Efficiency Effects Zimbabwe's Agricultural Mechanization and Fast Track Land Reform Programme: A Stochastic Frontier Approach

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Abstract

A development goal pursued by the Zimbabwean government even before the much-maligned fast track land reform programme (FTLRP) was expansion of agricultural production through agricultural mechanization. This goal has been pursued through the acquisition and use of tractors by arable crop farmers in communal and resettlement state land delineated during the period following the launch of the FTLRP. This research project investigated the combined impacts of mechanization and an unplanned land reform on agricultural productivity in the Bindura district of Zimbabwe. The existing land policy and the issue of technical efficiency in agricultural productivity are assumed to be the drivers of the programme. It is likely that these issues will be important considerations in determining the sustainability of the mechanization policy. A multistage sampling technique was used to randomly select 90 farmers in the study area and structured questionnaires were used to collect demographic, investment and production data which were subsequently fitted by means of the Stochastic Frontier Model. Results revealed that mechanization was an important factor in the performance of the farmers who participated in the programme. The results also suggest that availability of land and access to production resources are crucial to farm productivity. Despite these, overall production and productivity remain low and the hyperinflationary situation triggered by supply constraints are only beginning to slightly ease. As the national unity government grapples with the huge task to restore growth in the Zimbabwean economy, it is important that these issues are borne in mind.

KEY WORDS

Technical Constraints, Market Access, Agricultural Development, Induced Innovation Model, The Stochastic Frontier model, The Productive Efficiency and Mandate of Extension

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Measuring the Technical Efficiency of Zimbabwe's Smallholder Agriculture Under Limited Mechanization and the Fast Track Land Reform Programme

Abstract

A development goal pursued by the Zimbabwean government even before the much-maligned fast track land reform programme (FTLRP) was expansion of agricultural production through agricultural mechanization. This goal has been pursued through the acquisition and use of tractors by arable crop farmers in communal and resettlement state land delineated during the period following the launch of the FTLRP. This research project investigated the combined impacts of mechanization and an unplanned land reform on agricultural productivity in the Bindura district of Zimbabwe. The existing land policy and the issue of technical efficiency in agricultural productivity are assumed to be the drivers of the programme. It is likely that these issues will be important considerations in determining the sustainability of the mechanization policy. A multistage sampling technique was used to randomly select 90 farmers in the study area and structured questionnaires were used to collect demographic, investment and production data which were subsequently fitted by means of the Stochastic Frontier Model. Results revealed that mechanization was an important factor in the performance of the farmers who participated in the programme. The results also suggest that availability of land and access to production resources are crucial to farm productivity. Despite these, overall production and productivity remain low and the hyperinflationary situation triggered by supply constraints are only beginning to slightly ease. As the national unity government grapples with the huge task to restore growth in the Zimbabwean economy, it is important that these issues are borne in mind.

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1. Introduction

The intention of Zimbabwe in initiating the farm mechanization programme in 2007 was to support the land reform programme and improve agricultural productivity among the newly resettled farmers (FAO/WFP, 2007; Mugabe, 2007; The Final Call, 2008). Not long after the launch of the fast track land reform programme (FTLRP), it became clear that the expectations had been exuberant as production declined dramatically and only about 30-55% of the arable land was being cultivated (Chatizwa & Khumalo, 1996; Moyo, 2004; FAO/WFP, 2007). Although the area cultivated after the FTLRP was considerably larger than the 10-15% attained in the pre-land reform era (AfricaNewsNetwork, 2008), it was grossly inadequate to reverse the downward spiral of the Zimbabwean economy that was already underway as a result of a plethora of other factors (Kairiza, 2009). As the FAO/WFP (2007) mission noted, such problems as shortages of tractors and draught power, fuel, and fertilizers, under-investment in infrastructure, the disincentive effects of price controls, and absenteeism of beneficiaries of the earlier land reform, were already causing serious supply bottlenecks.

