Asset Ownership and Working Capital Constraints in a Post-Reform Environment: Implications for Second Generation Reforms in Zambia

Klaus Deininger and Pedro Olinto
World Bank

Prepared for American Agricultural Economics Association Annual Meeting, August 1998, Salt Lake City, Utah.

17 March, 1998

1 INTRODUCTION

In the early 1990s, Zambia initiated an ambitious program of liberalization that significantly opened the economy, shifting from a highly regulated and centralized to a more market-based and liberal economic paradigm. This paper provide an assessment of the impact of liberalization on economic performance in the rural sector and on productivity which could be used to identify remaining problems and challenges facing the Zambian Government in achieving its goals. In this introduction we first summarize the main questions and conclusions and then briefly touch upon the data sources and the institutional context of this exercise.

The work reported here is based on data from four years (1990/91, 1993/94, 1994/95, and 1995/96) of the annual Post Harvest Survey (PHS), administered to about 8,000 small- and medium scale farmers[1] by the Zambian Central Statistical Institute (CSO). This is complemented with data from the 1996 Living Conditions Measurement Survey (LCMS), conducted by the same institution. The 1993/94 and 1994/95 data cover the same households and, even though the panel spans only two years, there were large exogenous shocks -a drought and credit contraction owing to the closure of the traditional lending institutions at the beginning of the 1994/95 growing season- that generate sufficient "within" household variation in input use for panel data methods to be meaningful.

In an accompanying paper (Deininger, et al, 1998) we describe in more detail the reaction of the productive sector to the main changes introduced at the level of macro-economic policies. We find that both aggregate production and input use have decreased and that there is as of yet no strong aggregate supply response from the small-scale sector. Although the share of producers participating in output markets has slightly increased, diversification of the production base away from maize is still a distant goal and credit remains out of the reach of the large majority of rural producers. In sum, while adjustment policies have changed price signals, the impact in terms of contributing to a more effective and productive use of Zambia's abundant resource endowment -an issue that is mandatory in order to improve the prospects for sustained growth and poverty reduction- has thus far been limited, at least insofar as the small-scale sector is concerned.

In this paper we examine the structural factors underlying this phenomenon by using data from a two-year panel of about 5000 rural households to estimate a production function plus associated demand equation for land, fertilizer, and credit. Main findings include the following:

- Fertilizer does have a significant output-increasing effect; however the amount *applied* [2] by Zambian producers who do have access to fertilizer supplies (i.e. the mean amount of fertilizer used by them) is close to the profit maximizing optimum where marginal benefits do equal marginal costs.
- Cattle ownership increases income directly, and has a positive impact on the area of land cultivated as well as access to credit and fertilizer markets. While this points to the persistence of significant imperfections in markets for rural labor, credit, and draught animals, it also suggests that policies to increase cattle ownership in rural areas could have a high payoff.
- While we find, somewhat surprisingly, that credit has a direct productivity increasing effect (most likely through supervision that is associated with it), the main impact of credit is through the increase in area cultivated; as in the case of fertilizer major benefits are likely to be realized by providing access to producers who do currently not have access to any credit.
- Female headed households are as productive as male headed households (in total factor productivity terms), but have less access to credit, and therefore use less land and fertilizer, a fact that still could be in line with labor market imperfections, or higher risk aversion on the part of these households.

[1] Although CSO complements the PHS which provide information only on small farmers with an annual complete enumeration of large farms, the data for large farmers are still being entered and cleaned and were therefore not available for analysis. This is unfortunate not only because it prevents us from gaining a complete picture of the whole agricultural sector but also because the large farm sector appears to have responded to the aggregate policy changes more quickly, thus indicating the scope for a policy response from small-scale farmers if markets can be made to function reasonably well.
[2] We will discuss below that there are large differences between fertilizer purchases (at concessionary terms) and actual fertilizer use.

- Supply of extension has an insignificant though positive impact on total factor productivity and no significant impact on demand for cultivated area. Improving the quality of extension and gearing it more to be in line with Zambia's relative factor endowment would thus be necessary before additional investments are made in this area.
- Education is found to not have any impact on production or the amount of area cultivated if other inputs are accounted for. However, education does enable farmers to better overcome market imperfections, as reflected in the fact that more educated farmers use higher amounts of fertilizer and credit per hectare, and do tend to be more integrated into output markets.

2 EMPERICAL INVESTIGATION OF THE DETERMINANTS OF PRODUCTIVITY AND INPUT DEMAND IN ZAMBIA

This section describes the framework for a more thorough investigation of the determinants of agricultural productivity via panel data econometric methods. The available panel data set consists of information collected from 4853 farm households that were interviewed at the end of the 1993/94 and 1994/95 cropping seasons. As discussed in the text policy and weather shocks are likely to have induced farmers to significantly change their cropping patterns and therefore –even though the elapsed time span is quite short- generated sufficient "within" farm variation to identify the effects of land, fertilizer, and other factors affecting production.

