Quality adjusting agricultural machinery in South Africa

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Abstract

This paper quality adjusts machinery inputs for South African agriculture. It does this by treating different qualities of machinery as separate inputs. Thus, quality adjustment becomes quantity adjustment when there is sufficient disaggregation. This matters because many mechanical and chemical inputs have been transformed by technological progress. If this is not taken into account, the inputs are under-counted and total factor productivity (TFP) calculations are not accurate. Gandidzanwa and Liebenberg (2016) estimated the proportion machinery to implements and used this series to scale up the tractor series, instead of assuming fixed proportions. This study quality adjusts the machinery and implements input series by applying a greater level of disaggregation and by careful monitoring of model turnover. The number of models monitored was increased tenfold. Removing tractor improvements resulted in a price index that grew more slowly than the official index. Thus, the tractor stock value series is deflated less and by 2015 was 53% larger than in the official figures. The service flow entering the TFP calculations will be similarly increased, so there is less residual to be attributed to TFP growth. If all the inputs were equally undercounted, the TFP estimate would be double its true value.

Keywords: quality adjusted input series, farm machinery and implements, capital stocks, TFP

1. Introduction

Quality adjustment in agricultural outputs is a minor problem, relative to the difficulties with industrial inputs and primary factors. Craig and Pardey (1990) demonstrate the importance of quality adjustment for land and labour in the US case. Inputs should be measured in constant 'efficiency units', but often there is little quality adjustment. Griliches (1960) showed that lack of quality adjustment for tractors led to considerable under-counting. His approach was to quality adjust the tractor input series to incorporate improvements like the change from two to four wheel drive and from petrol to diesel power. In the resulting hedonic price series, that part of the price increases that could be attributed to the quality change was thus netted out.

Mechanisation is an important source of progress in modern agriculture. In South Africa, mechanisation is doubly important because of concerns that the labour market and land tenure reforms might have accelerated the mechanisation process. A reliable measure of the capital stock is needed to investigate if and how these changes affected competitiveness in the sector (Thirtle *et al.*, 1993; OECD, 2001; Anderson *et al.*, 2011; Liebenberg, 2013). Liebenberg (2013) identified two sources of mis-measurement in the post-apartheid period in the Department of Agriculture Fisheries and Forestry (DAFF) index. This index assumes a fixed proportion of expenditure on tractors relative to other farm machinery in gross capital formation. Gandidzanwa and Liebenberg (2016) replaced

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this 60–40 per cent assumption with variable proportions from the few available survey and census estimates. This source of mis-measurement undercounted gross capital formation by about 10 per cent over the last two decades.

However, the second and more serious source of mis-measurement is that the DAFF tractor index fails to account for model changes and monitors only one representative model per engine size (Liebenberg, 2013). The increased use of capital is often not just a matter of replacing one tractor with two, but of replacing a smaller, less sophisticated tractor with a bigger, more complex one (Griliches, 1961; FAO, 2008). Failing to quality adjust undercounts the amount of capital used in production, which *ceteris paribus* results in overestimates of the rate of TFP growth (Bosworth *et al*., 2003). This study follows the disaggregation approach of Star (1974), which increased the number of models monitored tenfold. The new series is compared with the DAFF machinery series to show the effect of quality adjustment on the capital stock. The DAFF machinery series is merely the tractor series scaled up by 40 per cent. The service flow from the capital stock will be similarly increased and this is what will eventually be used in future estimates of TFP. Due to data limitations, the series can only be constructed for the post-apartheid period (1995–2015), and uses tractor prices taken from the AGFACTS database to decompose the value series. Thus, updating the historical series in Thirtle *et al*. (1993), which is now a quarter of a century old, remains a problem, due to lack of data.