On the occasion of the 27th Anniversary of Zimbabwe's Independence, President Mugabe called attention to the creation of a Ministry of Agricultural Engineering and Mechanization to spearhead an agricultural mechanization programme to help realize the Government's aim of raising productivity "…following the successful implementation of the Land Reform Programme…" (Mugabe, 2007). According to official Zimbabwean sources (AfricaNewsNetwork, 2008), the main reason for the agricultural mechanization programme was to replace obsolete equipment on farms while ensuring enhanced access to farm equipment for farmers adjudged to be inadequately served at present. Under the programme, rehabilitation of irrigation infrastructure was also an important component. The contention was that land resettlement and the provision of inputs to farmers without the support of a strong mechanization programme would impact negatively on crop productivity and food security (Mugabe, 2007; Muchara, 2009). As farmers got land and inputs, the missing link had therefore been mechanisation, which had rendered land preparation ineffective across the country (Chisoko and June, 2007). The failure to prepare land on time because of the shortage of tractors and machinery resulted in dwindling crop yields and consequently falling agricultural productivity. For years after the Fast Track Land Reform (FTLR), the absence of an effective mechanization programme was seen as the major obstacle to increasing efficiency in crop production at the individual farmer level in Zimbabwe (Made, 2006).

Before the launch of the mechanization program, the District Development Fund (DDF), a department mandated by the government to control funds donated by Non-Governmental Organizations (NGOs) for fostering rural development, provided tillage operations to A1 and communal farmers (Singh and Singh, 1999). In most areas of Zimbabwe animal draft power is used in preparation of 70% to 90% of the cropped area, tractor power for between 2% to 15%, and hand tillage for 5% to 15% (Chisoko, 2006). Traditional Conservation Farming where farmers practice zero tillage is used in some areas. In areas where rains normally start late, the understandable anxiety of the majority of farmers to plant with the first rains often meets with frustration due to scarcity of equipment which entails long waiting times with the result that many of these farmers resort to minimum tillage practices (FAO, 2002). With the political atmosphere now largely normalized and the Government and the international community once again turning attention to crucial development concerns, it seems timely to undertake an assessment of the impact of some of the key strategies that will undoubtedly continue to play a pivotal role in the restructuring and realignment that will be required to restore growth to the Zimbabwean economy, hence the current interest in the agricultural mechanization programme.

2. Objectives

The main objective of this paper is to examine the performance of the agricultural mechanization programme launched to reverse negative production and productivity trends that emerged in the wake of the fast track land reform programme of Zimbabwe. A considerable amount of criticism has been leveled against the FTLRP and its attendant agricultural mechanization programme on account of their having been launched without proper planning and implemented in an almost arbitrary and haphazard manner. To what extent these programmes can be blamed for the difficulties of the past few years is not known in the absence of a systematic assessment, hence the present investigation. This paper tries to fill this gap by initially describing the key features of the fast track land reform programme, and highlighting the international experience in agricultural mechanization. Following these, the paper presents evidence from an empirical study to demonstrate the relative importance of agricultural mechanization, especially when introduced to kick-start a land reform programme.

3. Research Questions

The study on which this paper is based posed a number of research questions, including:

- To what extent has agricultural mechanization been adopted and implemented to boost land productivity in the area?

- What have been the impacts of fast track land reform and agricultural mechanization on crop production and productivity among A1, A2 and communal farmers in Zimbabwe?

- Has agricultural mechanization led to changes in efficiency of new farming systems?

4. The Fast Track Land Reform Programme in Zimbabwe

Following years of bitter armed struggle triggered by intolerable levels of oppression and deprivation that revolved around access to land, peace finally came to Zimbabwe as the 1970s drew to a close. Driven by commitments made at the Lancaster House Agreement that reinforced faith in the crucial steering role of Britain, Zimbabwe launched its ambitious land resettlement programme in September 1980, a mere 5 months after political independence was granted to this former British colony. The programme was intended to redress the huge imbalance in land distribution and enhance access to land for victims of the liberation struggle and the landless, while consolidating commercial agricultural production. However, by the end of the 1990s, there was widespread disenchantment with the slow progress in resettling the indigenous population. At that time, in spite of nearly two decades of implementation of land reform, a mere 4,500 white farmers still controlled 28% of the land while more than a million black farmers struggled to eke out a desperate existence in largely unproductive and dry "communal areas" (Mushunje, 2005). In between these two extremes, the political élites received preferential treatment in allocation of land expropriated from white owners even though much of that was promptly abandoned or mismanaged, with disastrous consequences for farm production and food prices. At the same time, Zimbabwe's macro economy began to experience serious balance of payment problems for which a structural adjustment programme was launched. As the hardships deepened, political interests capitalized upon the situation to manipulate an electoral process to seemingly obtain a popular mandate to accelerate the land transfers.

