Inequality and agricultural production: Evidence from aggregate agriculture and sugarcane farms in South Africa

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This article explores the determinants of inequality in productivity in South African agriculture and differentiates between small-scale and large-scale farms in the sugarcane sector. The findings suggest that inequality slows down productivity and that land redistribution slightly improves it. Farm type-specific effects reveal that redistribution per se does not lead to higher production, but only improves production for those who farm the land effectively and go on to harvest the crop. Much of the difference in land productivity between the two farm types arises from disparity in input use, particularly fertilizer and irrigation. Some mutually beneficial collaboration between the two types is possible, skewed in favor of small farms. For small-scale farmers, access to land is necessary but not sufficient: other factors such as fertilizer, irrigation, chemicals and human capital (particularly literacy) must be prioritized. Any policy that creates conflicts between the two types will jeopardize agricultural production, to the detriment of small-scale producers.

Keywords: inequality; land redistribution; time series; panel data; sugarcane; South Africa

JEL codes: Q11; Q15; C22; C23

Cet article explore les déterminants de l'inégalité en matière de productivité que connaît l'agriculture sud-africaine et distingue les petites exploitations du secteur de la canne à sucre des grandes. Les résultats suggèrent que l'inégalité ralentit la productivité et que la redistribution des terres la renforce légèrement. Les effets spécifiques aux types d'exploitation agricole révèlent que la redistribution en soi ne génère pas une plus grande production, mais qu'elle n'améliore la production que pour ceux qui savent cultiver la terre correctement et parviennent à obtenir des récoltes. Concernant la productivité foncière, c'est la disparité des intrants utilisés, en particulier les engrais et l'irrigation, qui crée la plus grande différence entre les deux types d'exploitation. Une collaboration réciproque et bénéfique entre les deux types est en quelque sorte possible, quand bien même ce sont les petites fermes qu'elle favorise. Pour les petits fermiers, l'accès aux terres est nécessaire mais pas suffisant : d'autres facteurs comme les engrais, l'irrigation, les produits chimiques et les ressources humaines (en particulier l'alphabétisation) doivent devenir une priorité. Toute politique entrainant des conflits entre les deux types mettra en péril la production agricole, au détriment des petits producteurs.

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Mots-clés : *inégalité ; redistribution des terres ; série chronologique ; ensemble de données ; canne à sucre ; Afrique du Sud*

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1. Introduction

International development agencies are showing renewed interest in agriculture's pro-poor potential. The 2008 World Development Report (World Bank, 2007) highlights three facts about the sector's ability to enhance pro-poor growth, especially in sub-Saharan Africa. Firstly, GDP growth in agriculture is four times more effective for reducing extreme poverty than GDP growth in other sectors. Secondly, in developing countries 75% of the poor live in (agriculture-dependent) rural areas, while only 4% of official development aid goes to agriculture. Thirdly, sub-Saharan African countries rely heavily on agriculture for overall growth, taxing the sector heavily while allocating to it only 4% of total government spending. The World Bank (2008) has therefore reiterated that if the goals of halving poverty and hunger are to be realized, agriculture must be placed at the centre of developing countries' policy agendas, with greater investment in the sector, especially in sub-Saharan Africa.

In South Africa, though agriculture contributes less than 3% of overall GDP, its employment per unit of GDP (relative to other sectors) remains the highest, as Figure 1 shows.

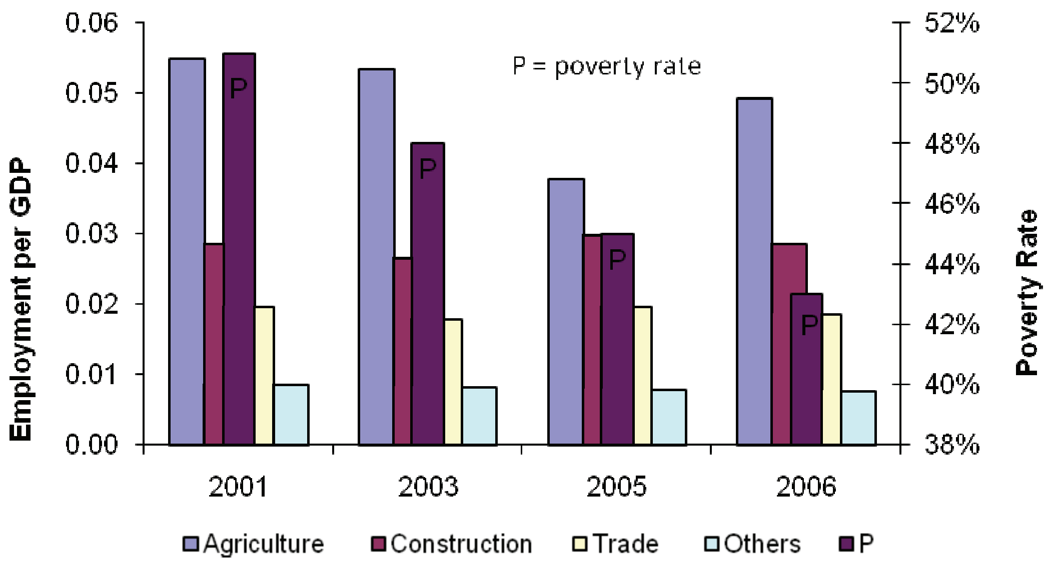

Figure 1: Sector-wise employment per unit GDP and poverty
Source: Labour force survey data (StatsSA, 2007)
Note: Except for poverty rate (labelled P), the bars are in the same order as the legend.

The main challenge for South Africa's policy authority is to uncover and harness agricultural potential in order to achieve the policy goals of the Growth, Employment, and Redistribution

(GEAR) strategy, in particular to 1) increase agricultural productivity and output in order to step up the sector's contribution to national economic growth, 2) increase the incomes of the poorest groups by creating production enhancing opportunities for small- and medium-scale farmers, 3) create additional employment in the sector, and 4) ensure a more equitable distribution of resources in the sector. South Africa's biofuel strategy and other policy options have highlighted the country's determination to pursue these objectives. The main objective of this strategy is to address the issues of poverty and economic development from a renewable energy angle. It aims to deal with these challenges, particularly 2) and 3) above, in formerly disadvantaged and underdeveloped areas of the community (DME, 2007).

