DETERMINANTS OF FARM SIZE IN LAND-ABUNDANT AGRARIAN COMMUNITIES OF NORTHERN GHANA

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ABSTRACT
Most farmers in sub-Saharan Africa use very little market inputs. Consequently output of the farm depends crucially on the size of the cultivated area each season. Moreover, larger farmers are known to be less risk averse and hence are more likely to adopt improved technologies. Thus the question of how farmers' decisions about farm size are informed is very significant. Using farm-level data from Northern Ghana, this article demonstrates the significance of access to family and market labour, as well as functional markets for both inputs and outputs. In particular, it is concluded that farmers will not adopt mechanical equipment to expand cultivated surfaces unless there are complementary technologies to accomplish post-land preparation field operations that are currently not mechanised, or they have the ability to recruit additional labour to overcome labour bottlenecks.

Keywords: Northern Ghana; West Gonja; agrarian communities; farm size; labour; simultaneous equation.

INTRODUCTION
In low-input agrarian societies with universal access to land, but who rely on basic cultivation technology, farm size is very critical to household food security. The reason is that farmers use very little external inputs and, accordingly, the principal means of expanding output is by extending the area under cultivation. Moreover, farmers that cultivate larger sown areas have been shown to possess a greater capacity to absorb risks, especially those originating from volatility in output markets (Feder, 1980) and hence have greater ability to adopt farm innovations. Thus there is a more or less direct correlation between the cultivated areas each season and the total output for the farm household. In this regard, the question of what factors influence farmers' decisions about farm size is of great significance in their livelihoods and for household food security in particular. Previous attempts in the study area as well as in similar areas have modelled farmers' decisions on farm size separately from their decisions on labour use. This is clearly inappropriate because decisions about farm size cannot be taken independently from those about labour inputs. For instance Eicher and Baker (1982) have stated for African agriculture that owing to universal access to land and reliance on basic cultivation implements the size of the cultivated area depends critically on the family labour force. Similarly Low 1986) has demonstrated the importance of labour in determining farm size in indigenous agriculture in Southern Africa. Therefore a more complete analysis will model farmers' decisions about farm size jointly with their decisions about seasonal labour input, especially market labour.

There is evidence to support the interdependence of farm size and labour in Northern Ghana agriculture. Because land preparation and other tillage practices are mainly carried out manually, labour has been a major constraint in farming larger areas (Ministry of Agriculture, 1990; Runge-Metzger and Diehl, 1993). Mainly for this reason large scale mechanised farming, involving the use of tractors was introduced into Northern Ghana agriculture during the 1970s (Shepherd, 1981; Van Heer, 1984; Samuels and Lepleideur, 1991). Nevertheless it is increasingly evident that the use of traction power has not necessarily resulted in larger cultivated areas (Panin, 1988; Runge-Metzger, 1991). This conclusion also applies to similar semi-arid areas of West Africa (Jaeger and Matlon, 1990). Therefore, the principal question posed in this study is: what factors determine the size of farm that a farming household cultivates each season?

Runge-Metzger and Diehl (1993) have provided some insights into the problem. Using a single equation multiple regression estimation, they showed that farm sizes in Northern Ghana mainly reflect the available household labour, the technology of cultivation, population density, and the onset of the rainy season in an area. Based on their results they assert that; "as soil preparation is mainly carried out manually by male adult members, farm sizes most likely primarily depend on the available male labour capacity." However, it should be recognised that population density and rainfall regime are entirely beyond the control of the farm household. Therefore the implicit inference from their results is that decisions about farm size each season are informed primarily by the amount of labour that a household can mobilise to accomplish *manual land preparation*. On the other hand, this inference lacks empirical support, as noted in the studies reported *supra*, and the availability of labour for soil/land preparation alone does not seem to provide a complete explanation about farmers' decisions about farm size.

