An empirical analysis of factors affecting the productivity of livestock in southern Botswana

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Abstract

This study attempts to identify factors responsible for differences in the productivity of cattle managed by private and communal livestock farmers in the southern region of Botswana during 1999/2000. Sample survey data are used to estimate the parameters of a block recursive regression model. Some of the equations postulated in the model are estimated with two-stage least squares (2SLS) to account for likely correlation between endogenous explanatory variables and the error term. The results show that (a) respondents with secure land tenure (private farms) and larger herds use more agricultural credit than do those who rely on open access communal grazing to raise cattle; (b) secure tenure and higher levels of liquidity from long-term credit and off-farm wage remittances promote investment in fixed improvements to land; (c) liquidity from short-term credit and wage remittances supports expenditure on operating inputs; and (d) herd productivity increases with greater investment in operating inputs and fixed improvements, and is therefore positively (but indirectly) influenced by secure land tenure.

It can be inferred that government should (a) uphold private property rights to land where they already exist; (b) privatise open access grazing to individual owner-operators where this is politically, socially and economically feasible; and (c) where privatisation to individuals is not feasible, government should encourage users to convert the grazing into common property by subsidising the transaction costs of defining user groups and the boundaries of their resources, and of negotiating and enforcing rules limiting individual use of common property. This first-step in a gradual shift towards private property might be followed by a conversion of user-groups into non-user groups organised along the lines of investor-owned firms where members exchange use rights for benefits rights.

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1. Introduction

This paper aims to identify factors thought to explain differences in the productivity of cattle managed by farmers in southern Botswana. The study was prompted by claims of poor herd performance, especially amongst communal farmers in Botswana. The livestock sector in Botswana is characterised by two distinct systems of land tenure, namely; communal grazing - an open access resource that accounts for 86% of the cattle and 71% of farmers in Botswana. Private grazing is characterised by secure land rights and accounts for 14% of the national cattle herd and five percent of the land area (Ministry of Agriculture, 1991).

An open access resource means that users have unrestricted use of the resource. Although the Ministry of Agriculture specifies maximum stocking rates for communal areas, these limitations are not enforced by local Land Boards nor are they observed by communal farmers (Carl Bro International, 1982). In addition, water rights assigned to farmers in communal areas do not impose any restrictions on the volume of water used or the number of animals kept by stockowners (Carl Bro International, 1982). High stocking rates in the communal areas have been linked to high soil erosion, land degradation and a general decline in Botswana's national herd from over three million in the early 1980's to about 2.4 million in the 1990's (Ministry of Agriculture, 1991).

The study is important because livestock make a significant contribution to the livelihood of farmers in Botswana. Livestock, especially cattle, are a major source of meat and milk, and provide a store of wealth (Ministry of Finance and Development Planning, 1996). As producer goods, cattle supply draught power, reproduce and increase the herd size. Cattle offer a hedge against inflation and can be readily converted into cash in times of need (Ministry of Agriculture, 1989; Fidzani, 1993:1). Beef exports account for most of the foreign exchange earned by agriculture because crop farming is severely constrained by erratic and unreliable rainfall (Behnke, 1987; Ministry of Agriculture, 1991; Panin *et al*, 1993; Abel, 1997; Panin & Mahabile, 1997; Mahabile *et al*, 2002). Cattle account for about three percent of Botswana's Gross Domestic Product (GDP) and for most of agriculture's share of GDP (Central Statistics Office, 1995; Ministry of Finance and Development Planning, 1996:11). Moreover, ranching is an important source of employment in rural Botswana where the majority of households live in communal areas and depend largely on cattle as a source of income (Ministry of Agriculture, 1989). The Bank of Botswana (1999:68) attributes about 16% of rural employment in 1999/2000 to the agricultural sector.

This paper begins with a discussion on herd productivity and land tenure systems. Section 3 describes the technique used to collect data and postulates a block-recursive regression model to identify the determinants of herd productivity. Section 4 presents and discusses descriptive statistics and the estimated regression model. The paper concludes with policy implications.

