FARM SIZE, LAND FRAGMENTATION AND ECONOMIC EFFICIENCY IN SOUTHERN RWANDA

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Abstract

Butare, where this study was conducted, exhibits one of the highest population densities in Rwanda. As a direct result of population growth, most peasants have small fields and land fragmentation is common. The purpose of this article is to examine the effect of land fragmentation on economic efficiency. Regression analysis shows that area operated is primarily determined by the population-land ratio, non-agricultural employment opportunities, ownership certainty and adequate information through agricultural training. Results from a block-recursive regression analysis indicate that the level of net farm income per hectare, which indirectly reflects greater economic efficiency, is determined by the area operated, use of farm information, field extension staff visits, formal education of a farm operator, and the fragmentation of land holdings. Economies of size are evident in the data. The results obtained using ridge regression support the findings of two-stage least squares. Policies should be implemented to improve the functioning of land rental markets in order to reduce land fragmentation, improve rural education and access to relevant information; and strengthen extension facilities to individual farmers.

1. INTRODUCTION

Rwanda, with a surface area of 26,338 square kilometers (km^2), is one of Africa's smallest countries, but exhibits one of the highest population densities of all African countries (about 300 inhabitants per km^2) based on a World Bank (1997) report. In Rwanda, as in many other countries, the major resource is land. As the population density figures indicate, the amount of land per household is extremely small and as the rural population grows, area operated declines. The overall average area operated was 0.79 hectares per household in early 1990's with some variation in the average area operated between regions (MINAGRI, 1992). The relatively high average area operated reported in this article (2.4 hectares per household) may be attributed to the

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fact that most of the sample farmers operated on lands belonging to relatives who died during the 1994 genocide.

The primary focus of the article is to examine land fragmentation in Southern Rwanda, where land fragmentation is defined as farmers operating two or more geographically separated tracts of land, taking account of the distances between those parcels. Fragmentation arises under land scarcity as farmers look farther for whatever parcels of land may be available. Research on land fragmentation often focuses on fragmentation as the source of inefficiencies in agricultural production. The object of this article is to examine the fragmentation issue in Rwanda by examining how efficiency of resource use on farms varies with the size of a farm business and what implications variations in performance might hold for the reallocation of resources between area operated groups in pursuit of land redistribution.

Data for this article were collected during 2001 from 100 randomly selected households in each of Rusatira and Muyira districts using a standardized questionnaire. Farms studied are privately owned, and varied from 0.04 to 6 hectares. The size of farm only included land operated by each household (allocated land cultivated and all land rented in). Lands left idle and lands rented out were excluded.

2. LITERATURE REVIEW

2.1 Measurement of farm size

Obtaining a universally accepted definition of farm size has been one of the problems encountered in farm size and efficiency studies (Mbowa, 1996). A review of literature, however, suggests that numerous definitions of farm size have been adopted, ranging from acreage, value of farm products sold, days worked off-farm (for small-scale farms), level of farm income, to the level of total family income. Many authors combine two or more of these definitions. Farm size has commonly been taken to be synonymous with farm acreage because it can easily be ascertained and is easy to understand.

However, Britton & Hill (1975:15) state that when it becomes necessary to specify the criterion of size of a farm as a business, acreage is shown to be rather unsatisfactory indicator of business size. This is because the proportions in which land and other factors (labour, capital and so forth) combine in production vary between types of farming, and also between farms of the same type. Britton & Hill (1975:15), further argue that the 'best' unit of measurement of farm size, and size of enterprises within farms will depend on the purpose for which the measurement is to be used. In this article area operated was used as a measure of farm size as agricultural potential appears fairly homogeneous in the area. Kay (1981:51) suggests that number of acres should be used only to compare farm sizes in a limited geographical area where farm type, soil type, and climate are very similar.

Huang (1973) questions whether average farm size variation across countries is a purely random phenomenon, primarily determined by noneconomic variables such as laws of inheritance, historical consequences of landlord-tenant relationships, or government policies restricting or increasing area operated. He further asserts that there are certain quantifiable economic determinants operating across all countries. The basic hypothesis is that area operated patterns have evolved under the influence of political, social, and economic conditions which vary greatly among countries. Social and political factors are less easily generalized and quantifiable, but the four factors selected in this article (population-land ratio, off-farm employment, tenure certainty and agricultural training) may prove to be of sufficient importance to merit their study in isolation.

