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Efficiency of resettled farmers in Mashonaland Central Province of Zimbabwe in crop production: A DEA approach

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The main aim of the paper is to determine the technical, allocative and economic efficiency of the resettled farmers in Zimbabwe in the production of field crops. Data were collected from 245 land reform beneficiaries using a structured questionnaire during the 2010/2011 agricultural production season. To empirically calculate efficiency, Data Envelop Analysis (DEA) was adopted mainly because of its capability of handling multiple inputs and outputs. Results obtained from DEA showed that commercial land reform beneficiaries (A2 farmers) had a higher average technical efficiency score of 0.839 than subsistence (small land size) land reform beneficiaries (A1 and the old resettled farmers) who had average technical efficiency scores of 61.7 and 65.9%, respectively. Small land holders were also on average less cost-efficient than large land holders (A2). The decomposition of cost-efficiency into technical and allocative efficiency suggests that cost inefficiency for A2 farmers was mostly due to the use of 'wrong' inputs at the prevailing input prices, rather than waste of inputs. Small land holders' cost inefficiency was mostly due to both the use of 'wrong' inputs at the prevailing input prices and waste of inputs. Efficiency in field crop production in Zimbabwe could be improved through improving the ability of the resettled farmers to choose optimum input levels for given factor prices and saving inputs through correct usage.

Key words: Allocative efficiency, cost efficiency, data envelop analysis (DEA), land reform, technical efficiency.

INTRODUCTION

Zimbabwe inherited a thriving agro-based economy upon independence in 1980 characterized by duality and a racially skewed land ownership pattern. This unequal access to use land forced the government of Zimbabwe to adopt land reform and a resettlement program premised on land acquisition and redistribution. According to Kinsey (1999), the main long standing objectives of this program have been to address the imbalances in land access while alleviating population pressure in the communal areas, extend and improve the base for productive agriculture in the smallholder farming sector, and bring idle or under-utilized land into full production. From 1980 to 2000, the Zimbabwean government used the willing buyer willing seller system. Disappointed with the slow pace of land redistribution using the willing buyer willing seller system, the Zimbabwean government officially launched the fast track approach to resettlement also termed Jambanja or the Third Chimurenga in Zimbabwe on 15 July, 2000 to speed up the pace of land acquisition and resettlement.

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A distinctive trend in most agricultural production since the fast-track land reform programme has been a decline in output largely due to drought, distorted markets, weak agricultural support services and acute shortages of seeds, fertilizer and fuel which have led to the shrinking of the Agro-based Zimbabwean economy (World Bank, 2007). The shrinking of the economy severely reduced employment opportunities in general and structural unemployment increased to more than 50% in the early 2000s and an estimated 80 to 94% in 2007/2008 (Scoones, 2008). Domestic productions of agricultural commodities have been inadequate and unable to bridge the increasing demand-supply gap. Poverty is widespread and increasing from 25.5% in 1990 to an estimated 63% in 2006 (World Bank, 2007). From being a regional breadbasket, Zimbabwe has become a food importer. As such, economic turnaround is predicated on good agriculture recovery. Given the importance of agriculture, specific interventions in the sector are necessary so that the land is effectively used to underpin the turnaround program. The battle cry at this stage is, therefore, for all those who hold land to view this resource as an effective means of economic unrestraint, rather than a status symbol.

The limited capacity of the Zimbabwe's agricultural sector to meet the domestic demand has raised a number of pertinent questions both in policy circle and among researchers. For example, what are the factors explaining why domestic agricultural production lags behind the demand for agricultural commodities in Zimbabwe? Central to this explanation is the issue of efficiency of the resettled farmers who now occupy the vast majority of the land in the country. Methods of attaining national food self-sufficiency in Zimbabwe include increases in area cultivated, productivity of land or both. The first possibility is difficult to achieve in Zimbabwe in the long run due to a high population growth. Certainly with a quarter million people being added to the world population each day, the demand for grains and all other food will reach unprecedented levels. In addition to population growth, fertile cropland is being lost at an alarming rate. For instance, by 1995, nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned within a period of 40 years because erosion has made it unproductive (Pimentel et al., 1995). Because of the high number of unaccounted emigrants, the recent increase of emigration, labour, one of the most important factors of production in agriculture has become so scarce. In Zimbabwe, HIV/AIDS pandemic has its own effect on food production by infecting more than 20% of adults (Gono, 2005). Even in years of normal rainfall, crop production has suffered due to the number of HIV positive adults who are too ill to carry out the hard labour required for subsistence farming (ZimVAC, 2009).