Conceptual Framework

Consider a household *i* that at time *t* may undertake production employing a *Cobb-Douglas* technology given by:

$$\ln(Y_{it}) = \ln(A_{it}) + \beta_1 \ln(T_{it}) + \beta_2 \ln(F_{it} + 1), \quad (1)$$

where T_{it} is the total area cultivated, F_{it} is the total amount of fertilizer applied, A_{it} is an index that measures the total factor productivity (TFP) achieved by household *i* at time *t*, and β_1 and β_2 are technology parameters assumed to be constants across households and time. For simplicity we assume that other inputs--as labor effort, seeds, mechanical and animal power--are employed in fixed proportions to the cultivated area [3]. This specification captures the fact that fertilizer is not an essential input, so that $F_{it}=0$ does not imply in $Y_{it}=0$.

We assume that the TFP index A_{it} is determined by household/farm *i*'s observed and unobserved characteristics at time *t*. For tractability, we specify the following log-linear equation for A_{it}:

$$\ln(A_{it}) = \alpha_0 + \alpha_1{}'\boldsymbol{X}_{it} + \alpha_2{}'\boldsymbol{Z}_i + \eta_i + \mu_{it}. \quad (2)$$

In (2), $\boldsymbol{X}_{it}$ and $\boldsymbol{Z}_i$ are vectors of observed household/farm specific time-variant and invariant characteristics, respectively, which will be described below. The error term in (2) has two components: (i) η_i is a household/farm specific time-invariant effect, which is known to the household at the time production decisions are made, but is unknown to us, the econometricians; and (ii) the stochastic exogenous shock μ_{it}, which is assumed to be independent and identically distributed (iid) across households and time, and is observed neither by the households nor the econometricians. For tractability we assume that the decision making household's conditional expectation of $\exp(\mu_{it})$ given $\boldsymbol{X}_{it}$, $\boldsymbol{Z}_i$, T_{it}, F_{it} equals one.

Thus, household *i* chooses T_{it} and $(F_{it}+1)$ in order to maximize expected profits at year *t* which are given by:

$$P_{it} = \mathrm{E}[Y_{it} \mid \boldsymbol{X}_{it}, \boldsymbol{Z}_i, T_{it}, F_{it}] - r_t T_{it} - q_t(F_{it}+1) + q_t, \quad (3)$$

[3] In other words, T_{it} represents the area of prepared and planted land.

where r_t is the market rental rate of prepared land, and q_t is the market price (plus transportation and application costs) of a unit of fertilizer.
The first order necessary conditions (FONCs) for maximum profit are respectively given by:

(4.a) $P_T - r_t \leq 0$, $(P_T - r_t)T_{it} = 0$, and $T_{it} \geq 0$;
(4.b) $P_{F+1} - q_t \leq 0$, $(P_{F+1} - q_t)(F_{it}+1) = 0$, $F_{it} \geq 0$.

The solution to system (4) yields the reduced form demand equations for fertilizer and cultivated area, which are given by:

(5.a) $\ln T_{it} = \psi_0(w_t, q_t, r_t; \boldsymbol{\beta}) + \psi_1(\boldsymbol{\beta})(\alpha_0 + \boldsymbol{\alpha}_1'\boldsymbol{X}_{it} + \boldsymbol{\alpha}_2'\boldsymbol{Z}_i + \eta_i)$;
(5.b) $\ln(F_{it}+1) = \gamma_0(w_t, q_t, r_t; \boldsymbol{\beta}) + \gamma_1(\boldsymbol{\beta})(\alpha_0 + \boldsymbol{\alpha}_1'\boldsymbol{X}_{it} + \boldsymbol{\alpha}_2'\boldsymbol{Z}_i + \eta_i)$,

where γ_k, ϕ_k, ψ_k, for $k = 0,1$ are functions of the structural parameters in $\boldsymbol{\beta}$ and the exogenously given prices w_t, q_t. Thus, under the above specification, the resulting reduced form demand equations are linear in the household/farm specific effects η_i, and moreover, η_i has a time-invariant coefficient.

Econometric Model and Estimation Issues.
The Production Function
Equations (1) and (2) suggest the estimation of the following regression equation:

(6) $\ln(Y_{it}) = \alpha_0 + \boldsymbol{\alpha}_1'\boldsymbol{X}_{it} + \boldsymbol{\alpha}_2'\boldsymbol{Z}_i + \beta_1\ln(T_{it}) + \beta_2\ln(F_{it}+1) + \nu_{it}$,

where ν_{it} is a random disturbance with two components: i.e., $\nu_{it} = \eta_i + \varepsilon_{it}$, where η_i is defined above, and ε_{it} is a idiosyncratic household/farm shock in productivity which might be observable by the household but not by the econometrician.
To estimate the structural parameters in (6) we must confront the problem of endogeneity of cultivated area $\ln(T_{ir})$, and fertilizer use $\ln(F_{it}+1_{it})$, a common feature in the estimation of production functions with household and farm level data. As seen in the reduced form equations (4.a)-(4.b), both $\ln(T_{ir})$ and $\ln(F_{it}+1_{it})$ are functions of the unobserved time-invariant household/farm characteristic η_i, which is a component of ν_{it}, the error term in (6). Therefore, $\ln(T_{it})$ and $\ln(F_{it}+1_{it})$ are clearly correlated with the disturbance ν_{it}, which implies that the OLS estimator of the parameters in (6) will be biased and inconsistent. As discussed in Mundlak (1996), panel-data can provide a wealth of Instrumental Variable (IV) estimators that tackles this common identification problem in the estimation of production functions via a primal approach. In what follows we discuss three IV estimators: (i) The within (or fixed-effects) estimator, (ii) the two-stage least squares estimator of Hausmann and Taylor (1981), hereafter the HT estimator, and the Amemyia and MaCurdy (1989), hereafter the AM estimator.