The ensuing "Fast Track" programme that began in July 2000 was marked by violent invasions of white-owned farms in which war veterans and their sympathizers unleashed a wave of terror on the large-scale farm sector. Subsequently, legislation was passed to institutionalize the "fast track" process, adopting two key implementation models, namely Model A1 (to decongest communal areas by targeting the tribal areas suffering severe land constraints), and Model A2 (to promote agricultural commercialization at various scales) (Zikhali, 2008; Muchara, 2009). But in the view of the donor community in Zimbabwe who had privileged access to the ideas as the land invasions were just beginning, this process "had no goal, no plan, no timetable, no budget, no capacity and no transparency" (Kinsey, 1999).While the FTLRP clearly led to substantial repossessions and transfers of land, it seemed to have created a number of other problems.

At one level, the FTLRP is blamed for directly leading to a 30% drop in agricultural production, a hyper-inflationary situation, and a 15% contraction of the economy that culminated in 2008 to an unemployment rate estimated to exceed 80% (Zikhali, 2008). At the other level, the human rights abuses came to a head with members of opposition parties being victims of extreme persecution, beatings and murders. Not even the landmark ruling by the Southern African Development Community (SADC) Tribunal on the court challenge mounted by the Commercial Farmers Union of Zimbabwe could stop the farm seizures which continued unabated (SADC, 2008). The installation of a transitional government of national unity in which the opposition party is playing a limited role has also not moderated the level of political intolerance. Targeted sanctions on the regime in Zimbabwe are still in place to force the regime's hands. Whether or not these sanctions are worsening the political and economic crises in Zimbabwe is now being debated but a recent effort by the South African government to secure some easing-off of the sanctions has failed as Britain insists on seeing real changes first (BBC-News, 2009).

5. International Experience with Agricultural Mechanization

Several studies have been conducted on the impact of agricultural mechanization on production, productivity, cropping intensity, human labor employment as well as income generation for sustainable livelihoods of households. The faith in agricultural mechanization as a panacea to the production and productivity problems of Zimbabwe has its roots in the policy and theoretical developments of the last half a century drawing from the major conclusions of the induced innovation literature much of which was motivated by the seminal works of Ruttan and Hayami

(1972, 1984), Mellor (1973, 1984), Binswanger (1986), Binswanger and Von Braun (1991), among others. Arguing along those lines, Nweke (1978) observed that for post-Independence Ghana, tractor mechanization may have accounted for production expansion arising from bringing more land under cultivation. The thinking then, as now, was that efficiency and tractor operations/ownership are highly correlated, with tractor efficiency increasing as farm size rises above 20 hectares (Nweke, 1978). But possibly as a result of the perceived substantial displacement of labour and effective subsidization of agricultural machinery prices relative to labour (Mellor, 1984), agricultural mechanization lost some popularity among academic economists who easily linked it to the growing unemployment in the wake of the introduction of the Basic Needs Strategy in many developing countries in the 1970s. Such sentiments have naturally resulted in considerable policy confusion as political élites have wavered between extremes depending on how loud and/or convincing the arguments have been. As a result, conflicting policy prescriptions have been given for the African agricultural mechanization problem by the academic, donor community and national governments but with little or no impact on productivity (Nandal and Rai, 1986). The failure of many Government sponsored tractorization projects initiated in the late 1950's and early 1960's emboldened the critics who easily attributed the decline in agricultural productivity and growing unemployment as witnessed in Zimbabwe to farm mechanization (Salokhe, 2003). Overall, it is safe to conclude that agricultural mechanization has had a chequered history in the African policy terrain and remains a questionable input in African agriculture particularly in the smallholder sector (Aggarwal, 1983).

Early literature on agricultural mechanization has defined it chiefly in terms of farm power and transportation. According to Binswanger (1986), agricultural mechanization implies the use of various power sources and improved farm tools and equipment, with a view to reducing the drudgery of farm work. Three main options were generally agreed for farm production and transportation of agricultural produce to markets, namely human power, animal power and the use of motors (Bordet and Rabezandrina, 1996). Human, animal and machine power is believed to complement one another in the same household, farm or village, the choice being determined by local circumstances. Ultimately, farm mechanization aims to enhance the overall productivity and production at the lowest cost. Possibly in recognition of this fact, the use of agricultural machinery has grown progressively over the past two to three decades, with its popularity growing in land-surplus areas where it has been clearly demonstrated that one labour unit working with suitable machinery can afford to plough in excess of 10 hectares in a day (Chatizwa and Khumalo, 1996).