In contrast to other developing countries, which have a wide range of farm sizes, South Africa's agricultural sector is sharply divided into small and large farms. Despite arguments for the existence of a positive relationship between farm size and production efficiency, some empirical evidence points to the fact that small-scale farmers in developing countries can be efficient (Lipton & Ellis, 1996; Vollrath, 2007). It has been argued that the only reason for any positive relationship is that markets are in many ways imperfect for the needs of the small producer. Kirsten and Van Zyl (1998) identify such imperfections in the case of South Africa (inadequate or inaccessible land, credit, insurance, etc.). These imperfections in input markets are factors generally considered to underlie the disparity between small and large farm production. However, there are considerable transaction costs in the labor market and managerial costs, and these interplay in favor of small farms (Kirsten & Van Zy1, 1998).

Figure 2 shows the evolution of difference in land productivity of sugarcane between small- and large-scale farmers in South Africa.[2] The values for each year are averages for all the cane growing localities. It is evident that the disparity between the productivities of small and large sugarcane farms is increasing.

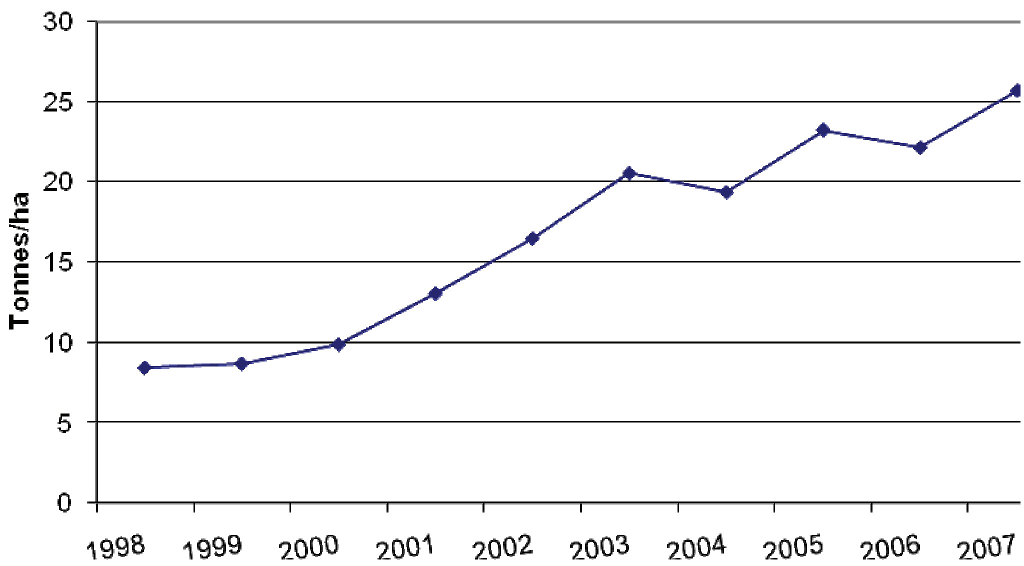

Figure 2: The average productivity gap between large and small farms

Source: Sugarcane production data from SA Cane Growers Association (2008)The post-apartheid government of South Africa has embarked on redressing some of the inequalities that have

[2] Small-scale growers are defined as those growers who currently deliver on average not more than 225 tonnes of Recoverable Value.

faced small-scale agriculture. Most important is the land reform program that kicked off in 1994. This program comprises restitution, tenure reform and redistribution.[3] The redistribution objective aims to reallocate not only government but also private land to the disadvantaged and poor, for productive and residential purposes. The South African Cane Growers Association reports that from 1999 to 2005 some 37,676 hectares of land were transferred from white large-scale growers to black growers in the sugarcane sector, on the basis of willing-seller-willing-buyer transactions. SA Cane Growers (2008) provides statistics which suggest that the figure has increased to 43,200 hectares, representing 13.6% of black ownership in the sector.

The mean inputs data from the Cane Growers Association for the sugarcane sub-sector suggests that small-scale farmers use more labor per unit of land than their large-scale counterparts, as Figure 3 shows. This may have poverty reduction implications. However, large-scale farmers use far more fertilizer, chemicals, and irrigation per unit of land than small-scale farmers. Though expenditure on inputs has increased over the years in all farm types, in general large-scale farmers recorded more increases in all inputs except labor from 1998 to 2007.

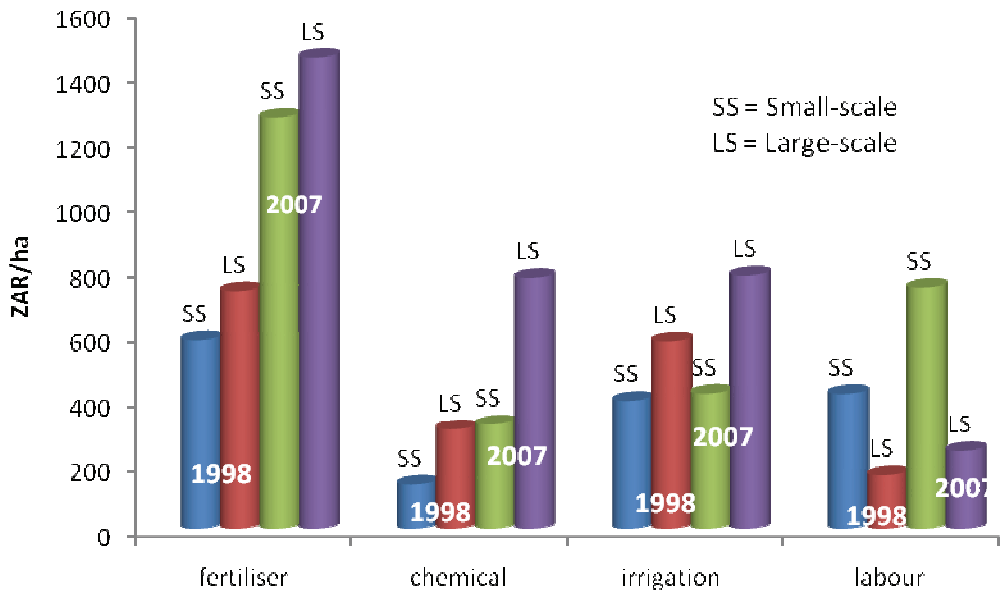

Figure 3: Mean inputs for small and large farms between 1998 and 2007

Source: Sugarcane production data from SA Cane Growers Association (2008)

