Spatial pattern of agricultural performance in the Eastern Cape Province of South Africa, 2002

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Abstract:

The measurement of agricultural productivity and efficiency at the magisterial district level has never been embarked on before for the Eastern Cape. The value of such disaggregated data lies in the way it can inform policy. With agricultural development highlighted in both the NDP and Provincial development plan as potential drivers of inclusive, pro-poor growth, it is important, for example, know how to allocate scarce investment funds. This paper draws on on-going research that uses an input oriented, Constant Returns to Scale (CRS) Data Envelopment Analysis to measure efficiency of input use at the magisterial district level for the commercial farming areas of the province in 2002, by adapting the methodology employed by Coelli and Prasada Rao (2003). We find an average level of technical efficiency for the province of 0.793, with thirteen fully efficient districts and a range of efficiencies of 0.258-0.987, if we exclude the frontier districts at full efficiency. Efficiency analysis at this level of aggregation allows us to identify winners and losers and provides policy makers with the requisite information to attempt to protect high performing producers and improve the outcomes for low performers through a number of evidentially informed interventions.

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1. Introduction:

In the long run, productivity growth in agriculture is the only way for food production to keep up with population growth as the production system is faced with limited opportunities for extensification in land use. Measuring agricultural productivity is hence of vital importance to inform pro-poor policy strategies in developing regions. Most countries now have a national data series on agricultural productivity growth, but spatially disaggregated analyses only began to appear in the early 2000s for the states of the USA and a small part of the UK (Acquaye et al., 2003; Ball et al., 2002). South Africa's first national series was put together as part of planning for the new South Africa (Thirtle et al., 1993). A disaggregated series for the Western Cape followed in 2009, which revealed high growth in horticulture, marginally positive growth in field crops and a deterioration of productivity for extensive livestock (Conradie et al., 2009a,b). The strong growth in horticulture was attributed to irrigation, improvements in the cold chain and the adoption of modern inputs such as pesticides and improved varieties. The Karoo's lack of growth was attributed to a combination of overgrazing /climate change and infrastructure collapse. The reappearance of predators could not be shown to be responsible for the lack of growth in the Karoo (Conradie et al., 2013). We concur with Conradie et al (2009a: 265) that, "[a]griculture is the most spatially diffuse of all industries, and local characteristics do not generalize to the national level". The value of such data for food, rural development and land reform policy making should be obvious as agriculture is diverse at disaggregated levels and one needs to take these differences into account when planning and policy making decisions are made.

The measurement of agricultural productivity and efficiency at the magisterial district level has never been embarked on before for the Eastern Cape. This paper employs Data Envelopment Analysis to measure efficiency in Eastern Cape commercial agriculture at the magisterial district level for the latest, most complete available data set, 2002. The 2007 farm census is more recent but less complete. The results yielded are preliminary findings of ongoing research that aims to employ the Tornqvist-Theil Approximation of the Divisia Index to estimate Total Factor Productivity for the Eastern Cape Province at a disaggregated level in a growth accounting model, as was done for the Western Cape (see Conradie et al., 2008). The idea of growth accounting is to decompose the growth rate of an economy's total output into that which is due to increases in the amount of inputs used and that which cannot be accounted for by observable changes in input utilization. The unexplained part of growth is then taken to represent increases in productivity.

Agricultural policy in South Africa is implemented from the national level, even though there are great differences in agro ecology and output mix at provincial and lower levels of aggregation. It is thus imperative for provincial departments of agriculture to be informed so as to assist constructively in implementing their policies effectively, as the sector is seen as strategically important in promoting poverty reduction through pro-poor growth. This is to be achieved in the shape of potential low- and semi-skilled job creation according to policy documents at both national and provincial levels (National Planning Commission, 2011; Eastern Cape Planning Commission, 2014).