The only way that food production can be increased in Zimbabwe is by increasing farm efficiency (Juana, 2006). Thus, strategies that focus on methods of increasing the productivity of land and other resources while conserving those which are over-utilized are preferred. This suggests that policy interventions of which land reform is one, should always be linked to increased farm efficiency. This study therefore determined the technical, allocative and the economic efficiency of the resettled farmers in Zimbabwe in the production of field crops.

MATERIALS AND METHODS

Study area

The study was conducted in the Mashonaland Central Province of Zimbabwe. It has an area of 28,347 km² and a population of approximately 998, 265 (Census, 2002), representing about 8.5% of the total Zimbabwe population. The Province mostly lies in the agro-ecological region II, which is good for cropping and intensive livestock production. Rainfall is confined to summer and is moderately high (750 to 1000 mm) in this region (Vincent and Thomas, 1960; Campbell 2003). The Province also has some small portions falling in regions III and IV which are good for semi-intensive farming and semi-extensive farming respectively (Utete, 2003). The Province had a total of 712 officially settled farms out of 778 gazetted farms. As at the end of July 2002, 14, 756 households had been settled under the A1 Model, while 1, 684 had been allocated land under the A2 Model (Utete, 2003).

Sampling procedure

From the 7 districts that exist in Mashonaland Central Province, Rushinga district was purposively excluded from sample population, as there were no fast track land reform beneficiaries within this district due to extreme climatic conditions and tsetse fly which resulted in former colonial masters not settling in this area. Shamva District was randomly selected from the remaining 6 districts. Communities that benefited from land reform were randomly selected. Stratification was done according to the model of land reform. The following strata were formulated:

1) Resettlement scheme: beneficiaries of land reform before 2000
2) Fast track A1 model
3) Fast track A2 model

The reason for this type of stratification is that the land reform emerged from different models and in most cases these models differ on how they were implemented and supported thus might lead to different efficiencies of the resettled farmers. During the 2010/2011 agricultural season the A1 and the old resettled farmers were given agricultural imputs which include seeds and fertilisers by the government. However these input were not delivered on time. The A2 farmers were given diseal and farm implements to till their land however most of diseal was sold on the pararell market by the beneficaries to meet family requirements such as purchasing food and paying school fees. From the A1, A2 and the old resettlement scheme, 79, 67 and 99 respondents were randomly selected respectively from a list of land reform beneficaries obtained from the Ministry of Lands and Rural Resettlements (Shamva Ditrict office). Respondents were interviewed at their homesteads by trained enumerators (extension officers) under the supervision of the reseacher. Respondents were household heads. In the absence of the household head, any adult member of the household was interviewed.

Data collection and analysis

To empirically investigate and calculate efficiency, 2 main streams of approaches compete in the literature: non-parametric and parametric approaches (Bojnec and Latruffe, 2008). Both have advantages and drawbacks; however in this study, the non-parametric method, DEA was adopted mainly because of its capability of handling multiple inputs and outputs (Coelli et al., 2005). The parametric approach has an important drawback in that the maintained hypothesis of the functional form cannot be observed (Banker and Maindiratta, 1988) and thus it imposes restrictions on the frontier production technology that may not hold; this affects the distribution and estimation of the efficiency measures (Chavas and Aliber, 1993). DEA estimates efficiency relative to the Pareto-efficient frontier which estimates best performance (Murthi et al., 1997). Furthermore, DEA can obtain target values based on the best practice units (peers) for each inefficient farm that can be used to provide guidelines for improved performance.