The next section begins by explaining the decomposition of the values series into prices and quantities. The disaggregation used to quality adjust the tractor price series is then explained. Section 3 applies time series tests, both the unadjusted and adjusted price indices and the variables that can best explain them, showing that the adjusted price series is an improvement. Section 4 starts by introducing the gross investment series for tractors which is shown in constant Rand. Accumulating and depreciating it, gives a quality adjusted net capital stock for tractors that is 53 per cent greater than the unadjusted version. Section 5 concludes by summarising the results and suggesting that if data collection is not improved, measurement of TFP change will become even less accurate. This has implications for the future health of agriculture in South Africa.

2. The DAFF and quality adjusted tractor price indices

In productivity analysis, index numbers are used to decompose value changes from one period to the next. Following Coelli et al. (2005), this can be expressed as:

$$V_{st} = \frac{\sum_{m=1}^{M} p_{mt} \cdot q_{mt}}{\sum_{m=1}^{M} p_{ms} \cdot q_{ms}} \tag{1}$$

where V_{st} is the value change from period s to period t; p_{mt} is the price of commodity m of a set of M commodities in period t; q_{mt} is the quantity of commodity m of a set of M commodities in period t; p_{ms} is the price of commodity m of a set of M commodities in period s; q_{ms} is the quantity of commodity m of a set of M commodities in period s. Equation (1) simplifies to a relative price index if the same combination of products in the same quantities is purchased throughout the period:

$$P_{st} = \frac{\sum_{m=1}^{M} p_{mt} \cdot q_{m0}}{\sum_{m=1}^{M} p_{m0} \cdot q_{m0}} = \frac{\sum_{m=1}^{M} p_{mT}}{\sum_{m=1}^{M} p_{m1}} \tag{2}$$

The tractor price index from DAFF uses the Laspeyers version of Equation (2), in which the index is based in period $t = 1$ compared with the Paasche index that uses $t = T$ as the base period. In the latest edition of the Abstract of Agricultural Statistics (AAS) (2017), the index begins in 1980 and uses 2010 = 100 as the base year. Any year could serve as the base period for deflation, although Sancheti and Kapoor (2005) argued that it should not be too distant from the present to minimise measurement error and that it should refer to a period of relative stability, as this is often assumed by users.

The accuracy of both the Laspeyers or Paasche method of index construction depends on how representative product quantities in the base year are of those in the overall index. Since buyers respond to price changes in their purchasing decisions, both methods suffer from a degree of measurement error, although this can be reduced if the index is constructed for a short period only. The DAFF index is constructed in blocks of six years, each allowing a one-year overlap with the previous block so that successive block indices can be chained into a long-term index and quantity adjustment effects are minimised.

Technological change introduces further mis-measurement if it is not captured in the index. When a specific tractor model is discontinued, Equation (2) becomes invalid, unless a replacement price is found for the remainder of the block. Since the most important tractor attributes are size in kilowatts and capacity in tractive force (Griliches, 1961), hedonic pricing methods can estimate missing prices based on relevant tractor attributes (Triplett, 2004; Milana, 2009). Although the hedonic method has become the standard tool for quality change measurement in the national statistical systems of many OECD countries, the data requirements for the implementation of this methodology present a limitation of this methodology, specifically the breakdown of product characteristics. This level of detail is not always available; therefore, this analysis is taken as far as the available data, even if the hedonic method is preferred.

The approach taken by Star (1974) is to quality adjust by disaggregation, in which case it is possible to replace the missing price of the discontinued model with the price of the direct replacement. The DAFF follows this method and builds its index from sub-indices that correspond to 17 engine size groups, of which 15 apply to tractors used in field crop production and two to orchard tractors. Within each size group all important models must be monitored. If price data is normally distributed, monitoring only a reference model per size group would be sufficient, provided that no models are discontinued, but this does not appear to be the case. Liebenberg (2013) suggested that the DAFF was not tracking model turnover and therefore not monitoring all models within each size category. The calculations that produced the revised index presented below address both of these concerns.