The Within Estimator
To simplify notation, we rewrite equation (6) as:

$$y_{it} = \boldsymbol{\pi}_1'\boldsymbol{x}_{it} + \boldsymbol{\pi}_2'\boldsymbol{z}_i + \eta_i + \varepsilon_{it}, \qquad i = 1,...,N;\ t = 1,...,T,$$

where $\boldsymbol{x}_{it}$ is a K x 1 vector collecting all the time-variant explanatory variables in equation (7), $\boldsymbol{z}_i$ is a G x 1 vector collecting all the time-invariant explanatory variables, and $\boldsymbol{\pi}_1$ and $\boldsymbol{\pi}_2$ are conformably dimensioned parameter vectors. We assume that the disturbances ε_{it} are *iid* $N(0,\sigma_\varepsilon^2)$ and the individual effects η_i are *iid* $N(0,\sigma_\eta^2)$. The time and household-variant component ε_{it} are assumed to be orthogonal to both the explanatory variables and the individual effects, while η_i may be correlated with parts of $\boldsymbol{x}$ and $\boldsymbol{z}$.
Combining all NT observations we can write (8) as:

$$y = \boldsymbol{x}\,\boldsymbol{\pi}_1 + \boldsymbol{z}\,\boldsymbol{\pi}_2 + \boldsymbol{V}\boldsymbol{\eta} + \boldsymbol{\varepsilon}$$

where $\boldsymbol{y}$ and $\boldsymbol{\varepsilon}$ are NT x 1, $\boldsymbol{x}$ is NT x K, $\boldsymbol{z}$ is NT x G, and $\boldsymbol{V}$ is an NT x N matrix of individual-specific dummy variables. Now define the matrix $\boldsymbol{P}_V = \boldsymbol{V}(\boldsymbol{V}'\boldsymbol{V})^{-1}\boldsymbol{V}$ as the projection onto the column space of $\boldsymbol{V}$. Then, $\boldsymbol{Q}_V = \boldsymbol{I} - \boldsymbol{P}_V$ is defined as the projection onto the null space of $\boldsymbol{V}$. Thus, $\boldsymbol{P}_V$ is a matrix that transforms a vector of observation into a vector of individual means across time: i.e., $\boldsymbol{Pv}y_{it} = (1/T)\Sigma_t y_{it} \equiv y_i$. Similarly, $\boldsymbol{Q_v}$ produces a vector of deviations from individual means: i.e., $\boldsymbol{Pv}y_{it} = y_{it} - y_i$.

The within estimator is computed by projecting (9) onto the null space of $\boldsymbol{V}$ and performing least-saquares. Because $\boldsymbol{Q_v z} = \mathbf{0}$, and $\boldsymbol{Q_v}\mathbf{n} = \mathbf{0}$, only $\boldsymbol{\pi}_1$ can be estimated. Therefore, the within estimator of $\boldsymbol{\pi}_1$ is:

$$\boldsymbol{\pi}_{1\mathrm{w}} = (\boldsymbol{x'Q_v x})^{-1}\boldsymbol{x'Q_v y}, \tag{10}$$

and is consistent whether or not the explanatory variables are correlated with the individual effects η_i. The problem with the within estimator is that it does not allow for the estimation of the vector $\boldsymbol{\pi}_2$. In what follows we explore two estimators that will be consistent under some mild orthogonality assumptions.

2SLS Estimators

As explained in Hausmann and Taylor (1981), a more efficient IV estimator can be computed if we are willing to assume that some explanatory variables in $\boldsymbol{x}$ and $\boldsymbol{z}$ are orthogonal to the individual effects η_i. Consider the partition of $\boldsymbol{x}$ and $\boldsymbol{z}$ given by $\boldsymbol{x} = (\boldsymbol{x}_1, \boldsymbol{x}_2)$ and $\boldsymbol{z} = (\boldsymbol{z}_1, \boldsymbol{z}_2)$, such that $\boldsymbol{x}_1$, and $\boldsymbol{z}_1$ are orthogonal to η_i, but $\boldsymbol{x}_2$ and $\boldsymbol{z}_2$ are not. The HT 2sls estimator is therefore given by:

$$[\, \tilde{\pi}_1\ ,\ \tilde{\pi}_2\,]' = [(\boldsymbol{x}, \boldsymbol{z})'\Omega^{-1/2}P_A\, \Omega^{-1/2}(\boldsymbol{x}, \boldsymbol{z})]^{-1}\ (\boldsymbol{x}, \boldsymbol{z})'\Omega^{-1/2}P_A\, \Omega^{-1/2}\boldsymbol{y}$$

where $\Omega^{-1/2} = \boldsymbol{Q_v} + \theta\boldsymbol{P_V}$, is a weighting matrix such that $\theta = \sigma_\varepsilon^2(\sigma_\varepsilon^2 + T\sigma_\eta^2)^{-1}$, $\boldsymbol{P_A} = \boldsymbol{A(A'A)}^{-1}\boldsymbol{A}$ is the projection onto the column space of $\boldsymbol{A}$. For the HT estimator, $\boldsymbol{A}$ is a matrix of instruments given by:

$$\boldsymbol{A} = (\boldsymbol{Q_v\, x}_1, \boldsymbol{Q_v\, x}_2, \boldsymbol{P_v\, x}_1, \boldsymbol{z}_1)$$