DEA was proposed by Charnes et al. (1978) and later developed further by Fa¨re et al. (1994) and it uses linear programming to construct a piece-wise efficient frontier with the best performing farm businesses of the sample used. Input oriented DEA model under the assumption of constant return to scale was used to estimate the technical efficiency in this study. It addresses the issue of, by how much can the amounts of inputs be proportionally reduced without changing the quantities of outputs produced? Coelli et al. (2002) argued that one should select orientation from input oriented DEA model or output oriented DEA model according to which quantities the operator has more control over. As the resettled farmers in Zimbabwe have more control over inputs than outputs, therefore, input oriented DEA model was used in the study. In the study, DEA software version 2.1 developed by Coelli (1996) was used. From DEAP Version 2.1, output orientation is not applicable in cost efficiency DEA.

The input-orientated DEA linear programming models to calculate technical efficiency (Equations 1 to 4) and economic efficiency (Equations 5 to 8) are as follows (Coelli et al., 2005):

$$\text{Min}_{\theta,\lambda}\ \theta \quad (1)$$

$$\text{s.t} - x_i + X\lambda \geq 0 \quad (2)$$

$$y_i - Y\lambda \geq 0 \quad (3)$$

$$\lambda \geq 0 \quad (4)$$

where, Y and X are, respectively, the output and input matrices of the sample; y_i and x_i are, respectively, the output and input matrices of the *i*-th farm; λ is a matrix of parameters.

$0 \leq \theta \leq 1$, 1- θ is the potential proportional decrease in all inputs for the *i*-th firm, and 1/0 defines the technical efficiency score that varies between 0 and 1:

$$\text{Min}_{\lambda, y_i^*} p_i y_i^* \quad (5)$$

$$\text{s.t} - x_i^* + X\lambda \geq 0 \quad (6)$$

$$y_i - Y\lambda \geq 0 \quad (7)$$

$$\lambda \geq 0 \quad (8)$$

where, x_i^* is the cost-minimising vector of inputs. Economic efficiency is given by the ratio $p_i x_i / p_i x_i^*$.

The above models are under the assumption of CRS. Allocative efficiency is given by the ratio of economic efficiency to technical efficiency.

In Zimbabwean agriculture, many types of field crops are produced and the assumption of homogeneous outputs does not hold if physical units of measurements are used. Therefore, physical outputs are multiplied by their respective market prices. The outputs include maize, groundnuts, round nuts, beans and cotton (most grown crops). That is market prices are used to convert outputs into similar units. The physical inputs required to produce maize for instance include arable land, seed, labour and fertilizer.

The variable in the objective function is market value of field crops measured in United States Dollar (US$). Variables that form the constraint set includes crop area (hectares), seed (kilograms), fertilizer (kilograms), pesticides (litres), ploughing costs (US$), labour for crop production (man days per production process). The following production processes were included: planting, weeding, fertilising, spraying and harvesting. In the past, studies have valued labour using man days (Bravo-Ureta and Rieger, 1991; Ngwenya et al., 1997; Mushunje et al., 2003). However, in this study man days per production activity were used as it was noted during interviews with key informants that cost of labour varied with farming activities and as noted by Deere (1982). Family labour and use of own machinery was valued using opportunity cost while the rest of the inputs and outputs was valued using the market value.

RESULTS

Results obtained from the application of the input-orientated DEA under the assumption of constant returns to scale are illustrated in Figure 1. The resultant efficiency scores from DEA were further divided into 3 categories: namely technical, allocative and economic efficiency. Model differences in technical efficiency proved to be substantial. During the studied cropping season of 2010, A2 farmers (large land owners) topped the list with an average technical efficiency score of 0.839, while the lowest ranking model (A1) had an average score of 0.618. Consequently, it can roughly be stated that the A1 land reform beneficiaries produces on average about 20% less outputs than the A2 land reform beneficiaries for the same inputs, or alternatively, if the A1 resettled farmers had been as efficient as the A2 beneficiaries of land reform, they would have produced their outputs with an average of 20% less resources.