This paper assesses the agricultural production impacts of inequality and land redistribution, first in the agricultural sector as a whole, then in the sugarcane sub-sector, comparing small-scale and large-scale farm performances. Specifically, its aims are to:

[3] Restitution covers cases of indigenes who were forcefully removed from their land after 1913. Tenure reform addresses the issue of tenure security of all South Africans in order to accommodate the diverse tenure systems. This study focuses on redistribution because of available data.

- Analyze the impact of inequality on agricultural production, with emphasis on the land redistribution process as a measure of inequality attenuation.
- Analyze the comparative productivity[4] performances of large- and small-scale sugarcane producers with respect to various production inputs.
- Attempt to explain the determinants of the widening productivity gap between small- and large-scale producers using the South African sugarcane sector as a case study.
- Draw policy recommendations.

The rest of the paper is structured as follows. Section 2 explores related literature, Section 3 explains the methodology, Section 4 presents and interprets the results, and Section 5 concludes with some policy recommendations.

2. Literature review

The literature in this area is framed by the growth-inequality-poverty hypothesis (for example, Easterly, 2002; Bourguignon, 2004; Ravallion, 2004). The impact of inequality on development has received much attention since the early 1990s. The works of Galor and Zeira (1993), Persson and Tabelini (1994), and Alesina and Rodrik (1994) are pioneers in this area. Three main topics are worth exploring: capital markets, labor markets, and the political economy, all of which have implications for human and physical capital accumulation.

2.1 Capital markets

The underlying mechanism here can be explained as follows. In the credit market, if 10% and 50% are the respective interest rates for rich and poor individuals (because the poor lack collateral), then all projects with return rates of 10% and above will be undertaken by the rich while only projects with return rates 50% and above will be undertaken by the poor. But if there is redistribution of wealth (or resources) from the rich to poorer individuals, this will reduce their need to borrow while allowing them to undertake projects with returns lower than 50%. In this case, redistribution will lead to higher investment and/or higher return to capital (Bourguignon, 2004:17). More formalized models (such as Galor & Zeira, 1993; Banerjee & Newman, 1993; Aghion & Bolton, 1997) put information asymmetry at the centre of credit constraints. In these models, outputs are unequal because credit rationing limits the choice of occupations and investments for poor people (and possibly also for middle class people). When the poor are thus prevented from making productive investments (that would benefit them and society), the growth process may be low and inequitable. Land can be used either as input or as collateral for investment loans, thus helping to ease credit rationing. These models establish the link between persistent high inequality, inefficiencies, and slower production.

2.2 Labor markets

In contrast to the capital market imperfections that work against small farmers, labor market imperfections can be to their advantage. This is because of the considerable transaction and

[4] Productivity here and elsewhere in this paper refers to cane output per hectare.

supervision costs in the labor market (Kirsten & VanZyl, 1998). The literature generally suggests that the nature of labor relations on family farms (typical of small scale) makes them more efficient and superior to other types of farming (Binswanger & Elgin, 1992; Binswanger & Kinsey, 1993). On a family farm, the owner is the operator, and the family provides a large share of the required labor. This arrangement allows (small-scale) family farmers to put more time and energy into their farm business than they could if they employed labor at market wages (Delgado, 1996). Relying on family labor can make small farms more efficient than large ones.

2.3 The political economy

Two main topics are identified here. One is the notion of the median voter, where wealth inequality increases the gap between the median voter and the average capital endowment of the economy. This leads the median voter to support higher capital tax rates, which in turn reduces incentives to invest in physical and human capital, hence reducing growth. Persson and Tabelini (1994) suggest another version, in which the rich spend their wealth to lobby for preferential (tax) treatment, leading to more inequality and slower production.

The other topic is social conflict and political instability. Alesina and Perotti (1993) argue that higher political instability can result from high inequality; the resulting uncertainty then reduces investment levels, and Rodrik (1998) points out that divided societies with weak institutions also witnessed the sharpest fall in post-1975 growth.

Empirical attempts have been made to test the hypothesis that high inequality leads to low investment in physical and human capital, resulting in slower growth. Various authors have found a negative impact of initial inequality on growth. Persson and Tabelini (1994), using data for nine OECD countries, found that a one standard deviation increase in income share of the top quintile reduces growth rate by half a percentage point. Others have verified this, using a sample of developing countries (Clarke, 1995) and a combination of both developed and developing countries in an extended data set (Deininger & Squire, 1996).

A number of studies of the agricultural sector have considered cross-country productivity determinants (Kawagoe et al., 1985; Fulginiti & Perrin, 1993; Craig et al., 1997). All these attempt to model the role of factors such as capital, land quality, infrastructure, and research and development (R&D) in agricultural production. The time dimension of such analysis has been considered. For example, Vollrath (2007) introduces the role of inequality while investigating the inverse farm size-productivity relationship empirically. Using panel data, he finds that the Gini coefficient has a significant negative effect on agricultural production per hectare.

Prior to this study, Jeon and Kim (2000) looked at land reform, focusing on its impact on rice production in Korea and using dummy variables to capture land reforms. They found a significant positive impact. Similarly, Besley and Burgess (2000) used a panel data model to investigate the impact of land reforms on poverty reduction in India. Their finding suggests that the fourth lag of land reform variable is significantly associated with poverty reduction.