Thus, each variable in $\boldsymbol{x}_1$ provides two instruments ($\boldsymbol{Q_v\ x}_1$ and $\boldsymbol{P_v\ x}_1$), while the variables in $\boldsymbol{x}_2$ and $\boldsymbol{z}_1$ provide one instrument each ($\boldsymbol{Q_v x}_2$ and $\boldsymbol{z}_1$). The order condition for identification gives the result that the number of columns in $\boldsymbol{x}_1$ must be at least as large as the number of columns in $\boldsymbol{z}_2$.

Amemyia and MaCurdy (1986) suggests the following set of alternative instruments:

$$\boldsymbol{A} = (\boldsymbol{Q_v\, x}_1, \boldsymbol{Q_v\, x}_2, \boldsymbol{x}_1^{*}, \boldsymbol{z}_1)$$

where $\boldsymbol{x}_1^{*}$ is a NT x TK matrix where each column contains values of $\boldsymbol{x}_{1it}$ for a single time period. The AM estimator uses each of the $\boldsymbol{x}_1$ variables as $(T+1)$. Its order condition for existence is that T times the number of columns in $\boldsymbol{x}_1$ must be greater than or equal to the number of columns in $\boldsymbol{z}_1$. As shown by Amemyia and MaCurdy (1986), consistency of the AM estimator will depend on a stronger exogeneity assumption than the HT estimator. While the HT estimator requires only the means of the $\boldsymbol{x}_1$ variables to be orthogonal to the individual effects, the AM estimator requires orthogonality at each point in time. Nevertheless, as Amemyia and MaCurdy (1986) and Breusch, Mizon and Schmidt (1989) point out, orthogonality between $\boldsymbol{P_v\, x}_1$ and the individual effects $\boldsymbol{n}$ is likely to result from the orthogonality between $\boldsymbol{x}_1^{*}$ and $\boldsymbol{n}$.

Fertilizer and credit use equations

The IV methods described above are employed to estimate the parameters of the production function and of the demand for cultivated land. Fertilizer and credit use are both censored at zero, which requires a Tobit specification. We use two types of estimators: (i) Bo Honore's (1992) trimmed least squares estimator (TLS) for fixed-effects panel data models, and a simulated maximum likelihood (SML) estimator which assumes a farmers specific random effect which is assumed orthogonal to the the explanatory variables (for a description of SML estimators for panel data Tobit type models, see…).

3 RESULTS AND CONCLUSIONS

To look at the issues discussed earlier in more detail, we estimate a production function, plus associated demand function for land, fertilizer, and credit on panel data from the 1993/94 and 1994/95 PHS surveys. While the time period considered is short, it coincides with significant exogenous variation thus allowing us to estimate a production function as explained in above. Time-varying explanatory variables are: log-area, log-fertilizer used, log-household population, the value of the cattle herd, the stock of draught animals (oxen) and farm equipment, the amount of credit received, weather variables,[4] their interaction with oxen, a time trend, and 60 interaction terms between the time trend and the district dummies. The time-invariant explanatory variables are: sex of the household head, access to extension, primary and secondary education dummies and sixty district dummies.[5] Main results for the production function estimates as derived from instrumental variable estimators are summarized in table 1.

Area cultivated has by far the strongest impact on output with an estimated elasticity between 0.63 to 0.72. Availability of *family labor* is an important determinant of output, indicating that labor markets in rural Zambia are thin or non-existent. The elasticity of output with respect to household population is between 0.07 and 0.12, suggesting that even once other factors such as area, fertilizer use, and ownership of oxen are controlled for, larger households tend to be more productive than small households. The rationale for such a relationship is that, as one would expect in an environment where land is relatively abundant, larger households would have less difficulty to muster the necessary labor to complete critical tasks during seasons of peak demand (e.g. weeding) when spot labor markets dry up. Total household size is also by far the most important determinant of demand for cultivated land. The estimated elasticity is between 0.25 and 0.42, suggesting that the amount of area cultivated increases less than proportionately with household size.[6] Ownership of *draught animals* provides multiple advantages by allowing households to cultivate more area, by providing manure that could be used to enhance soil-fertility, and by possibly serving as a collateral to obtain credit. Indeed we find that a 1000K (approximately $1) increase in the value of draught animals and implements increases total factor productivity between .014% and .039%. Providing a farming household with a pair of oxen (which has a mean value of K 310,000 in the sample) would increase output between 4.3% and 12% per year, even if area cultivated and all other inputs stayed the same, pointing to the presence of significant imperfections in the markets for draught animals. Moreover, as indicated by the negative coefficient of the interaction between oxen and planting season rainfall, the positive effect of oxen ownership (plus implements) on TFP is amplified when rainfall is below the long term historical average. The intuition underlying this is straightforward: As the soil hardens up during the dry season, farmers are unable to till until after the first rains. If these rains are delayed (as captured by them being below the long-term average) possession of animals would allow to complete planting a given area faster and thus minimize the yield loss incurred. Obviously, owners would tend to till their own fields before renting out to others, which could account for the significance of the sign in drought but not in normal years. This would imply that farmers who own draught animals are –at least to some extent- less vulnerable to climatic shocks.