2. Herd productivity and land tenure systems

There is a strong view that the productivity of the livestock sector in Botswana is primarily influenced by land tenure status. Economic theory suggests that land tenure institutions influence decisions about stocking rates (Gordon, 1954) and investments in improvements and operating inputs (Place *et al*, 1994:16-17). Gordon (1954) shows that an open access resource will be used at an equilibrium rate when the private cost (Pc) of exploiting the resource is equal to the value of the herd's average product (VAP). At this point the resource is over-utilised in the economic sense (and possibly in the biological sense) because rents are zero. This is a departure from the profit maximising neoclassical model where property rights are presumed to be exclusive. In this case, the profit maximising equilibrium is reached when Pc is equal to the value of the herd's marginal product (VMP).

Stocking rates are therefore expected to be higher on open access communal grazing lands than on privately owned farms, *ceteris paribus*. Conversely, herd productivity is expected to be lower on open access communal grazing land. In KwaZulu-Natal where tenure conditions follow a pattern similar to those observed in southern Botswana, Lyne and Nieuwoudt (1990) report much lower calving rates and much higher herd mortality rates in communal areas than on private farms. This study takes the accepted view that herd productivity improves with a higher calving rate and with a lower mortality rate. By implication, a higher off-take rate (sales and slaughter) is also an objective measure of better herd productivity (Hubbard, 1986:46; Scoones, 1992; Ministry of Finance and Development Planning, 1996:19; Lange *et al*, 1998). Upton (1993) expresses herd productivity in his 'herd growth model' as a function of calving, mortality, off-take rates and other production traits such as yield of milk and draught power.

There is no incentive for a communal farmer to reduce the size of his own herd, or to finance fixed improvements (such as boreholes to water livestock), on open access grazing land because the benefits would accrue largely to free-riders. Lyne and Nieuwoudt (1990) refer to the low investment problem as the 'real tragedy of the commons'. Under-investment in fixed improvements leads to under-investment in operating inputs (Place & Hazell, 1993). Kille and Lyne

(1993) also anticipate lower investment in operating inputs applied to open access resources owing to allocative inefficiency. This problem arises because there is no market for open access land owing to prohibitively high transaction costs. By contrast, the market for privately-owned farmland creates an opportunity cost for under-utilised land that encourages the owner to sell or rent the land out to more effective farmers (Place *et al*, 1994:17; Nieuwoudt, 1990).

Private farmers whose land tenure is secure (in the economic sense of possessing fully exclusive and transferable property rights) have a stronger incentive to invest in fixed improvements as they have a much higher probability of internalising the benefits of their investment (Place & Hazell, 1993; Graham & Darroch, 2001). In Botswana, these farmers also find it easier to finance improvements because there is a market for privately owned land. Banks do not accept land as collateral for loans unless it has market value (Place *et al*, 1994:17; Kille & Lyne, 1993; Migot-Adholla *et al*, 1991). An active land market strengthens incentives to improve land because capital gains can be realised at any time by selling or leasing out (Pasour, 1990:200-201). Improvements to land and livestock tend to raise the productivity of operating inputs, encouraging more intensive use of supplementary feed and medications that prevent disease and injury.

For these reasons it is postulated that herd productivity and investment indicators in southern Botswana will be higher on private ranches than on (open access) communal grazing land. This hypothesis is consistent with the 1991 policy objective of converting open access grazing into common and private property (Ministry of Agriculture, 1991; Ministry of Finance and Development Planning, 1998-2003:247) and with the view that common property user-groups should be converted into non-user groups resembling company operations. In this case, members of the group surrender their use rights for benefit rights by exchanging livestock for equity (shares) in the operating entity, they hire or elect experts to manage the farm, and share profits in proportion to their own equity contributions (Lyne & Graham, 2001). To test the hypothesis, this paper develops and estimates a block-recursive regression model of the relationships anticipated between secure land tenure, agricultural credit, investment in fixed improvements to land, investment in operating inputs, herd productivity and relevant household and farmer characteristics.

3. Methodology

The data used in this study were gathered in a sample survey of 96 livestock owners in the southern region of Botswana during 1999/2000. The southern

region is representative of most other cattle-farming regions in terms of terrain, rainfall patterns and population characteristics (Ministry of Agriculture, 1980:4). Rainfall is typically low, averaging about 550mm per annum (Ministry of Agriculture, 1980:4-5). The study area comprised of two strata, one for communal farmers and the other for private farmers to ensure variation in land tenure arrangements. Households with cattle were identified and listed, and a simple random sample was drawn from each list. A total of 65 (black) communal farmers and 31 (30 black and one white) private farmers were interviewed using a pre-tested and structured questionnaire. Although a larger sample (n=120) was drawn, several of the selected farmers had left the study area and some were not willing to participate in the survey. Additional cases were not selected owing to the high cost of travelling long distances between farmers, especially those on private ranches.