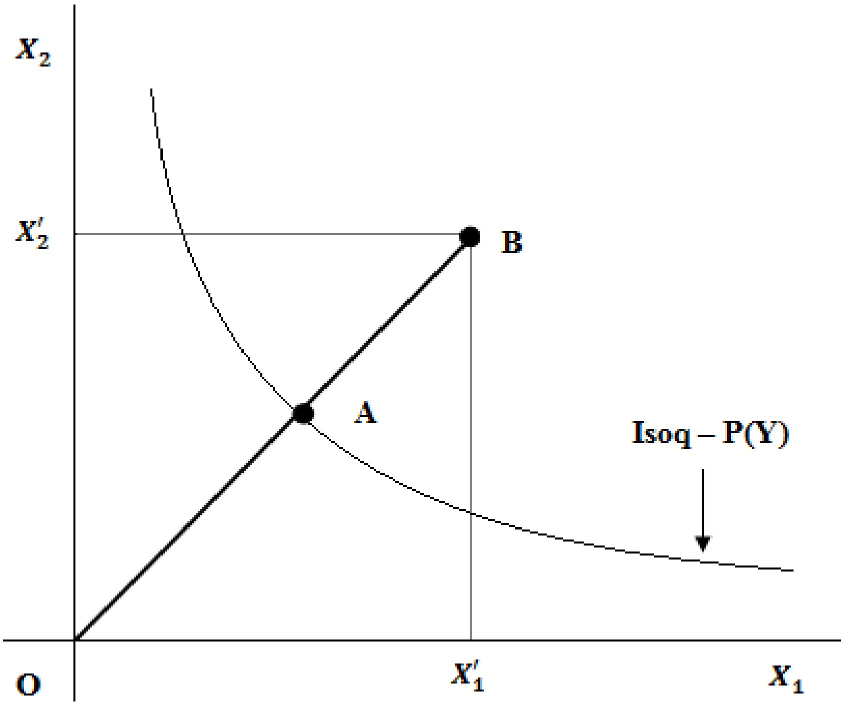
2. Objective:

This paper has three main objectives. Firstly, we compare district-level efficiencies across the Eastern Cape for 2002. Secondly, we explain efficiency differences with differences in output mix and labour absorption. Thirdly, we begin to explore the policy implications of the presented results, whilst acknowledging the limitations of this technique and the data.

3. Theory:

The measurement of productivity and efficiencies have been attracting much attention in the agricultural sector for a number of years. These terms are often used interchangeably, which is not technically correct. To illustrate the difference it is useful to think of a simple production process utilising one input to produce one output. One can then visualise a production frontier that represents the relationship between the input and the output, showing the maximum output attainable from each input level. The frontier thus represents the current state of technology in the industry. Efficient firms or decision making units will produce on the production frontier. A firm may be technically efficient (on the production frontier), but may still be able to improve its productivity by exploiting scale economies. The efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency, which reflects the ability of said firm to use inputs in optimal proportions given their respective prices and production technologies (Coelli et al., 2005).

According to Farrell (1957), efficiency is defined as the actual productivity of a firm in relation to its maximum potential productivity. The maximum productivity, which is also called the "best practice", is defined by the production frontier. DEA can be either input-orientated or output-orientated. In the input-orientated case, the DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage, with output levels held constant. In the output-orientated case, the DEA method defines the frontier by seeking the maximum possible proportional expansion in output, with input levels held constant. The two measures provide the same technical efficiency scores when a constant returns to scale (CRS) technology applies, but are generally unequal when variable returns to scale (VRS) are assumed.



Source: Coelli et al., 2003

Figure 1: Technical Efficiency Measure

Assuming constant returns to scale (CRS) as Farrell (1957) initially does in his paper, in Figure 1, the technological set is fully described by the unit isoquant P(Y) that captures the minimum combination of inputs per unit of output needed to produce a unit of output. Thus, under this framework, every package of inputs along the unit isoquant is considered as technically efficient while any point above and to the right of it, such as point B, defines a technically inefficient producer since the input package that is being used is more than enough to produce a unit of output. Hence, the distance AB along the ray OB measures the technical inefficiency of producer located at point B. This distance represents the amount by which all inputs can be divided without decreasing the amount of output. Geometrically, the technical inefficiency level associated to package B can be expressed by the ratio AB/OB, and therefore; the technical efficiency (TE) of the producer under analysis (1-AB/OB) would be given by the ratio OA/OB (Murillo-Zamorano, 2004; Coelli et al, 2005; Hoang & Alluadin, 2011). This model provides us with the tools to evaluate technical efficiencies of agricultural production in the Eastern Cape at the magisterial district level for commercial farming, excluding the former homeland regions in the Eastern part of the province.

4. Methods and Data:

The standard approach for analysing longitudinal productivity growth is the Tornqvist-Theil index number approach, which calculates weighted input and output indices directly from accounting data (Coelli et al., 2005; Ball, 1985). Conradie et al. (2009ab) and Thirtle et al (1993) used the same method to construct the Western Cape and national data series. The alternative is a Malmquist index which improves on the Tornqvist-Theil index by disaggregating overall productivity growth into technical efficiency improvements (catch up) and technical change (innovation). Both of these methods require time series data. When faced with just cross sectional data, as we are for 2002, the production frontier can be estimated in several ways, either parametrically - for example, through Stochastic Frontier Analysis - or non-parametrically, through Data Envelopment Analysis. In this paper, the latter approach is used. The mathematical exposition of the DEA model, which follows, is based upon Coelli, Rao and Battese (2005).