The present study adapts Vollrath's approach (2007) to the South African agricultural sector to investigate the impact of inequality and land redistribution on agricultural production and cane production, distinguishing between small and large growers. Finally, building on Kawagoe et al. (1985), a simple framework is developed to assess the determinants of the difference between the productivity levels of large- and small-scale farmers.

3. Methodology

3.1 Model for inequality and production

The model applied to the agricultural sector and to (both small- and large-scale) sugarcane farmers to analyze land redistribution and agricultural productivity follows Vollrath (2007). Rather than a cross-section regression, this method is here applied first to time series data covering 1980 to 2006 for South Africa's agricultural sector and then to a panel of 14 cane producing regions in South Africa over the period 1998 to 2007.

The model considers a simple decomposition of all farms into $1-\lambda$ small farms and λ large farms. As such, λ is a proxy for land inequality. Let θ_s and θ_l be the respective average land areas of small and large farms, with $\theta_l > \theta_s$. The total output per hectare can be expressed as the weighted average of each type as follows:

$$y = A[(1-\lambda)\theta_s f_s(x_s) + \lambda\theta_l f_l(x_l)] \quad (1)$$

where *A* is Total Factor Productivity (TFP), *x* is a vector of per hectare inputs, and *f* denotes the production function. If we suppose that both farm types share a common production function *f(x)* with a vector of aggregate inputs *x*, then:

$$y = A[(1-\lambda)\theta_s + \lambda\theta_l]f(x) \quad (2)$$

While Vollrath (2007) focuses on the inverse relationship between farm size and productivity, this study uses the model to assess the impact of inequality in general and land redistribution (an inequality attenuating measure) on production. If we assume that the above framework can be generalized not only to land distribution but also to other farm input distribution, then the relationship between λ and y can reveal information on the link between general input distribution and productivity. Following the credit market explanation (Section 2.1 above) of how inequality affects production, we can conveniently proxy input inequality with income inequality, such that $\lambda = Gini$. Since agriculture is a substantial contributor to GDP and employment (see Figure 1), especially for the relatively poorer unskilled workers, use of the national inequality index in the agricultural sector can be appropriate.

The empirical specification adopted for this is as follows:

$$\ln y_t = \beta_0 + \gamma t + \beta_1 g_t + \beta_2 Nred_t + \sum_i \alpha_i X_{it} + \varepsilon_t \quad (3)$$

where γ is productivity growth rate, t is time trend, β and α are parameters, g is the Gini coefficient, *Nred* is cumulative land redistributed as a share of total crop land, X_i is input *i*, and ε_t is an error term.

The model for small and large farm production is the panel specification of (3), i.e.

$$\left(\ln y_{jt} = \beta_0 + \lambda t + \beta_1 g_t + \beta_2 Nred_t + (\sum_i \alpha_i X_i)_{jt} + \eta_j + \varepsilon_{jt} \right)_{l,s} \quad (4)$$

where *j* denotes cane producing regions (*j* = 1, …, 14), the subscripts *l,s* denote turn by turn consideration of equation (4) as large- and small-scale farms respectively, and $\eta_j + \varepsilon_t$ is a composite error term including unobserved region-specific effects.

3.2 Model for large- and small-scale productivity difference

The following model is developed to explain the widening productivity differential between large- and small-scale farmers.

Consider the production functions y_l and y_s for large- and small-scale farmers respectively, and assuming that both farmer categories are faced with the same technology, such that:

$$y_l = Ae^{\lambda t}\Pi_i X_{li}^{\alpha_i} \quad (5)$$

$$y_s = Ae^{\lambda t}\Pi_i X_{si}^{\beta_i} \quad (6)$$

where *i* denotes input *i* and Π is the product operator, α and β are the respective parameters for large-scale and small-scale production functions. Dividing (5) by (6) and taking log implies:

$$\log y_l - \log y_s = \log(\Pi_i X_{li}^{\alpha_i}) - \log(\Pi_i X_{si}^{\beta_i}) \quad (7)$$

$$\Delta_p y = \sum_i \alpha_i \log X_{li} + \sum_i \beta_i \log X_{si} \quad (8)$$

where $\Delta_p y$ is the productivity difference between large and small farms. The empirical specification of (8) in panel data form is:

$$\Delta_p y_{jt} = \left(\sum_i \alpha_i \log X_{li} \right)_{jt} + \left(\sum_i \beta_i \log X_{si} \right)_{jt} + \eta_j + \varepsilon_{jt} \quad (9)$$

3.3 Variables, theoretical expectations and data sources

Following is the description of the variables with the theoretically expected signs and their data sources.

The dependent variable in most of the models is production. In the agricultural sectors model we use the total value of all agricultural production from 1983 to 2007, after deduction of feed and seed. This was obtained from the FAOSTAT online database[5] and also the South African Department of Agriculture's Abstract of Agricultural Statistics (NDA, 2007). The time series of Gini coefficient and quantity of land redistributed was obtained from the SA Development Indicators (2007) published by the Presidency of South Africa. Both series span the period 1993 to 2007. The Gini coefficient is therefore truncated for the 10 observations from 1983 to 1993. These were replaced with the mean of the observed 15 observations. Theoretically, the Gini coefficient is expected to have a negative impact. The land redistribution variable (taken as cumulative land area redistributed as a share of total crop land from FAOSTAT) was not truncated, since observation starts at the beginning of the process, and prior to this the variable was zero. To avoid the problem of log of zero, the ad hoc method common in the trade literature is used, i.e. a near zero (0.00001) value was added to the land redistribution series (Wang & Winters, 1991; Raballand, 2003). The land redistribution variable is theoretically expected to have a positive impact on production. However, this sign can be ambiguous, especially if large farmers are land constrained, and then the impact would be negative for large-scale farmers and positive for small-scale farmers.

The input variables, all expected to have a positive effect on agricultural production, are as follows:

- Labor: As employment in the agricultural sector, taken from SA Department of Agriculture (NDA, 2007).
- Fertilizer: As kilograms of fertilizer used, taken from the Fertilizer Society of South Africa.
- Tractors: Measured as agricultural tractor in use. This was obtained from the World Development Indicators (World Bank, 2008).
- To control for land quality and, to some extent, weather and other land uses, two other variables were added: the percentage of irrigated land, derived as irrigated land divided by total crop land, and the percentage of pasture land, derived as the ratio of the amount of permanent pasture land to total agricultural land. These two variables were obtained from the FAOSTAT database.