The mean technical efficiency scores for small land holders (A1 and the old resettled farmers) were almost similar, ranging between 60 and 65%. On average, the ability to choose optimum input levels for given factor prices (AE) was almost similar and lower than for technical efficiency for all the studied models of land reform. Small land holders also observed lower average economic efficient scores of 0.288 and 0.289 for A1 and the old resettlement land reform beneficiaries respectively. The average cost-efficient score for A2 farms for the 67 observations over the 2010 crop production season was 0.45 (Table 1), that is, the sampled A2 farmers could on average have produced the

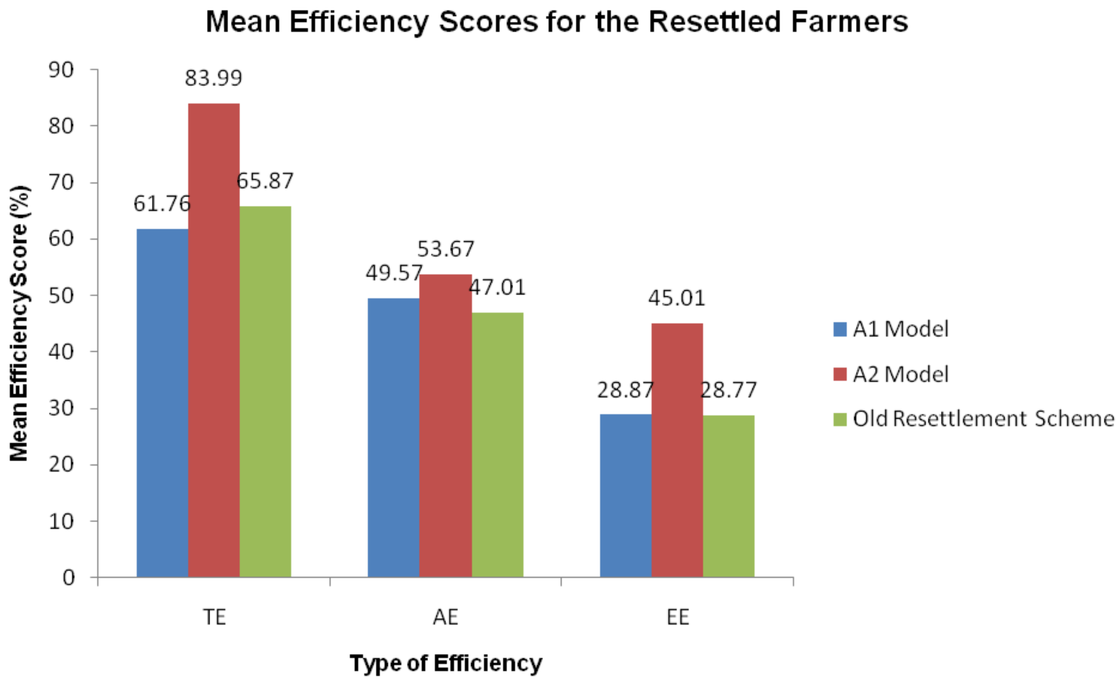

Figure 1. Mean technical, allocative and economic efficiency scores.

Table 1. Least square means of efficiency scores of the resettled farmers.

Efficiency	Model of land reform		
	A1 Model	**A2 Model**	**Old resettlement scheme**
Technical	61.76±19.57[a]	83.99±18.52[b]	65.87±19.58[a]
Allocative	49.57±15.03[ab]	53.67±16.14[a]	47.01±16.08[b]
Economic	28.87±10.45[a]	45.01±17.49[b]	28.77±8.51[a]

Means in the same row with different superscripts are significantly different at P<0.05.