Assume there are data on N inputs and M outputs for each of the I firms, or in our case, districts. For the i-th firm these are represented by the column of vectors x_i and q_i respectively. The Nx1 input matrix X, and Mx1 Output matrix Q, represent the data for all the I firms. According to Coelli et al. (2005) the linear programming model is solved I times where I = the number of decision making units, as follows:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ st\ &-\mathbf{q}_i + \mathbf{Q}\lambda \geq \mathbf{0} \\ &\theta\mathbf{x}_i - \mathbf{X}\lambda \geq \mathbf{0} \\ &\lambda \geq 0 \end{aligned}$$

Where θ is a scalar and λ is a I x 1 vector of constants. The value of θ obtained is the efficiency score for the i-th firm. It satisfies: θ≤1, with a value of one indicating a point on the frontier and hence a technically efficient firm. Note that the linear programming problem must be solved I times, once for each district in the sample. A value for θ is obtained for each district (Coelli et al, 2005).

In our case the units of observation are magisterial districts. The degree of technical inefficiency of each district (the distance between the observed data point and the frontier) is produced as a by-product of the frontier construction method. The maximum value is 1.00, or a hundred per cent. There is no minimum value. Constant returns to scale was assumed as scale efficiency cannot be interpreted meaningfully for districts as they are not individual decision making units, but an aggregation of farms according to geographical position. An input orientated calculation was specified, as the same efficiency results as output orientation is obtained when constant returns to scale are assumed. The algorithm of the Centre of Efficiency and Productivity Analysis at the University of Queensland in Australia was used to solve the model.

We use the 2002 Census of Commercial Agriculture to compile the dataset at the magisterial District level for the Eastern Cape Province (Statistics South Africa, 2002). The analysis comprises the 41 magisterial districts of the Eastern Cape. Two outputs were considered, namely the value of crop production and the value of livestock production. The crop variable includes all crops (horticultural and field crops) and are recorded as value of products livestock variable is recorded as values of all animals and animal products sold in 2002 Rand as recorded in the 2002 Census. Given the constraints on the number of input variables that could be used in the DEA analysis, we have opted to consider only three input variables, namely Land (in hectares of natural grazing and cultivated land for each magisterial district), Labour (total wage bill for each district) and Modern Inputs, which aggregates the expenditure on Fertilizer, Feed and Remedies (all recorded as Rand spent per district in 2002). We would have liked to have used irrigated area as an input, but that the census did not record this information. Land area farmed was not recorded in the 2002 census; we thus assumed that the figures for 2002 were the same as what was recorded in 1993.

5. Empirical Results:

Thirteen of the 41 districts operated at full efficiency in 2002. The average efficiency was 0.793. The median efficiency was 0.853. Cathcart recorded the lowest efficiency of 0.258. In total 7 districts were less than fifty per cent efficient. The thirteen fully efficient frontier districts were Cradock, Adelaide, Steynsburg, Aliwal North, Hankey, Alexandria, East London, Hofmeyer, Humansdorp, Lady Grey, Molteno, Sterkstroom, Uitenhage and Venterstad. The lower efficient districts in the North-East of the province (Middelburg, Graaff-Reinet and Aberdeen) have a large number of farms converted into lifestyle and game farming enterprises, which are not recorded in the agricultural census. This low efficiency in the Karoo region of the province corresponds with the Western Cape findings of Conradie et al (2009b).