The revised Laspeyres index is consistent with the DAFF index and is constructed in five year blocks, which are then chained to form the final tractor price index. The first step was to assign each model from the comprehensive list of models for sale to a specific engine-size group. We started with the same groups as the DAFF index, but following Griliches (1961), additional sub-indices were defined to retain price movements for two- and four-wheel drive tractors respectively. The 2wd and 4wd engine size baskets were defined according to the size of the tractors. The purpose of these different baskets of tractor models was to ultimately construct a disaggregated tractor price index, based on different tractor size in kilowatts and tractive force. Within each group, all models that accounted individually for more than 10 per cent of sales, were monitored. Group-level indices were aggregated according to the share of that group in the value of sales. This was repeated at the beginning of each price block and discontinued models were replaced like for like. Table 1 shows the number of models included in each group.

2.1 Results: a quality adjusted tractor price index

Figure 1 shows the DAFF and revised quality adjusted indices of tractor prices in South Africa from 1995 to 2015. The two series coincide between 1995 and 2000 but diverge thereafter. Deviations are driven by price increases due to a weakening US$/ZAR exchange rate in the period 2001 to

Table 1. Level of disaggregation and model turnover.

	2000	2005	2010
Tractor models for sale	359	359	125
4wd engine size baskets	15	16	17
2wd engine size baskets	9	10	10
Tractor models monitored	91	91	88
Tractor models discontinued	30	46	4
Monitored models discontinued	13	8	4

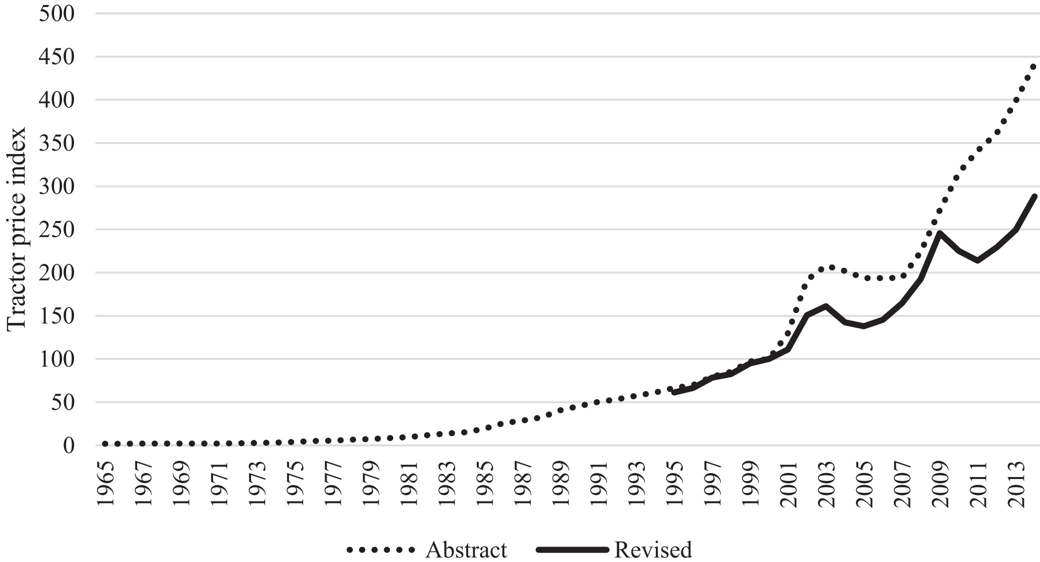

Figure 1. The DAFF and quality adjusted price indexes for tractors, 1980–2014. Source: DAFF and authors own calculations.

2003 and again from 2008 and 2009 during the global financial crisis. In 2007 the Rand traded at R7.1/USD and it depreciated to over R8.6/USD. Tractors in particular have a high import component and are thus vulnerable to exchange rate fluctuations (AGFACTS, 2016). For example, in 2009 and at the beginning of 2010, the Rand depreciated, resulting in increased tractor prices.

