Farm Household Production Efficiency: Evidence from The Gambia

Jean-Paul Chavas, Ragan Petrie, and Michael Roth

This article investigates the economic efficiency of farm households, with an application to The Gambia. The efficiency analysis is conducted not at the farm level but at the household level, thus capturing the importance of off-farm activities. Output-based measures of technical, allocative, and scale efficiency are generated using nonparametric measurements. An econometric analysis of factors affecting the efficiency indexes is then conducted using a Tobit model. Technical efficiency is fairly high indicating that access to technology is not a severe constraint for most farm households. The cost of scale inefficiency is modest. Allocative inefficiency by contrast is found to be important for the majority of farm households. On the basis of the Tobit results, imperfections in markets for financial capital and nonfarm employment contribute to significant allocative inefficiency.

Key words: efficiency, farm household, nonparametric, production, The Gambia.

Economic efficiency at the microlevel focuses on the ability of firms to utilize the best available technology and to allocate resources productively. It is typically decomposed into three sources: technical, allocative, and scale efficiency. Technical efficiency is attained when the best available technology is used. Taking market prices as given, allocative efficiency (AE) holds when resource allocation decisions minimize cost, maximize revenue, or more generally maximize profit. Scale efficiency means that firms are of the appropriate size so that no industry reorganization will improve output or earnings.

Much research has investigated the economic efficiency of farm households. In general, previous investigations have focused on the efficiency of farm activities (see the literature review below). Yet, off-farm activities can contribute to significant improvements in the welfare of agricultural households (Hill). This is true in developed as well as developing countries. For example, Gardner (2002) documented how the growth of off-farm income in the United States over the last forty years reduced income inequality in agriculture and contributed to the catch-up of farmers' incomes with those of the nonfarm population. Phimister and Roberts found evidence of significant linkages between off-farm work and farm decisions in Scotland. In the context of Africa, Reardon, Delgado, and Matlon, and Reardon documented the importance of nonfarm earnings for African rural households. For example, Reardon reports estimates of nonfarm income as a share of total household income ranging from 22% to 93%, with an average of 45%. In Africa, considerable income diversification between farm and off-farm activities may be seen as a response to poorly functioning capital markets: the cash from nonfarm earnings can help stimulate farm investments and improve agricultural productivity (Haggblade, Hazell, and Brown; Hazell and Hojjati). Given that very poor households often lack access to nonfarm income (Reardon, Delgado, and Matlon), imperfections in the labor market can contribute both to inefficient labor allocation in rural households and to a more unequal distribution of income. This stresses the need to include off-farm activities in the analysis of farm household efficiency, particularly for poor African rural households where incomes are low and small inefficiencies can have large impacts on income and welfare.

Then it would appear that analyzing farm-household welfare should include both farm and off-farm activities. This can be done in the context of a household production model (e.g., Singh, Squire, and Strauss). Under efficiency,

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competitive markets for commodities and labor, and perfect substitution between family labor and wage labor,[1] Singh, Squire, and Strauss have shown that farm decisions (including labor allocation) are separable from other household decisions.[2] This result can be used to motivate an analysis of efficiency at the farm level. Yet, the separability between farm and other household decisions does not always hold. Hence, a narrow focus on farm activities can be inappropriate for several reasons. First, it neglects possible inefficiency of labor allocation between farm and off-farm activities (e.g., due to frictions and imperfections in the labor market), particularly for farm households, which rely significantly on off-farm income. Second, the technology supporting off-farm activities may be joint with farm activities (e.g., off-farm activities facilitating access to farm technology). Third, in the presence of credit rationing, access to off-farm income can affect the use of farm inputs, and thus allocative efficiency. As a result, market imperfections can imply significant interactions between farm and off-farm activities in the analysis of household efficiency. Capturing these interactions suggests a need to conduct the economic analysis at the household level, reflecting the efficiency of both farm and off-farm activities.

The objective of this article is to investigate the efficiency of farm households exhibiting significant off-farm earnings, with an application to The Gambia. First, we review previous research on production efficiency in farm households and present methods used to measure economic efficiency. Next, a conceptual model of a farm household is presented along with implications for the separability of farm and off-farm decisions. The analysis shows how rigidities in the labor market and/or jointness between farm and nonfarm activities are sufficient to invalidate efficiency measures conducted solely at the farm level. Indices of technical, allocative, and scale efficiency are obtained from an output-based approach estimated using a nonparametric representation of the underlying technology of farm households in a peri-urban area of The Gambia. The analysis is applied at the household level, thus capturing the importance of off-farm activities. Finally, using a Tobit model, an econometric analysis is conducted of determinants affecting the efficiency indices. The analysis indicates that, on average, technical efficiency is fairly high but allocative efficiency is much lower. The Tobit results provide evidence that these findings can be attributed to imperfections in the market for financial capital and barriers to the flow of labor between farm and nonfarm sectors.

Background

Two approaches have been used to obtain estimates of technical feasibility: parametric and nonparametric (for an overview, see Coelli, Prasada Rao, and Battese). The parametric approach consists of specifying and estimating a parametric production function (or its dual cost or profit function) representing the best available technology (e.g., Forsund, Lovell, and Schmidt; Bauer). While this approach provides a convenient framework for conducting hypothesis testing, the results can be sensitive to the parametric form chosen. The nonparametric approach builds on the work of Afriat and Varian and has the advantage of imposing no a priori parametric restrictions on the underlying technology (e.g., Färe, Grosskopf, and Lovell; Seiford and Thrall). The latter approach is used in this article.

Extensive empirical research has been conducted on the economic efficiency of farm household decisions. The analyses have relied on parametric methods as well as nonparametric methods, and have provided evidence on the efficiency of agricultural decision making around the world. Examples include Chavas and Aliber in the United States; Battese and Coelli, Sharif and Dar, Wang, Wailes, and Cramer, and Jha and Rhodes in Asia; Ray and Bhadra in India; Sotnikov in Russia; Adesina and Djato, and Gurgand in Côte d'Ivoire; Croppenstedt and Demeke, and Seyoum, Battese, and Fleming in Ethiopia; Aguilar and Bigsten in Kenya; Audibert in Mali; Olowofeso in Nigeria; Mbowa, Nieuwoudt, and Despins in South Africa; and Heshmati and Mulugetya in Uganda. In general, these studies provide some evidence of agricultural inefficiency, and show heterogeneity across farm households in terms of their access to the best available technology and their ability to manage scarce resources efficiently. Particularly relevant to this research, a number of studies attribute inefficiencies to imperfections in credit and capital

[1] Another condition needed is that there is no utility (or disutility) associated with either farm or off-farm work (Lopez).

[2] In the context of farm household labor allocation, this separability condition has been investigated empirically by Benjamin in Java, Jacoby in Peru, and Skoufias in India.

markets (e.g., Aguilar and Bigsten; Ray and Bhadra; Adesina and Djato).

A Household Model

In the presence of labor market rigidities and/or joint technology of farm and nonfarm activities, the appropriate level of analysis is the household. Measuring production efficiency at the farm level (rather the household level) would be invalid in this context as argued below.

Consider a farm household with m family members making production, consumption, and labor allocation decisions during a specific time period. Let $\mathbf{F} = (F_1, \ldots, F_m)$ be the amount of family labor used working on the farm, where F_i is the amount of time spent by the ith member, $i = 1, \ldots, m$. The household uses family labor $\mathbf{F}$, hired labor H, and nonlabor inputs x (including land) to produce a vector of farm outputs $\mathbf{y}$. The m household members can also spend their time in off-farm activities. Let $\mathbf{L} = (L_1, \ldots, L_m)$ be the amount of off-farm labor used by the m family members, generating nonfarm income N. The technology facing the household is represented by the feasible set X, where $(x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) \in X$ means that inputs $(x, \mathbf{F}, H, \mathbf{L})$ can feasibly produce outputs $(\mathbf{y}, N)$,[3] and farm and off-farm labor productivity is allowed to vary across family members. Over the time period of interest, let T be the total amount of time available to any family member. The m family members thus allocate their time between leisure activities $\boldsymbol{l} = (l_1, \ldots, l_m)$, on-farm labor $\mathbf{F} = (F_1, \ldots, F_m)$, and off-farm employment $\mathbf{L} = (L_1, \ldots, L_m)$, subject to satisfying the time constraint:

$$(1) \qquad l_i + F_i + L_i = T$$

$i = 1, \ldots, m$. The farm-household consumes goods $\mathbf{z}$, purchased at market prices $\mathbf{q}$. Assume for the moment that the household faces competitive markets.[4] Denote market prices by $(\mathbf{p}, \mathbf{r}, w)$, where $\mathbf{p}$ is the price vector for farm outputs $\mathbf{y}$, $\mathbf{r}$ is the price vector for nonlabor inputs x, and w is the wage rate for hired labor H. Consumption decisions are made subject to the following budget constraint:

$$(2) \qquad \mathbf{q}'\mathbf{z} \leq \mathbf{p}'\mathbf{y} - \mathbf{r}'x - wH + N.$$

Equation (2) states that consumer expenditures $(\mathbf{q}'\mathbf{z})$ cannot exceed farm revenue $(\mathbf{p}'\mathbf{y})$, minus farm production cost $(\mathbf{r}'x + wH)$, plus nonfarm income (N).