The contribution of agricultural mechanization has been well recognized in enhancing production together with irrigation, biological and chemical inputs, high yielding seed varieties, fertilizers, pesticides and mechanical energy. The Indian Green Revolution which is regarded as one of the greatest achievements of the 20th century (Madras, 1975), is well-known for the manner in which it promoted the adoption of mechanization on a large scale for the benefit of small, medium and large sized farms. Effects of mechanization such as its impact on human labor employment in a labor abundant economy have always evoked sharp responses from the policy makers (Jafry, 2000). The notion of "appropriate technology" has evolved as a compromise to ensure that adequate scope is provided for human labour to participate while equipment is phased in to respond to the need for expanded output at minimum human costs. But even the concern about equipment replacing human labour and thus increasing unemployment rates has been shown to be unfounded. For instance, it has been shown that agricultural mechanization led to overall increase in the employment of human labor (Chatizwa and Khumalo, 1996). The reduction in aggregate labor used on tractor operated farms was quite nominal (1.3 to 12%) compared to bullock operated farms (Sidhu & Grewal, 1991). The increase in employment of casual male labor was reported to be up to 38.55% and the mechanized small farms used 3.7 more labour NCAER (1973). As Mellor (1984) noted, the role of farm machinery in shortening land preparation time has often made it possible for households to plant a second crop within the year, thus providing year-round employment for labour that would otherwise have been redundant for much of the time.

Of course, even before Mellor (1984), many researchers had observed that mechanization does not lead to decrease in human labor employment because with mechanization, the demand for hired labor increased while participation of family labor in crop production declined. Carney

(1998) also indicated that net human labor displacement in agricultural operations was insignificant and it was more than compensated by increased demand for human labor due to multiple cropping, greater intensity of cultivation and higher yields. Furthermore the demand for non-farm labour for manufacturing, servicing, distribution, repair and maintenance as well as other complementary jobs substantially increased due to mechanization. As observed by Chatizwa and Jones (1997), farm mechanization displaced animal power from 60 to 100% but may have resulted in less time for farm work. Also mechanization has probably led to increase in the human labor employment for the on-farm and off-farm activities as a result of manufacture, repair, servicing and sales of tractors and improved farm equipment (Farrington, 1985).

Over the past half a century developing regions, with the exception of Sub-Saharan Africa, have seen labor-saving technologies being adopted at unprecedented levels (Jafry, 2000). Intensification of production systems created labour bottlenecks around land preparation, harvesting and threshing operations. Alleviating these labour bottlenecks with the adoption of mechanical technologies has been linked to the enhancement of agricultural productivity and lowering of the unit cost of crop production even in the densely populated countries such as China (Bergmann, 1978). Economic growth and the commercialization of agricultural systems are leading to further mechanization of agricultural systems in Asia and Latin America (Rijk, 1999). Sub-Saharan Africa continues to have very low levels of mechanization and available data indicate declining rather than increasing levels of adoption, even among the countries that were the early trendsetters, such as Kenya and Zimbabwe (Binswanger, 1978; FAO/UNIDO, 2008). Granted that the recent macroeconomic history in many of these countries may account for the low adoption rates, but the fact remains that many of them were already under-performing even before the economic crisis of the 1980s and 1990s.

According to FAO (2000), the general trend is that agricultural production in most African countries still relies on the centuries- old hand tool technology. Whereas, everybody agrees that this has to change, the main question has been on how the change should come about. One question that has often been posed (Binswanger, 1978) is: should African countries go through the evolutionary path from hand tool through animal powered to mechanically powered agricultural mechanization as it has happened in the developed countries, or should they aim at skipping the intermediate stage of animal powered mechanization? The experience of seven African countries (Botswana, Ghana, Kenya, Nigeria, Swaziland, Tanzania and Zambia) in agricultural mechanization policy confirms that these have failed to yield positive results (FAO, 2000).