Among other manufacturers affected by exchange rate fluctuations, tractor manufacturers such as John Deere, New Holland and Kubota, were faced with increases in import costs and consequently the price of tractors and other equipment rose by as much as 45 per cent (AGFACTS, 2016). The 2009 tractor price index differs from that reported in the official statistics (DAFF, 2016) and the decline in tractor prices after 2009 is also under-played in the official statistics (Abstract of Agricultural Statistics). Since April 2009, the Rand and currencies of other prominent developing markets started to recover and slowly progressed to the current stronger trading levels. Prices of tractors and other agricultural equipment progressively fell throughout this period to approximately levels prior to the sharp weakening of the Rand.

3. Properties of the index: co-integration and causality

The discussion in Section 2 suggested that, on the supply side, the exchange rate was a key determinant of price changes, due to the high import content of tractors. On the demand side, net farm income would seem to be a likely factor to explain a rise in purchases of machinery, as farmers are commonly known for buying new equipment when times are good, rather than paying taxes. This is shown by an increase in tractor sales in years where commodity prices rise, such as 2007/2008. Conversely, in hard times, tractors have to last longer as the funds for replacements are not available. Thus, Figure 2 shows the official abstract tractor price index and the quality adjusted version, along with the exchange rate and net farm income. The initial impression is that all four series may well be correlated and this can be tested by trend analysis of the Abstract Tractor Price Index (ATPI), Revised Tractor Price Index (RTPI), net farm income (NFI) and exchange rates.

3.1 Stationarity and the co-integrating regression

Figure 2 illustrates the differences made by quality adjusting the tractor price index and its properties can be tested using co-integration analysis, here using Eviews. If one series is to explain another, they

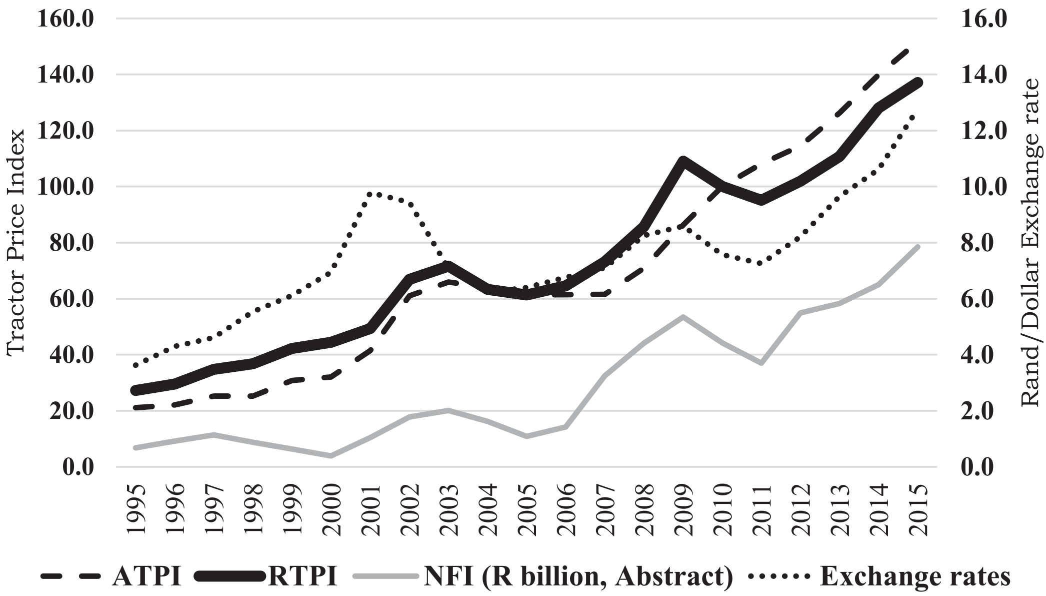

Figure 2. Revised tractor price indexes, net farm income and the exchange rate. Source: Author's calculations and AAS.

should be of the same order of integration. That is, if they are not stationary in the levels (order zero), they should be differenced and re-tested for stationarity, thereby informing the order of integration. In particular, a series of a higher order cannot be explained by one of a lower order, as it does not contain the necessary complexity. The Augmented Dickey-Fuller (ADF) test for a unit root is the most suitable tool, as it is simple and has good small sample properties appropriate for short series such as these. The null hypothesis is that the series has a unit root, meaning it is non-stationary. The test should include a constant and/or a time trend, if their coefficients are significantly different from zero.