Production, consumption, and labor decisions are made by members of the household. Consider the case where such decisions are made under cooperative bargaining by household members. Assume that household preferences can be represented by a household utility function $U(\mathbf{z}, \boldsymbol{l})$ defined over $(\mathbf{z}, \boldsymbol{l}) \geq 0$, where $U(\mathbf{z}, \boldsymbol{l})$ is a "social utility function" aggregating preferences across household members and reflecting their relative bargaining power. We assume that that the utility function $U(\mathbf{z}, \boldsymbol{l})$ is nonsatiated and quasi-concave in $(\mathbf{z}, \boldsymbol{l})$. Under cooperative bargaining, household decisions are made according to the following optimization problem:

$$(3) \qquad \max_{x, \mathbf{F}, H, \mathbf{L}, \mathbf{y}, N, \mathbf{z}, l} \{U(\mathbf{z}, l) : \text{equations (1) and (2)}; (x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) \in X\}.$$

The utility maximization problem (3) represents economic rationality for the household, and $x^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $\mathbf{F}^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $H^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $\mathbf{L}^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $\mathbf{y}^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $N^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, $\mathbf{z}^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$, and $\mathbf{l}^+(\mathbf{q}, \mathbf{p}, \mathbf{r}, w)$ denote the supply-demand functions representing utility maximizing household behavior.

Under nonsatiation of the utility function $U(\mathbf{z}, \boldsymbol{l})$, the budget constraint (2) is necessarily binding, and the optimization problem (3) can be decomposed into two stages: first, choose $(x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N)$; and second, choose $(\mathbf{z}, \boldsymbol{l})$. The first stage optimization with respect to $(x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N)$ can be written as

$$(4a) \qquad \pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l}) = \max_{x, \mathbf{F}, H, \mathbf{L}, \mathbf{y}, N} \{\mathbf{p}'\mathbf{y} - \mathbf{r}'x - wH + N : (x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) \in X; \; F_i + L_i = T - l_i, \; i = 1, \ldots, m\},$$

where $(\mathbf{T} - \boldsymbol{l}) \equiv (T - l_1, \ldots, T - l_m)$ are the amounts of time the m family members spend working either on or off the farm. Equation (4a) establishes profit maximization with

[3] Without loss of generality, we normalize prices such that the price of off-farm output is equal to 1. In this context, N is both a measure of off-farm income and an index of off-farm output.

[4] Competitive markets are necessary to establish the separability results obtained below. In the presence of market imperfections that restrict market access, such separability results may no longer hold. However, the empirical analysis presented below requires only well-functioning output markets. Thus, our approach and findings remain valid in the presence of factor market imperfections.

respect to the household choice of (x, $\mathbf{F}$, H, $\mathbf{L}$, $\mathbf{y}$, N), with $\pi(\mathbf{p}, \mathbf{r}, w, T - \boldsymbol{l})$ being the indirect profit function conditional on $(\mathbf{T} - \boldsymbol{l})$. To see that household utility maximization (3) implies profit maximization (4a), it suffices to note that, for a given $(\mathbf{T} - \boldsymbol{l})$, a failure to maximize profit would reduce household income, which would restrict consumer expenditure (from equation (2)). Under nonsatiation, this would make the household worse-off. Thus, a failure to maximize profit would be inconsistent with household utility maximization. Let the solution to (4a) be $x^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$, $\mathbf{F}^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$, $H^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$, $\mathbf{L}^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$, the profit maximizing input and labor decisions, and $\mathbf{y}^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$ and $N^*(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$, the profit maximizing output decisions. Note that the profit function $\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$ and associated production decisions do not depend on $\mathbf{z}$ because these variables appear only in the utility function (i.e., they are not arguments of the technology). This implies that production decisions are "separable" from consumption decisions. However, the profit function $\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - \boldsymbol{l})$ and production decisions depend on the amount of time allocated to work, $(\mathbf{T} - \boldsymbol{l})$. The nature of this relationship is discussed subsequently.

Given that utility maximization (3) implies profit maximization (4a) as a first stage optimization, the second stage decisions with respect to $(\mathbf{z}, \boldsymbol{l})$ become

$$\text{(4b)} \quad \max_{\mathbf{z},l} \{U(\mathbf{z}, l) : \mathbf{q}'\mathbf{z} \leq \pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l)\}.$$

Equation (4b) is a standard utility maximization problem subject to the household budget constraint. Combining the two stages (4a) and (4b) is fully consistent with utility maximization (3). Below, we will focus on profit maximization (4a) as the relevant framework to analyze production efficiency at the household level. In the presence of market imperfections and/or poor managerial skills, it is possible that households may not behave in a way consistent with (4a) because they do not or cannot respond to economic incentives. Then, an economic analysis based on (4a) can yield useful insights into the nature and causes of economic inefficiency.

Note that equation (4a) includes farm and nonfarm activities, both in terms of labor allocation ($\mathbf{F}$ and $\mathbf{L}$) and income ($\mathbf{p}'\mathbf{y}$ and N) at the household level. It involves the general technology X, allowing for joint household decisions between farm and nonfarm activities. Examples of jointness include skills acquired in nonfarm employment that improve farm management, and nonfarm income that reduces the adverse effects of credit market imperfections on farm decisions.

In previous literature, the economic analysis of farm production efficiency has often been done at the farm level (and not the household level). Under what conditions would a farm level approach be appropriate? As we argue below, a farm focus may be appropriate if there is nonjointness in the technologies underlying farm and nonfarm activities. Under nonjointness, the farm technology is represented by $(x, \mathbf{F}, H; \mathbf{y}) \in X_f$, while nonfarm technology is $(\mathbf{L}; N) \in X_n$. Then, the general household technology is $X = \{(x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) : (x, \mathbf{F}, H; \mathbf{y}) \in X_f;\ (\mathbf{L}; N) \in X_n\}$. This simply states that, except for the time constraint (1), the household technology X can be expressed completely in terms of the separate technologies X_f and X_n. Let the production frontier $N = g(\mathbf{L})$ represent the boundary of the off-farm technology, where $X_n = \{(\mathbf{L}; N) : N \leq g(\mathbf{L}), \mathbf{L} \geq 0\}$. Under nonjointness, the profit maximization in equation (4a) becomes

$$\text{(4a}'\text{)} \quad \pi(\mathbf{p}, \mathbf{r}, w, \mathbf{T} - l) = \max_{x,\mathbf{F},H,\mathbf{y}} \{\mathbf{p}'\mathbf{y} - \mathbf{r}'x - wH + g(\mathbf{T} - l - \mathbf{F}) : (x, \mathbf{F}, H; \mathbf{y}) \in X_{\mathrm{f}}\}$$

where $(\mathbf{T} - \boldsymbol{l} - \mathbf{F}) \equiv (T - l_1 - F_1, \ldots, T - l_m - F_m) = (L_1, \ldots, L_m)$ from the time constraint (1).