Sticking to the wholly optimistic and positive view, various researchers have concluded that farm mechanization has managed to achieve enhancement of the production and productivity of different crops due to timeliness of operations, better quality of operations and precision in the application of the inputs. Madras (1975) found that the productivity increase on tractor owning and hiring farms ranged between 4.1 and 54.8 per cent. The per cent increase was comparatively low on non-mechanized farms as compared to tractor-owning farms due to higher level of inputs and better control on timeliness of operations. These productivity increases were attributed to higher doses of fertilizer, irrigation and mechanization (Bina, 1983). Several studies have indicated that there was significant increase in cropping intensity due to the use of tractors and irrigation as a consequence of mechanization. The increase in cropping intensity has been reported to be 165, 156 and 149 per cent, respectively for tractor-owning, tractor using and bullock operated farms respectively (NCAER, 1980). Similar results have been reported in other studies which concluded that as a consequence of mechanization, cropping intensity increased significantly. Furthermore, irrigation and mechanical power helped the farmers in raising the cropping intensity of their farms (Patil & Sirohi, 1987). Singh (2001) concluded that cropping intensity was mainly dependent on annual water availability and nature of the farm power available.

Farm mechanization has been credited with the significant upliftment of the economic circumstances of farming communities in which this technology has been popular. Tractor owners and users derived higher per hectare gross income compared to traditional subsistence farms (NCAER, 1980). The gross income per hectare was reported to be about 63% higher on tractor owning farms compared to the traditional farms. The average net return from a tractor owning farm on per hectare basis was reported to be 152% that of a non-tractor owning farm (Chopra, 1974).

6. The Model and Methodology

This paper adopts the approach of estimating farm level technical efficiency to determine the extent to which the agricultural mechanization programme has contributed to attainment of the goals of the fast track land reform programme of the Government of Zimbabwe. Since it was proposed by Knut Wicksell (1851-1926) and tested against statistical evidence by Charles Cobb and Paul Douglas in 1928, the Cobb-Douglas functional form has been widely used to represent the relationship of an output to a set of inputs. They considered a simplified view of the economy in which output is determined by the amount of labor and capital involved in production. In the Cobb-Douglas model, capital represents various forms of non-labour inputs, including mechanical power. While there are many other factors affecting economic performance, their model proved to be remarkably accurate.

Cobb-Douglas production function shows physical output as labor and capital inputs; that is:

$$Q = AL^{\alpha} K^{b} \quad \text{……………………………………………………………………………}(1)$$

Where

Q is output,

A, α, b are constants, and

L and K are labor and capital, respectively.

Capital can be interchanged with labor without affecting output. Or

$$P(L, K) = bL^{\alpha} K^{b} \quad \text{………………………………………………………………………}(2)$$

Where:

P = total production (the monetary value of all the produce or goods produced in a year)

L = labor input (the total number of person-hours worked in a year)

K = capital input (the monetary worth of all machinery, equipment, and buildings)

b = total factor productivity

The terms α and *b* are the output elasticities of labor and capital, respectively. These values are constants determined by available technology. Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production, ceteris paribus.

Due to its flexibility, the stochastic frontier production function specification of the Cobb-Douglas model is used in this study. Defined in logarithmic form, the stochastic frontier production function in this case can be expressed as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + ... + \beta_n \ln(X_{it}) + V_{it} - U_{it} \text{ ---------------------------(3)}$$

Where the subscripts *i* and *t* refer to the *i-th* farmer and *t-th* observation, respectively, and
Ln is the natural logarithm
Y represents the output
β's are the regression coefficients, and
L, K, X are the inputs labour, capital, and others, respectively
$V_{it} - U_{it}$. are random errors.

The study used both primary and secondary data. Secondary data were useful for background information and to obtain a deeper understanding of the study area. The main sources of secondary data were the previous studies conducted in the study area and the data provided by the Ministries of Agriculture (Arex), Lands and Resettlement, Local Government and Agricultural Engineering and Mechanization. Primary data were obtained from different stakeholders and farmers in Communal Areas as well as selected Resettlement Areas in the District. A formal method of data collection was used. Workshops and focus groups were also conducted with key informants and other stakeholders with a relevant knowledge. The sample comprised 90 farmers drawn from both communal and resettlement areas of Bindura district. Farmers were classified into three groups:
Group 1: farmers with cattle and ox drawn machinery
Group 2: farmers with tractor drawn or powered machinery and

Group 3: farmers without machinery or non beneficiaries of the mechanization program

The study was based in the Mashonaland Central Province of Zimbabwe which has large areas of good crop land especially in the districts of Mazowe, Bindura and Guruve. Fine grained archaelian rocks, granodiorites soils with pockets of dolerite and gneiss are predominant in the study area. The underlying geology has a marked influence on soils in the study area, which are mostly sandy fersialitic soils with inherent low fertility and low water holding capacity (Nyamapfene, 1991). Masembura and Musana communal areas are dominated by Miombo woodlands, and most predominantly bush land with canopy 28–80%. Musana communal area is characterized by more intensive cultivation of horticultural crops and mixed rangelands than woodlands.