2.2 Farm size and property rights

Variants in forms of land tenure cause a range of optimal farm size in countries at various stages of economic development (Heady, 1971). Tenancy and small-sized farms are generally related in terms of the problems that they generate (Medina, 1980). Communal land tenure creates incentive problems to invest in land improvements, and tenancy arrangements that restrict farm sizes affect farm productivity (Lyne & Nieuwoudt, 1991).

Some authors (Johnson, 1972; Barrows & Roth, 1990) state that the traditional African system of 'communal' land tenure has been empirically demonstrated by economists as inefficient when land has scarcity value. Since property rights are not broad enough, costs and rewards are not internalized, and contracts are not legal or enforceable (Barrows & Roth, 1990). Individualized freehold tenure, on the other hand, is viewed as superior because owners are given incentives to use land efficiently and leads to the maximization of agriculture's contribution to social well being (Barrows & Roth, 1990). Johnson (1972) further argues that in situations where individuals cannot sell land, the value of investment to the farmer declines because of lost flexibility in converting a fixed-place asset into another asset form. In this article, land tenure was one of the important considerations in the selection of the study sample. Land rights are not defined according to land titles. None of the sampled farmers in the study area possessed a legal title for any parcel.

2.3 Meaning of efficiency

Conventional definitions of efficiency are in terms of optimality conditions associated with the perfectly competitive norm, that is, 'the marginal rates of substitution between any two commodities or factors must be the same in all their different uses' (Pasour, 1981). This implies a comparison of the observed situation with a defined efficiency norm. Pasour (1981) argues that it is, therefore, difficult to measure efficiency, because individual decision makers have different cost functions as they value opportunity costs differently and display different attitudes to risk. Such perceptual differences can also be expected to influence an individual's scale of operation, contributing to divergence in size of business (Groenewald, 1991).

In this article the term 'efficient farm' refers to a farm utilizing less resources than other farms to generate a given quantity of output. Alternatively, for a given quantity of resources they generate a greater output. This superior performance is manifested in higher efficiency ratios (output per unit of input), and a lower cost per unit of production. Therefore, agricultural efficiency is attained when the greatest possible product is achieved from a given stock of resources, or conversely, when a minimum input of resources is used to produce a given level of output.

2.4 Sources of efficiency

Experience in agriculture as well as in manufacturing industry has frequently confirmed that average costs per unit produced (or sold) decline as fixed costs are spread over a greater output, so that the small farm or firm with a limited output and certain unavoidable costs finds itself at a disadvantage (Britton & Hill, 1975:7). Fixed costs such as management, supervision, information and machinery can be spread over more units of output (Kay, 1981:52), resulting in reductions in cost per unit of output (increasing returns to scale or size). Returns to scale are defined as the proportionate change in output when all inputs are increased in the same proportion (Hallam, 1991). The term 'economies of size' is used to describe the fall in total cost per unit of production found on larger farms.

2.5 Land fragmentation and efficiency

Various factors are responsible for agricultural land fragmentation. Among the main factors that have directly or indirectly contributed to subdivision and fragmentation is the traditional system of inheritance of land (inheritance laws, which divide a family's land among all the remaining sons, ensure that, as the population increases, not only does the size of holdings fall, but they are increasingly fragmented into small plots, scattered over a wide area (Gebeyehu, 1995). The most common problems of fragmentation include the fact that fragmentation makes supervision and protection of the land difficult; it entails long distances, loss of working hours, the problem of transporting agricultural implements and products; and results in small and uneconomic size of operational holdings (Webster & Wilson, 1980). In this article the impact of land fragmentation on economic efficiency is analyzed in terms of geographic dispersion of plots (i.e. number of arable plots cultivated and distance traveled by farm operators from the farm house).

3. DATA SOURCES AND CHARACTERISTICS OF RESPONDENTS

3.1 The study areas

The study areas chosen for this research are Rusatira and Muyira districts. These districts are respectively 97 and 135 km^2 in extent and have respective population densities of 289 and 255 inhabitants per km^2. The annual population growth rate is estimated at 3.1% (MINECOFIN & ONAPO, 1998). These study areas were chosen because they have the highest population densities in the central plateau.

