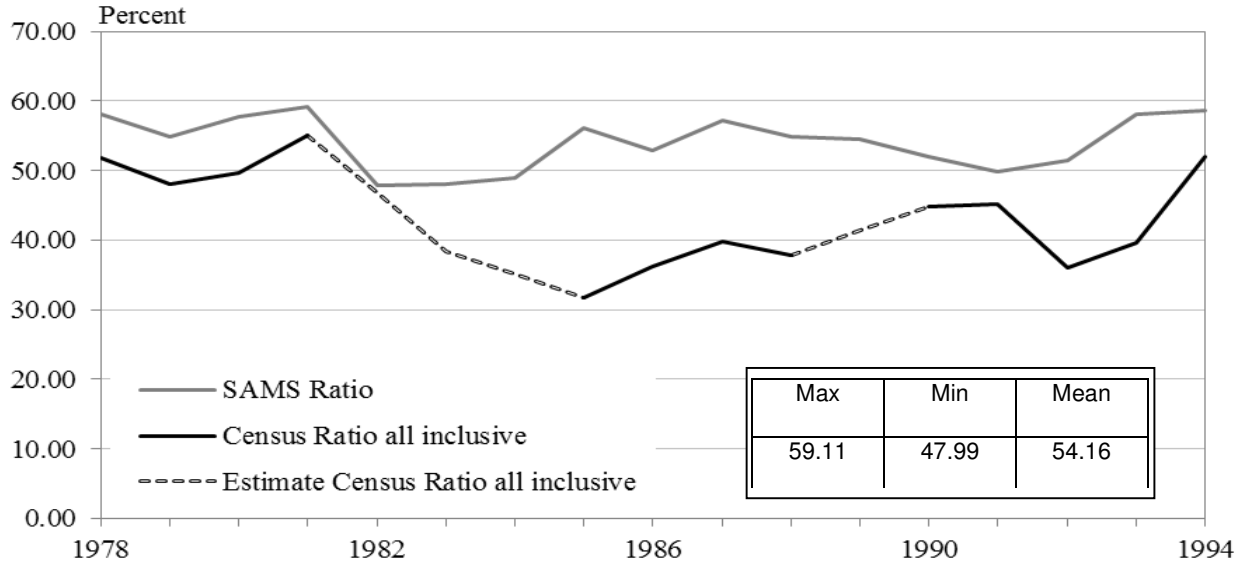

Figure 2: Comparative share of tractors to a different basket of machinery inputs

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 2 shows that on average the census based share of expenditure on tractors to overall machinery expenditure is about ten per cent lower than the share derived from the data of the *Survey of Agricultural Mechanisation Sales.* The range 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 per cent (1981) and a minimum of 47.9 per cent (1983). The shares based on census data also show a maximum of 55.1 per cent in 1981, but it reached a minimum of 31.7 per cent in 1985.

Two observations can be made from the trends presented in Figure 2. First is that there are loose relations between the shares estimated using the two sources. Estimates derived from sales data are less variable compared to estimates when the census data is used. Secondly, the composition of the aggregate of capital expenditure on machinery may be variant and require further analysis.

4.3 Machinery inputs monitored in Agricultural Census/Survey reports

Agricultural Censuses/Surveys serve as a valuable source of information to track the changing structure of agriculture if it remains stable in terms of its basis of elicitation (and reporting). During the early years prior to the first round of the World Agricultural Census of 1930, detailed attention was spent on the development of a uniform basis to conduct the census, both 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). In many of the member countries of the United Nations (before that the League of Nations) agricultural surveys based on a sample of the frame for the census were conducted for the inter-census years. South Africa participated in this endeavour since 1918 and adhered to these guidelines in both the variable coverage and the detailed level of reporting, albeit with the primary focus on commercial agriculture. Sadly, the Censuses and Surveys systematically excluded black farmers in the homeland areas and self-governing territories since 1975. Since 1983 (and more pertinently so since 1993) the detailed scope in terms variables covered and the

level of aggregation in reporting began to deviate from the norms provided by the FAO (Liebenberg, 2013).

From 1994 the agricultural census/survey the sampling frame changed to only include large commercial farms registered for tax. With specific reference to capital expenditure, the information is sourced in an increasingly aggregated form that varies from year-to-year in terms of composition. Very little, to no, information is provided on the composition of the items included within each aggregated capital category for instance the survey for 2005 (Stats SA, 2006).