The province has one of the most productive communal lands, producing both food and cash crops. Maize is the dominant crop; however the main sources of income include cotton, tobacco, sunflower, soya bean and sugar bean production. Employment on A1 (small scale resettlement) and commercial farms is also an alternative source of livelihood. Poor households depend equally on their own crops, daily wages from casual labour, selling of sugar cane and gold panning. In general, crop production (food and cash crops), livestock rearing or a combination constitutes the primary livelihoods in the rural provinces. These livelihood options in turn define most of the secondary livelihood options – such as employment on commercial farms and game reserves.

7. The Data

The variables collected in the field survey are presented in the table above are explained below.

- GINC: Refers to total gross income in 2008. Gross value of annual farm production from crops and livestock. It is hypothesized that low values signify lack of machinery, finance and access to vital resources.

- AGE: this variable measures the actual age of the household head in years. Younger farmers are expected to be mechanically constrained than older farmers who are perceived to have acquired access resources. Therefore, it is hypothesized that age of household head and machinery access are positively correlated. This is supported by an observation by Belete and Fraser (2003) that older farmers are likely to have more resources at their disposal.

- LAND: This variable refers to the size of land in hectares. Increase in land size may enhance production if the land is effectively utilized. At the same time, land may be available but not being effectively utilized. Effective utilization will entail application of appropriate farm practices that will lead to higher physical output than otherwise would be the case. In the absence of more direct means of assessing effectiveness, this can only be inferred from the results. Intuitively, one can expect higher output if there is effective utilization of available land, and lower output otherwise. It is also reasonable to expect that the more physical output a farmer produces, the more surplus is marketed, and hence higher gross farm income.

- FERT**:** A number of studies have established that fertilizer usage is positively related to productivity (Reardon *et al.,* 1996; Xu, Guan, Jayne and Black, 2009). Conversely, a farm unit that is too constrained to afford adequate amounts of fertilizer will most probably experience lower productivity which will translate to lower physical output.

- SEED: this variable refers to farm inputs such as hybrid seeds, pesticides and chemicals. It is hypothesized that farmers with inadequate inputs are less likely to achieve higher levels of production leading to lack the purchasing power for machinery and equipment.

- TOTPRDMZ: Physical production of maize in kg. It is hypothesized that the total physical output of maize is positively associated with the gross farm income and explains differences in income between farming households. The physical production of maize will also be related to the area cultivated which will equally be a function of the availability of mechanical power required to bring more land under cultivation that would otherwise be the case.

- TOTPRDSB: Physical production of soybean in kg. It is hypothesized that the total physical output of soybean is positively associated with the gross farm income and explains differences in income between farming households. The physical production of soybean will also be related to the area cultivated which will equally be a function of the availability of mechanical power required to bring more land under cultivation that would otherwise be the case. As a leguminous crop, it is obviously a high value crop with high potential contribution to household earning from farming.

- LVSTK: Whether or not farmer kept livestock. Livestock farming is important in many parts of Mashonaland Central Province of Zimbabwe although as much as 50% of the population live in the so-called "high potential zone" where crop production is important. Livestock is kept principally for draught power, milk, meat and marginally as a source of income. There is no doubt that livestock plays a positive economic role in Zimbabwe and it is hypothesized that a positive relationship will exist between livestock ownership and gross farm income for farming households.

- MECH: Whether farmer used equipment and machinery. This is calibrated as a dummy as shown in Table 7.1. Despite the agricultural mechanization programme being described as "…the largest in the whole of Africa", not all farmers have access as would be expected. The hypothesized relationship between use of machinery and gross income is a positive one and it is expected that farmers using equipment would bring more land under cultivation and potentially realize larger revenues that those who did not.

- IRR: Use of Irrigation for farming was calibrated as a dummy. Part of the agricultural mechanization programme is the development of irrigation facilities and rehabilitation/maintenance of existing ones. Water availability has always been a challenge especially in the regions 3-5 of the province. It is hypothesized that farmers using irrigation stand a better chance of realizing increased gross farm income than those who do not use irrigation for crop production.