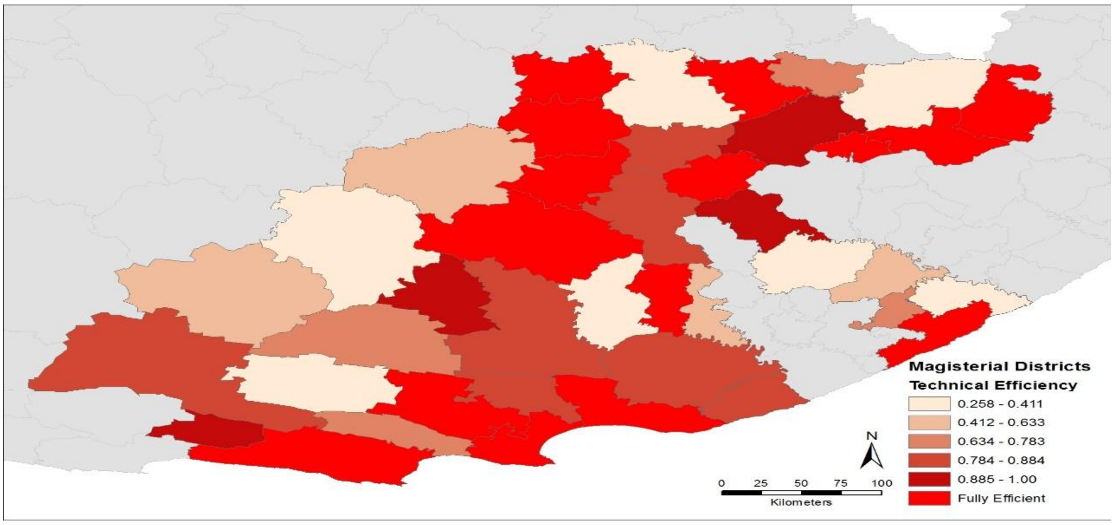


Figure 2: Spatial Representation of Technical Efficiencies

What figure two illustrates is three distinct high efficiency regions in the province. These are in the South West. Central to North, and North East, bordering the former Transkei. To begin exploring efficiency differences districts were grouped into three equal sized groups according to their efficiency scores. Following Conradie et al (2009b) we tested for difference in the composition of output across the productivity classes (See Table 1). The average efficiency in the top group was 100%. The middle group was on average 86.6% efficient compared to an efficiency level of only 47.9% for the bottom group. The implication of this result is that the bottom group are theoretically able to maintain their 2002 output with 52.1% fewer inputs. Since a district's agricultural resources are pretty much given, it may have been more meaningful to have specified output orientation in which the interpretation of the efficiencies would have been how much output could be increased by with the current level of input.

For the top fourteen districts, dairy is the most important agricultural enterprise. Dairy comprised 37% of the value of outputs for 2002, followed by extensive livestock products which contributed 28%. At 19% and 11%, horticulture and poultry respectively contributed very little. For the second group of thirteen districts, which had a technical efficiency range of 0.987 for Jansenville, to 0.778 for Indwe, the picture is very different. Extensive livestock products made up the lion's share at 64%. The high potential dairy and poultry industries contributed 12% and 8% each. The lowest scoring thirteen districts have horticulture as the dominant output at 51%, followed by extensive livestock products at 34%. Poultry and dairy are marginal contributors at 3% and 6% respectively.

	Top Third	Middle Third	Bottom Third	Provincial
Horticulture Share	18.9%	8.0%	51.3%	26.1%
Dairy Share	36.7%	11.8%	5.9%	22.8%
Extensive livestock Share	27.9%	64.0%	34.3%	36.5%
Poultry Share	11.1%	8.3%	2.9%	7.0%
Other Share	5.5%	8.0%	5.5%	7.7%
TE Mean	1.00	0.866	0.479	0.793

Source: Author's Own Calculations

Table 1: Efficiencies and Output Mix by Descending Efficiency Grouping

As can be gleaned from Table 1, animal production (in the form of extensive livestock production, Dairy and poultry) is the most important contributor to output in the most efficient districts. The least efficient districts appear to be predominantly horticulture producers, at 51.34%. The districts with the highest horticulture output shares, Joubertina (97%), Kirkwood (91%) and Fort Beaufort (74%) all fall in the bottom third grouping of efficiencies.

The picture painted by looking at labour absorption also yields interesting results. There are a total of 63748 workers employed in Eastern Cape commercial agriculture in 2002. The two districts with the lowest number of labourers, Sterkstroom (21) and Venterstad (47) are both fully efficient and have extensive livestock products as their dominant outputs at 92% and 72% respectively. Kirkwood and Joubertina, with the most workers employed at 10756 and 8448 respectively, have efficiency scores of 0.272 (the second lowest score) and 0.748. They are both dominant in horticulture, with it comprising shares of 91% and 97% respectively. What we thus deduce is that animal production is most efficient, whilst using the least amount of labour and horticultural production tends to be least efficient whilst employing the most labour on district levels. With the current output mixes, it will be difficult to maintain these levels of employment if there is to be an improvement in efficiency for the districts with large shares of horticultural production.