Next, consider the case where $g(\mathbf{L})$ is linear in $\mathbf{L}$, where $g(\mathbf{L}) = \sum_{i=1}^{m} w_{Li} L_i\ L_i$, and w_{Li} can be interpreted as the wage rate received by the ith family member from off-farm activities, $i = 1, \ldots, m$. In this case, letting $\mathbf{w}_L = (w_{\mathrm{L}1}, \ldots, w_{\mathrm{Lm}})$, equation (4a′) implies the following optimization problem at the farm level (instead of the household level):

$$\text{(4a}''\text{)} \quad \pi_{\mathrm{f}}(\mathbf{p}, \mathbf{r}, w, \mathbf{w}_{\mathrm{L}}) = \max_{x,\mathbf{F},H,\mathbf{y}} \left\{\mathbf{p}'\mathbf{y} - \mathbf{r}'x - wH - \sum_{i=1}^{m} w_{Li} F_i : (x, \mathbf{F}, H; \mathbf{y}) \in X_{\mathrm{f}}\right\}$$

where $\pi(\mathbf{p}, \mathbf{r}, w, \mathbf{w}_L, \mathbf{T} - \boldsymbol{l}) = \pi_f(\mathbf{p}, \mathbf{r}, w, \mathbf{w}_L) + \sum_{i=1}^{m} w_{Li}\ [\mathrm{T} - l_{\mathrm{i}}]$, and $(\sum_{i=1}^{m} w_{Li} T)$ is "full income" measuring the total value of household time. Equation (4a″) shows that the wage rate w_{Li} measures the opportunity cost of farm labor L_i for each family member, $i = 1, \ldots, m$. When the wage rate is unique with

$w = w_{L1} = \cdots = w_{Lm}$, this reduces to the standard agricultural household model (e.g., Singh, Squires, and Strauss). Equation (4a″) gives the profit maximizing input, farm labor, and farm output decisions, but at the farm instead of household level. As shown by Singh, Squires, and Strauss, these farm-level decisions are separable from both consumption and off-farm activities. As in equation (4a), the optimal production decisions for x, $\mathbf{F}$, H, and $\mathbf{y}$ in equation (4a″) do not depend on the consumption decisions $\mathbf{z}$. However, in contrast with equations (4a) or (4a′), they no longer depend on $(\mathbf{T} - \boldsymbol{l})$. This is an important difference between equations (4a″) and (4a″).

Equation (4a″) can provide the basis for analyzing efficiency at the farm level, as commonly used in previous research. However, we have just shown that two key assumptions are needed to make equation (4a″) consistent with equation (4a″): (*a*) the farm and nonfarm technology must be nonjoint; and (*b*) the wage rates $\mathbf{w}_L$ must measure the opportunity cost of farm family labor $\mathbf{L}$. This means that both assumptions must be satisfied to justify the standard farm-level approach to efficiency analysis in agriculture. Indeed, under joint technology, neither equation (4a′) nor equation (4a″) holds. Then, technical, allocative, and/or scale efficiency analyses must be conducted at the household level (based on equation [4a]) to capture the jointness between farm and off-farm activities. If nonjointness holds, then equation (4a′) still applies, meaning that technical efficiency analysis can be conducted at the farm level. However, this is still not sufficient to obtain equation (4a″). Indeed, going from equation (4a′) to equation (4a″) requires that the opportunity cost of farm family labor $\mathbf{L}$ must be the wage rate $\mathbf{w}_L$. If this assumption does not hold, then allocative efficiency (including time allocation) cannot be based on equation (4a″): it must be based either on equation (4a′) under nonjointness, or on equation (4a) under jointness.

This shows that, if the opportunity cost of family labor is not the wage rate $\mathbf{w}_L$ (e.g., due to rigidities in the labor market) and if farm and off-farm activities are part of a joint technology, then measurements produced by equation (4a″) would be invalid. In this context, equation (4a″) would be the preferred approach. In addition, equation (4a″) provides the appropriate framework to investigate the efficiency of both farm and off-farm activities. The empirical implementation of equation (4a″) is discussed next.

Measuring Production Efficiency

The literature on production efficiency measurements is extensive (e.g., Debreu; Farrell; Farrell and Fieldhouse; Färe, Grosskopf, and Lovell, 1985). Both input- and output-based efficiency measures have been used. Although the two approaches are equivalent under constant return to scale, they differ under variable return to scale (Färe, Grosskopf, and Lovell 1985). In this research, given the available data, we opt to use output-based efficiency measures (e.g., as discussed in Färe, Grosskopf, and Lovell 1985, 1994).

Consider a household involved in both farm and off-farm activities characterized by use of inputs (x, $\mathbf{F}$, H, $\mathbf{L}$) producing outputs ($\mathbf{y}$, N). The output-based technical efficiency index, TE, is defined as

$$(5) \qquad \mathrm{TE}(x, \mathbf{F}, H, \mathbf{L}, \mathbf{y}, N, X) = \min_{\theta}\{\theta : (x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}/\theta, N/\theta) \in X, \theta > 0\}.$$

In general, $0 \leq \mathrm{TE} \leq 1$, where $\mathrm{TE} = 1$ when the household is producing on the production frontier and is said to be technically efficient, while $\mathrm{TE} < 1$ implies that the farm is not technically efficient. Under variable return to scale (VRTS), this is illustrated in figure 1 where point A is an observed point below the production frontier $f(x)$, and point B is a point on the production frontier. Being at point A implies a technical efficiency index $\mathrm{TE} = \mathrm{OA}/\mathrm{OB}$ in figure 1(a) and (b).

Note that the profit maximization problem (4a) implies the following revenue maximization

$$(6) \quad R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) = \max_{\mathbf{y}, N}\{\mathbf{p}'\mathbf{y} + N : (x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) \in X\}$$

where $R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X)$ is the revenue function, conditional on inputs (x, $\mathbf{F}$, H, $\mathbf{L}$). By focusing on output allocations, equation (6) only assumes well-functioning output markets. This is important in the sense that the analysis presented below remains valid in the presence of factor market imperfections. Let the index of allocative efficiency, AE, with respect to farm outputs be

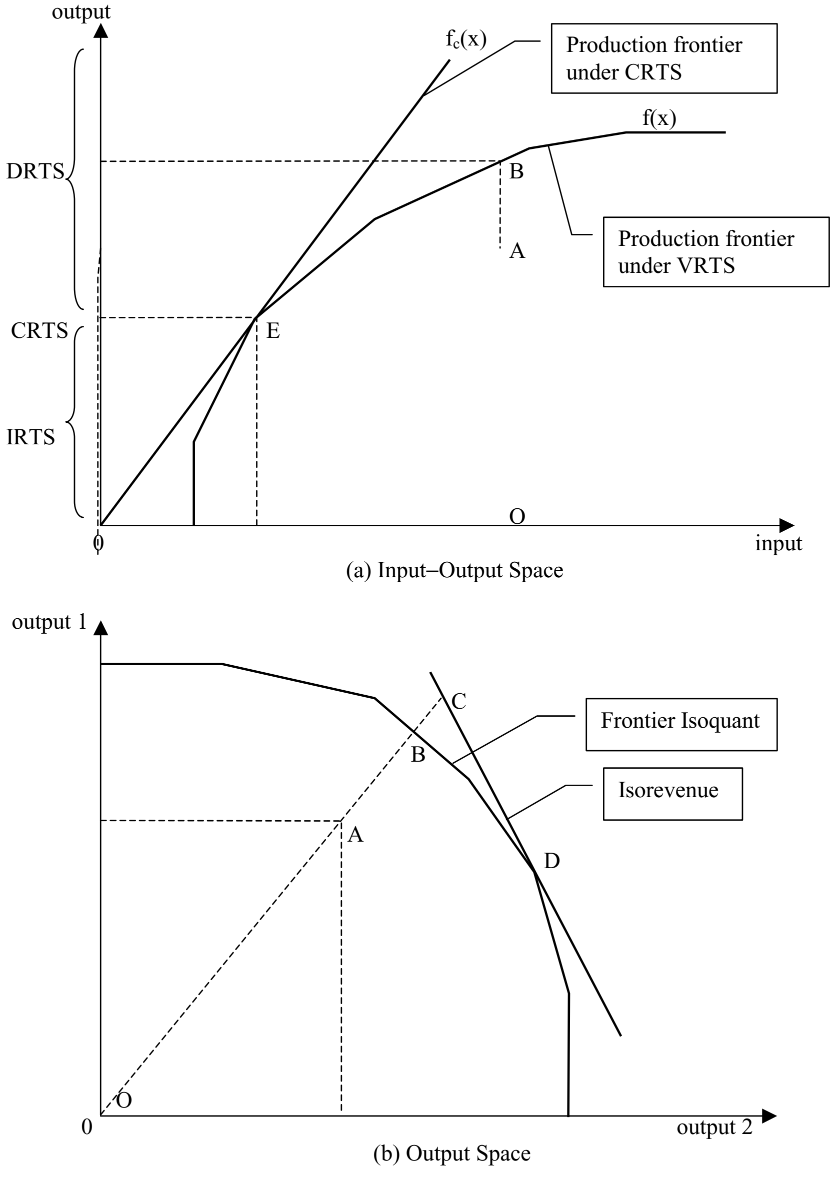
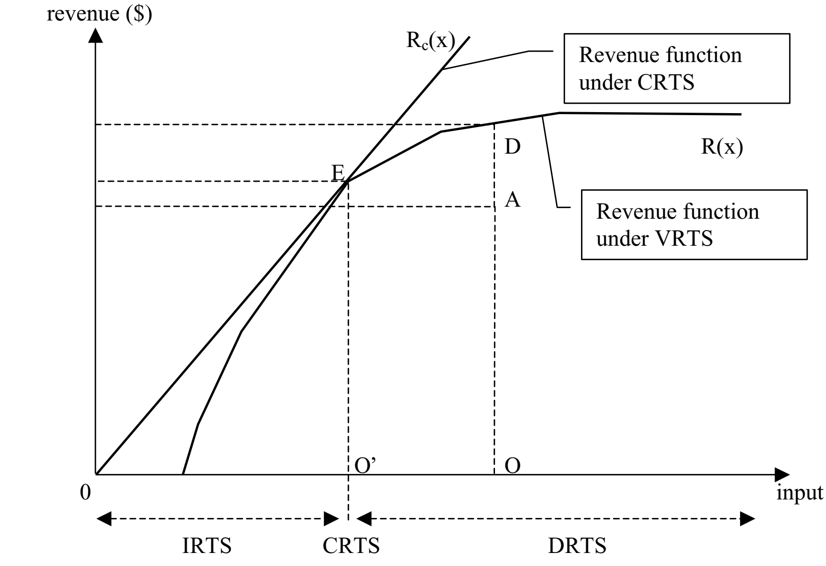