Table 2 begins by testing net farm income (NFI) in the levels. The test statistic of −1.68 is not smaller than even the 10 per cent confidence level mark of −3.31, so NFI is non-stationary, as is confirmed by the probability value of 0.71. The test includes an intercept and a time trend, as both were significant. Then, on the right hand side of the table, the test is repeated once NFI has been differenced. Now the *t* value is less than even the 1 per cent mark ($p = 0.007$) and the series is stationary, with 99 per cent confidence, so it is integrated of order one (I(1)). The same results follow for the exchange rate and the quality adjusted tractor price index. However, the Abstract price index is not stationary in the levels or in first differences, as the table shows. It is stationary in second differences, where the ADF test statistic is −3.84 and the 1 per cent critical value is −2.71, so it is I(2). This matters because a series that is I(2) of order cannot be co-integrated with series that are I(1).

These results show that the official tractor price index cannot be explained by the two most obvious supply and demand variables, so the next step is to see if the quality adjusted index can be explained by NFI and the exchange rate. Although the three series are I(1), they are co-integrated in levels if some linear combination of them is stationary. If the residual from regressing the adjusted price series on NFI and the exchange rate is stationary, then there is said to be a co-integrating regression. This is evidence of the possible existence of a long-run relationship between the revised tractor price index, exchange rates and farm income. The co-integrating regression results are reported in Table 3, which shows that NFI, exchange rates and a constant explain 93 per cent of the variance and all three are significantly different from zero. The residuals were retrieved and the ADF test statistic with no intercept or trend was −2.54, against critical values of −2.68 at the

Table 2. Augmented Dickey-Fuller Unit root tests.

	In the levels		First differences	
Variables	*t*-statistic	Critical values (1%, 5%, 10%)	*t*-statistic	Critical values (1%, 5%, 10%)
Real Net Farm income (Real NFI)	−1.68	−4.66	−4.85***	−4.67
Intercept and trend	*p*-value = (0.71)	−3.73	*p*-value = (0.007)	−3.73
		−3.31	Intercept and trend	−3.31
Abstract Tractor Price Index (ATPI)	−1.84	−4.53	−1.21	−2.69
Intercept and trend	*p*-value = (0.64)	−3.67	*p*-value = (0.20)	−1.96
		−3.28	No intercept or trend	−1.61
Quality Adjusted Tractor Price Index (RTPI)	−3.05	−4.53	−2.60***	−2.70
Intercept and trend	*p*-value = (0.06)	−3.67	*p*-value = (0.01)	−1.96
		−3.27	No intercept or trend	−1.60
Exchange Rate (ExRate)	−2.39	−4.53	−2.32**	−2.69
Intercept and trend	*p*-value = (0.37)	−3.67	*p*-value = (0.02)	−1.96
		−3.28	No intercept or trend	−1.61

Note: Significance at 10%, 5% and 1% levels are indicated by *, **, and *** respectively.

1 per cent level and −1.96 at the 5 per cent level and the probability of 0.0140, meaning we can be 95 per cent confident that the residuals are stationary and we have a co-integrating regression.

The simple co-integrating regression is the most trustworthy test with this small number of observations, but the multivariate Johansen trace and Eigen value tests applied to the exchange rate, net farm income and the quality adjusted tractor price index, confirm that co-integrating vectors exist. These results are shown in Table 4 and Table 5. The Trace statistic and Max-Eigen statistic indicate two co-integrating equations $r = 2$, between exchange rates, net farm income and the tractor prices series. Therefore, the null hypothesis of no co-integration with $r = 0$ is rejected and we fail to reject that there is $r = 2$, where H_A: $r = 0$ ($0.17 < 3.84$) for both Trace and Max-Eigen statistics, with 95 per cent confidence.