Interviews were conducted over a period of nine months with the assistance of four enumerators who speak both Setswana and English. Questions were addressed to the household head in all cases. The data were captured in a computerised database, and analysed using the Statistical Packages for Social Science version 10 (SPSS, 1999). Estimates of mean herd size, herd composition, and the off-take, calving and mortality rates compared favourably with national and regional statistics obtained from the Ministry of Agriculture (2000), Central Statistics Office (1999) and the Botswana Meat Commission (2000).

Independent t-tests were calculated to check for significant differences between group means computed for private and communal farmers (SPSS, 1999:108-112; Gujurati, 1995:122-127; Koutsoyiannis, 1977:86-91). Table 1 presents the group means and their t-values for relevant variables. Land tenure status was measured as a dummy variable scoring one for private farmers and zero for communal farmers. Zero-order correlation coefficients were also computed to assess the degree of linear association between pairs of variables relevant to the objective of the study. Variables that were strongly correlated were subjected to Principal Components Analysis (PCA) to reduce multicollinearity between explanatory variables included in the block-recursive regression model. The model was estimated using OLS and 2SLS regression techniques as suggested by Place *et al* (1994:28-30).

3.1 Principal component analysis (PCA)

The main aim of principal component analysis (PCA) is to transform the original set of variables, X_j's (j = 1,2… p) into a new set of variables called principal components (Y_i) which are linear combinations of the old variables.

The model for PCA is expressed as follows:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + \ldots + a_{1P}X_P$$
$$Y_2 = a_{21}X_1 + a_{22}X_2 + \ldots + a_{2P}X_P$$
$$\vdots$$
$$Y_P = a_{P1}X_1 + a_{P2}X_2 + \ldots + a_{PP}X_P$$

Where Y_i represents the ith principal component, a_{iP} the loading coefficients and X_P the original variables (Koutsoyiannis, 1977: 424; Anim & Lyne, 1994). Principal component analysis is another example of a mathematical maximisation procedure where each successive component accounts for the maximum amount of variance remaining in the original data (Stevens, 1986:75-376; Maddala, 1977:193) and where the principal components are orthogonal or uncorrelated. Principal component analysis can be used to economise on variables, to analyse relationships between variables or, as is in this study, to address the problem of multicollinearity (Koutsoyiannis, 1977:424-436).

3.2 Recursive regression model

The regression model was postulated as follows:

(a) $c = f(X^a, T, H)$
(b) $l = f(X^a, T, C_L)$
(c) $i = f(X^a, C_S, l)$
(d) $h = f(l, i)$

where c represents the present value of agricultural credit (expressed in 2000 prices) used to finance past fixed improvements and current operating expenses, l measures past investment in fixed improvements to land, i is current investment in operating inputs per livestock unit, and h represents herd productivity. The vector X^a represents household and farmer characteristics, T is land tenure status, H the herd size, and C_L and C_S are separate measures of the present value of credit used to finance past fixed improvements and current operating expenses respectively. An important and realistic assumption underlying this model is that tenure is predetermined, i.e. farmers cannot change their initial property rights at will. The variables c, l, i and h are endogenous. For this reason only equations (a) and (b) can be estimated using OLS regression. In equations (c) and (d) the endogenous explanatory variables must be replaced with instrumental variables to eliminate correlation with the error term. For this reason, 2SLS regression was

used to estimate equations (c) and (d) with the instrumental variables predicted from all of the exogenous variables in the model.