All the data for the sugarcane sector were obtained from the SA Cane Growers Association (2008). This data is a panel for small and large growers organized around 14 mill areas over

[5] http://faostat.fao.org/site/613/default.aspx#ancor

the period 1998 to 2007. Input information for small-scale growers did not cover all years. The assumption was made that the gap in input use between large and small farmers varied across regions but remained constant over time. This allowed for the generation of inputs for small growers to fill the omitted years. Land productivity difference was generated as indicated in equations (7) and (8) above.

A number of variables had data missing between periods. The missing values were interpolated based on the assumption that the series follows a relatively smooth path over time (see Vollrath, 2007: 215). Thus for a variable *X*, with missing value at time s, falling between two observations at time t and $t+n$,

$$X_s = X_t + (s-t)(X_{t+n} - X_t)/n \, .$$

This technique was applied particularly to labor, livestock, irrigation and inputs used by small-scale farmers.

3.4 Estimation procedure

Most agricultural time series are non-stationary. A stationary stochastic time series is one in which a joint distribution of any set of observations is invariant to a change of time origin (Box & Jenkins, 1976). In the presence of non-stationarity, Ordinary Least Squares (OLS) yields biased estimates. The first step in estimating the agricultural production function in equation (3) starts with an analysis of the time series properties of the variables in the data. The most prominent and most frequently used of all the methods proposed in the literature are Dickey and Fuller's Augmented Dickey Fuller (ADF) test (1979, 1981) and Phillips and Perron's PP test (1988). The PP test is used here because of its advantages over the ADF test.[6] Following the unit root test results, the model is specified with variables at their appropriate difference. The model is then estimated using the Iteratively Re-weighted Least Squares (or robust regression) option, which is robust to heteroskedasticity and outliers.

In the estimation of the three panel data models, an issue is the choice between fixed (FE) and random effect (RE) models. Hausman tests are carried out to compare both specifications in order to make the right choice. This test, developed by Hausman (1978), is based on the idea that under the null hypothesis of no correlation between individual effects (η_i) and the other regressors in the model, both ordinary least squares (OLS) and generalized least squares (GLS) are consistent, but OLS is inefficient, whereas under the alternative only OLS is consistent. The test statistics indicate whether the two sets of coefficients (OLS and GLS) are significantly different.

4. Results

This section presents the results from the estimation of the models described above. The summary statistics for the agricultural output and inputs and other determinants are shown in

[6] There are two main advantages. One is that PP tests are robust to general forms of heteroskedasticity in error terms. The other is that the test regression does not require user specification of lag length (Zivot & Wang, 2006).

Table 1a. Outputs and inputs for small- and large-scale farmers in the sugarcane sector, together with land redistribution, inequality and poverty measure are shown in Table 1b.

Table 1a: Summary statistics for agricultural sector

Variable	Obs	Mean	Std. dev.	Min	Max
Agric output per ha (lcu)	27	2.27E+00	2.34E-01	1.65E+00	2.68E+00
Agric machinery/1000ha	27	8.23E+00	3.53E+00	4.01E+00	1.33E+01
Labor /1000 ha (number)	27	6.87E+00	1.34E+00	4.66E+00	9.20E+00
Fertilizer/1000ha (tonnes)	27	4.23E+01	7.47E+00	3.27E+01	6.60E+01
Share of irrigated crop land	27	9.63E-03	2.04E-03	4.24E-03	1.16E-02
Share of pasture land	27	8.49E-04	7.97E-06	8.41E-04	8.61E-04

Table 1b: Summary statistics for sugarcane sector, inequality-poverty variables

Variable	Obs	Mean	Std. dev.	Min	Max
Large-scale					
Output (tonnes)	136	1.12E+06	3.25E+05	2.76E+05	2.00E+06
Output (tonnes/ha)	136	7.48E+01	1.58E+01	4.20E+01	1.09E+02
Fertilizer (R/ha)	136	1.08E+03	4.19E+02	4.89E+02	2.85E+03
Chemicals (R/ha)	136	5.14E+02	2.36E+02	1.82E+02	1.27E+03
Labor(R/ha)	136	1.91E+02	1.35E+02	2.53E+01	8.24E+02
Irrigation(R/ha)	136	6.79E+02	2.41E+02	3.27E+02	1.36E+03
Other inputs(R/ha)	136	4.10E+03	1.76E+03	1.70E+03	8.47E+03
Area under cane (ha)	136	2.04E+04	7.10E+03	6.23E+03	3.33E+04
Area harvested (ha)	136	1.53E+04	4.88E+03	3.98E+03	2.63E+04
Small-scale					
Output (tonnes)	136	1.95E+05	1.19E+05	3.53E+04	5.23E+05
Output (tonnes/ha)	136	5.25E+01	2.80E+01	1.00E+01	1.78E+02
Fertilizer (R/ha)	136	8.71E+02	5.99E+02	1.56E-09	2.71E+03
Chemicals (R/ha)	136	2.10E+02	1.73E+02	1.56E-09	8.39E+02
Labor(R/ha)	136	6.42E+02	8.28E+02	1.56E-09	7.60E+03
Irrigation(R/ha)	136	3.96E+02	8.19E+02	1.00E-05	3.21E+03
Other inputs(R/ha)	136	3.36E+03	2.47E+03	1.56E-09	1.01E+04
Area under cane (ha)	136	5.72E+03	3.81E+03	1.20E+03	1.80E+04
Area harvested (ha)	136	4.58E+03	3.32E+03	5.31E+02	1.62E+04
Others variables					
Redistributed land (% of crop land)	136	5.52E-01	7.39E-01	6.58E-15	2.57E+00
Gini coefficient	136	6.80E-01	7.92E-03	6.60E-01	6.86E-01

As earlier shown in Figure 2, the land productivity gap between large and small farms increased from 1998 to 2007. An examination of the area under cane and the area harvested reveals that substantial areas of land planted by farmers are harvested. Figure 4 shows the evolution of non-harvested area as a share of area under cane for small- and large-scale farmers. The figure suggests that while the share of non-harvested land for large farms has remained fairly high and stable between 1998 and 2007, that for small-scale farmers has been steadily increasing during that period. This implies a possible loss of interest in agriculture, more for small- than large-scale farmers. This lack of interest may be a result of the increasingly high cost of harvesting, to the disadvantage of small over large farms.