The central hypothesis in this study is that there is a strong linkage between the area cultivated and the ability to mobilise sufficient labour to accomplish all farm operations, *and not just land preparation*. Therefore farmers will not adopt mechanical land preparation or exploit favourable household male labour capacity to expand cultivated areas unless they can mobilise sufficient labour to accomplish the other on-season operations that are not mechanised. Rainfall uncertainties and the shorter growing cycle in Northern Ghana means all farm operations, including soil preparation, planting, weeding and harvesting are time-bound and must be done within the shortest possible time in order to optimise yield. Therefore area expansion also places extra labour demands on households to accomplish tasks such as planting, weeding and harvesting, which are not currently mechanised. There is evidence to support this contention. Van Heer (1984) reports that large-scale agriculture in Northern Ghana during the late 70s led to an increased recruitment of labour for weeding and harvesting. Using farm level data, Ohene-Yankyera (2000) showed that farmers who adopted mechanised land preparation to expand cultivated areas were also those who hired in extra labour to complete weeding activities. Jaeger and Matlon (1990) have demonstrated, through a Linear Programming model, that traction ploughing was maximised when the model permitted the use of a weeding implement whereas the use of the ox-plough alone generated no area expansion. This paper presents evidence to demonstrate that decisions about farm size and labour needs are jointly determined; it is those households that have the ability to mobilise labour to fulfil the extra demand for labour imposed by weeding and other post-soil preparation activities that can operate larger farms.

Characteristics of the Study Area

The study is based on farm household survey data in four villages in the West Gonja District of the Northern Region of Ghana for the 1996/97 cropping season. In all, sixty farmers were randomly sampled and interviewed as part of a major survey of farming households in Northern Ghana (Ohene-Yankyera, 2000). West Gonja lies in the Guinea Savannah agro-ecological zone. Compared to other districts of the region, West Gonja is clearly a more climatically favoured zone, with annual precipitation exceeding 1000mm, reasonably adequate for plant growth. In general, the soils have low fertility and managing soil fertility is a critical issue in crop production. It is not very surprising that, in the past when chemical fertiliser was heavily subsidised, about 90 per cent of all fertiliser imports to Ghana were consumed in the region (KOCKS Consult GMBH, 1989). The principal land use is farming, which reflects the totally rural base of the regional economy. With a population density of about 10 persons per km^2, West Gonja is one of the most sparsely populated areas in Ghana. Partly for this reason, the existing land tenure system is sufficiently flexible and stable to permit ready access to land by all cultivators. A land tenure system that permits ready access to land for all individuals in the community has implications for factor combinations. It means that farmers can wander around the settlements to cultivate new land rather than intensify production on old plots.

A Model for the Determinants of Farm Size in Northern Ghana

Farmers' access to farm labour consists of household labour and any labour that they are able to recruit from the labour market. In the short term, household labour is fixed by the size of its working members. Therefore decisions about farm size and labour requirements reduce essentially to the ability to hire in extra labour to supplement household labour to overcome seasonal labour constraints. Simply put, farmers' decisions about farm size and labour requirements are jointly made. The technical implication of these arguments is that the decisions about farm size would be best modelled by simultaneous-equation estimation and not single equation estimation as used by Runge-Metzger and Diehl (1993). In estimating the determinants of farm size for peasant farm households in Zaire, Shapiro (1990) acknowledged the importance of these joint decisions when he stated that; "a more complete treatment of the determination of farm size would attempt to model the use of hired labour as an endogenous choice variable." In spite of that, he ignored this problem and argued that his main findings were unaffected by the endogeneity problem. However, Quisumbing (1996) has highlighted some of the interpretational problems that could arise in overlooking the endogeneity problem.