Equation (a) argues that the present value of (long plus short-term) agricultural credit is positively influenced by secure land tenure (private ownership), higher liquidity and a larger herd size (wealth). Positive relationships are expected because farmers with greater wealth and liquidity are more creditworthy as they have more collateral and better repayment ability (Stanton, 1997). Private ownership of land not only strengthens the incentive to invest but also adds to the owner's stock of wealth and collateral as argued in Section 2. The household and farmer characteristics include family size, off-farm income, marital status and the farmer's age, education and gender (a dummy variable scoring one for male farmers and zero for females). Off-farm wage income is a relatively important and reliable source of liquidity for many rural households and is therefore expected to impact positively on access to credit owing to better debt-servicing ability. Age could also carry a positive sign as it measures accumulated farming experience and social standing. A high social standing can reduce transaction costs (Goetz, 1992). On the other hand, age could carry a negative sign as older farmers may be more risk averse and less inclined to innovate than younger farmers (Basabrain, 1983). Education is expected to impact positively on the use of credit because it reduces transaction costs in formal markets and enhances allocative efficiency, so improving a farmer's creditworthiness (Fidzani, 1993:188). Gender may also influence transaction costs and creditworthiness. Fenwick and Lyne (1999) argue that this is true in rural KwaZulu-Natal where women married under customary law create greater legal uncertainty for lenders. In Botswana, women married in community of property (including women married under customary law) cannot borrow without legal consent from their husbands.

Equation (b) postulates that investment in fixed improvements is positively influenced by private ownership and better access to long-term credit. Secure land tenure strengthens the farmer's incentive to invest. Few improvements are expected where land tenure is insecure as future returns are discounted at a high rate owing to uncertainty (Kille & Lyne, 1993). In this case, uncertainty stems largely from future returns lost to other stockowners (free-riders) who share inclusive rights to communal grazing. Access to long-term credit improves a farmer's ability to finance fixed improvements. Positive collinearity between secure tenure and the present value of long-term credit is likely in view of the arguments presented in section 2. Household and farmer characteristics are included largely as control variables although education is expected to carry a positive sign as it serves as a proxy for permanent income

(Graham & Darroch, 2001) and family size is expected to carry a negative sign owing to a trade-off between consumption and investment. Age on the other hand is expected to carry a positive sign as it proxies experience and exposure to investment opportunities.

Equation (c) states that current investment in operating inputs per livestock unit is positively influenced by fixed improvements to land and better access to short-term credit. Again, the ability to finance operating inputs is expected to improve with better access to short-term credit, while investment in fixed improvements is expected to increase the productivity of these inputs so strengthening the incentive to purchase them Place & Hazell, 1993). Hayes *et al*, (1997) show that investment in wells positively influenced expenditure on commercial inputs in the Gambia. Household and farmer characteristics are included largely as control variables with expected signs similar to those postulated for equation (b). Pudasaini (1983) found that better education raised agricultural productivity in Nepal.

Equation (d) expresses herd productivity as a positive function of past investment in fixed improvements and current investment in operating inputs per livestock unit. Fidzani's (1993) study of cattle off-take rates in Botswana supports Place *et al*'s (1994:28-29) argument that investment in fixed improvements (like boreholes and fences) and operating inputs (such as feed supplements and vaccines) will increase herd productivity. Investment in boreholes, supplementary feed and vaccines is expected to reduce mortality rates and improve calving and off-take rates. Positive collinearity between investment in fixed improvements and expenditure on operating inputs per livestock unit is likely following the logic of equation (c).

For estimation purposes, equations (a) through (d) were specified as follows:

$$c = B_{01} + B_{11}\text{AGE} + B_{21}\text{GENDER} + B_{31}\text{MARRIED} + B_{41}\text{EDUCATION} + B_{51}\text{LIQUIDITY}_1 + B_{61}\text{FAMILY} + B_{71}\text{HERD} + B_{81}\text{TENURE} \quad (1)$$

where;

c = present value of agricultural credit used to finance past fixed improvements and current operating expenses measured in Pula[4],
AGE = age of the household head measured in years,
GENDER = a dummy variable scoring one for male heads and zero for females,
MARRIED = a dummy variable scoring one for married heads and zero otherwise,

[4] *1 Pula = 0.1865 US$ at the time of the survey (2000).*

EDUCATION = years of formal schooling completed by the household head,
$LIQUIDITY_1$ = monthly income remitted by household wage workers measured in Pula,
FAMILY = household size,
HERD = herd size, and
TENURE = a dummy variable scoring one if land is privately owned and zero if it is an open access communal resource.

$$LN\ (l) = B_{02} + B_{12}AGE + B_{22}GENDER + B_{32}MARRIED + B_{42}EDUCATION + B_{52}LIQUIDITY_1 + B_{62}FAMILY + B_{72}C_L + B_{82}TENURE \quad (2)$$

where;