Geographically the two regions are similar. They have similar climates with an average annual temperature of 18°C. Annual rainfall averages between 1,500 mm and 2,000 mm and is well distributed throughout the year. Both districts have a mountainous landscape, with altitude ranging from 1,400 to 2,000 m above sea level but differ in that Muyira is a planned district whereas Rusatira is not, which accounts for farms being on average larger in Muyira (3.30 hectares) than Rusatira (1.50 hectares). Similar crops are grown in the two regions, coffee being the main cash crop produced in both regions.

Tenure in this article was captured as the future use certainty. This appears to vary somewhat between households. For instance women have less secure rights than men. Customary laws governing access to, utilization of and transfer of land in Rwanda are diverse (Place *et al*, 1994) and have led to land being excessively fractionated through heritage, and settlements generally scattered in rural areas (Takeuchi & Marara, 2000:27). Although the government has declared some policy change and enacted legislation affecting land rights, land transactions, size of holdings, imposed land taxes, the substance of the law, and the extent to which laws are enforced, an analysis of World Bank data has revealed that these changes have been largely ineffectual (Place *et al*, 1994). Further, Takeuchi & Marara (2000:27) contend that coexistence of this written (or 'modern') law with the customary laws has resulted in rights to land being so ambiguous that investment tends to be hindered.

3.2 Data collection

This article is based on data collected by the senior author from December 2000 to February 2001 in Rusatira and Muyira districts using a standardized questionnaire that consisted of both pre-coded and open-ended questions. The sample was selected at random from a population list provided by extension officers in the two areas. Questions were designed to be answered by household heads who typically manage farm operations in Rwanda. In addition to the survey of households, some questions were posed to agricultural officials in order to obtain data at regional and national levels.

3.3 Descriptive statistics

Descriptive statistics illustrating a demographic profile of respondents, characteristics specific to land use and performance indicators, evaluation of sources of farm information and tenure characteristics in the sample are presented in Table 1.

Table 1: Sample household characteristics in Rusatira and Muyira, 2001

Characteristics	Rusatira (n = 100)	Muyira (n = 100)
Mean age of farm operator (years)	52	44
Gender of farm operator (% male)	71.0	79.0
Education of farm operator (index)	0.8	1.3
Full-time farming (%)	85.0	76.0
Farming experience (years)	24.3	20.2
Mean household size (people)	5.0	4.5
Mean area operated (hectares)	1.5	3.3
Agricultural training (%)	60.0	92.0
Extension visits (frequency)	1.0	2.2
Farm information (average score)	0.7	1.1
Mean number of plots cultivated	3.1	1.8
Mean distance between parcels (km)	1.3	0.9
% Farmers confident of secure long-term tenure	42.0	54.0
Net farm income (RWF/ha)(i)	1728	3808
Inputs costs (RWF/ha)(ii)	525	456
Labour cost (RWF/ha)(iii)	1358	1385

Notes: Figures in parenthesis represent valid cases
RWF denotes Rwandan Franc (During January 2001, 1 ZAR = 52.5 RWF)
(i)Net farm income per hectare reflects returns to management, rent earned on land and other fixed inputs; (ii)Includes farm variable costs; (iii)Includes family and hired labour costs

Table 1 compares household characteristics between study areas. The farm operators in Muyira appear to be younger, wealthier, better educated, with relatively larger and less fragmented farms; have greater tenure certainty, and good access to agricultural training; and information sources compared to farm operators in Rusatira despite having similar per hectare labour and variable input costs. Quantity discounts on bulk purchase of inputs like fertilizers and herbicides may explain the lower input costs per hectare on the larger-scale farms.

Data on farmers' education were captured using the scale ranging from zero to three to symbolize; no education, grade 6 and below, grade 7 to grade 12 (matric), and tertiary education, respectively. In Rwanda, formal education comprises six years for primary school, six years for secondary school, and from four to five years for University. Such categorization in the different levels of education had to be followed due to difficulties experienced by respondents in stating the exact number of years taken to attain a certain standard of education.

Data on farm information sources (i.e. economic advisors, experiment stations, field extension officers, field day demonstrations, other farmers, and farm magazines) were captured on a Likert-type scale ranging from zero to three representing rankings; not useful, less useful, useful, and very useful, respectively, to indicate the importance of a range of extension facilities to individual farmers. Information is the average score of the ratings for all the farm information source data. Visits by field extension officers represent frequency of visits on a farm in the last two seasons, and were captured on a scale as ranging from zero to four (i.e. none; 1-3 times; 4-6 times; 7-9 times; and 10+ times, respectively). The categories of the extension visits variable were determined after a means test showed significant changes in adoption of farm practices and farm visits by extension officers at the above intervals. Tenure certainty was classified as dichotomous, equal to one if a farm operator is confident of his long-term tenure, and zero otherwise.