The value of disaggregated analyses of agricultural production has been shown for the Western Cape Province (Conradie et al. 2009). Major changes in TFP tend to be very long term, and at the district level, it is possible to identify the main historical drivers to this growth or decline. High levels of aggregation can disguise significant differences between component parts if we lump together the winter rainfall areas of the Western

Cape that focus on horticultural production with the summer rainfall provinces across the rest of the country that produce mainly wheat and beef. They conclude that the most striking finding is the degree of diversity in TFP growth, which ranges from seriously negative for the least favoured districts in the Karoo to about 3% per annum and more in the seven irrigated districts in the south west of the province. At the extremes, the extensive animal rearing areas have negative productivity growth, whereas districts with irrigated export fruit and/or chickens and pigs have achieved rapid positive growth, which is directly linked to high levels of technological change. The districts with a predominance of field crops and wine lie between these extremes. These results confirm the view that anything more aggregated than district-level results is not useful for advising farmers as it is the detail that is necessary for policy (Conradie et al., 2009: 278).

6. Discussion/Policy implications:

The most efficient districts are mainly engaged in some form of animal production, either extensive livestock production of dairy and poultry. The horticulture sector is underperforming and would require more intervention to improve. The underperforming horticulture sector, which has the highest potential in job creation because of its relatively high labour intensity is already seen as a priority sector.

A lot needs to be done to improve efficiency of this important sector through expansion of irrigation to improve land productivity and creating better access to markets and research and development. Basically, what is required is intensive, industry level integrated research and more capital investment to try and improve labour productivity if the poverty reducing potential of this sub-sector is to be exploited as suggested in The National Development Plan (NPC, 2011).

The impact of disaggregated productivity and efficiency analysis is undoubtedly important for land reform policy if one wants to allocate land with high agricultural potential to alleviate the high failure rate of beneficiaries of land reform. While there have been significant efforts to reform land ownership, the overall rural context has changed relatively little since the advent of democracy in 1994. Commercial agriculture continues to occupy the lion's share of arable land. Land reform efforts have been limited with the amount of actual land being transferred not coming close to meeting targets. By 1999 only 1% of commercial agricultural land had been transferred (Vink and Hall, 2010:77) and by 2007 this had risen but was still below 4% (Kirsten et al, 2007). Between 1994 and 2014, each land reform beneficiary household 'received' almost 20 hectares of farmland, but this did not translate into family-owned, or even family-operated, farms. Commercial farms purchased by beneficiaries with financial support from the government were rarely partitioned into smaller farms that could be allocated to individuals or families. According to Lynne (2014: 4), in 2010, 90 percent of redistributed land was deemed 'no longer productive' (Africa Research Institute 2013). New owners have received little support and as a result, in many cases, output has fallen dramatically (See Black et al, 2014 & Black and Gerwel, 2014).

Identifying efficiently producing regions and industries within agriculture could inform where land reform needs to be focussed and turn around the dismal performance of the land reform process by assessing where beneficiaries have the greatest chance of success based on sound empirical analysis. Evidence based policy making is important in the agricultural sector as "[p]lans for rural towns should be tailor-made according to the varying opportunities in each area" (NPC, 2011: 217). Both the provincial and national governments have earmarked this sector as a strategic intervention point for promoting pro-poor growth. Without detailed analysis of where the winners and losers are situated both spatially and in terms of output mix, we are taking shots in the dark in terms of creating an enabling environment for land reform beneficiaries, as well as creating more opportunities for job creation and productivity improvements in commercial agriculture.

7. Limitations of Study

The analysis, though useful, has a number of limitations that need highlighting. DEA provides a snap-shot of the situation and is influenced by external conditions such as climactic conditions (droughts, etc.) and prices. The analysis of 2002 data is historical and does not cover agriculture in communal areas of the province, which has the largest population density. Without the inclusion of these important areas, we are painting an incomplete picture. The 2002 Census did not record land use, so the data used in this analysis was the value of land per district recorded for 1993. This creates an unreliable picture, as numerous forms have been converted to game farms, which is not recorded in the agricultural surveys. As these are preliminary analyses of ongoing research, a better picture of the commercial agricultural sector in the province will be available once the Tornqvist-Theil Approximation for the full data set from 1951-2002 is completed.

8. Conclusions:

Planning and policy making for agriculture is an intricate and multifaceted process that requires detailed analyses to make it evidence based. Having an all-encompassing plan for agriculture as if it is a homogenous industry can be misleading and detrimental to developmental goals. Although we are currently looking at agriculture in South Africa as comprising a dichotomous structure with commercial agriculture on the one end of the spectrum and small scale production on the other, it is clear from this study that there in no one agriculture, even amongst commercial operations.