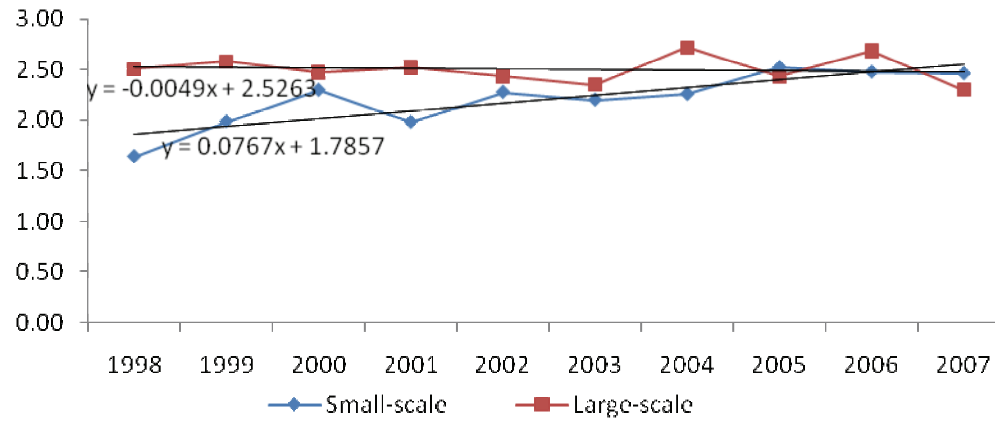

Figure 4: Trends in shares of non-harvested sugarcane plots

Table 2 below gives the PP unit root test result for the variables considered in the agricultural productivity model. Lag lengths are selected using the Akaike Information Criterion (AIC).

Table 2: Unit root test results

Log of	level			1st difference			Inference
	Lag AIC	PP-stat	p-val	Lag AIC	PP-stat	p-val	
Production	1	-3.408^{**}	0.010	-	-	-	I(0)
Land	2	-1.261	0.653	1	-4.694	0.488	I(2)[a]
$\ln landred$	1	-0.914	0.783	0	-5.11^{***}	0.000	I(1)
$\ln gini$	0	-3.668^{***}	0.005	-	-	-	I(0)
$\ln fer$	2	-3.407^{**}	0.011	-	-	-	I(0)
$\ln mac$	2	-0.172	0.942	2	-3.350^{*}	0.06	I(1)
$\ln lab$	2	-1.336	0.613	1	-3.378^{**}	0.012	I(2)
$\ln irrig$	2	-12.66^{***}	0.000	-	-	-	I(0)
$\ln pasture$	2	-1.221	0.665	1	-1.694	0.434	I(2)[b]
$\ln le$	2	-0.211	0.937	1	-2.610	0.109	I(2)[c]

[a] PP statistics for second difference are -22.516 with corresponding p-value of 0.000.
[b] PP statistics for second difference are -5.182 with corresponding p-value of 0.000.
[c] PP statistics for second difference are -7.936 with corresponding p-value of 0.000.

The results suggest that agricultural output, Gini coefficient, share of irrigated cropland and fertilizer use are not integrated, so these are considered in the model as levels. Land redistribution[7] and agricultural machinery variables are first-order integrated, and are therefore specified as first differences. The rest of the variables – crop land, agricultural labor, share of pasture land and life expectancy – are second-order integrated and are therefore specified in the model as second differences.

Table 3 presents robust estimations of the four models. The first contains only inequality variables – Gini coefficient and land redistribution, with a constant term. The second includes

[7]To save degrees of freedom because of few observations for land redistribution, it was specified as a level and the first lag was considered.

other inputs and labor. The third adds agricultural machinery, and the fourth adds the other variables plus a time trend.

Table 3: Robust estimation results for agricultural sector

Dependent variable: Log of agric. output (at constant ZAR2000)												
Log of	**Model 1**			**Model 2**			**Model 3**			**Model 4**		
	Coef	**SE**	**t-stat**	**Coef**	**SE**	**t-stat**	**Coef**	**SE**	**t-stat**	**Coef**	**SE**	**t-stat**
Constant	14.218***	0.085	168.21	14.207***	0.057	250.08	14.231***	0.052	272.61	30.588	20.30	1.51
Land	4.431**	0.1.829	2.42	3.303**	1.274	2.59	2.573**	1.039	2.476	2.160	1.557	1.39
Redistribution	0.111***	0.020	5.58	0.112***	0.013	8.39	0.112***	0.012	9.39	0.030*	0.017	1.79
Inequality	-0.162***	0.031	-5.20	-0.165***	0.021	-7.88	-0.165***	0.019	-8.79	-0.044*	0.025	-1.78
Labor				0.367***	0.108	3.40	0.311***	0.078	3.99	0.171**	0.074	2.32
Machinery							0.608***	0.087	7.01	0.388**	0.151	2.57
Fertilizer										0.401***	0.095	4.20
Irrigation										0.074**	0.034	2.19
Pasture										-2.346**	1.107	-2.12
t										-0.027***	0.004	7.07
OBS	**24**			**24**			**26**			**24**		
F-STAT	**36.43**			**66.52**			**68.93**			**140.29**		
P-VAL	**0.000**			**0.000**			**0.000**			**0.000**		

*, ** and *** denote 10%, 5% and 1% levels of significance respectively.