LN (l) = natural log of one plus the present value of investment in boreholes measured in Pula, and
C_L = present value of long-term credit used to finance boreholes, the most frequently observed improvement and the only one for which reliable data could be gathered.

$$LN\ (i) = B_{03} + B_{13}AGE + B_{23}GENDER + B_{33}MARRIED + B_{43}EDUCATION + B_{53}FAMILY + B_{63}LN\ (l) + B_{73}\ (C_S + LIQUIDITY_1) \quad (3)$$

where;

LN (i) = natural log of one plus current expenditure on operating inputs per livestock unit measured in Pula, and
C_S = value of seasonal credit used to finance current operating inputs.
Positive collinearity anticipated between C_S and $LIQUIDITY_1$ was removed by summing the two variables (i.e. C_S + $LIQUIDITY_1$) to create an index called $LIQUIDITY_2$

$$h = B_{04} + B_{14}LN\ (l+i) \quad (4)$$

where;

h = herd productivity measured as the calving rate.

Off-take and mortality rates were not used as measures of productivity because animals in poor condition are sold or slaughtered for own consumption. This tends to understate mortality rates and to overstate off-take rates (Fidzani, 1993:188-189). Positive collinearity anticipated between investment in boreholes

and expenditure on operating inputs per livestock unit was addressed by summing these variables (LN(l+i)).

4. Empirical results

4.1 Farmer characteristics

Table 1 summarises key attributes of sample farmers and their households. No significant differences were detected between the mean age, gender, family size or residential status (where heads residing on their farms scored a one, and zero otherwise) of private and communal livestock farmers. Racial differences were not considered because all but one of the respondents were black. Most herds are managed by older, married men who reside on-farm with their (large) rural families, and who regard livestock farming as their main occupation. These findings are consistent with results from an earlier study in Botswana by Panin (1999).

Table 1: Descriptive statistics for demographic characteristics of 96 stockowners in the southern region of Botswana, 2000 (n=96)

Variable	Unit	Private ranches (n=31)	Open access communal grazing (n=65)	t-value
Average age	Years	55	52	1.37
Gender	% male	94	95	0.40
Average size of household	#	6	7	1.12
Married	%	97	63	4.62**
Residential status	% on-farm	88	92	0.61
Average years of schooling	Years	10	2	8.32**
Average years of farming	Years	31	20	4.85**
Main source of income:				
Farming	%	55	55	
Wage work		10	23	
Other		35	22	
Mean monthly income remitted by wage workers	Pula	2308	715	2.74**
Wage (Pula) per month:				
0-2000	%	61	85	
2001-4000		21	12	
>6000		18	3	
Gross annual livestock income	Pula	98363	3049	1.49

Note: ** shows statistical significance at the one percent level of probability.

Despite these similarities, private and communal farmers in the sample differed on some important household variables. Private farmers appear to have accumulated a much greater stock of human capital through both formal

education and farming experience. In addition, private farmers have much larger cash inflows from wage remittances and livestock sales, and are therefore more liquid than communal farmers.

4.2 Livestock ownership and herd productivity indicators

Sample means and proportions for indicators of herd productivity and investments made by private and communal farmers are presented in Table 2. Average herd size is substantially larger on private farms, as is expenditure on operating inputs per livestock unit (LU) and the incidence of boreholes. Both the calving and off-take (i.e. sales plus slaughter) rates are much higher on private farms than amongst communal farmers. This is consistent with findings reported by Behnke (1987); Scoones (1992) and the Central Statistics Office (1995).

Table 2: Mean productivity and investment indicators for open access and private livestock owners in the southern region of Botswana, 2000 (n=96)

Variable	Unit	Private ranches (n=31)	Open access communal grazing (n=65)	t-value
Number of breeding cows and heifers	#	273	26	4.05***
Number of calves	#	141	8	3.36**
Number of bulls	#	5	1	3.43*
Aggregate herd size	LU[1]	262	30	2.59*
Calving rate	%	66	35	7.75**
Off-take rate	%	20	12	2.46*
Mortality rate	%	2	5	2.15*
De-worm	%	87	37	5.64**
De-horn	%	86	84	3.00**
Practice supplementary feeding	%	80	63	2.91**
Vaccinate	%	87	38	5.74**
Treat cattle against ticks	%	71	44	3.21**
Financed own borehole	%	77	7	8.20**
Annual operating inputs per LU	Pula/LU	620	51	1.67*

Notes: [1] LU = Livestock Unit defined as a mature animal with a live weight of 500 kg.
*and ** show statistical significance at the five and one percent level of probability respectively.