Figure 1. Efficiency measures

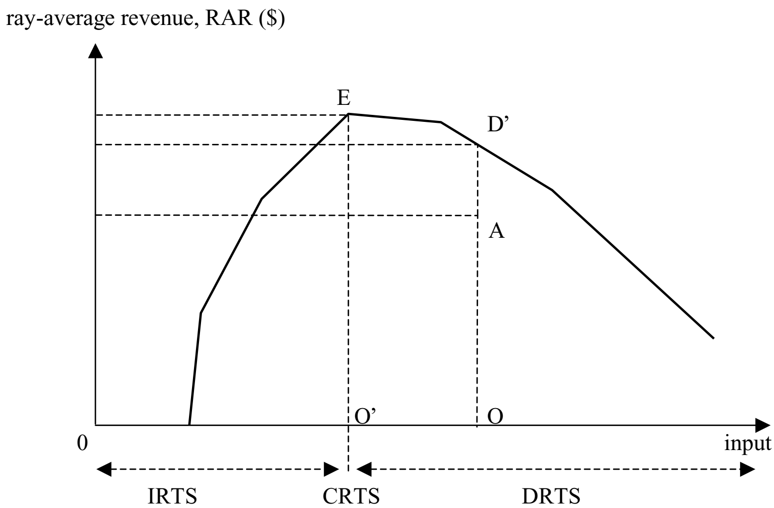
$$(7) \quad \text{AE}(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) = [\mathbf{p}'(\mathbf{y}/\text{TE}) + N/\text{TE}]/R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X)$$

where ($\mathbf{y}$/TE, N/TE) is a technically efficient output vector from equation (5). In general, $0 \leq \text{AE} \leq 1$, where AE = 1 represents a revenue maximizing firm that is allocatively efficient with respect to outputs. This is illustrated in figure 1(b), where D is the revenue maximizing point, and the allocative efficiency index is AE = OB/OC. This is also illustrated in figure 2(a) using the revenue function, where OA measures actual revenue, OD is the maximized revenue, and OA/OD = TE · AE.

Finally, in figure 1(a), E identifies a scale efficient point under the production function $f(x)$. Firms of size smaller than E are "too small" as they exhibit increasing return to scale, IRTS (where a proportional increase in inputs generates a more than proportional increase in outputs), and firms of size larger than E are "too large" as they exhibit decreasing return to scale, DRTS (where a proportional increase in inputs yields less than proportional increase in outputs). Point E is scale efficient in the sense



(a) Input–Revenue Space



(b) Input–RAR Space

Figure 2. Efficiency measures from the revenue function

that it is the firm size that corresponds to locally constant returns to scale (CRTS). Using the revenue function, returns to scale can be expressed in terms of the ray-average revenue (RAR) function

$$\mathrm{RAR}(k, \mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X\} = R(\mathbf{p}, k \cdot x, k \cdot \mathbf{F}, k \cdot H, k \cdot \mathbf{L}, X)/k$$

for some scalar $k > 0$, where the revenue function $R(\cdot)$ is defined in equation (6), and k measures a proportional rescaling of all inputs. Then, IRTS, CRTS, or DRTS corresponds to $\mathrm{RAR}(k, \cdot)$ being an increasing, constant, or decreasing function of k, respectively. In the case where $\mathrm{RAR}(k, \cdot)$ has an inverted U-shape, then scale efficiency or CRTS is attained at the maximum of the function $\mathrm{RAR}(k, \cdot)$. As illustrated in figure 2(b), this suggests the following index of scale efficiency

$$\text{(8)} \qquad \mathrm{SE}(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) = R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X)/ AR(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X)$$

where $\text{AR}(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) = \sup_k\{R(\mathbf{p}, k \cdot x, k \cdot \mathbf{F}, k \cdot H, k \cdot \mathbf{L}, X)/k: k > 0\}$ is the largest ray average revenue with respect to k, and $0 \leq \text{SE} \leq 1$. Inputs $(x, \mathbf{F}, H)$ satisfying SE = 1 identify an efficient scale of operation corresponding to the largest ray average revenue. Alternatively, finding SE < 1 implies that the inputs $(x, \mathbf{F}, H)$ are not an efficient scale of operation. In this case, $(1 - \text{SE})$ can be interpreted as the relative increase in ray-average revenue obtained by proportionally rescaling all inputs to achieve the efficient scale of operation (where inputs exhibit locally constant returns to scale). This is illustrated in figure 2(b), where $\text{SE} = \text{OD}'/\text{O}'\text{E}$. The Appendix presents an equivalent measurement of SE used below.

Nonparametric Measurements

The above efficiency indexes can be estimated empirically only if a representation of the underlying technology is available. Following the nonparametric approach (e.g., Färe, Grosskopf, and Lovell 1985), consider a sample of n observations of farm-households. Let $(x^j, \mathbf{F}^j, H^j, \mathbf{L}^j)$ and $(\mathbf{y}^j, N^j)$ be the vectors of inputs and outputs, respectively, chosen by the jth household, $j = 1, \ldots, n$. Technical feasibility means that $(x^j, \mathbf{F}^j, \text{H}^j, \mathbf{L}^j, \mathbf{y}^j, N^j) \in X$, where X is the feasible set of household production possibilities.

How can these production data be used to provide a representation of the technology X? Let X^e be the smallest convex set consistent with the data under VRTS.[5] It can be interpreted as the inner-bound representation of the underlying production possibility set X (Afriat; Varian). This is illustrated in figure 1(a), where $f(x)$ represents the production frontier as the tightest concave envelope of all data points. Using X^e as the representation of technology, the measurement of the technical efficiency index TE in equation (5) for the jth farm-household can be obtained by solving a linear programming problem,[6] whereby technical efficiency is the distance between the observed input–output mix and the empirical production possibility frontier. Production decisions located on the production frontier are technically efficient, and those below the frontier are technically inefficient.