4. SPECIFICATION OF THE MODEL

Determinants of area operated and economic efficiency are analyzed in this section. To this end, the model developed explains the relationship between area operated, land fragmentation and economic efficiency. The model is specified as follows:

Area Operated (ha) (AREA) = f_1 (demographic characteristics, non-agricultural employment, tenure certainty, and agricultural training). (1)

Net Farm Income per ha (NFI) = f_2 (area operated, farmers' characteristics, contact with field extension staff, usefulness of farm information, land fragmentation, and input and labour costs). (2)

The model hypothesizes that factors affecting area operated include demographic and tenure characteristics, off-farm employment opportunities and access to training. In turn, net farm income per hectare is dependent on characteristics specific to farm size, sources of farm information, land use and performance indicators. Empirically, the two equations constitute a block-recursive model (Gujarati, 1995:680).

4.1 Factors influencing area operated

Exogenous regressors include population-land ratio, off-farm employment, tenure certainty, and agricultural training status of the farm operator. Equation (1) was generalized as:

Area operated = f (PLR, OFE, TNR, TRG) (3)

Area operated is measured in hectares and the explanatory variables; their measurement and their expected signs are defined in Table 2.

Table 2: Hypothesized variables associated with small and large farms in Rusatira and Muyira, 2001

Variable	Code	Description	Expected sign
Population-land ratio	PLR	Dummy variable representing the ratio of the total population in the study areas in 1998 to the total area in hectares	-
Off-farm employment	OFE	Dummy variable representing a proxy for off-farm employment available in the area	+
Tenure certainty	TNR	Dichotomous (1,0) one if farm operator feels assured of his long term tenure, zero otherwise	+
Training	TRG	Dichotomous (1,0) one if farm operator had received agricultural training, zero otherwise	+
Dependent variable: Area operated (hectare) (AREA)			

Rwanda is a country in the very early stages of development with the overwhelming majority of the population economically dependent on land (Waller, 1993). There are negligible employment opportunities in the non-agricultural sector. Aside from the effects of particular social and political factors, according to Huang (1973), the average area operated is primarily determined by the population-land ratio in such a situation. The greater the population-land ratio the smaller the expected average area operated. The population-land ratio (PLR) was thus included in the empirical model explaining area operated (Table 2).

Off-farm employment exposes the farm operator and other members of farm households to outside opportunities, and so influences off-farm migration (Huang, 1973). This migration will release land to be used by the remaining farmers, thus increasing area operated. Off-farm employment, following Huang (1973), was thus included as an independent variable in the empirical model explaining area operated. The information for this variable was obtained from the survey. Different off-farm employment opportunities could arise because (a) of an improvement in off-farm income; or (b) an improvement in the farmer training or education which enables him to obtain a job outside of agriculture. If it is due to (a) then it needs to be hypothesized that labour is not perfectly mobile otherwise the difference in off-farm income will disappear in different areas. Off-farm job opportunities in the study appear largely a function of education of the head of the household (Pearson Correlation = 0.55; correlation is significant at the 1% level of probability), which differ in the two areas (Table 1). This implies that improving education will improve labour mobility from agriculture.

Agricultural training status of the farm operator is expected to have a positive relationship with area operated (Berger *et al*, 1984:33). The higher the level of farmers' training the larger the area operated. Training may assist off-farm migration while it may enable the farmer to operate larger acreages.

Tenure certainty was measured through farmers' judgment as to whether they feel assured of their long-term tenure or not. Tenure certainty is expected to be positively related to area operated, given that farmers are more likely to improve parcels over which they have a long-term interest, in terms of their rights to cultivate the land on a continuous basis, to make and enforce a lease or sale contract, and to dispose of the land in ways that provide adequate compensation for the value of any improvements (Place & Hazell, 1993). Thompson (1996) argues that tenure security depends on both the actual and the perceived rights of individuals. These include whether or not farmers perceive rights to cultivate for the whole year, fence-off their arable land, and claim compensation for crops damaged by stray animals.