Based on the above reasoning, a model was proposed in which farm size and hired labour are endogenously determined. The structural model is presented as a two-equation system as follows:

$$\mathit{ln}\text{as} = \alpha_1 + \alpha_2 \mathit{ln}\text{hl} + \alpha_3 \mathit{ln}\text{fl} + \alpha_4 \mathit{ln}\text{ad} + \alpha_5 \mathit{ln}\text{np} + \alpha_6 \mathit{ln}\text{tr} + \varepsilon \quad \ldots..1$$

$$\mathit{ln}\text{hl} = \beta_1 + \beta_2 \mathit{ln}\text{as} + \beta_3 \mathit{ln}\text{fl} + \beta_4 \mathit{ln}\text{fy} + \beta_5 \mathit{ln}\text{ly} + \beta_6 \mathit{ln}\text{tr} + \beta_7\text{dm} + \beta_8\text{da} + \beta_9\text{db} + \mu \quad \ldots..2$$

A detailed list of the variables, their definitions, some selected statistics, and expected impacts are shown in Table 1

The first equation specifies farm size as a function of hired labour, family labour, average distance of a farm, the number of parcels (as index of farm fragmentation) and outlays on traction cultivation. Concerning labour, both family and hired labour are expected to have a positive impact on sown area per season because the technology of cultivation is based predominantly on hand tools. Moreover, both sources of labour are expected to complement each other because family labour is fixed in the short-run and farmers who use family labour to cultivate larger areas will most likely have a greater need to recruit extra labour to sow, weed and harvest the extra sown area.

Table 1: Variable list, definitions and some selected statistics and expected impact on farm

Variables	Definition	Mean	Standard Deviation	Expected impact
*ln*as	Natural logarithm of total sown area per season in hectares	1.2830	0.6429	Eq 2 = +
*ln*hl	Natural logarithm of hired labour input in man-days per season	4.0648	1.7081	Eq 1 = +
*ln*fl	Natural logarithm of ex-post family labour in man-days per season	5.3598	0.6377	Eq 1 = + Eq 2 = +
*ln*ad	Natural logarithm of average distance of a farm from the settlement in km	1.2289	0.6636	Eq 1 = +
*ln*np	Natural logarithm of number of parcels cultivated per season	0.9800	0.3862	Eq 1 = +
*ln*tr	Natural logarithm of cash outlays on traction hiring per season in dollars	3.4657	2.0820	Eq 1 = + Eq 2 = +
*ln*np	Natural logarithm of off-farm income per season in dollars	2.8377	2.3282	Eq 2 = +
*ln*ly	Natural logarithm of livestock income in dollars per season	4.3258	2.3688	Eq 2 = +
dm	Dummy for settlement: Damongo =1, 0 otherwise	-	-	Eq 2 = +
da	Dummy: Achubinyo = 1, 0 otherwise	-	-	Eq 2 = +
db	Dummy: Busunu = 1, 0 otherwise	-	-	Eq 2 = +

The distance of the farm from the settlements is expected to be positively associated with farm size. If farmers want to expand their tilled areas they will have to wander off into remote parts of the settlements. Without that it will be more difficult to add substantial areas to existing plots without infringing on the boundaries of other farmers who have plots near the settlement. In this regard the existing land tenure system is sufficiently flexible to permit farmers to colonise new land.

Fragmentation will have a similar impact on farm size as the distance of the plot. Natural barriers such as rivers and wastelands, as well as boundaries with neighbours, often make it difficult to expand existing fields so that farmers who decide to extend cultivated areas will require seeking and cultivating new plots. Moreover land is not homogenous but differs in soil quality, water retention capacity and other aspects so that farmers try to farm in different parts of the village so as to satisfy the agronomic requirements of different crops and, in so doing, increase their tilled areas.

Access to traction tillage appears in this equation as well as equation 2 because the technology is expected to relax the labour constraint during land preparation when most potential labourers may be preparing their own fields. Therefore expenditure on tractor cultivation is expected to have a positive linkage with farm size.

The second equation arises because agricultural activities in the study area are time-bound, as a result of a shorter growing season. It specifies the seasonal hired labour requirement as a function of farm size, family labour, off-farm income, livestock income, expenditure on traction cultivation and three dummies representing the four settlements in the study.