Table 2 shows the evolving nature of the categories against which the data on capital expenditure on new machinery as elicited from farmers were reported. Here the data reported in census and survey reports that 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 apparent. 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 mechanization when using the annual Agfacts estimates on new tractor 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.

Table 2: Machinery expenditure aggregates in the *Agricultural Census/Survey*

New machinery categories	1993	1994	1995	1996	2002	2005[a]	2006[a]	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: Agricultural Census/Survey

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

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 therefore limits this analysis where the exact amount of expenditure on tractors is required to base overall expenditure on machinery and implements. However, 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.

4.4 Revised machinery investment series (1995 to 2012)

Using AGFACTS sales data from 1994 to 2012 and projecting the trend in the variant ratios from the census and survey reports to impute the value of overall machinery sales yield a significantly different level of investment in machinery when compared to the fixed ratio estimates of Agfacts. The results are shown in Figure 3 and Table 3. Figure 3 shows that the use of a constant ratio leads to an underestimation of the overall value machinery sales throughout the period. The difference increased over time and by 2012 amounted to about R861 million — 11.4 per cent higher than the results reported by AGFACTS, which uses a constant ratio of tractor sales to overall sales.

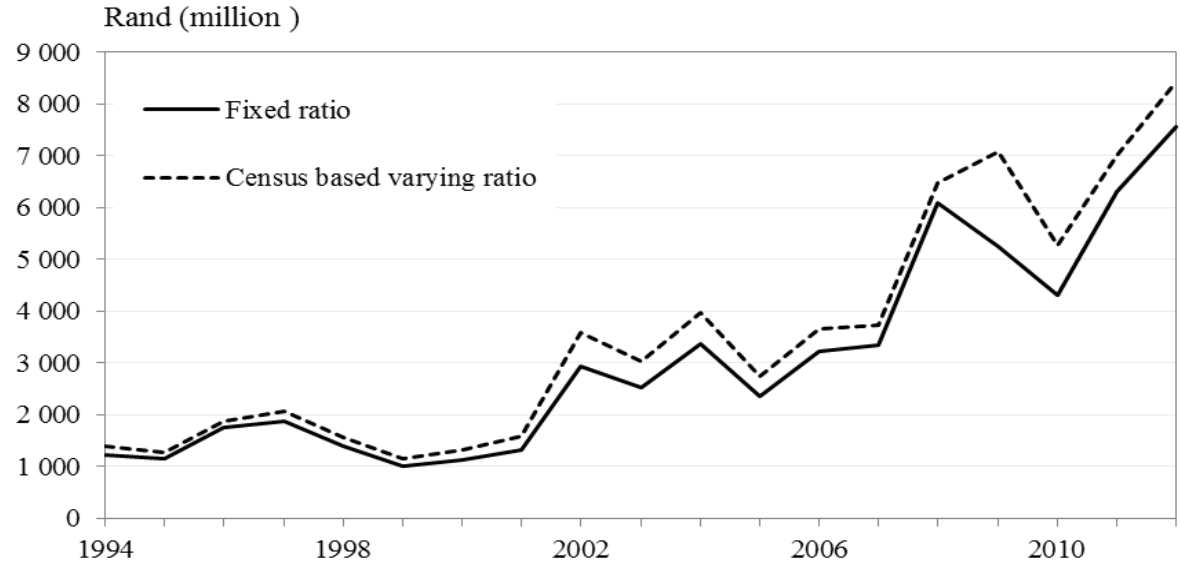

Figure 3: Overall machinery sales trends

Source: Agfacts (2013) and own calculations

The detailed results of this analysis are shown in Table 3 together with the difference between the two methods of estimation for the period since 1994. The differences between the two series vary between a minimum of 6.3 per cent in 2008 and a maximum of 35.3 per cent for 2009. However, the results for 2009 (specifically) and 2010 should be treated with caution and clearly need further analysis of the exact nature of the aggregated data available from survey reports. The general observation from the revised series is that it reflects a marginally higher rate of mechanization expenditure, which is growing over time.