4.2 Factors influencing economic efficiency

The variables used to estimate equation (2) are presented in Table 3, along with their expected signs. Economic efficiency is measured by net farm income per hectare, and is dependent on area operated, education of the farm operator, visits by field extension officer, usefulness of farm information, number of plots cultivated, distance between parcels, input and labour costs per hectare. Area operated is seen as endogenous and estimated from equation (3). Thus, equation (2) was estimated as:

$$NFI = f(\hat{AREA}, EDU, VST, INFO, PLT, DST, INP, LAB) \quad (4)$$

The dependent variable - net farm income per hectare – reflects returns to management, rent earned on land and other fixed inputs.

Equation (2) could be estimated using ordinary least squares regression analysis (OLS) if it is assumed that the error term is not correlated with the stochastic variable 'area operated'. However, to account for possible correlation with the error term, the stochastic variable was replaced with an instrumental variable (estimated area operated). Two-stage least squares (2SLS) regression analysis involves the application of OLS regression analysis in two stages.

Table 3: Hypothesized variables for the economic efficiency model, Rusatira and Muyira, 2001

Variable	Code	Description	Expected sign
Area operated	*ARÊA*	Predicted value for are operated	+
Education	EDU	Formal education of farm operator	+
Extension visits	VST	Number of times a farmer was visited by field extension staff in the last two seasons	+
Farm information	INFO	The assessment of the usefulness of farm information in assisting farmers to improve farm productivity	+
Number of plots	PLT	Number of arable plots cultivated (continuous number)	-
Distance between parcels	DST	Total distance in kilometres between each plot cultivated and the household residence	-
Input costs	INP	Input costs per hectare (RWF/Ha)	
Labour costs	LAB	Labour costs per hectare (RWF/Ha)	
Dependent variable: Net Farm Income per hectare (NFI)			

Area operated, formal education of farm operators, visits by field extension officer, and tenure certainty are expected to bear positively on net farm income per hectare, while number of plots cultivated and distance between parcels, characteristics of land fragmentation, are expected to have a negative impact on economic efficiency.

4.3 Ridge Regression

Ridge Regression (RR) is one of several methods that have been proposed to remedy multicollinearity problems by modifying the method of least squares to allow biased estimators of the regression coefficients. When an estimator has only a small bias and is substantially more precise than an unbiased estimator, it may well be the preferred estimator, since it will have a larger probability of being close the true parameter (Neter *et al*, 1996:411). The ridge standardized regression estimators are obtained by introducing into the least squares normal equations a biasing constant $K \geq 0$. The constant K reflects the magnitude of bias in the estimators and usually varies between 0 and 1. When $K > 0$, the ridge regression coefficients are biased but tend to be more stable (i.e. less more variable) than ordinary least squares estimators (Neter *et al*, 1996:412).

A commonly used method of determining the optimal biasing constant K is based on the ridge trace and the variance inflation factors (VIF). Therefore, by examining the ridge trace and VIF values, the smallest value of K will be chosen where the regression coefficients first become stable in the ridge trace and the VIF values become sufficiently small.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1 Results of the area operated model

Following the specification of the model, results of the OLS regression analysis of the area operated equation are presented in Table 4.

According to the results, population-land ratio has a strong negative impact on determination of area operated. t-values and beta-coefficients (standardized coefficients), indicating the relative importance or impact of each variable in the model, suggest that population-land ratio has the greatest impact on area operated (i.e. the increase of population is the major factor leading to scarcity of farming land, reducing farming activities to small-sized and fragmented farm units).

Table 4: Results of OLS regression analysis of the area operated equation (n=179), 2001

Variable	Expected sign	Coefficient	Beta	t-value
PLR	-	-0.996	-0.635	-12.939**
OFE	+	0.525	0.321	7.137**
TNR	+	0.413	0.276	5.725**
TRG	+	0.104	0.066	1.363*
CONSTANT		2.820		14.065**
Dependent variable: AREA F-statistic: 2.083** R^2: 0.654 Adjusted R^2: 0.646				

Note: **, * denote statistical significance at the 1 and 20% levels of probability, respectively

Likewise, whether or not the farm operator has off-farm employment influences positively the area operated. Off-farm employment is also seen as a proxy for off-farm jobs. As job opportunities are created in the non-agricultural sector, migration out of agriculture will occur. All of these relationships are consistent with *a priori* expectations and agree with findings of previous research (e.g. Huang, 1973; Abdulkadir, 1992).