Access to family labour is expected to have both direct and indirect effects on hired labour. On the one hand a larger household labour force can directly reduce the need to hire in additional labour. On the other hand, a larger family work force will increase the consumption needs of the household, prompting it to crop a larger surface area to fulfil this need. Given that subsequent farm operations, after initial clearing, must be accomplished manually within a short span of time, the larger initial clearing is expected to increase the demand for hired labour since family labour is fixed by the size of the available workforce. Accordingly, the overall impact of family labour is expected to be positive

Outlays on traction technology appear also in the equation for labour hiring. Traction technology is used exclusively for land preparation but other operations must be done manually. Since the household's own labour supply is fixed in the short-run, using traction technology to prepare larger sown areas will increase the requirement for wage labour. Accordingly, access to traction power is hypothesised to have a positive impact on hired labour recruitment.

Off-farm income is included in Equation 2 but excluded from Equation 1 because it is not expected to have any direct impact on farm size. It is, however, expected to influence farmers' ability to recruit labour. With no viable credit markets, off-farm jobs can provide households with the working capital to buy in inputs, including labour and machinery. On the other hand, if off-farm jobs compete with farm work as the principal source of household income, then labour hiring could decline because there would be a lower need for the family to cultivate its own food. However, given that self-cultivation is a general feature of livelihoods in the study area, if a significant section of members work outside the farm then the remnants will either have to work harder or recruit additional labour to surmount the additional consumption requirements. Accordingly, the overall influence of off-farm income will be positive.

Livestock income is expected to generate similar impacts as off-farm income in providing working capital to hire in extra labour when needed. Farmers are known to sell livestock during the growing season to hire in labour. Therefore it has been excluded from Equation 1 because its impact on farm size is through the recruitment of additional labour to overcome labour constraints during the season.

There are three dummy variables in Equation 2, representing the four communities. They have been included to capture differences in cropping systems and mixtures, and variability in micro-climate and soil conditions. Runge-Metzger and Diehl (1993) have shown that these characteristics of farming systems do influence labour requirements considerably. In addition differences are expected in the efficiency of local labour and other input markets, as well as in food crop markets, which can all influence the use of hired labour and other purchased inputs. Given that Damongo, and to a lesser extent, Achubinyo are more urbanised, input and output markets are expected to be more efficient which will impact positively on labour hiring.

Model Estimation and Results

Both equations are over-identified and the structural parameters of the model were estimated by the 2SLS (two-stage least squares) estimation procedure, which is regarded as very useful in estimating structural parameters in over-identified equations (Pindyck and Rubinfeld, 1981). In the first stage, each of the endogenous variables was regressed on all the exogenous variables in the model to produce fitted values of farm size and hired labour, respectively (Pindyck and Rubinfeld, 1981; Maddala, 1992). Although the fitted values will be uncorrelated with the error terms in the model, Blarel *et al.* (1992) argue that their usefulness as instruments to replace the endogenous variables in the right-hand side of the equations depends on their correlation with the observed values. The authors suggest a correlation coefficient of 0.5 or greater between the fitted and observed values as well as high coefficient of determination (R^2s). The correlation between the fitted and observed values of farm size was 0.876 ($p< 0.001$) and R^2 of 0.767. Similarly the correlation between the predicted and observed values of hired labour from stage one was 0.667< 0.001) with and R^2 of 0.446. In stage 2, the observed values of hired labour and farm size at the right-hand side of Equation 1 and 2, respectively, were replaced by their corresponding fitted values from stage 1. Also both equations were estimated in their log-linear form, where all the variables were transformed into logarithms in order to minimise potential problems of heteroscadasticity (Maddala, 1992). The results are presented in Table 2.