same output quantities with only 45% of the observed costs were as the A1 and the old resettled farmers could on average have produced the same output quantities with only 29% of the observed costs. Simple comparison suggests that small land holders are on average less economic-efficient than large land owners (A2), with a score of 0.29 for the former compared with 0.45 for the latter. For A2 farmers, the decomposition of economic-efficiency into technical and allocative efficiency (Figure 1) suggests that economic inefficiency was mostly due to the use of 'wrong' inputs at the prevailing input prices, rather than waste of inputs. Small land holders' cost inefficiency was mostly due to both the use of 'wrong' inputs at the prevailing input prices and waste of inputs. Mean efficiency scores varied significantly across land reform models as shown in Table 1. The frequency distribution of technical, allocative and economic efficiency scores of sampled households are tabulated in Table 2. The results clearly showed that given level of output with a minimum quantity of inputs under certain technology, the majority of the farmers who benefited from the A2 Fast track land reform model in Zimbabwe are clustered around 0.9 to 1. The minority of A1 farmers have their ability to produce a given level of output with a minimum quantity of inputs under certain technology lower than 50% that is 42%. For A2 farmers the percentage that scored above 50% is 6% whilst that scored above 50% is 94%. For the old resettled farmers the percentage of land reform beneficiaries with a technical efficiency score below 50% is 17% whilst the majority (83%) of these old resettled farmers had efficiency scores above 50%.

The results on the frequency distribution for allocative efficiency show that the majority of the A1 and the A2 farmers have efficient score above 50% whereas for the old resettled farmers the minority scored above 50%. For the A1 and A2 farmers, 44 and 45% of these farmers that benefited under these 2 models of land reform had

Table 2. Frequency distribution of efficiency scores.

Scores	Efficiency level frequency											
	Technical efficiency				Allocative efficiency				Economic efficiency			
	A1	A2	OR	Total	A1	A2	OR	Total	A1	A2	OR	Total
0.01 - 0.10	0 (0)	0(0)	0(0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
0.11 - 0.20	0 (0)	0(0)	0(0)	0 (0)	3 (4)	0 (0)	6 (6)	9 (4)	7 (9)	3 (4)	13 (13)	23 (9)
0.21 - 0.30	0 (0)	0(0)	1(1)	1 (0)	10 (13)	4 (6)	20 (21)	40 (16)	47 (60)	11 (17)	48 (48)	106 (44)
0.31 - 0.40	3 (4)	1(1)	2(2)	6 (2)	9 (11)	14 (21)	5 (5)	28 (11)	20 (25)	19 (29)	34 (34)	73 (30)
0.41 - 0.50	30 (38)	3(5)	14(14)	47 (20)	13 (16)	12 (18)	19 (19)	44 (18)	3 (4)	9 (13)	1 (1)	13 (5)
Sub Total	33 (42)	4 (6)	17 (17)	54 (22)	35(44)	30(45)	50(51)	121(49)	77 (98)	42(63)	96 (97)	215 (88)
0.51 - 0.60	10 (13)	4(6)	41(42)	55 (22)	19 (24)	10 (15)	26 (26)	55 (21)	1 (1)	9 (13)	2 (2)	12 (5)
0.61 - 0.70	12(15)	11(16)	11(11)	34 (14)	23 (30)	16 (24)	20 (20)	59 (24)	0 (0)	10 (15)	0 (0)	10 (4)
0.71 - 0.80	8 (10)	8 (12)	5(5)	21 (9)	1 (1)	9 (13)	3 (3)	13 (5)	0 (0)	4 (6)	1 (1)	5 (2
0.81 - 0.90	4 (5)	6(9)	3(3)	13 (5)	0 (0)	2 (3)	0 (0)	2 (1)	0 (0)	2 (3)	0 (0)	2 (1)
0.91 - 1.00	12 (15)	34(51)	22(22)	68 (28)	1 (1)	0 (0)	0 (0)	1 (0)	1 (1)	0 (0)	0 (0)	1 (0)
Sub Total	46 (58)	63 (94)	82 (83)	191(78)	44 (56)	37 (55)	49 (49)	124 (51)	2 (2)	25 (37)	3(3)	30 (12)
Total	79 (100)	67 (100)	99 (100)	245 (100)	79 (100)	67 (100)	99 (100)	245 (100)	79 (100)	67 (100)	99 (100)	245 (100)
Minimum	0.33	0.39	0.29	0.29	0.18	0.23	0.19	0.18	0.12	0.16	0.11	0.11
Maximum	1.00	1.00	1.00	1.00	1.00	0.90	0.75	1.00	1.00	0.90	0.75	1.00