Overall, the model F-statistics and probability values indicate a good fit. The inequality variables have the expected signs and are all significant throughout the four models. In the first three models, the coefficients of land redistribution and inequality remain stable, while that of land falls to 3.3 and 2.6 with the introduction of labor and machinery. After addition of all the control variables, the magnitudes of the inequality coefficients drop while their significance improves. The control variables have their theoretically expected signs and are all significant. The time trend is also significant. According to model 4 with all control variables, a percentage increase in the inequality index and land redistribution brings about a 0.04% and 0.03% decrease and increase, respectively, in agricultural output.

This positive effect of land redistribution could have four possible explanations. The first is the inverse farm size/productivity relationship, which is contrary to general opinion in the South African community, especially as cases of good performance are among emerging black farmers who cannot be classified as small-scale. The second is that land constraints on large South African farms may not be binding, since they often ration production, especially at times of unfavorable crop prices (Collier, 2002; FAO, 2002) so that the negative impact on large farms does not dominate. The third and most plausible is that as land is being redistributed, the remaining lands under large farms are more efficiently exploited with greater mechanization. The fourth explanation is that sub-sector organization may affect the impact of redistribution on production, so that crop specific case studies may reveal varying impacts. As for the control variables, crop land has the strongest impact on agricultural production with an elasticity of 2.16. This high and significant coefficient suggests that land is not abundant. Fertilizer, agricultural machinery, labor and the share of irrigated land have elasticities of 0.401, 0.388, 0.171 and 0.074, respectively. The share of land devoted to pastures significantly reduces production, with up to 2.4% decrease following a 1% increase in the share of land devoted to pasture.

The Hausman test results with panel data for large- and small-scale sugarcane production and their productivity difference favored the choice of a fixed effect (FE) model. The fixed effect estimation results are presented in Table 4a for large- and small-scale sugar cane production. In model 1, the variable 'land' captures areas under cane, and in model 2 it captures effective land (i.e. area harvested).

Table 4a: Fixed effect estimation results for large- and small-scale production

Log of	**Dependent variable: Sugarcane output (tonnes)**							
	Large-scale				**Small-scale**			
	Model 1		**Model 2**		**Model 1**		**Model 2**	
	Coef	**t-stat**	**Coef**	**t-stat**	**Coef**	**t-stat**	**Coef**	**t-stat**
Constant	45.163**	2.63	41.440**	2.55	170.548***	5.52	166.424***	5.53
Land	0.292**	2.24	0.519***	4.38	0.195**	2.88	0.228***	3.62
Fertilizer	0.002	0.03	0.043	0.72	0.007*	1.66	0.049**	2.07
Irrigation	0.056*	1.78	0.064*	1.94	0.068*	1.82	0.098**	2.12
Chemicals	0.068	1.36	0.052	1.10	0.034**	2.35	0.054**	2.57
Labor	0.025	1.20	0.022	1.14	0.032	0.75	0.035	0.82
Other inputs	0.255	3.24	0.245	3.29	0.104	0.61	0.073	0.43
Redistribution	-0.021	-0.89	-0.016	-0.72	0.071	1.47	0.072*	1.77
Cross yield	0.149***	3.51	0.139***	3.53	0.801***	4.34	0.816***	4.52
t	-0.021**	-2.39	-0.020**	-2.37	-0.087***	-5.39	-0.085***	-5.41
OBS	**136**		**136**		**136**		**136**	
R-sq	**0.89**		**0.85**		**0.65**		**0.67**	
F(8, 114)	**11.66 (0.000)**		**14.58 (0.000)**		**23.86(0.000)**		**25.29(0.000)**	
Hausman	**61.74 (0.000)- FE**		**66.17 (0.000) - FE**		**56.02(0.000)-FE**		**58.09 (0.000) - FE**	

Judging by the Fisher probability, the overall model statistics are satisfactory for all four models. The coefficient of land is positive in both models for all farm types. A one percent increase in area under sugarcane leads to 0.29% and 0.20% increases in output for large and small farms, respectively. When corrected for un-harvested area, the coefficient of the land variable improves. However, this improvement is higher for large farms than for small ones. These findings suggest that large-scale producers make better use of land than their small-scale counterparts. Judging from the improvement in the level of significance of land after correcting for non-harvested area, it can be suggested that the land constraint is not as acute in the sugarcane sub-sector (i.e. land is not a limiting factor for both farm types) as in the entire agricultural sector in South Africa.

The coefficient of land redistribution is negative for large farms and positive for small farms, but is significant only for effective land harvested by small-scale producers. Since land may not be a binding constraint in the sugarcane sub-sector, redistribution per se neither reduces the production of large farms nor improves that of small farms, but only improves production for those who put the redistributed land into agriculture effectively, and follow it through to harvest the crops. Most of the land redistributed in the sugarcane sector is 'mill area', i.e. owned by organizations, not individual large farmers. This minimizes conflicts and reduction in production. Besides, there is a remarkable difference between area under cane and area effectively harvested for both large-scale and small-scale growers. So the associated question for land redistribution policy is: What other factors are necessary for redistributed land to be put into effective agriculture?

Cross-yields are significant in both models for large and small-scale producers. A one percent rise in large-scale output results in more than a 0.8% increase in small-scale production. However, the same increase in small-scale output brings about less than a 0.15% improvement in large farm production. This suggests that there is a considerable degree of symbiosis between large and small farms, from which small farms benefit far more.

Generally, the coefficients of all other inputs suggest that there is more room for small-scale farmers' production enhancement than large-scale. This suggests that land redistribution should also be accompanied by identification of various constraints to accessing other inputs, especially fertilizer and irrigation facilities. The result of the determinants of productivity difference in Table 4a corroborates this view. In model 1, land captures area under cane, in model 2, it captures effective land, i.e. land harvested, while model 3 makes use of the difference between land and effective land, i.e. non-harvested area.