Table 7.1: Definition and units of measurements of key variables modeled

Dependent variable	Definition	Value
GINC	Gross Farm Income	Continuous
Independent Variables	**Definition**	**Value**
GENDER	Gender of the household head	A dummy variable coded 1 if male and 0 otherwise.
AGE	Age of the household head in years	Actual age in years
TOTPRDMZ	Physical production of maize in kg	Continuous
TOTPRDSB	Physical production of soybean in kg	Continuous
FERT	Expenditure on fertilizer in US$	Continuous
SEED	Expenditure on seeds in US$	Continuous
LVSTK	Whether farmer kept livestock	A Dummy variable = 1 if the farmer kept livestock; 0 otherwise
MECH	Whether farmer used equipment and machinery	A dummy variable coded 1 if farmer used equipment and machinery and 0 otherwise
LAND	Area cultivated by farmer in hectares	Continuous
IRR	Use of Irrigation for farming	Coded 1 if the farmer uses irrigation, and 0 otherwise

Source: Field study (2009)

8. Estimation and Results

The estimates of the maximum likelihood ratios for the parameters in the single equation reduced form proposed in equation (3) above are presented in Table 8.1. Since the functional form of the model cannot be definitively predicted by visual inspection, a multivariate Ordinary Least Squares (OLS) was fitted and the results are presented in Table 8.2. The indication is that the model is more or less linear and that most of the gross incomes earned in the smallholder sector examined are explained by the model. Looking at Table 8.1 specifically, it is clear that land ownership and use of mechanical power are important contributors to the gross income of smallholder farmers, without prejudice to the absolute levels of incomes eventually attained. The indication is also that purchased inputs such as seeds and fertilizer strongly influence gross income in the farming system studied. As indicated earlier, Table 8.2 presents the results of the multivariate OLS which are close enough to the frontier estimates to suggest a generally linear model. Thus, if all that was needed was to explain the causation of gross income in the farming system, a linear model of this sort would have sufficed. The model fit is also adequate, both in terms of the whole model and the individual regression coefficients. The R-Squared value of 88% which adjusted to 86% suggests a good-fit, while the F-statistic of more than 58 confirms a whole model adequacy.

But from the point of view of technical efficiency, the lower panel statistic denoting "Insig2V" and "Insig2U" probably yield more policy-relevant information. Based on the relationship depicted in equation (3) above, it is obvious that the estimates indicate high random errors with the high variance of the random component. Further, the "rho", calculated by the formula:

$$rho = (SIGMA\_U)^2 \Big/ \left((SIGMA\_U)^2 + 1\right) \qquad \text{..........(4)}$$

is almost close to zero, at 0.00577 (not different from zero). Given that the LR test actually tests the hypothesis that "rho" =0 (see Table 8.1), and "rho" gives the proportion of the total variance contributed by the variance components, it can be concluded that all the variance in the estimates come from the variables themselves and not due to error. This would suggest high degrees of inefficiencies in resource use in the smallholder system. Thus, while mechanization and land reform can potentially contribute to gross income growth, there is clear evidence of sub-optimal resource utilization which is consistent with generally-held views about the arbitrariness and poor planning that have characterized Zimbabwe's recent economic management processes. Recent evidence from other parts of Zimbabwe (Obi, 2010) has shown that without proper planning, land reform can lead to supply bottlenecks as a result of declining productivity and production. Some of the effects have already been felt in the weakening of the primary markets that serve smallholders, with negative consequences for smallholder livelihoods and welfare.