On the other hand, the mortality rate is lower on private farms where the incidence of de-worming, dehorning, supplementary feeding, vaccination and dipping against tick-borne diseases is much higher (Table 2). Communal farmers tend to have fewer calves and bulls per cow than do private farmers. These findings are consistent with the arguments in Section 2 that decisions about stocking rates and investment (in operating inputs and improvements to

land and herds) are adversely affected by insecure property rights to open access grazing. Unable to internalise benefits, maximise profits, or raise loan finance, communal farmers tend to keep cattle as a store of wealth rather than as a commercial enterprise (Jarvis, 1980).

4.3 The block recursive regression results

The regression results presented in Table 3 show that all four of the equations estimated for the recursive model are statistically significant. The corresponding R^2 values range from 40 to 58% and compare favourably with other similar cross-section studies Place & Hazell, 1993; Hayes *et al*, 1997; Matangul *et al*, 2001). In equation 1 the regression coefficient estimated for the variable GENDER is positive and has a t-value larger than unity suggesting that the present value of short and long-term credit used by respondents is higher for farmers who are male. The variables HERD and TENURE are not independent (r = 0.376) and it was not possible to estimate their separate contributions to the level of agricultural credit. Principal Components Analysis (PCA) was therefore used to construct an index from these two variables. The first principal component was estimated as:

PC_1 = 0.829(standardised HERD) + 0.829(standardised TENURE)

with an eigen value of 1.4. This index accounted for 69% of the variation in HERD and TENURE and was included in Equation 1 as a positive measure of these variables. The regression coefficient estimated for this index is positive, highly significant and carries the largest beta value. TENURE therefore appears to be the underlying determinant of agricultural credit used by respondents because current herd size is more likely to be influenced by tenure status than vice versa. Respondents with private farms and larger herds are both willing and able to access more agricultural credit - as argued in Sections 2 and 3.2. Contrary to expectations, $LIQUIDITY_1$ is not statistically significant when proxied by wage income. To some extent this might reflect Botswana's Financial Assistance Policy (FAP) and the generous terms of government lending agencies (such as the National Development Bank (NDB)) and its grant schemes. The Arable Lands Development Programme (ALDEP) and Services to Livestock Owners in Communal Areas (SLOCA) provided financial support to many producers, including farmers who may not have been considered creditworthy by commercial banks (Bank of Botswana, 2000:60-61). The NDB disbursed P98 million in agricultural loans, mostly to livestock farmers (Bank of Botswana, 2000:51).

Table 3: Estimates of the block recursive regression model

Equation	1 (OLS)			2 (OLS)			3 (2SLS)			4 (2SLS)		
Dependent variables	**Agricultural credit (*c*)**			**Fixed improvements (LN (*l*))**			**Operating inputs (LN (*i*))**			**Herd productivity (*h*)**		
Predictors	**Coef**	**Beta**	**t-value**	**Coef**	**Beta**	**t-value**	**Coef**	**Beta**	**t-value**	**Coef**	**Beta**	**t-value**
Intercept	28165		0.40	4.81		1.92*	4.50		5.29***	16.89		2.85***
Endogenous variables												
LN (*l*)							0.037	0.12	0.82			
LN (*l*+*I*)										3.91	0.66	5.92***
Exogenous variables												
AGE	674	0.01	0.05	0.003	0.00	0.01	-0.390	-0.27	-2.02**			
GENDER	65727	0.12	1.10	0.12	0.01	0.06	-0.930	-0.15	-1.25			
MARRIED	35986	0.10	0.78	1.65	0.11	1.02	-0.790	-0.18	-1.29			
FAMILY	3124	0.05	0.43	-0.27	-0.12	-1.11	0.000	0.001	0.008			
EDUCATION	5123	0.12	0.79	0.16	0.10	0.75	0.050	0.09	0.62			
$LIQUIDITY_1$	-1.23	-0.02	-0.02	0.00047	0.21	2.03**						
TENURE and HERD index[a]	71233	0.51	3.14***									
C_L and TENURE index[a]				3.14	0.52	3.82***						
$LIQUIDITY_2$							0.000060	0.40	2.91***			
R^2		0.40			0.58			0.40			0.40	
Adj R^2		0.32			0.52			0.31			0.39	
F		5.21***			10.01***			4.42***			35.02***	

Notes: [a] First Principal Component.
*** Significant at one percent level of probability.
** Significant at five percent level of probability.