Tenure certainty is significant at the 1% level of probability and, according to the beta coefficients and t-values, is the third most important determinant of area operated after population-land ratio and off-farm employment. Heady (1971) reported a similar result that variants in forms of land tenure cause a range of optimal farm sizes in countries at various stages of economic development. Heady (1971) further argues that while conditions of development and resource suppliers or markets do relate to farm size, tenure conditions also pose differences in the opportunity cost of capital for landowners.

Access to agricultural training is related positively to area operated. Removing obstacles to small-scale farmers' access to training, will give them the opportunity to engage in market transactions, thus supporting the findings of Berger *et al* (1984).

5.2 Results of the economic efficiency model

2SLS regression analysis was found suitable for determining the socio-economic factors contributing to the economic efficiency model. The model explains the relationship between area operated, land fragmentation and economic efficiency. Results of the 2SLS regression analysis are presented in Table 5.

Table 5: Results of 2SLS and ridge regression analysis of economic efficiency model (n = 179), 2001

Variable	Expected sign	2SLS Regression			Ridge Regression		
		Coefficient	Beta	t-value	Coefficient	Beta	t-value
ARÊA	+	475.153	0.402	7.125***	454.596	0.385	8.323***
INFO	+	628.777	0.424	6.414***	445.971	0.301	6.167***
VST	+	591.959	0.398	5.652***	423.194	0.284	5.637***
EDU	+	401.293	0.253	5.553***	386.634	0.244	5.938***
PLT	-	-340.445	-0.223	-3.958***	-331.291	-0.217	-4.683***
LAB		-305.137	-0.151	-3.402**	-275.490	-0.136	-3.388**
DST	-	-100.934	-0.067	-1.434	-104.651	-0.070	-1.675*
INP		-75.521	-0.050	-1.098	-51.937	-0.034	-0.849
CONSTANT		1328.824		6.648***	1385.738		8.266***
		F-statistic: 48.296*** R^2: 0.694 Adjusted R^2: 0.680			K = 0.10 F-statistic: 46.480*** R^2: 0.686 Adjusted R^2: 0.671		

Note: ***, **, * denote statistical significance at the 1, 5, and 10% levels of probability, respectively

Table 5 summarizes the results of the economic efficiency equation. The results from the 2SLS regression analysis are consistent with the hypothesized relationships. This is particularly true with respect to the significant and strongly positive effects of area operated (AREA), farm information (INFO), extension visits (VST), and education (EDU); and the strong negative effect of number of plots (PLT) on net farm income per hectare. Beta coefficients indicate that farm information, area operated and extension visits have the strongest impacts on net farm income per hectare, which indirectly reflects economic efficiency. In absolute terms, the results suggest that a unit (hectare) increase in area operated will increase net farm income per hectare by 475 RWF.

The number of arable plots cultivated is negatively and significantly correlated with net farm income per hectare, indicating that land fragmentation leads to small and uneconomic size of operational holdings (Gebeyehu, 1995). This implies that efficiency of very small-scale farms can be enhanced by land consolidation. Likewise, distance between parcels negatively influences the level of net farm income. According to King & Burton (1982), the long distances between parcels reduce the level of crop income.

As regards farm indicators, results indicate an economy of scale within the farming process itself (internal economies), due to better utilization of labour and other inputs (technical economies). Labour cost per hectare is negatively and statistically significant at the 5% level of probability, and according to its relative importance in the model, the results show that it has a significant impact on economic efficiency. Variable input costs per hectare are also negatively but not statistically significantly associated with net farm income per hectare, due probably to the fact that inputs used in the two study areas are mainly confined to small projects.

Despite the relatively high R^2 statistic and the relatively high t-statistics of the estimated regression coefficients, the Condition Index of 20.6 indicates the presence of a moderate to high multicollinearity in the 2SLS regression equation (2) (Gujarati, 1995:338). The Condition Index is the square root of the ratio of the largest eigenvalue to the minimum eigenvalue. Following Maddala (1992:280) and Neter *et al* (1996:411), ridge regression (RR) was used to remedy for multicollinearity in the original equation (2). RR overcomes the multicollinearity problem by adding a biasing constant; $K \geq 0$ to the least squares normal equations and then by estimating the standardized ridge estimators (Neter *et al*, 1996:412). A careful examination of the ridge trace, which is a graph of the beta coefficients against the biasing constant, K, and the VIF help to determine the value of K, which stabilizes the beta coefficients. The results are presented in Table 6.