Taking all of these effects together ox ownership would increase household income by about 22% or K 56,000 per year. Even with a real interest rate of 15%, the capitalized value of this benefit would be greater than the cost of the oxen, suggesting that even in a high-interest rate environment, and neglecting indirect benefits, acquisition of oxen would be a profitable investment and that the issues involved should be explored in more detail.[7] While the value of the cattle herd owned by the household is significant (indicating the positive contribution to household income), its magnitude is much lower than the coefficient on the value of draught animals.

The data also allow ascertaining the impact of *fertilizer* on output without the biases induced by unobserved land quality and farmer skills which commonly plague cross-sectional analysis. We find that the output elasticity of fertilizer varies between 0.07 and 0.08. This suggests that, at the mean level of fertilizer application among the producers who have access to fertilizer the marginal benefit from applying

[4] Based on monthly precipitation data we construct a variable for the percentage deviation of precipitation from its 30-year mean during the planting season, as well as two growing and one harvesting seasons and introduce this variable both by itself as well as squared, cubed and raised to the forth power and, to account for the possibility that farmers who own animals may be able to perform operations in a more timely manner, interacted with the value of the farm's stock of draught animals and farm equipment. Among these variables, log-household population, the non-interacted weather variables, the time trend and the district dummies-time trend interactions are assumed to be exogenous while the remainder are assumed to be endogenous (i.e., correlated with unobserved individual effects).

[5] Extension and the education dummies are assumed to be endogenous while the remaining time-invariant explanatory variables are assumed exogenous.

[6] Part of this may be due to the fact that our data provide only the number but not the age of household members, thus making it impossible to adjust for labor quality.

[7] The purpose of this example is to highlight the implication from regression results rather than to provide an in-depth economic calculation. We therefore implicitly assume that the cost of feeding the animal is approximately equal to the indirect benefits such as manure, milk, beef, insemination services, etc. from the animal that are not captured in our output measure.

additional fertilizer is slightly lower than marginal cost, suggesting that (if prices equal real cost) there is no indication for supply-side problems.[8] By contrast, providing producers who are rationed out of the fertilizer market with access to moderate amounts of fertilizer can increase their welfare – providing the average amount of fertilizer applied by users (170kg) to a producer without access would increase her income by between US $ 80 and 90, more than the US$ 50 that would be incurred in buying the input, thus suggesting that fertilizer supply through the private sector (and even on credit) should be feasible – and might actually lead to more productive use of this input than the current practice of Government intervention that undermines private sector entry and, in addition to being costly, is associated with severe non-price rationing.

Results also indicate a positive and statistically significant (at the 5% level) relationship between the amount of *credit* received and total factor productivity. An extra $100 (100,000 K) of credit received by an average farm household, is expected to increase output by between 2.6 and 4%, even when cultivated land and fertilizer use are held constant. This is surprising, as one would normally expect any impact of credit on total factor productivity to come through the higher input use it facilitates. One possible explanation is that lenders have an incentive to monitor the behavior of their borrowers and provide advice in the process or that credit constraints are preventing farmers from diversifying into higher value commodities. While either of these explanations would support the government's emphasis on outgrower schemes in an attempt to alleviate the credit constraints that prevent small producers from adopting more profitable techniques and output combinations, they also suggest that lenders in regular credit markets – where repayment is appropriately enforced- would be able to perform some of the supervisory functions that Government appreciates in formal outgrower schemes – possibly even at lower cost.

To illustrate the magnitude of the effects involved, we note that increasing access to credit from zero to the mean value for the sample of credit users (K 150,000) would, according to the estimates, augment output of non-users by about 18% (K 51,000). This increase in production results from a predicted 21% increase in cultivated area (to 1.90 hectares) and a 3% increase in total factor productivity.

Despite being as productive as male-headed households (in total factor productivity terms), *female-headed households* cultivate significantly less area (39%), receive only about half of the mean credit amount in the sample, and also use significantly less fertilizer, *ceteris paribus*. Thus, even after controlling for access to credit, imperfect labor markets appear to make it difficult for female headed households to secure the resources to undertake crop production at the same scale as their male colleagues.

The state of rural *infrastructure* is often viewed as a major obstacle to expansion as well as diversification of agricultural production. Our estimates indicate that, while a producer's distance to markets does not affect total factor productivity, it does have a significant negative effect on cultivated area. Increasing market distance by 10 km would directly reduce area cultivated by 7%, in addition to being associated with lower amounts of fertilizer and credit use.