Also, one can evaluate the revenue function for the jth farm-household, $R(\mathbf{p}, x^j, \mathbf{F}^j, \text{H}^j, \mathbf{L}^j, X^e)$,[7] and obtain the allocative efficiency index AE by substituting the measures obtained for technical efficiency and the estimated revenue function into equation (7).

Finally, X_c^e can be defined as the smallest convex cone consistent with the data under CRTS.[8] It can be interpreted as the inner bound representation of the technology under CRTS (Afriat; Varian). This is illustrated in figure 1(a), where $f(x)$ is the production frontier under VRTS, while $f_c(x)$ is the production frontier under CRTS. Using the CRTS representation, one can calculate the revenue function $R(\mathbf{p}, x^j, \mathbf{F}^j, H^j, \mathbf{L}^j, X_c^e)$.[9] Substituting this into equation (A1) in the Appendix yields an estimate of the scale efficiency index, SE, for the jth household, thus enabling the analysis of production efficiency for each household using standard optimization tools.

Application to The Gambia

The above analysis of production efficiency is applied to a 1993 survey of 120 households in three peri-urban villages surrounding the capital city of Banjul, The Gambia: Sinchu, Sanyang, and Pirang. The village of Sinchu is located at the periphery of Greater Banjul, has a low land per capita ratio, and rapid population settlement. The villages of Sanyang and Pirang are each in an agricultural zone, about 18 km from Sinchu. Of the 120 households sampled, five were dropped from the analysis because of data inconsistencies. Descriptive statistics for 115 households are presented in table 1.

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[5] Technically, X is represented by $X^e = \{(x, \mathbf{F}, H, \mathbf{L}, \mathbf{y}, N) : \mathbf{y} \leq \Sigma_i\lambda_i\mathbf{y}^i, N \leq \Sigma_i\lambda_i N^i, x \geq \Sigma_i\lambda_i x^i, \mathbf{F} \geq \Sigma_i\lambda_i\mathbf{F}^i, H \geq \Sigma_i\lambda_i H^i, \mathbf{L} \geq \Sigma_i\lambda_i\mathbf{L}^i, \Sigma_i\lambda_i = 1, \lambda_i \geq 0, i = 1, \ldots, n\}$. The set X^e is closed and convex. Under nonnegative marginal productivity and variable returns to scale, it is the smallest convex set that is consistent with the data.

[6] For jth household, the linear programming problem is $\text{TE}(x^j, \mathbf{F}^j, H^j, \mathbf{L}^j, \mathbf{y}^j, N^j, X^e) = \min_{\theta,\lambda}\{\theta : \mathbf{y}^j/\theta \leq \Sigma_i\lambda_i\mathbf{y}^i, N^j/\theta \leq \Sigma_i\lambda_i N^i, x^j \geq \Sigma_i\lambda_i x^i, \mathbf{F}^j \geq \Sigma_i\lambda_i\mathbf{F}^i, H^j \geq \Sigma_i\lambda_i H^i, \mathbf{L}^j \geq \Sigma_i\lambda_i\mathbf{L}^i, \Sigma_i\lambda_i = 1, \lambda_i \geq 0, i = 1, \ldots, n\}$.

[7] The maximum revenue for jth household under the nonparametric representation X^e is obtained by solving the linear programming problem $R(\mathbf{p}, x^j, \mathbf{F}^j, H^j, \mathbf{L}^j, X^e) = \max_{\mathbf{y},N,\lambda}\{\mathbf{p}'\mathbf{y} + N : \mathbf{y} \leq \Sigma_i\lambda_i\mathbf{y}^i, N \leq \Sigma_i\lambda_i N^i, x^j \geq \Sigma_i\lambda_i x^i, \mathbf{F}^j \geq \Sigma_i\lambda_i\mathbf{F}^i, H^j \geq \Sigma_i\lambda_i H^i, \mathbf{L}^j \geq \Sigma_i\lambda_i\mathbf{L}^i, \Sigma_i\lambda_i = 1, \lambda_i \geq 0, i = 1, \ldots, n\}$.

[8] Consider the following nonparametric representation of technology under CRTS $X_c^e = \{(x, \mathbf{F}, H, \mathbf{L}, \mathbf{y}, N) : \mathbf{y} \leq \Sigma_i\lambda_i\mathbf{y}^i, N \leq \Sigma_i\lambda_i N^i, x \geq \Sigma_i\lambda_i x^i, \mathbf{F} \geq \Sigma_i\lambda_i\mathbf{F}^i, H \geq \Sigma_i\lambda_i H^i, \mathbf{L} \geq \Sigma_i\lambda_i\mathbf{L}^i, \lambda_i \geq 0, i = 1, \ldots, n\}$, where the set X_c^e is a closed and convex cone, and satisfies $X^e \subset X_c^e$.

[9] The ray-average revenue function under CRTS can be calculated by solving the following linear programming problem for the jth household $R(\mathbf{p}, x^j, \mathbf{F}^j, \text{H}^j, \mathbf{L}^j, \text{X}_c^e) = \max_{\mathbf{y},N,\lambda}\{\mathbf{p}'\mathbf{y} + N : \mathbf{y} \leq \Sigma_i\lambda_i\mathbf{y}^i, N \leq \Sigma_i\lambda_i N^i, x^j \geq \Sigma_i\lambda_i x^i, \mathbf{F}^j \geq \Sigma_i\lambda_i\mathbf{F}^i, \text{H}^j \geq \Sigma_i\lambda_i H^i, \mathbf{L}^j \geq \Sigma_i\lambda_i\mathbf{L}^i, \lambda_i \geq 0, \text{i} = 1, \ldots, n\}$. The solution for the λ_i's has the following useful interpretation. Finding $\Sigma_i \lambda_i < 1$ $(= 1, \text{or} > 1)$ means that, under variable return to scale, jth firm exhibits IRTS (CRTS or DRTS).

Table 1. Farm and Household Characteristics by Village

	Sinchu ($n = 37$)	Sanyang ($n = 40$)	Pirang ($n = 38$)	Total ($n = 115$)
General				
Land area (ha)	0.436	2.069	1.483	1.349
Gender of head (% male)	97.3	90.0	86.8	91.3
Education (%)				
Koranic	59.5	87.5	86.8	78.3
Primary	2.7	—	—	0.8
Secondary	10.8	2.5	10.5	7.8
Partial/none	27.0	7.5	2.6	12.2
Founding family (% yes)	8.1	45.0	39.5	31.3
Recent migrants (% yes)	27.0	0	2.6	9.6
Food security				
Household food insecurity (% yes)	27.0	37.5	7.9	24.3
Farm food insecurity (% yes)	59.5	12.5	5.3	25.2
Land				
Risk of losing land if rent out for 5 seasons or more (% yes)	5.4	0	28.9	11.3
Simpson index	0.320	0.539	0.495	0.454
Percent land borrowed	22.7	31.6	30.8	28.0
Labor				
Average number of adult males (>15 years old)	2.18	3.2	2.68	2.68
Average number of adult females (>15 years old)	2.38	2.9	2.85	2.71
Average number of children	4.02	5.58	4.7	4.77
Kafo membership (% yes)	18.9	2.5	76.3	32.2
Major herder (% yes)	0	17.5	10.5	9.6
Percent that are male	0	100.0	100.0	100.0
Female to male adult ratio	1.293	1.297	1.088	1.227
Children to adult ratio	0.965	0.958	0.938	0.954
Hired labor costs	33.11	101.18	173.29	103.10
Off-farm income				
Percent income from off-farm earnings	73.5	29.6	49.2	50.2
Financial capital				
Proportion loans from *Osusu*	0.194	0	0.537	0.240
Household income (dalasis)				
Farm level earnings	856.44	2,442.69	4,916.18	2,749.66
Off-farm revenue	8,415.35	3,909.88	8,086.39	6,739.53
Remittances received	71.35	2.5	981.32	348.09
Household level total income (Farm, off-farm, remittances)	9,343.14	6,355.06	13,983.89	9,837.28

Note: Figures are mean values, unless noted otherwise.

Control over resources in the study area is exercised at various levels of social organization. A village typically consists of several patrilineal kin groups (*kabilo* in Mandinka) that serve the primary basis for land access and reciprocal exchanges of labor and credit (Shipton; McPherson and Radelet). A *kabilo* in turn consists of several compounds (*kordoteos*) that may be composed of one or more production units (*dabada);* the latter is the unit for the farm-household used in this analysis.