The upper block of Table 2 shows the estimated equation for farm size while the lower panel corresponds to hired-labour use. Concerning the equation predicting farm size, the F-statistic was statistically significant. Therefore the hypothesis that none of the explanatory variables was related to farm size was rejected. The adjusted R^2 indicates that over 70 per cent of the variation in farm size was explained by changes in the explanatory variables included in the model. The standard error of regression (SER) was considerably lower than the standard deviation of the sample mean farm size (Table 1), implying that the estimated model is a better predictor of farm size in the study area than the sample mean farm size. Moreover, the tolerance statistics for all the variables are fairly large and greater than 0.50 suggesting that the estimation was not adversely affected by intercollinearity among the independent variables in the equation. Each of the explanatory variables had the expected impact and in addition all, but one, were significantly related to farm size. However their respective systematic impact varied considerably.

Table 2: 2SLS regression results for the determinants of farm size and hired labour in West Gonja District of Northern Ghana

Explanatory variable	Coefficient	t-statistic	Significance level	Tolerance statistic
Dependent variable is the natural logarithm of farm size				
*ln*fl	.4450	4.697	.000	.564
*ln*hl	.0936	1.724	.002	.538
*ln*tr	.0554	2.194	.033	.746
*ln*np	.7260	4.475	.000	.525
*ln*ad	.1540	1.674	.100	.553
Constant	-2.466			
Adj. R^2	.711			
F-statistic	29.527		.000	
SER	.3457			
N	59			
Dependent variable is the natural logarithm of hired labour				
*ln*as	1.512	4.374	.000	.845
*ln*ly	.0146	.176	.861	.834
*ln*tr	-.0602	-.647	.521	.855
*ln*ny	.0732	.902	.371	.899
dm	2.266	3.998	.000	.528
da	1.669	2.774	.008	.539
db	.6650	1.143	.258	.521
Constant	.6160			
Adj. R^2	.363			
F-ratio	5.720		.000	
SER	1.363			
N	59			

The elasticity of farm size with respect to family labour was about 0.5 per cent. Therefore around the mean farm size and family labour input, a 10 per cent increase in household labour spent on farm work will generate about 5 percent expansion in cultivated area per season, if all other important factors are held at some reasonable level. Farm fragmentation had a significant and fairly large impact allowing farmers to extend farm size by about 7 percent if they cultivated 10 per cent more fields. This supports the contention that farmers who intend to increase sown areas cultivate new plots rather than extend existing plots. Although average parcel distance was significantly related to farm size, its systematic impact was rather weak. West Gonja is still a land-abundant community and farmers do not need to travel farther from the settlements so as to extend sown areas. Hired labour also had the predicted impact on farm size generating about 1 per cent expansion in cultivated areas for every 10 per cent increase in labour recruitment. However, compared to family labour its systematic impact was weaker, implying that the response of farm size to changes in labour supply differed according to the source of labour. In fact, a test of hypothesis that hired and family labour generated the same effects on farm size was rejected and family labour had a greater quantitative impact on farm size than did hired labour[1]. Outlays on traction land preparation had a significant but a small positive effect on farm size and a 10 per cent increase in farmers' spending on the equipment generated less than 1per cent jump in the size of cultivated area. The rather low elasticity of farm size with respect to spending on traction equipment highlights an important limitation of the spread of the technology in the study area. Since its adoption to extend cultivated areas tends to increase, rather than reduce, labour requirements, it is only those households who have the ability to mobilise extra labour who are most likely to use mechanical equipment to crop larger areas. Their neighbours are likely to adopt it just to save time on land preparation, rather than prepare larger sown areas.