Table 4b: Fixed effect estimation results for large/small land productivity difference

Dependent variable: log of ratio of large- and small-scale outputs per ha									
	Model 1			**Model 2**			**Model 3**		
	Coef	**SE**	**t-stat**	**Coef**	**SE**	**t-stat**	**Coef**	**SE**	**t-stat**
Large-scale inputs per ha									
Land	0.481**	0.247	1.95	0.639**	0.289	2.21	-0.389***	0.079	-4.91
Fertilizer	-0.017	0.894	-0.02	1.107*	0.634	1.75	1.483**	0.546	2.72
Irrigation	0.392**	0.141	2.77	0.580**	0.172	3.37	0.585***	0.163	3.58
Chemical	-0.060	0.871	-0.07	-0.409	1.100	-0.37	-1.591*	0.951	-1.67
Labor	-0.071*	0.044	-1.61	-0.050	0.054	-0.93	-0.083*	0.058	-1.42
Small-scale inputs per ha									
Land	0.732***	0.082	8.92	0.464***	0.101	4.59	0.090***	0.019	4.76
Fertilizer	-2.053**	0.893	-2.30	-1.476***	0.497	-2.97	-1.415**	0.678	-2.09
Irrigation	-0.162*	0.106	-1.53	-0.381**	0.130	-2.93	-0.764***	0.104	-7.35
Chemical	-0.36	0.572	-0.63	-0.244	0.151	-1.60	-1.315**	0.557	2.36
Labor	0.026	0.021	1.23	0.003	0.026	0.12	-0.021	0.023	-0.94
Other determinants									
Redistribution	-0.11*	0.057	-1.93	-0.13**	0.062	-2.10	-0.122**	0.053	-2.30
Literacy	-3.170***	0.548	-5.78	-2.761***	0.663	-4.17	-2.582***	0.625	-4.13
Constant	-3.272	2.439	-1.34	-8.253**	2.893	-2.85	-8.716***	1.462	-5.96
OBS	**136**			**136**			**136**		
R^2	**0.78**			**0.66**			**0.74**		
F(11, 111)	**31.78**			**17.78**			**23.84**		
$\Pr ob > F$	**0.000**			**0.000**			**0.000**		

$Hausman\chi^2$	**66.99**	**68.71**	**68.83**
$\Pr ob > \chi^2$	**0.000**	**0.000**	**0.000**

*, ** and *** denote 10%, 5% and 1% levels of significance respectively

An increase in large farm size appears to exacerbate the gap. However, effective land has a higher positive effect on the gap, while non-harvested land by large-scale farmers helps to reduce the gap. An increase in small-scale land size tends to increase the productivity gap but, unlike large farm size, the coefficient is higher for land under cane than for effective land. This implies that the ability of small farmers to make effective use of the land they have matters more for enhanced production and reduction of the large-scale/small-scale productivity gap than simply accumulating more land.

Large-scale farmers' use of fertilizer has significant positive impacts on the land productivity gap, while chemical and labor use attenuate the difference, but only chemical is significant. All small-scale inputs have negative impacts on the gap, but only fertilizer and irrigation are significant. One percent increases in large-scale fertilizer and irrigation increase the gap by 1.48 and 0.59%, respectively, while they decreases it by 1.42 and 0.76%, respectively, for small-scale use of the same factors. After controlling for the non-harvested area by small-scale farmers, their chemical use becomes significant in reducing the gap, with an elasticity of -1.32. The significant negative impact of large-scale chemical use on the gap suggests a type of positive externality. This externality can happen in two ways. First, most large-scale farmers are contractors to small farmers. There is a possibility that chemical leftovers are carried over to small farms within contractual agreements. Secondly, the application of chemicals for pest control on large farms can easily have positive external effects on small neighboring farms.

The coefficient of redistributed land is positive and significant, but the magnitude and significance are highest when non-harvested land is controlled for. This also contributes to the suggestion that land redistribution can enhance production only in cases where the redistributed land is put to effective agricultural use. Such effectiveness depends not only on other inputs such as fertilizer, irrigation and chemical use, but also on human capital (particularly literacy level). A one percent rise in literacy rate is significantly associated with a more than 2.5% reduction in the land productivity gap between small and large farms. Other potential factors which are not analyzed here are disparities in the effect of market forces. The negative trend in all models possibly reflects most farmers' lack of interest in agriculture, particularly in the case of small farmers, as evidenced by the increasing non-harvested area shown in Figure 4.

5. Conclusion and policy recommendations

The aim of this study was to investigate the determinants of inequality in agricultural productivity in South Africa, distinguishing between small- and large-scale farms in the sugarcane sector. The impact of inequality was captured by the Gini coefficient, and land redistribution is an inequality attenuating measure. Using data from a variety of sources, the study investigated the time series properties of the data for the agricultural sector as a whole, and carried out Hausman tests for sugarcane panel data models. These led to robust estimation of time series and fixed effect specification of the sugarcane panel.

The results suggest that inequality is associated with slower productivity, and land redistribution with weakly enhanced production. Four possible explanations are suggested for the positive effect of land redistribution: the inverse farm size/productivity relationship, which contradicts general opinion in South Africa; the fact that land constraints on South African large farms may not be binding, since production may be rationed, especially when crop prices are unfavorable, so that the negative impact on large farms does not dominate; the fact that as land is redistributed, the remaining lands under large farms are more efficiently exploited with greater mechanization; and the way sub-sector organization may affect the impact of redistribution on production, so that crop specific case studies may reveal varying impacts.

Farm type-specific effects reveal that the coefficient is negative for large farms and positive for small ones, but significant only for land actually harvested by small-scale producers. This implies it is not redistribution per se that increases production; rather, the increase comes from the efforts of those who farm the land effectively and harvest the crops. This implies that redistribution efforts should include easing other constraints that hamper small farmers. Providing inputs such as fertilizer, chemicals and irrigation facilities is more likely to help small farmers than just giving them land. The determinants of differences in productivities of both farm types corroborate this view. Much of the difference comes from disparities in input use, particularly fertilizer and irrigation. It may be that there is some mutually beneficial collaboration between large-scale and small-scale farmers, but benefiting the latter more than the former. This implies that any policy that leads to conflict between the two types will jeopardize agricultural production, to the detriment of the small farmers. To reduce the productivity gap between the two types, access to land for small-scale farmers is necessary but not sufficient. Other factors such as inputs and human capital (particularly improvement of literacy) must be prioritized for the small producers.

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