Efficiency analysis allows us to identify winners and losers and provides policy makers with the requisite information to attempt to protect high performing producers and improve the outcomes for low performers through a number of evidentially informed interventions. Finally, we can also make the land reform process more effective by introducing beneficiaries into the viable regions where there could be a diffusion of technology and technical expertise from the successful farmers to the new entrants through mentorship programmes. Finally, it is important for more recent data, recorded at the same level of aggregation (magisterial district) to be made available by the DAFF and Statistics South Africa to make a consistent and more current time-series analyses possible.

9. References:

Acquaye, A.K.A., Alston, J.M., Pardey, P.G., 2003. Post-war productivity patterns in U.S. agriculture: Influences of aggregation procedures in a state-level analysis. Am. J. Agric. Econ. 85(1), 59–80.

Ball, V. Eldon, Bureau, J.C., Butault, J.P., Nehring, R., (2001) "Levels of Farm Sector Productivity: An International Comparison", *Journal of Productivity Analysis*, 15, 5-29.

Ball, E, Butalt, J.-P., Nehring, R.H., (2002). "US agriculture, 1960–96: A multilateral comparison of total factor productivity". In: Ball, E., Norton, G.W. (Eds.), *Agricultural Productivity: Measurement and Sources of Growth*. Kluwer Academic Publishers, Boston, pp. 1–36, Chapter 1.

Black, A. Conradie, B. & Gerwel, H. (2014) *Should agriculture receive greater support as part of an inclusive growth strategy?.* Online: http://www.econ3x3.org/article/should-agriculture-receive-greater-support-part-inclusive-growth-strategy [12-01-2015]

Black, A. & Gerwel, H. (2014) Shifting the growth path to achieve employment intensive growth in South Africa, *Development Southern Africa*, Vol. 31, No. 2: 241-256.

Conradie, B. Piese, J. & Thirtle, C. (2008) 'Total Factor Productivity at the District Level for the Western Cape, 1952-2002: Data and Methods'. Research Paper 50. King's College London.

Conradie, B. Piese, J. & Thirtle, C. (2009a) 'District-level total factor productivity in agriculture: Western Cape Province, South Africa, 1952-2002'. *Agricultural Economics*. 40(2009): 265-280.

Conradie, B. Piese, J. & Thirtle, C. (2009b) 'What is the appropriate level of aggregation for productivity indices? Comparing district, regional and national measures'. *Agrekon*. Vol. 48(1): 9-20.

Conradie, B., Piesse, J., Thirtle, C., Vink, N. And Winter, K. (2013). Explaining declining total factor productivity in the Karoo districts of the Western Cape, 1952 to 2002 *Agrekon* 52(S1): 1-23

Coelli, T. Prasada Rao, D. O'Donnel, J. Battesse, G. (2005) 'an Introduction to Efficiency and Productivity Analysis' (2e). Springer: Ney York.

Hoang, V. and M. Allauddin. (2011). Input-orientated data envelopment analysis framework for measuring and decomposing economic, environmental and ecological efficiency: an application to OECD agriculture. *Env. Res. Econ.* 51:431-452.

Kirsten, J. Edwards, L. and Vink, N. (2007) Distortions to Agricultural Incentives in South Africa. *Agricultural Distortions Working Paper 38*, World Bank: Washington DC.

Lissitsa, A. Coelli, T. ad Prasada Rao, D. (2005) Agricultural Economics Education in Ukrainian Agricultural Universities: An Efficiency Analysis using Data Envelopment Analysis. Paper prepared for presentation at the *XI International Congress of EAAE*: Copenhagen.

Lyne, M. (2014) The F.R. Tomlinson memorial lecture: Two decades of land reform in South Africa: Insights from an agricultural economics, *Agrekon*: Agricultural Economics Research, Policy and Practice in Southern Africa, 53:4, 1-15

Murillo-Zamorano LR (2004). Economic Efficiency and Frontier Techniques.' *Journal Economic Survey* 18(1): 33-77.

Statistics South Africa (2002), Farm Census, 2002. Census of Commercial Agriculture 2002 Provincial Statistics: Eastern Cape (Farm Census). StatisticsSouthAfricaReportno.11-02-03(2002).Availableat:http://www. statssa.gov.za

Vink, N. and Hall, R. (2010) Agricultural and land policy, in Jones, S and Vivian, R. (eds.) *South African economy and policy,1990-2000*. Manchester: Manchester University Press.