Concerning *education*, we find that completion neither of primary nor of secondary education does (in the IV estimates) not have a significant impact on total factor productivity or on the amount of land cultivated. However, higher levels of education do to enhance producers' ability to overcome imperfections in markets for credit and fertilizer; secondary education increases fertilizer consumption and both education variables have a positive impact on credit use. While surprising at first glance, this result is consistent with the literature which indicates that education has an impact on productivity only in dynamic environments characterized by rapidly changing technology.

Given the considerable amount of resources spent on providing farmers with *extension*, it is of interest to ascertain the impact of supply of extension services on agricultural production and input use.[10] The share of individuals in any given village who have access to extension (excluding the producer under concern) has a positive but statistically insignificant impact on total factor productivity. This suggests that

[8] Increasing the amount of fertilizer applied by 1% (1.3kg) would, at a price of 390 K, increase output by of

[9] Uassumptions discussed in the the estimators are not biased by the likely correlation between unobserved managerial skills and credit access.

[10] Actual demand for extension is generally associated with individual-specific characteristics that are unobservable to us. The coefficients obtained in a regression where individual access to extension is used as independent variable would thus generally be biased upward. To avoid this problem, we use the share of producers who have access to extension in a given enumeration area – which is more likely to capture (exogenous) supply of extension services rather than (endogenous) demand-- as independent variable. The fact that access to extension is measured only at one point in time forces us to use IV estimates.

improving incentives and messages for the existing extension service would be important and that the possibility of sub-contracting and greater private sector involvement should be seriously considered to fully realize the existing potential. If it is true that, in a rapidly changing environment, extension enables farmers to quickly diversify and adapt to market signals, public funding of this activity would –in view of the significant spillover effects that are generally associated with it- still be justified.

References:

Amemyia, T. and T.E. MacCurdy, (1986), "Instrumental variables estimation of an error components model", *Econometrica*, **54**, 869-880

Breusch, T.S., G.E. Mizon and P. Schmidt, (1989), "Efficient estimation using panel data", *Econometrica*, **57**, 695-700.

Deininger, Klaus, Pedro Olinto, Mukata Wamulume, and Dennis Chiwele, "Agricultural sector performance in a post-reform environment: Implications for second generation reforms in Zambia, World Bank, mimeo.

Gourieroux, C. and A. Monfort (1993). "Simulation-Based Inference: A Survey with Special Reference to Panel Data Models," *Journal of Econometrics*, 59:5-33.

Hausmann, J. A. and W. Taylor, (1981) "Panel data and unobservable individual effects", *Econometrica*, **49**, 1377-1399

Honoré, B.E. (1992). "Trimmed LAD and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects," *Econometrica* 60:533-565.

Mundlak, Y., (1996), "Production Function Estimation: Reviving the Primal", *Econometrica*, **64**, 431-438.

Table 1: Summary of regression results

	Production function equation				Land demand equation			
	Within estimator		IV Estimator		Within estimator		IV Estimator	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
ln(area)	0.6292	46.8726	0.7157	37.322				
ln(HH population)	0.1238	5.6355	0.0908	3.857	0.247	12.6558	0.4185	7.6
Value of Cattle (1000ks)	0.0001	9.189	0.0001	8.018	0	1.6613	0	1.208
Credit Received (1000ks)	0.0003	3.1614	0.0004	4.122	0.001	15.2649	0.0016	5.407
Value of Oxen + Implements (1000ks)	0.0004	4.2267	0.0001	2.455	0.0002	2.5575	0.0008	8.171
ln(Fert+1)	0.0723	17.1508	0.0755	5.684				
Dummy for 95	-0.7321	-2.7064	0.337	2.841	-0.125	-5.982	-0.1683	-2.651
Rainfall dev, planting period	0.114	4.7054	0.0198	1.993	0.0072	6.0029	0.0079	2.715
Rainfall dev squared	-0.0047	-4.373	-0.0005	-1.071	-0.0001	-3.8391	-0.0002	-3.056
Rainfall dev cubic	-0.0001	-4.4121	0	-1.267				
Rainfall dev forth	0	4.4256	0	1.263				
Rainfall dev, growing period	0.0056	6.2458	0.0019	3.876				
Rainfall dev, harvest period	-0.0092	-3.687	0.0005	0.511				
Rainfall dev X Fertilizer	-0.0008	-6.1354	-0.0004	-1.928				
Rainfall dev X Oxen	0	-2.0854	0	-3.001	0	-6.7952	0	-0.821
Rainfall dev X Oxen squared					0	5.5469	0	2.426
Rainfall dev X HH pop	0.0001	0.235	-0.001	-1.207	-0.0017	-2.8529	-0.0015	-1.231
Rainfall dev X HH pop squared					0	1.9335	0.0001	2.503
Sex of head (1 = female)			-0.0691	-0.703			-0.4231	-1.512
Dist. To market			-0.003	-0.172			-0.0915	-1.725
District Extension %			0.0109	1.456			-0.0223	-1.392
Primary education			-0.0463	-0.099			-1.0837	-0.863
Secondary education			0.3193	0.668			0.5431	0.585

Table 2: Demand for Fertilizer / ha.