Table 8.1: Stochastic frontier maximum likelihood estimates

Ginc	Coef	Std. Err	Z	p>|z|	(95% coef. Interval)	
GENDER	42.49213	56.0706	0.76	0.449	-67.40421	152.3885
AGE ACTUAL	-1.804542	2.273684	-0.79	0.427	-6.260882	2.651798
TOT PROD MZ	.1517116	.0217881	6.69	0.000	.1090077	.1944156
TOT PROD SB	-.4569862	.0604846	-7.56	0.000	-.5755338	-.3384386
FERT	.7127523	.2765718	2.58	0.010	.1706815	1.254823
SEED	-15.52525	3.039578	-5.11	0.000	-21.48271	-9.567789
LAND	347.9645	63.21514	5.50	0.000	224.0651	471.8639
LVSTK	-68.52655	56.23232	-1.22	0.223	-178.7399	41.68677
MECH	134.5086	66.01683	2.04	0.042	5.118034	263.8992
IRRIGATION	93.83527	73.69449	1.27	0.203	-50.60327	238.2738
-CONS	8.883757	3202.386	0.00	0.998	-6267.678	6285.446
|INSIG2V |INSIG2U	10.81111 -5.148053	.1491386 105240.8	72.49 -0.00	0.000 1.000	10.51881 -206273.4	11.10342 206263.1
SIGMA-V SIGMA-U SIGMA2 LAMBDA	222.6399 .076228 49568.54 .0003424	16.6021 4011.15 7399.489 4011.683			192.3665 0 35065.81 -7862.754	257.6775 . 64071.27 7862.754

Likelihood-ratio test of sigma-u=0: chibar2(01)=0.00 prob>=chibar2=1.000

Table 8.2: Multivariate regression results

	Coef	Std. Err	t	p>|t|	95% conf. interval	
GINC						
GENDER	44.99384	49.0565	0.92	0.362	-52.6317	142.6194
AGE ACTUAL	-1.64166	1.011684	-1.62	0.109	-3.654974	.3716549
TOT PROD MZ	.1513992	.0227257	6.66	0.000	.1061735	.1966248
TOT PROD SB	-.4568934	.0641437	-7.12	0.000	-.5845435	-.3292434
FERT	.7157122	.2906488	2.46	0.016	.1373028	1.294122
SEED	-15.52149	3.223673	-4.81	0.000	-21.9368	-9.106173
LAND	348.2635	66.93156	5.20	0.000	215.0655	481.4616
LVSTK	-67.95647	59.15114	-1.15	0.254	-185.6709	49.7581
MECH	134.5513	70.0215	1.92	0.058	-4.795972	273.8985
IRRIGATION	94.56949	77.5421	1.22	0.226	-59.7442	248.8832

Number of obs = 90
F (10, 79) = 58.33
Prob > F = 0.0000
R-squared = 0.8807
Adj R-squared = 0.8656

9. Conclusion

The primary focus of this paper was on the way the fast track land reform programme and the follow up agricultural mechanization programme have impacted on the smallholder sector in terms of their importance in explaining variations in earnings. Related to this was the need to ascertain the extent to which the sector has made use of the opportunity afforded for enhanced access to the vital resources of land and farm machinery. This latter aim referred to the issue of technical efficiency which was looked at deliberately in an oblique fashion without any attempt to relate observed productivity to any norms since such norms will at best be only subjective. The procedure of examining technical efficiency in terms of contributions of error variance components to total variance is novel but is justified by the fact that more direct approaches would call upon data that for Zimbabwe have become highly unreliable in the wake of the considerable degree of political interference into even the most common-place and basic human processes.

The study does find that the expected positive relationships between key productive inputs and farm performance still hold for Zimbabwe. This is important for policy since it confirms that incentive mechanisms can still be effectively manipulated to achieve real growth if attention is paid to the rational allocation principles devoid of political influence as has been the case in recent years. What seems to be lacking, as confirmed by a large number of studies, is proper planning. Without a doubt, proper planning is non-negotiable for a land reform programme to successfully deliver the benefits of equitable distribution of land and enhanced agricultural productivity. As well, a farm mechanization programme requires that needs are more precisely determined in terms of the nature of equipment required for particular purposes and environments. It smacks of unbridled politicization when the senior government functionary quoted earlier boasts of Zimbabwe having the "largest farm mechanization programme in the whole of Africa". There is definitely a mismatch there and an anxiety to appeal to sectional sentiments. As serious as Zimbabwe's economic crisis can be, it does not qualify to mount the largest farm mechanization programme on the continent where most of the beneficiaries of the land reform programme are either absent from the farms or lack the skills to utilize the resources put at their disposal. It is also unclear how Zimbabwe can afford to finance the "largest farm mechanization programme in the whole of Africa".

Technical efficiency at the production level is also meaningless in the absence of enhanced market access. And real marketing is impossible in the absence of goods and services. So there is a two-way link. Anything that chokes off supply of physical output is bound to weaken primary markets serving the poor. Policies to empower small farmers by re-distributing land in order to boost food production and link them to markets must undoubtedly be sensitive to these issues.

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