Most households in the sample are headed by males (between 87% and 97%) and have little formal education. A household typically consists of several children and a couple of female and male adults. Many male adults have migrated to the urban areas in search of work. Households use household labor, hired labor, and *Kafo* labor for agricultural production. A *Kafo* mobilizes group labor on a contract basis at various points in the agricultural season. The revenue collected by the group can be shared

Table 2. Household Head's Perceptions of Land Rights Held by Family Members

	Sinchu (%)	Sanyang (%)	Pirang (%)	Total (%)
Sell upland crop plots				
Without authorization	8.1	42.5	28.9	26.9
With authorization	2.7	10.0	10.5	7.8
Rent-out land crop plots				
Without authorization	8.1	45.0	28.9	27.8
With authorization	5.4	12.5	10.5	9.6

Note: Percentage of household heads who perceive they have such a right.

or lent out on a credit basis. About 32% of households have members who participate in *Kafo* arrangements.

Land use is strongly associated with plot location. On compound land, where the extended family resides, family members grow vegetables, cassava, maize, or fruit trees. Inner fields, like compound plots, are usually very fertile due to applications of household waste and livestock tethering. Such land is highly valued and is the site of vegetables and maize grown by family members, or fruit trees grown by men. Outside the concentric ring of inner fields lie the upland fields that men use to grow maize, millet, sorghum, and groundnuts. Women are primarily responsible for the rice and vegetable cultivation, the latter done in low-lying areas, inner fields, or in a communal garden provided with fencing and wells. Women may also grow groundnuts on upland fields although this practice is less common in villages with access to swamp land for irrigated rice.

The sample villages were settled between the late 1800s and mid-1970s and originated in a land grant by the paramount chief or king. Families were later invited or welcomed to clear the land, and by right of settlement came to be recognized as village founding families with preferential rights of cultivation and exclusion. Roughly 31% of the sample households are founding families with a higher concentration in Sanyang and Pirang. More recent migrants generally solicit land from the chief or founding families. Newcomers who demonstrate a willingness to settle permanently may be granted land rights as robust as the founding families themselves possess. However, if permanent status cannot be obtained, plots may be borrowed on a seasonal or annual basis (in practice, borrowings run several years). About 28% of all household land is borrowed, a figure that is consistent across the three villages.

Land tenure security comprises multiple dimensions: breadth or the number of rights held on a given plot; duration or the length of time a particular right is held; and assurance referring to the degree of certainty embodied in holding a given right (Place and Hazell). In the sample, use rights[10] are more widely distributed than inter-vivos transfer rights, and the right to rent or lend land is slightly more widely distributed than the right to sell (see table 2). Within use rights, the percentage of households enjoying the right to make an improvement is inversely related to the improvement's durability. Not unexpectedly, each right category is reported more frequently on plots managed by founding families and by men. Possession of the right to sell is more valuable than the right to bequeath or rent because land may be permanently alienated to users outside the principal land holding group. A landholder who has the right to dispose of a plot has extensive rights to its use. In the sample, any plot whose manager perceived the right to sell also perceived possession of every other use and transfer right, hence the right to sell serves as a good proxy for a complete rights bundle.

Households are dependent on nonfarm sources of employment at the ebb of agricultural activity in the dry season, but also work on wage- and self-employment activities throughout the year. Roughly 40% of survey households have one or more members engaged in off-farm employment. An average household gets 69% of its income from off-farm earnings. This ranges between 58% for Pirang and 90% for Sinchu and is well within the range found in previous research (Reardon). The importance of off-farm earnings can also be seen in average household income at the farm and household-level. Looking at mean farm income only, households in Sinchu make 856 dalasis a year ($1 = 10 dalasis at the time of the survey), 4,916 dalasis in Pirang, and 2,443 dalasis in Sanyang. When off-farm earnings and remittances are added, household income increases dramatically to 9,343, 13,984, and 6,355

[10] They include right to build a house, wall or fence, to construct water control structures, or to plant fruit trees.

dalasis, respectively. On average, half of nonfarm income comes from wage employment, and half from self-employment. About 70% of wage employment involves work between nine and twelve months per year, mainly on teaching, service and commercial activities, and construction (see Roth et al.). With respect to self-employment, jobs involve commerce, construction, service and fisheries, most lasting five to six months per year.[11]

Empirical Model

The production efficiency analysis is conducted at the household level, where production activities are disaggregated into eight inputs used to produce seven outputs.[12] The inputs are: (*a*) child labor (measured by the number of children less than fifteen years old); (*b*) male labor (number of male adults more than fifteen years old); (*c*) female labor (number of female adults more than fifteen years old); (*d*) hired labor (cost of hired labor paid to nonfamily workers, including *Kafo* labor); (*e*) area cultivated within the compound (ha); (*f*) area cultivated on inner fields near the compound (ha); (*g*) area cultivated on outer fields (ha); and (*h*) variable inputs (cost of fertilizer, pesticides, tractor services, animal traction services, and seeds). The outputs are: (*a*) vegetable production (measured by an output index for all vegetable crops); (*b*) fruit production (including mangos, oranges, limes, and cashew trees); (*c*) rice production (kilograms); (*d*) sorghum and millet production (output index); (*e*) groundnut production (kilograms); (*f*) maize and cassava production (output index); and (*g*) off-farm earnings (income earned from any wage or self-employment activity). Livestock herding and confinement rearing are important activities as well. Unfortunately, missing data on livestock earnings prevented including them among the outputs. The analysis was conducted by pooling households from all three villages.[13] The estimates of technical efficiency are obtained by comparing the input–output bundle of each farm household with the nonparametric representation of the frontier technology.

The disaggregation of inputs and outputs is intended to capture both quantity and quality effects. Land cultivated within, near and outside the compound jointly captures both area and land fertility differences. Labor allocation within the household indicates a fairly high degree of specialization by gender on labor tasks and crop enterprises. Male adults within the household tend to concentrate their time (more than 85% of plots farmed used male adult labor)[14] on tasks of land preparation, planting, weeding and harvesting of cereals, groundnuts, and orchards (crops controlled by men) but provide very little labor (less than 5% on all tasks) on women's rice fields. Female adults worked on 30–50% (percentage varies by task) of plots cultivated in cereals and groundnuts, but this figure rises to 80–90% for the same tasks on rice and vegetable gardens (women's crops). Children tend to assist with all labor tasks on the fields of male adults (between one-third and two-thirds of plots use child labor).[15]

A high number of inputs (8) and outputs (7) relative to the sample size ($n = 115$) will tend to produce a larger number of "efficient" households by expanding the shape of the technology frontier. Reducing the number of variables in the production function would increase the number of "inefficient" households, but would bias efficiency estimates when quality differences in land and labor are not taken into

[11] One reviewer pointed out that seasonality in farm and nonfarm activities could affect the need to conduct the analysis at the household level. Indeed, if most nonfarm activities were to take place in the dry season while most farm activities are done in the rainy season, then the temporal separation may suggest that farm and nonfarm allocations can be analyzed separately. First, such argument is not sufficient to imply that the technology is nonjoint between farm and nonfarm activities (e.g., it neglects nonlabor aspects of jointness). Second, 41% of households in the sample earned income from wage-employment. Of the 58 total jobs worked by these households, 70% involved 9–12 months contracts (Roth, Carr, and Cochrane). This indicates that the temporal separation of farm and nonfarm activities does not hold for a large proportion of our sample data. This strengthens the need to conduct our analysis at the household level (rather than the farm level).

[12] Besides providing a more comprehensive analysis of household efficiency in the presence of significant off-farm income, a household focus has another important advantage. It does not require data on how household labor is allocated between farm and off-farm activities. Since obtaining such data is onerous and costly, the household approach helps improve the empirical tractability of efficiency analysis of rural households facing significant off-farm opportunities.

[13] This seems a reasonable assumption considering that each village is located within close proximity. The assumption is also validated by the efficiency analysis measures; there is a relatively even distribution of efficient households across all three villages, suggesting that no one village has access to more efficient (or different) technology.