EXPLANATORY VARIABLES	*SML estimator*		*TLS estimator*	
	ESTIMATES	*STD. ERRORS*	*ESTIMATES*	*STD. ERRORS*
Intercept	-3.01**	0.22		
Time Trend (T)	-0.41**	0.12	-0.59**	0.13
Log of HH adult population (POP)	1.01**	0.09	0.54**	0.18
Credit Received (1000 Ks)	0.48**	0.02	0.13*	0.07
Cattle Stock (1000 Ks)	0.05	0.07	0.11	0.10
Draught Animals and Implements (1000 Ks)	1.21**	0.25	0.46	0.77
DM01	-0.01**	0.00	-0.04	0.04
Sex of HH's head (Women = 1)	-0.68**	0.13		
Distance to Markets	-0.22**	0.02		
Extension	-0.15	0.20		
Primary education	-0.09**	0.12		
Secondary Education	1.53**	0.11		
σ^2	3.34**	0.01		
Mean Log- Likelihood	-1.10792			
Number of Observations	9706		9706	

* Indicates statistically different from zero at the 10% significance level.

** Indicates statistically different from zero at the 5% significance level.

Table 3: Credit Use Equation

EXPLANATORY VARIABLES	*SML estimator*		*TLS estimator*	
	ESTIMATES	*STD. ERRORS*	*ESTIMATES*	*STD. ERRORS*
Intercept	-450.65**	36.94		
Time Trend (T)	-161.94**	13.98	-170.48**	28.97
Log of HH adult population (POP)	113.35**	13.69	112.22**	56.31
Cattle Stock (1000 Ks)	-37.44**	13.98	-56.11**	29.13
Draught Animals and Implements (1000 Ks)	386.62**	56.84	333.18	236.07
Sex of HH's head (Women = 1)	-90.40**	18.23		
Primary education	5.80**	1.54		
Secondary Education	64.80**	15.93		
Distance to Markets	-34.98**	2.94		
s^2	359.20**	19.83		
Mean Log- Likelihood	-1.27			
Number of Observations	9706		9706	

* Indicates statistically different from zero at the 10% significance level.

** Indicates statistically different from zero at the 5% significance level.

Table 4: Agricultural production

	Total production value			Area cultivated			Fertilizer use		
	1990/91	1995/96	Change	1990/91	1995/96	Change	1990/91	1995/96	Change
	Million US $		%	1000 ha		%	1000 MT		%
Central	38.20	25.89	-32.24	144.37	141.25	-2.16	24.39	8.90	-63.51
Copperb.	6.49	11.51	77.54	40.44	49.33	22.00	3.56	3.63	1.72
Eastern	70.28	57.67	-17.94	286.45	278.59	-2.74	31.37	7.52	-76.04
Luapula	20.99	21.79	3.81	46.34	99.80	115.37	1.32	3.03	130.12
Lusaka	2.29	4.49	95.83	11.68	24.11	106.54	2.43	2.07	-14.81
North	41.09	42.02	2.25	157.28	256.34	62.98	20.56	8.69	-57.75
Northwest	17.55	11.17	-36.36	53.57	52.53	-1.93	2.08	1.67	-19.71
South	43.45	34.90	-19.67	227.53	204.44	-10.15	27.36	7.19	-73.73
West	14.33	11.67	-18.56	101.33	100.53	-0.79	5.05	1.08	-78.71
All Zambia	254.68	221.12	-13.18	1115.09	1274.92	14.33	118.14	43.77	-62.95

Source: Own calculation from PHS data (various years)

Table 5: Crop-level indicators of agricultural production

	Area cultivated 1000 hectares					
	1990/91	1995/96	1996/97	Change	1990/91	1995/96
Maize	624.80	675.57	649.04	3.88	1835	1888
Cassava	138.59	188.95	250.38	80.66		1809
Groundnut	112.60	89.49	126.57	12.41	510	549
Millet	54.62	76.93	85.73	56.97	786	1193
Cotton	46.84	66.22	101.00	115.62	1339	1232
Sunflower	46.54	47.62	20.75	-55.43	468	714
Sorghum	42.27	47.89	44.68	5.72	879	851
Bean	23.03	43.24	41.54	80.35		539
Rice	12.43	9.89	12.41	-0.11	1386	1336
Soybean	11.40	25.49	17.27	51.56	645	917
Tobacco	1.05	3.65	4.81	355.88		2117
Total	1114.17	1274.94	1354.19	21.54		

Source: Own calculation from PHS data (various years)