Table 6: R-square and the Beta coefficients for different values of the biasing constant, K

K	R^2	*ARÊA*	INFO	VST	EDU	PLT	LAB	DST	INP
.00	.6944	.4023	.4241	.3975	.2535	-.2229	-.1513	-.0673	-.0503
.05	.6917	.3950	.3518	.3298	.2493	-.2194	-.1433	-.0686	-.0405
.10	.6863	.3849	.3008	.2842	.2442	-.2169	-.1366	-.0698	-.0346
.15	.6797	.3740	.2625	.2513	.2388	-.2147	-.1308	-.0709	-.0308
.20	.6729	.3630	.2326	.2265	.2334	-.2126	-.1257	-.0718	-.0284
.50	.6316	.3069	.1341	.1509	.2034	-.1975	-.1035	-.0743	-.0232
1.00	.5705	.2454	.0717	.1067	.1670	-.1721	-.0821	-.0717	-.0213

Table 6 shows that the ridge estimators first stabilized when the value of the biasing constant, K, equals 0.10 and the values of VIF for the regression coefficients are close to one (unity) as shown in Table 7. The small K value (K = 0.10) implies that the bias introduced through the use of RR is small.

Table 7: VIF values for regression coefficients for different values of the biasing constant, K

K	*ARÊA*	INFO	VST	EDU	PLT	LAB	DST	INP
.00	1.774	2.433	2.752	1.159	1.765	1.100	1.226	1.165
.05	1.407	1.704	1.869	1.026	1.410	.980	1.067	1.014
.10	**1.158**	**1.288**	**1.376**	**.916**	**1.162**	**.880**	**.941**	**.897**
.15	.978	1.024	1.070	.824	.980	.795	.838	.803
.20	.841	.844	.866	.745	.842	.723	.752	.726
.50	.430	.393	.379	.449	.428	.445	.444	.440
1.00	.213	.194	.184	.241	.212	.244	.237	.241

The value of K = 0.10 was then used to determine the final beta coefficients. The results of ridge regression of socio-economic variables on NFI are presented in Table 5. The signs of the explanatory variables retained in the final model agree with *a priori* expectations. All the variables were included in the final RR model. The standardized coefficients of the ridge regression in Table 5 suggest that area operated (AREA) is the most important variable influencing net farm income per hectare (NFI) followed by farm information (INFO), visits by field extension staff (VST), education (EDU), number of plots (PLT), labour cost per hectare (LAB), distance between parcels (DST), and input costs per hectare (INP).

Comparing 2SLS and RR results, the beta coefficients of RR are generally smaller in magnitude than the beta coefficients obtained by using 2SLS, while t-values of RR are a bit higher than the ones obtained from 2SLS. The adjusted R^2 obtained using RR is only a bit smaller than when using 2SLS, as the biasing coefficient (K = 0.10) is small. The RR results in general support the findings of 2SLS regression analysis.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Effect of fragmentation on economic efficiency is examined based on information collected from a sample of 200 small and large privately owned farms in the Rusatira and Muyira districts in Butare province during 2001.

Farms studied ranged from 0.04 to 6 hectares. The sample was chosen randomly from a population list provided by extension officers in the two areas.

Investigations of characteristics of the sample farmers using regression analysis revealed that, within a 'stage of development' framework, the area operated can be viewed as being initially determined by a country's resource endowment, which over time may change with population growth and clearing of land (Huang, 1973). With development, increases in nonagricultural employment opportunities, changes in customary tenure security and provision of adequate information through training will cause pressures for the area operated to increase. An implication of the findings of this article is that the area operated will be constantly changing in response to dynamic conditions.

The second important conclusion of this article is that the need for consolidating land, allocating land to more proficient farmers, and enabling proficient farmers to access relatively larger land holdings can be attained through institutions and policies promoting efficiency in human resources and an efficient land (rental) market. This is in line with the recent Rwandan policy to reallocate relatively larger holdings to farmers in order to reduce the present dispersed distribution of land (MINAGRI, 1997). Rural development implications indicate that emphasis on small farms will certainly require more resources to be invested in the improvement of human capital capacities, which will definitely involve intensive extension support and access to relevant information.

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