[14] Detailed time allocation data were not collected. Rather, each plot manager was asked to indicate whether each of six types of labor (male wage, female wage, *Kafo* wage, male adult family labor, female adult family labor, and child labor) was used on each major plot under his/her management.

[15] We investigated alternative aggregations of household labor. We found that these alternatives had little effects on the empirical results. Also, note that our treatment of household labor has the advantage of not imposing a priori restrictions on the productivity of child labor, adult male labor, and adult female labor in farm as well as nonfarm activities.

consideration. Inputs and outputs were thus chosen to represent a minimal set to describe the production frontier, while shifting less important quality effects to the subsequent Tobit analysis.

The analysis of allocative and scale efficiency requires output price information. Price variations were observed across villages,[16] and across households within each village. The latter result from seasonal effects (since output may have been sold at various points during the previous year), differential access to markets, and a small market surplus relative to production. Since output price variations reflecting differences in resource scarcity across households seems unlikely, median output prices were chosen as measures of resource scarcity for each village. Therefore, for each farm household, output prices are calculated at the median prices of its village.[17]

Production Efficiency Estimates

Applying the methodology, estimates of technical, allocative, and scale efficiency were obtained for each household and are presented in table 3. The mean technical efficiency measure at the household level ranges from 0.895 in Sinchu to 0.995 in Pirang. While gains from improving technical efficiency exist, they appear to be somewhat limited: across all villages, 85.2% of households in the sample are technically efficient (TE = 1).

Households appear to be less allocatively efficient: mean allocative efficiency measures are 0.512 in Sanyang, 0.551 in Sinchu, and 0.639 in Pirang. Only 31% of the sample households are allocatively efficient (AE = 1). On average, allocative inefficiency accounts for a 43% loss in household income suggesting both lack of revenue maximizing behavior and space for improving income by increasing allocative efficiency.

On average, households are found to be more scale efficient than they are allocatively efficient. Mean scale efficiency SE ranges from 0.798 in Sinchu to 0.856 in Pirang, with only 35% of households being completely scale efficient (SE = 1). The analysis was further disaggregated into those households that exhibit increasing returns to scale (IRTS) and are "too small," and those that exhibit decreasing return to scale (DRTS) and are "too large." The number of farm households that are "too large" versus "too small" is similar across villages. In Sinchu and Sanyang, the inefficiency of being "too small" is found to be a little more severe than the inefficiency of being "too large." However, opposite results are obtained for Pirang, which also exhibits higher estimates of scale efficiency.

Table 3. Mean Production Efficiency Estimates

	Sinchu	Sanyang	Pirang	Total
Household level TE	0.895	0.963	0.995	0.952
Household level AE	0.551	0.512	0.639	0.567
Household level SE	0.798	0.803	0.856	0.818
IRTS, $n = 79$	0.811	0.834	0.927	0.856
DRTS, $n = 76$	0.901	0.864	0.864	0.876

Note. For simplicity, households exhibiting CRTS are included in both the IRTS and the DRTS subsample.

Finally, to see how the results would compare with a more traditional farm level focus, we also conducted the efficiency analysis at the farm level. Although not reported here,[18] the farm-level technical efficiency indices were similar to those reported in table 3, while allocative efficiency was found to be higher. The average AE estimate changed from 0.567 at the household-level (as reported in table 3) to 0.757 at the farm-level.[19] This indicates the presence of significant allocative inefficiency in labor allocation between farm and off-farm activities. Factors contributing to such inefficiency include poorly functioning labor markets and inefficient intra-household organization. These issues are further investigated next.

Tobit Analysis of Factors Influencing Efficiency

The results reported in table 3 indicate the presence of production inefficiency, especially

[16] Price variations across villages for some crops were larger than for others. For example, the median price for cassava was 2.0 in Sinchu, 1.2 in Sanyang, and 2.75 in Pirang. However, the median price for groundnuts was 2.31 in Sinchu, 4.27 in Sanyang, and 2.48 in Pirang.

[17] To conduct sensitivity analysis, alternative price measurements were also investigated, including the use of the lower quartile price and the upper quartile price. They have little effects on the empirical results. We selected the median price based on the a priori ground that it seems more reasonable.

[18] The results from a farm-level analysis are available from the authors upon request.

[19] These findings were found to be consistent across villages. In Sinchu, Sanyang, and Pirang, respectively, the average AE estimate changed from 0.551, 0.512, and 0.639 at household-level (as reported in table 3) to 0.693, 0.713, and 0.866 at the farm level.

allocative inefficiency, among the Gambian farm households. Possible sources of inefficiency include poor managerial abilities, poorly functioning factor markets (including land, labor, and credit market), as well as household organizations that do not support cooperative bargaining among household members. For example, credit rationing can have adverse effects on both technical and allocative efficiency. And noncooperative bargaining within the household would imply that intra-household allocations can contribute to technical as well as allocative inefficiency. In addition, inefficiency could be due to idiosyncratic factors specific to each household, or to managerial ability or to structural factors that can be altered through policy action (such as improving the quality of physical and human capital, the functioning of land markets and access to financial capital). To answer these questions and discern sources of inefficiency, the efficiency indices (TE, AE, and SE) were regressed on a set of explanatory variables. Since all the efficiency indices have 1 as an upper bound and 0 as a lower bound, a censored regression or Tobit model was estimated by maximum likelihood. The econometric analysis is conducted by pooling data across all three villages. The explanatory variables are presented in table 4.

In contrast with the input and output variables used in estimating efficiency indices, variables in table 4 reflect idiosyncratic factors that affect decision making and control of resources within the household, or proxies for factor market endowments and institutions that

Table 4. Explanatory Variables in the Tobit Models

Category Groupings	Variable Name	Definition
Household idiosyncrasies	Gender	= 1 if the household head is male
	Founding	= 1 if household is a founding family
	Herder	= 1 if there is a major herder in the household
	Migrant	= 1 if household head moved to the village in the past five years
	Food insecure	= 1 if household income is in the lowest quartile and it reported itself as being unable to produce enough grain to feed everyone in the family throughout the year
Relative labor endowments and labor institutions	Female/male adult ratio	= Ratio of adult females to adult males in household
	Child/adult ratio	= Dependency ratio of children to adults in household
	Kafo	= 1 if any household member is a member of a *Kafo*
Financial market access	*Osusu* loans/withdrawals	= Proportion of total household loans or savings withdrawals originating with an *Osusu*
	Remittances	= Amount of money household receives in remittances
	Off-farm earnings	= Proportion of total household income coming from off-farm earnings
Land fragmentation and land tenure security	Simpson	= Simpson index (1 indicates complete fragmentation)
	Sell with authorization	= 1 if household head perceives right to sell upland cropland with authorization of the compound head, founding family or *Akalo*
	Sell without authorization	= 1 if household head perceives right to sell upland cropland without authorization
	Borrowed land	= Proportion of household land that is borrowed
	Land loss	= 1 if household head perceives *some* risk of losing land if it is rented out for five seasons or more

affect access to and utilization of land, labor, and financial capital. For example, land tenure can potentially affect allocative efficiency under credit market imperfections if land tenure insecurity contributes to credit rationing. Idiosyncratic factors include gender of household head, founding family status, whether the family is involved in livestock herding (to control for the absence of herding output or income in the production function), and whether the family has recently immigrated to the area. The dummy variable for food security captures both the effect of poverty status and inability to acquire enough food to feed the family during the year.

The ratio of female adults to male adults, and the dependency ratio of children to adults reflect possible restrictions in labor allocation among men, women, and children. In addition, the dependency ratio partially captures the time lost to farm production and off-farm earnings by demands for household reproduction. Membership in a *Kafo* organization may either increase household earnings if the activity involves financial remuneration, or help relax the household's labor constraint if participation involves reciprocal group labor on one's own fields.