The equation predicting hired-labour use has similar characteristics as the one for farm size. Family labour has been excluded from this equation as a predictor in the final estimation because of acute problems of multicollinearity between this variable and the variable representing farm size. However, only farm size and two of the three village dummies were significantly associated with market labour recruitment. The systematic impact of sown area on labour recruitment was particularly large. A 10 per cent increase in the size of the cultivated areas will generate a more than 15 per cent rise in labour hiring. To some degree, this large response can be explained by the exclusion of the household labour variable. The simple correlation of hired labour with family labour was statistically significant; a greater use of family labour to prepare larger areas also generated a greater need to recruit additional labour. Thus some of the impact of family labour has been captured by the variable representing farm size. All the village dummies were positive, as expected. However, only the two representing Damongo and Achubinyo were significantly related to wage labour use, implying that farmers in these settlements recruit more wage labour for crop production than their neighbours in Busunu or Fulfulso. The underlying data revealed that farmers in the former settlements received higher prices for their output and tended to use more market inputs, including hired labour. By contrast, off-farm earnings and livestock income were not significantly associated with increased labour hiring, although their coefficients had the expected signs. The main survey showed that the returns to off-farm jobs were rather low and were undertaken mostly by female members of the household who tended to keep the income for their own cash expenditures. Rather surprisingly, the coefficient of the variable representing traction land preparation had a negative sign. However, its systematic impact was marginal and statistically insignificant.

CONCLUSIONS AND POLICY IMPLICATIONS

Applying a simultaneous equation model to farm household survey data, the results from the study showed that the available labour force was an

[1] *This is equivalent to a t-test of the hypothesis that* $\alpha_3=\alpha_2$ *in Equation 1 against the alternative that* $\alpha_3>\alpha_2$. *The test statistic can be calculated as* α^*/s_α^*, *where* $\alpha^*=\alpha_3-\alpha_2$ *and* $s_\alpha^* = \{var.(\alpha_3) + var.(\alpha_2) - 2cov.(\alpha_3,\alpha_2)\}^{1/2}$, *which has a t-distribution, under the null hypothesis, with N-k degrees of freedom (where N = sample size and k = number of estimated parameters in Equation 1). Thus* $\alpha^*/s_\alpha^* = 0.4450-0.0936/\{0.095^2 + 0.054^2 - 2(-0.00077)\}^{1/2} = 0.3541/0.1161 = 3.05$. *In this case the alternative hypothesis is* $\alpha_3>\alpha_2$, *and is equivalent to a one-sided test for which the appropriate critical region at 5% and 53 degrees of freedom equals 1.676. Hence the null hypothesis is rejected in favour of the alternative.*

important factor that determined differences in sown areas between communities in Northern Ghana and the farm households within them. In that respect, the area cultivated had a greater response to access to family labour than it did to market labour. Although access to traction cultivation was important in overcoming pre-season labour bottlenecks, its systematic impact on farm size was marginal, reflecting the increasing difficulty that farmers encounter in the area in replacing manual cultivation with traction power for operations other than land preparation. The policy implication is that unless technologies are developed to replace manual operations such as sowing, weeding, and harvesting farmers will use the traction equipment just to overcome pre-season labour bottlenecks in land preparation but not to expand cultivated areas. The disparities in access to labour, and especially market labour, has an important influence on farm size and hence on farm income. Discussion with farmers during survey showed that labour supply is not a constraint to local agriculture in the study area. Therefore the main problem seems to be a failure of demand for labour, as many farmers lack the cash to recruit labour at existing wage rates. Provision of on-season credit may provide them the working capital to surmount the labour bottlenecks. Farmers who farmed bigger surface areas usually did so by cultivating several plots in different areas of the settlement. While extensification may be possible in the short to medium term, it is doubtful whether in the long-term period this system will be sustainable under increasing population pressure and urbanisation. This raises the case for granting some level of subsidy on market inputs, especially fertiliser and improved seeds, so as to enable farmers intensify and raise the productivity of land and labour. The principal factor that explained variations in the use of market labour among farms was farm size, and this seems to support the contention that farmers take decisions about farm size and labour commitments jointly. Also farmers in the more urban areas seemed to have greater opportunities to recruit additional labour owing to more functional input and output markets and hence better prices for their inputs and farm products. An important means to remove some of these disparities is to improve accessibility to the more remote communities through the provision of roads and market place infrastructure.

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