3.2 Granger causality

The final step in the time series tests is to establish the direction of causality, using simple pairwise Granger causality tests. The first differences are stationary so these are used in the tests. The tests check the significance of lagged values of the explanatory variable against the lagged values of the dependent variable. The results in Table 6 show that NFI and the exchange rate is Granger prior to the quality adjusted price index, but in all other cases the null hypothesis of no causality holds. These results entirely support the supposition that the quality adjusted tractor price index is an improvement on the DAFF index. More complex block exogeneity Wald tests for vector auto

Table 3. Cointegrating regression − dependent variable = quality adjusted price index.

Variable	Coefficient	*t*-stat	Prob.
Net farm income	1.144	8.82	0.00
Foreign exchange	3.177	2.37	0.03
Constant	16.401	2.10	0.05
$N = 21$			
Adjusted R^2	0.931		

Table 4. Johansen co-integration 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

Note: Trace test indicates two co-integrating equations at the 0.05 level.

Table 5. Johansen co-integration test using Max-Eigen Statistic.

Eigen value	Max-Eigen value 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

Note: Max-Eigen value test indicates two co-integrating equations at the 0.05 level.

regression (VEC) Granger causality gave the same results, but these are not reported here as the more complex technique is less trustworthy with these short series.

In summary, 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; e.g., the effect of the exchange rate in 2009. Co-integration 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 expectation, the tractor price reported in the Abstract does not show a co-integrating 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 co-integrated 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. 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.

4. Revised gross investment and the capital stock

The flaws in the evaluation of tractor prices and the failure to incorporate the quality changes in reporting and monitoring of machinery and implements means the estimations of the capital investment series for South African commercial agriculture remain questionable. The valuation of the capital investment series and capital stock is derived from price and quantity data, and if the data is not well documented to reflected reality, then the result is imprecise capital valuation. DAFF publishes a gross capital formation series and the value of assets on commercial farms in the Abstract of Agricultural Statistics. In both cases, the unit of measurement is Rand in millions. Gross capital formation is the value of fixed improvements, tractors, implements and farm machinery purchased and livestock inventory changes. In the 2015 AAS, this series is for the period 1970 to 2014 (DAFF, 2015). The value of assets on commercial farms is divided into land and fixed improvements, tractors, implements, machinery and vehicles, and livestock, including game. This series begins in 1980 in the 2015 AAS, while earlier editions contain more historical data.

4.1 Quality adjusted gross investment in machinery

Quality adjustment affects both gross investment in tractors and the associated price index, discussed in Section 2. The revised annual machinery sales series differed slightly (average of 10 per

Table 6. Pairwise Granger causality test with first differences.

Null hypothesis	Observations	f-stat	Probability
D (foreign exchange) does not Granger cause D (revised prices)	18	5.74	0.016**
D (revised prices) does not Granger cause D (foreign exchange)		0.056	0.946
D (NFI) does not Granger cause D (revised prices)	18	3.64	0.056**
D (revised prices) does not Granger cause D (NFI)		1.26	0.316
D (NFI) does not Granger cause D (foreign exchange)	18	0.30	0.75
D (foreign exchange) does not Granger cause D (NFI)		0.68	0.52

Note: ***t*-stat significantly different from 0 at 5% significance level.

Figure 3. AAS official and quality adjusted real gross capital formation. Source: Gandidzanwa (2018).

cent for the entire period) from the official version as Gandidzanwa and Liebenberg (2016) showed, but it is the substantial difference between the price indices in Figure 1 that has a major impact. When the values are deflated and expressed in constant Rand, the full effect of quality adjustment becomes apparent.

Figure 3 shows the DAFF and quality adjusted series in constant 2010 Rand. The quantity adjusted series is greater than the unadjusted equivalent in all but one year, so the cumulative effect is a considerably greater gross capital stock. This is not surprising, as separating the categories of tractor to reflect the size in kilowatts and whether they are two or four wheel drive, is important. Thus, the revised gross investment series is more responsive to changes in the market than the series deflated with the AAS tractor price index (ATPI). The figure shows that the quality adjusted series responds more to the exchange rate fluctuations in 2009 and movements in net farm income.