Table 3: Implications of a revised investment series

Year	Yearly Sales	Fixed ratio	Census based ratio	Difference	Percentage difference
1994	729.8	1216.3	1395.2	179.0	14.7
1995	687.1	1145.2	1271.9	126.6	11.1
1996	1048.8	1748.0	1883.1	135.1	7.7
1997	1124.0	1873.3	2058.8	185.5	9.9
1998	842.0	1403.4	1574.1	170.7	12.2
1999	606.1	1010.2	1156.9	146.7	14.5
2000	677.9	1129.8	1321.6	191.8	17.0
2001	793.2	1322.1	1580.4	258.4	19.5
2002	1764.0	2939.9	3593.3	653.4	22.2
2003	1520.1	2533.5	3037.5	504.0	19.9
2004	2026.4	3377.4	3973.5	596.0	17.6
2005	1422.9	2371.5	2738.7	367.2	15.5
2006	1932.7	3221.2	3652.9	431.7	13.4
2007	2013.6	3356.0	3738.3	382.3	11.4
2008	3655.7	6092.9	6477.5	384.7	6.3
2009	3147.7	5246.2	7090.6	1844.4	35.2
2010	2594.3	4323.9	5280.7	956.8	22.1
2011	3780.7	6301.2	7019.0	717.8	11.4
2012	4538.8	7564.7	8426.5	861.8	11.4

Source: Compiled from Agfacts Sales data 1994- 2013, Agricultural Survey/Census

If one were to use the exact ratios of the census – instead of trend projecting the ratio – the revised series would have resulted in an estimated underinvestment of about 33 per cent of the AGFACTS estimates, or R2 530 million by 2012. The difference comes 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 that 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 spurious results such as observed for 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 still being investigated, but an underestimate of the units sold and incorrect valuation of the price at which tractors are sold will lead to a further source of potential underestimation of the total value of machinery investment imputed from the value of tractor sales.

4.5 Implications of the revised investment series

A number of implications may result from the underestimation of overall machinery investment. Butzer, Mundlac and Larson, (2010) articulate 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. Capital enters the production function as an input. The concept of a production function is a useful abstraction from the real world complexities with two measurable aspects of the function as returns to scale and elasticity of substitution. Firstly returns to scale explains how output increases when all inputs are increased while elasticity of substitution explains how easily one input, say labour, can be replaced by another, for example capital, while maintaining the same output level (Snyder & Nicholson,

2012). Technical improvements can also be reflected in the production function. The production function is a technical relationship depicting the technical transformation of inputs into outputs. 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. The quantification of these inputs becomes important.

By extension, productivity is defined as a ratio of a quantity measure of output obtained to a quantity measure of input use. Capital together with other production inputs forms part of the input denominator of the Total Factor Productivity (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). An increase in productivity might actually be as a result of an increase in input quality. Thus Griliches (1961) proposed that the discrepancy that is referred to as productivity requires further analysis to establish whether it is returns to scale, changing quality of inputs or pure technical change. But this analysis is only informative in as much as the data and methods of analysis are appropriate.

Past studies on productivity in South Africa used national aggregates to derive the capital index (Thirtle, Von Bach & van Zyl, 1993). This limits analysis at national aggregates and aggregation results in the invalid assumption of homogeneity of inputs. Alston, Andersen, James, & Pardey (2010) show that input analysis has to be disaggregated as far as possible in order to capture the changing composition of inputs. Therefore, in their analysis of agricultural inputs, Alston *et al* (2010) argue that simple quantity counts of each input category are not useful metrics of input use when there are changes occurring that have to be captured. This therefore calls for precision of the valuation methods and a more detailed disaggregation of the machinery investment series. There clearly is a need to separate analysis of the different forms of capital; this paper provides the first step in analysis of machinery and implements towards refining the capital formation series.

5 Conclusion

The use of a constant series from 1994 leads to an underestimation of the overall machinery sales in South Africa. This is in line with the thinking that the mechanisation process has evolved in South Africa. It is clear that the nature of agricultural mechanisation 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 and translates to the share of tractors to overall machinery sales. Therefore by fixing this ratio, an underestimation of the expenditure in the industry results in the analysis.

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, this paper recommends that the allocation of resources in monitoring capital investment series components at a disaggregated level. National aggregates limit 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 incorporation of quality adjustments in the valuation of the inputs. 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 paper mainly contributes to. This initial analysis will enable a further step in refining earlier studies that improve on precision of measures of productivity. This study will therefore contribute to correcting the current series to provide precise evidence 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.

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