X(Y) where X is the number of households the class and Y is the frequency of households in the class expressed as a %age.

allocative efficient scores below 50% respectively. On aggregate the majority of the sampled farmers have an allocative efficiency below 50%. As for economic efficiency, most of the sampled farmers in all the studied models of land reform have efficiency scores below 50%. The A1 beneficiaries lead in this regard with 98% of the sampled farmers who benefited under this model having less than 50% efficiency score closely followed by the old resettled farmers with 97%. The A2 land reform beneficiaries had the least percentage of 63% having economic efficient score of less than 50%.

The low economic efficiency scores imply that there is a wide room for improving efficiency among all the land reform beneficiaries. Improving efficiency would be important because most of the productive land in Zimbabwe is now under the hands of the newly resettled farmers and there is heavy grain shortage and consequently hunger in the country. The only way hunger could be reduced is through improving the efficiency of the resettled farmers.

DISCUSSION

Using the data envelop analysis, the average technical, allocative and economic score for the sampled households are all less than 60%, which is relatively low indicating a heterogeneous sample. This suggest that although the sample contains very different production systems in terms of farm size, farms have different management practises and make use of the existing technology differently, with A2 farmers utilising available technology better than the small land holders (A1 and the old resettled land reform beneficiaries). The finding that large land owners are more technical efficient concurs with the findings of Philip (2007) in his study on efficiency of farmers in the production of crops used in bio fuel production in Tanzania. The study conducted in Tanzania observed that farms measuring more than 9 ha have higher

DEA technical efficiency scores than those who have farms measuring between 3 and 6 ha. The higher efficiency scores for farms with areas of more than 9 hectares could be attributed to improvements in supervision of hired labourers. Large farms which hire many labourers are likely to employ field officers or hired labourers' supervisors. The employment of hired labour supervisors is likely to increase the productivity of hired labour and hence improving the efficiency of the farm as a whole. Furthermore, since the number of supervisors does not change with slight changes in the number of hired labourers, farmers who employ many hired labourers are likely to benefit from scale economies in hired labour supervision.

Heltberg (1998), Ngwenya et al. (1997) and Himayatullah (1995) also reported a similar farm size-efficiency relationship. In addition, the high technical efficiency scores for A2 farmers can be attributed to better technology used by the A2 farmers. The Government distributed farm machinery to boost agricultural production to communal, A1 and A2 farmers. Tractors, combine harvesters, disc harrows, ploughs, generators, motorbikes, grinding mills, planters and fertilizer spreaders were among the implements that were made available to farmers. However the A2 benefited most with them getting tractors, planters and other sophisticated machinery which are more technically efficient than the ox-drawn equipment that the A1 and the old resettled farmers got. The Farm Mechanisation Programme was meant to replace obsolete equipment on farms while providing machinery to farmers that were inadequately capacitated following the land reform programme.

Education has a positive effect on technical efficient as noted by Battese et al. (1996). A2 farmers from the previous chapter were more educated than the small land holder counterparts. Large farm land holders possess higher education and have greater access to better irrigation arrangements, extension services, and apply higher doses of chemical fertiliser with more balanced nutrients. Moreover, they are usually financially better off and thus are in a position to use and adopt modern technologies more efficiently and effectively (Ghura and Just, 1992). This may be the reason why A2 farmers are more technically efficient than small land reform beneficiaries.

Educated farmers have better access to information as they can read magazines such as farmers weekly that may boost their knowledge base on farming and they comprehend agricultural experts' advice better than the uneducated farmers (Musemwa et al., 2010). In addition educated farmers are more likely to practice crop rotation unlike the uneducated farmers which are in this scenario small land holders. The low technical efficient score of the small land holders can therefore be attributed to the degradation and depletion of land resources caused by practicing the same crops years after years, and the prevalence of higher cropping intensity as evidenced by higher yield per hectare in the previous chapter. This scenario is expected to worsen further due to the fact that the rate of extraction of nutrient contents from the soil is much higher than it is being replenished.