Figure 3 also shows the annual investment in machinery in real values and this can be cumulated to estimate the gross capital stock series. This is not shown as it is the net capital stock, while the gross stock net of depreciation is of most interest. The service flow emanating from this net stock is the machinery input required for calculating changes in TFP. Consistent with the methodology used by the United States Department of Agriculture (USDA), the net capital stock is computed from the investment series, using the perpetual inventory method, assuming a 15-year asset life and a 10 per cent depreciation rate (Anderson *et al.*, 2009):

$$K_t = I_t + (1-\delta)I_{t-1} + (1-\delta)^2 I_{t-2} + \ldots + (1-\delta)^L I_{t-L} \quad (3)$$

where K_t is the capital stock in period t; I_t is gross capital formation in period t; L is the life of the asset; δ is the rate of depreciation.

While a 10 per cent depreciation rate is uncontroversial, the expected asset life is more debatable since the tractor replacement decision depends on the size of the harvest, the exchange rate and the tax liability. The annual service flow from the adjusted capital stock is the depreciation, which is capital usage.

Table 7. Real capital stocks before and after quality adjustment.

Year	Net real stock Not quality adjusted	Net real stock Quality adjusted
1995	11540	12537
1996	12236	12832
1997	12477	12693
1998	13083	13464
1999	12181	12450
2000	12157	12157
2001	9728	11353
2002	6954	8841
2003	7512	9701
2004	8551	12117
2005	10118	14183
2006	10681	14244
2007	11625	13710
2008	10904	12665
2009	10555	11713
2010	10073	14132
2011	9736	15532
2012	10001	15761
2013	9956	15924
2014	9910	15185

4.2 Quality adjusted real net capital stock

The effect of quality adjustment on the real capital stock net of depreciation is shown in Table 7, which compares an estimate, derived entirely from data in the AAS, to the quality adjusted estimates. The machinery capital stock in constant Rand is 53 per cent higher by the end of the period, which by itself may not reduce TFP estimates by much, but this is but one input that needs to be adjusted. Since there is no similar data on other machinery and implements, the machinery input is estimated by grossing up the tractor series, using the real proportions for other machinery and implements calculated by Gandidzanwa and Liebenberg (2016). This is a reasonable assumption. In the absence of any data, if it is assumed that all the inputs were under-counted by 50 per cent, it would follow that the output, Y, is being divided by only one half of the input, X. Thus, it follows that TFP = Y/X would be estimated at twice the correct level.