Table 6: Indicators of technology level

	Fertilizer use			***Use of hybrid seed***			***Cattle ownership***			***Maize share (area)***		
	1990/91	1995/96	Change	1990/91	1995/96	Change	1990/91	1995/96	Change	1990/91	1995/96	Change
	Share of producers		%	Share of producers		%	Share of producers		%	Percentage		%
Central	51.03	33.31	-34.73	49.95	24.10	-51.74	22.34	13.97	-37.46	0.687	0.699	1.73
Copperb.	23.47	33.14	41.21	20.02	18.88	-5.69	1.51	4.11	172.37	0.939	0.815	-13.24
Eastern	37.56	17.61	-53.10	12.15	2.30	-81.06	19.14	16.25	-15.07	0.721	0.766	6.28
Luapula	8.94	13.43	50.34	7.56	8.40	11.04	0.48	0.30	-38.92	0.702	0.423	-39.76
Lusaka	53.03	26.39	-50.24	66.06	23.97	-63.72	28.58	11.29	-60.49	0.879	0.928	5.57
North	39.40	22.64	-42.53	27.36	10.85	-60.33	6.89	6.11	-11.30	0.886	0.451	-49.15
Northwest	15.14	13.01	-14.08	11.16	5.51	-50.66	7.40	6.03	-18.48	0.531	0.605	13.90
South	42.96	26.66	-37.95	49.16	36.79	-25.17	44.79	33.09	-26.13	0.760	0.806	5.95
West	12.30	4.16	-66.19	18.35	7.25	-60.48	26.28	15.85	-39.69	0.640	0.647	1.01
Total Zambia	31.36	19.91	-36.51	24.79	13.41	-45.90	18.03	12.82	-28.89	0.735	0.691	-5.89

Source: Own calculation from PHS data

Table 7:
Marketparticipation

	Output markets			*Value of sales*			*Credit markets*			*Avg. credit received*		
	1990/91	1995/96	Change	1990/91	1995/96	Change	1993/94	1995/96	Change	1993/94	1995/96	Change
	Share (pct)		%	1000 Kw		%	Share (pct)		%	1000 Kw		%
Central	49.21	52.60	6.89	396.39	293.23	-26.03	18.26	4.48	-75.49	337.12	150.82	-55.26
Copperb.	45.20	55.73	23.30	153.48	291.81	90.13	2.28	6.03	163.84	152.61	216.74	42.03
Eastern	46.16	49.97	8.27	373.17	315.58	-15.43	21.49	18.64	-13.26	189.66	83.38	-56.04
Luapula	23.19	35.54	53.25	300.66	201.04	-33.13	9.44	5.55	-41.27	172.30	124.51	-27.73
Lusaka	42.45	27.82	-34.47	273.09	169.38	-37.98	22.14	3.32	-85.02	121.09	310.51	156.44
North	40.64	51.45	26.60	304.17	265.56	-12.69	13.48	5.15	-61.80	238.43	134.02	-43.79
Northwest	33.15	49.05	47.99	251.13	202.83	-19.23	4.52	4.21	-6.78	119.29	121.59	1.92
South	40.54	32.75	-19.23	382.74	312.21	-18.43	10.58	5.15	-51.36	454.40	121.96	-73.16
West	19.92	16.12	-19.08	130.10	118.90	-8.61	1.97	2.55	29.51	340.53	124.01	-63.58
Total Zambia	37.99	42.21	11.13	300.99	254.42	-15.47	12.93	7.57	-41.49	244.03	111.63	-54.26

Source: Own calculation from PHS data
Note: Value of sales/credit received is average for market participants in thousands of 1996 Kw

Table 8:
Access to credit over time for the same producers

	Share receiving credit			*Mean amount received*			*Reasons for not applying (96)*					
	1993/94	1994/95	1995/96	1993/94	1994/95	1995/96	No Interest	Other	Down payment	Interest high	Bank too far	Defa
	Percent of producers				1000 K							
Central	4.60	1.06	5.04	489.83	306.42	150.823	35.74	23.66	20.45	10.98	7.54	1.
Copperb.	4.52	5.48	6.20	239.66	195.82	216.744	33.43	18.75	23.69	17.01	5.52	1
Eastern	6.11	8.37	19.02	140.13	65.76	83.384	34.75	23.75	15.25	13.5	9.75	
Luapula	2.74	2.02	5.96	149.75	115.40	128.796	44.39	24.47	15.11	9.08	5.28	1.
Lusaka	3.29	2.08	4.12	129.35	309.67	310.508	39.09	27.08	22.92	4.29	5.76	0.
North	4.95	3.01	5.22	140.74	120.64	134.515	30.83	29.32	17.29	14.29	7.52	0.
Northwest	3.19	3.07	4.26	88.58	93.81	121.585	27.1	25.93	20.96	12.86	10.81	2.
South	3.15	2.59	5.16	260.61	92.74	122.207	27.97	17.05	29.69	14.75	7.66	2.
West	1.89	0.75	2.71	310.19	216.91	124.01	43.55	21.49	19.86	8.59	5.46	1.
All Zambia	4.12	3.58	7.84	202.32	106.98	111.971	36.17	24.11	19.74	9.81	9.46	0.

Source: Own calculation from PHS data

Table 9: Domestic resource cost for main commodities under different types of cultivation

	Smallscale	Emergent	Commercial
Maize	0.35	0.29	0.46
Sorghum	0.67	0.32	0.55
Millet	0.18	0.23	
Rice	1.10	1.00	
Sunflower	0.31	0.48	0.57
Soyabean	0.74	0.63	0.56
Groundnut	0.50	0.53	
Cotton	0.21	0.23	0.20
Tobacco	0.29	0.33	0.32

Source: Keyser (1996)