In equation 2 the regression coefficient estimated for $LIQUIDITY_1$ is positive and statistically significant. Investment in fixed improvements is higher amongst respondents who get more off-farm wage income. Credit used to finance fixed improvements (C_L) is positively correlated with TENURE (r = 0.587) and it was not possible to estimate the separate contributions of these variables to investment in fixed improvements. Again, Principal Component Analysis was used to construct an index of the correlated variables. The first principal component was estimated as;

PC_1 = 0.765(standardised C_L) + 0.765(standardised TENURE)

with an eigen value of 1.2. This index accounted for 59% of the variation in C_L and TENURE and was included in Equation 2 as a positive measure of these variables. The regression coefficient estimated for this index is positive, highly significant and carries the largest beta value. Since TENURE is predetermined and not influenced by the amount of credit used to finance fixed improvements, it could again be viewed as the underlying determinant of such investment followed by C_L, and the independent determinants $LIQUIDITY_1$, FAMILY and MARRIED - all of which have absolute t-values greater than unity. FAMILY has a negative coefficient suggesting that there is a trade-off between consumption and investment. Respondents with private farms use more long-term credit to finance fixed improvements, and invest more in these improvements than do communal farmers who rely on open access grazing land - especially if they get more off-farm wage income, are married and have smaller families.

In equation 3 the regression coefficient estimated for $LIQUIDITY_2$ is positive and statistically significant. This is consistent with the arguments made in section 3.2. Contrary to some arguments, the results indicate that older, married, male respondents are less inclined to invest in operating inputs. According to its beta value, liquidity (from short-term credit and off-farm wage income) is the most important, and the only positive, direct determinant of expenditure on operating inputs per livestock unit.

In equation 4 the regression coefficient estimated for the present value of investment in fixed improvement plus current expenditure on operating inputs per livestock unit is positive and highly significant. This result is consistent with the arguments made in sections 2 and 3.2. Secure land tenure has an indirect effect on herd productivity through its direct impact on agricultural credit and investment in fixed improvements. The Ministry of Agriculture (1991) also found that farmers who owned boreholes and who purchased supplementary feed had higher calving rates than those who did not.

In equation 4 the regression coefficient estimated for the present value of investment in fixed improvement plus current expenditure on operating inputs per livestock unit is positive and highly significant. This result is consistent with the arguments made in sections 2 and 3.2. Secure land tenure has an indirect effect on herd productivity through its direct impact on agricultural credit and investment in fixed improvements. The Ministry of Agriculture (1991) also found that farmers who owned boreholes and who purchased supplementary feed had higher calving rates than those who did not.

5. Conclusions and policy implications

Results of the regression analysis suggest that secure land tenure is a fundamental determinant of agricultural credit use. Respondents with private farms and larger herds use more agricultural credit than those who rely on open access communal grazing to raise cattle. Secure tenure is also a fundamental determinant of investment in fixed improvements. Respondents with private farms and higher levels of liquidity from long-term credit and off-farm wage remittances tend to invest more in fixed improvements. Liquidity from short-term credit and wage remittances is the most important direct determinant of expenditure on operating inputs. Herd productivity, in turn, increases with greater investment in operating inputs and fixed improvements, and is therefore positively (but indirectly) influenced by secure land tenure.

It can be inferred that government should (a) uphold private property rights to land where they already exist; (b) privatise open access grazing to individual owner-operators where this is politically, socially and economically feasible; and (c) where privatisation to individuals is not feasible, government should encourage users to convert the grazing into common property by subsidising the (transaction) costs of defining user groups and the boundaries of their resources, and of negotiating and enforcing rules limiting individual use of common property. This first-step in a gradual shift towards private property might be followed by a conversion of user-groups into non-user groups organised along the lines of investor-owned firms where members exchange use rights for benefits rights.

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