From observing the data from the study, A2 farmers tend to specialise in the production of few field crops than the small land holders. According to Zhu and Lansink (2010), farm size reflects the impact of economies of scale which may partly materialise through a higher technical efficiency. Degree of specialisation captures any advantages related to specialisation such as the ability to gain more in-depth knowledge about a single activity or the ability to capture economies of size by increasing the relative size of a single activity. This therefore can be the reason why A2 farms that have some degree of specialisation are more technically efficient than the A1 and the old resettlement farms which are characterised by diversification of agricultural activities.

The slight difference on average technical scores between the A1 and the old resettled farms can be attributed to the homogeneity of land size, level of education, access to agricultural inputs and other social-economic characteristics amongst these 2 categories of farmers. However the old resettled farmers are more experienced than the A1 land reform beneficiaries in terms of farming. This may be the reason why the old resettled farmers are slightly more technical efficient than their small land holder counterpart. In addition, the old resettled farmers might also have acquired more assets used in agricultural production than the relatively new A1 farmers. During the period of study, allocative efficient was very low to all the farmers across all the models of land reform. This may indicate that the input market in Zimbabwe agriculture is still distorted by government policies, despite the efforts that the government has made to liberalize the market after the formation of the Government of national Unity in September 2009.

With some farmers being catered for by the government and the donor community, most of the inputs in the shops were specifically meant for the large-scale commercial farmers and other smallholder farmers who do not qualify for subsidized inputs. Due to poor planning on the part of the government, the donor community and agricultural companies in relation to importing inputs on time, farmers who qualify for subdised inputs ended up purchasing inputs such as seeds and fertilizers from the black market as the inputs in the shops were being bought in bulk by scrupulous people who were active in the black market as sellers (Gono, 2005). This resulted in price of agricultural inputs being very high due to supply and demand forces. This therefore created distortion in the market resulting in low allocative efficient scores among the resettled farmers.

On the output side, the prices which were offered by the grain marketing board and cottco (major buyers of grain and cotton respectively) were low very low. The resettled farmers in Zimbabwe had limited options when selling their produce due to high transactional costs which are barriers to the efficient participation of farmers in different markets (Musemwa et al., 2008). Producers will not use a particular channel when value of using that channel is outweighed by the costs of using it. Remote location of most resettled farmers coupled with poor road networks resulted in high transactional costs (especially transport costs). On the input side, this will increase the price that inputs suppliers will charge the farmers due to the high transactional costs they incur in bringing the inputs closer to the farmers. This increase in input prices and reduction in output prices worsens the situation which resulted in farmers scoring very low allocative efficient scores. The aggregate of the reasons that causes low technical efficiency and allocative efficient scores justifies the low economic efficient score among the resettled farmers.

Conclusion

The limited capacity of the Zimbabwe's agricultural sector to meet the domestic demand can be explained by the inefficiency of these resettled farmers. Improving efficiency of the resettled farmers would be important because most of the productive land in Zimbabwe is now under the hands of the newly resettled farmers. The low economic efficiency scores imply that there is wide room for improving efficiency among all the land reform beneficiaries. For large land reform beneficiaries economic inefficiency was mostly due to the poor use of inputs at the prevailing input prices, rather than waste of inputs. Small land holders' economic inefficiency was mostly due to both the poor use of inputs at the prevailing input prices and waste of inputs. Efficiency could be improved through improving the ability of the resettled farmers to choose optimum input levels for given factor prices and saving inputs through correct usage. If the right inputs are made available at the right time, allocative efficiency could also be improved amongst the land reform beneficiaries. The study is based on data from a single production period. It may be important to investigate the time pattern of inefficiencies and also see whether there is a tendency towards convergence in the efficiency levels over time.

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