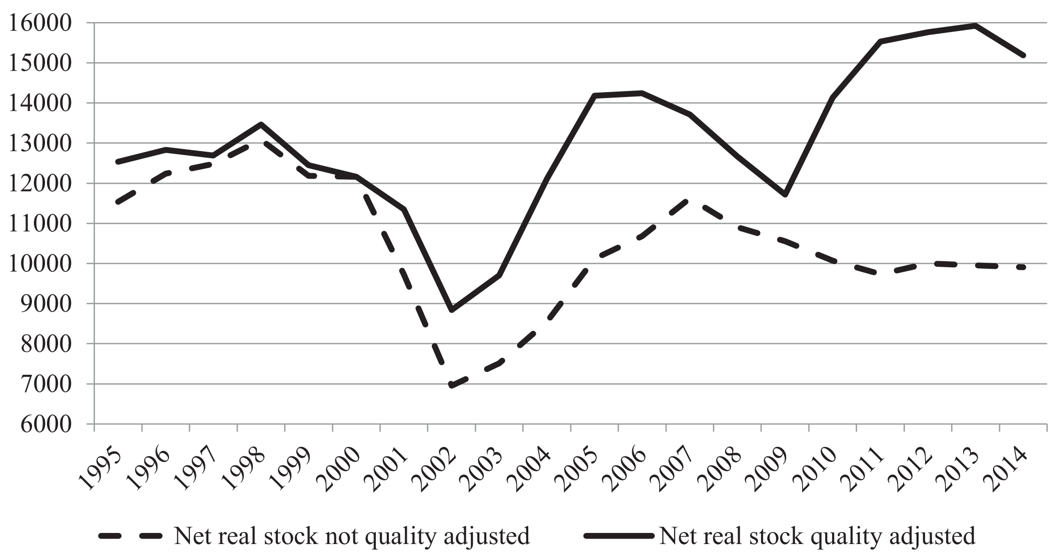

Figure 4. Capital stocks for machinery and implements (constant 2010 Rand). Source: Author's own calculations.

This is confirmed by Figure 4 which again shows the effect of incorporating quality adjustment. The main difference between the AAS capital stock and the quality adjusted version is that the revised series is consistently higher over the period. Thus, mis-measurement of the investment series results in underestimation of the net capital stock. The machinery input series in a TFP calculation is the service flow from this stock, plus running costs (fuel and maintenance), so it will be similarly under-estimated.

Table 7 and Figure 4 show the extent of the measurement error for tractors and extend this to other machinery and implements, for which there is no data. This covers a considerable proportion of capital items, but fixed improvements may be equally undercounted, as these include drainage and irrigation (much enhanced by drip technology), terracing, fencing and farm buildings, which would include milking parlours (which have also seen transformation). Nor are capital items the only problem. Of the basic inputs, land is a problem because little attempt has been made to quality adjust across space, although hectares in the Karoo are not at all comparable to those in Stellenbosch vineyards. Labour has improved with education levels and Craig and Pardey (1990) demonstrate the importance of quality adjustments for both land and labour in the US case. Thirtle *et al.* (2004) list historical attempts at quality adjustment for other variables, where the intermediate inputs are perhaps the most obvious problem. Agricultural chemicals have been transformed and precision agriculture means that smaller quantities of a few accurately placed drops or granules can replace larger quantities of dangerous and polluting chemicals. Biotechnology has contributed to this trend with BT and herbicide tolerant (HT) seeds and prophylactic antibiotics now common in animal feed.

5. Conclusion

Quality adjustment of the machinery and implements capital stock series results in an increase of over 50 per cent in the value of the series for the period 1995–2015. This increases the service flows by 50 per cent over the period. If all the inputs included in the TFP denominator have been under-estimated by 50 per cent, it follows that the estimate of TFP growth would be double its real value. This is clearly an unacceptable level of error. A number of data limitations have been identified in the estimation of precise capital stocks specific to this study. Service lives of the capital inputs are not readily available in South Africa, and one way of collecting this information would be through a national statistics survey. This is because it is not clear what replacement patterns or service lives properly represent South African farmers' use of machinery and implements, and whether these differ according to the type of capital input. Although the expected life of capital items is important in the estimation of the service stocks, when using the perpetual inventory method, the availability of these, based on statistical information, is scarce, which introduces limitation when using this method. Given these limitations, this article provides a basis for arguing that underestimation of capital stocks in productivity analysis will be large, if quality adjustments are not incorporated in capital valuation estimates. The cumulative effect of using quality adjusted aggregates and proxies in the AAS estimates, results in lower capital stocks that better represent reality.

Thirtle *et al.* (2004) show that as the data and methods in developed nations have improved, estimates of TFP growth in these countries have fallen. The point made by Jorgensen and Griliches (1967), that outputs must be explained by inputs and that any residual is due to measurement error, is becoming more obvious. Thus, this analysis supports the construction of quality adjusted data for all input series. Not only does this entail a great deal of work, but it will become increasingly difficult in South Africa if data becomes less detailed and reliable in future.

In such a context, it is important that a rigorous approach to performance measurement exists in order to develop and implement national agricultural policy. As Lipton (1989) put it:

> We have every reason to believe that nation states with a clear accounting system do better than those without. Indeed, one of the reasons commonly given for the failure of economic development in African economies is poor policy, frequently the result of a lack of information and effective measurement – we simply do not know what is going on.

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