For assessing the role of access to financial capital, three indicators are included: access to loans or savings withdrawals through an *Osusu* (local rotating saving and credit association), remittances received, and importance of off-farm earnings to the household's budget constraint. Finally, a number of indicators were included for land quality and land tenure security including the Simpson index of land dispersion, percentage of household land borrowed, the risk of losing land if it is rented out, and the right to sell upland cropland with and without authorization.[20]

Table 5. Tobit Analysis of Technical Efficiency (TE)

Variable	TE—Household	Marginal Effects
Intercept	1.434*** (.448)	
Gender	0.232 (0.311)	0.0056
Founding	0.129 (0.204)	0.0031
Herder	−0.701** (0.300)	−0.0169
Migrant	−0.153 (0.284)	−0.0037
Food insecure	−0.392* (0.215)	−0.0095
Female/male adult ratio	0.168 (0.112)	0.0041
Child/adult ratio	−0.174 (0.134)	−0.0042
Kafo	0.740** (0.337)	0.0178
Osusu loans/ withdrawals	−0.757** (0.330)	−0.0182
Remittances	0.0009 (0.0006)	0.0000
Off-farm earnings	−0.296 (0.252)	−0.0071
Simpson	−0.148 (0.345)	−0.0036
Sell with authorization	0.066 (0.280)	0.0016
Sell without authorization	0.522** (0.264)	0.0126
Borrowed land	0.329 (0.269)	0.0079
Land loss	−0.586** (0.272)	−0.0141

Notes: Standard errors are reported in parentheses below the parameter estimates. Statistical significance is indicated by stars: * for the 10% significance level, ** for the 5% significance level, and *** for the 1% significance level.

Technical Efficiency

The Tobit results for technical efficiency are reported in table 5. Incidence of herding has a strong negative effect on technical efficiency, picking up the exclusion of livestock earnings as an output in the household production function. The impacts of gender, founding family, or migrant status on technical efficiency are found to be statistically insignificant. However, food insecurity combined with poverty status is shown to have a negative and significant effect on TE. This suggests that food insecurity, through low nutrition, is dampening labor productivity within the household. It means that low-income status is weakening access to and the efficient use of household resources.

Neither female/male adult ratio nor child/adult ratio is found to have a significant effect on technical efficiency. However, membership in a *Kafo* is shown to have a positive and significant impact on technical efficiency.[21] *Kafo* labor is commonly used by founding families with a high land/resident ratio in Pirang and Sanyang villages. In the presence of relatively fixed land endowments and limited access to financial capital, *Kafo*

[20] Other explanatory variables were also tried in the Tobit analysis but they showed no significant effect. They include education of the household head, whether the household head thought it difficult to acquire new land in the village, whether the household owned a plow, and whether the household rented in land. We also tried dropping some of the variables that were found to be statistically insignificant. In general, we found that, while this influenced the quantitative estimates, this did not affect the qualitative conclusions reported below.

[21] Households were also asked whether they hired *Kafo* labor. For weeding, *Kafo* labor was used on 5% of the plots in the sample. For all remaining tasks—land preparation, planting, and harvesting, *Kafo* labor was used on 1–3% of the plots cultivated. *Kafo* labor tends to more important on land preparation (grains, rice, groundnuts, and gardens), planting (rice), weeding (cereals, rice, and groundnuts), and harvesting (rice).

participation can help ease labor imbalances by either employing surplus household labor or through reciprocity, securing group labor for use on one's own fields during key bottleneck periods. It is also possible that the positive *Kafo* effect is capturing efficiency gains of group labor over individual labor for certain tasks. In addition, the substitution of *Kafo* for hired labor would be productivity enhancing when financial capital constraints are creating severe illiquidity and cash flow problems.

Somewhat surprisingly, *Osusu* withdrawals are found to have a negative impact on technical efficiency. By relaxing the financial budget constraint, we might have expected households to be better positioned to purchase inputs, rent in land, or hire labor in efficiency enhancing ways. However, the amount withdrawn is small (the average *Osusu* withdrawn per household is 402 dalasis),[22] particularly when compared with average household income (9,837 dalasis) or average farm input costs (374 dalasis). In addition, *Osusu* withdrawals tend to be used for consumption purposes; for example, 43% were used for social obligations, and few were used to start a business or purchase farm inputs or equipment. Thus, the negative relationship between *Osusu* and technical efficiency may be due to the fact that *Osusu* loans are used mostly for consumption/social purposes that possibly induce labor reallocation away from productive activities. Among the other financial variables, we find that neither remittances nor off-farm earnings have a significant effect on technical efficiency.

Is land tenure security a concern? The results in table 5 show that neither the Simpson index, nor "selling with authorization," nor "borrowed land" has a significant effect on technical efficiency. However, we find that land tenure security significantly affects technical efficiency via two different mechanisms: the right to sell without authorization has a positive impact, while the land-loss variable has a negative impact. Households with greater tenure security (measured by the right to sell land) appear better able to achieve higher TE through either leasing arrangements that adjust the land/labor ratio, or enhanced capital investment that improves land productivity. The negative influence of the land-loss variable suggests the inability or unwillingness of affected households to use land-leasing options to adjust land–labor imbalances. This issue is particularly important for households heavily engaged in off-farm activities, especially when it involves labor migration and borrowed land from the *Akalo* (chief).

Allocative Efficiency

The Tobit estimates for allocative efficiency are reported in table 6. It is found that a significant barrier to allocative efficiency is male household head status. Although both men and women are engaged in self-employment activity, female participation is lower and skewed toward petty trading. The differences between women and men are even more apparent in the wage employment sector: of the 58 wage or salaried jobs in the sample, only 3 were held by women. Also, note that the effects of the female/male adult ratio or child/adult ratio on AE are not statistically significant in table 6. Why then the strong negative relationship between AE and the gender of household head? Factors related to the household's life cycle might play a role. While female- and male-headed households tend to have the same number of adults (5 per household),

Table 6. Tobit Analysis of Allocative Efficiency (AE)

Variable	AE—Household	Marginal Effects
Intercept	1.111*** (0.242)	
Gender	−0.493*** (0.179)	−0.3664
Founding	0.078 (0.112)	0.0580
Herder	−0.326** (0.155)	−0.2421
Migrant	−0.049 (0.163)	−0.0364
Food insecure	−0.252** (0.123)	−0.1872
Female/male adult ratio	−0.031 (0.045)	−0.0229
Child/adult ratio	−0.055 (0.074)	−0.0412
Kafo	0.146 (0.125)	0.1086
Osusu loans/ withdrawals	−0.142 (0.138)	−0.1054
Remittances	−0.000 (0.000)	0.0000
Off-farm earnings	0.286** (0.138)	0.2126
Simpson	−0.123 (0.197)	−0.0912
Sell with authorization	0.168 (0.172)	0.1250
Sell without authorization	0.049 (0.115)	0.0371
Borrowed land	0.117 (0.133)	0.0867
Land loss	−0.023 (0.145)	−0.0173

Notes: Standard errors are reported in parentheses. Statistical significance is indicated by stars: * for the 10% significance level, ** for the 5% significance level, and *** for the 1% significance level.

[22] *Kafo* loans tend to be slightly less frequent than *Osusu* withdrawals in number, involve even smaller amounts, but tend to be used for similar purposes: social obligations, purchase of consumer goods, and home construction.

male-headed households have significantly more children (5 versus 2.5). As a result, female-heads can spend less time child rearing and more time in remunerative production activities. Another interpretation is that female-headed households have superior managerial skills, are less labor constrained in farm production activities, or choose a crop mix with higher marketed surplus (vegetables and rice).[23] While women hold 58% of the plots farmed, they are typically less able than men to secure rights to land, or secure greater access to land, particularly inner and outer fields typically controlled by men. To the extent that women in female-headed households gain greater access to land rights, this suggests that the intra-household allocation of labor and land rights contributes to significant allocative inefficiencies in male-headed households. In other words, rigidities in land and labor rights within the household or community together with stronger control typically exercised by men contribute to low allocative efficiency. Given the scale of nonfarm opportunities in the peri-urban area, it appears that too few land and labor rights are flowing to women.

Table 6 reports that food insecurity (reflecting low-income status) has a significant negative effect on allocative efficiency: food insecurity lowers AE by 19%. It shows how low-income status has a large adverse impact on the ability of households to make efficient use of their resources. This can be due to either adverse effects on labor productivity, or liquidity constraints curtailing market access.

Neither *Kafo*, nor *Osusu*, nor remittances are found to have statistically significant effects on allocative efficiency. However, table 6 reports that off-farm income has a positive and significant impact on allocative efficiency. If capital markets worked smoothly, the introduction of outside sources of income should not affect allocative efficiency. Our findings indicate the presence of poorly functioning capital/credit markets, where liquidity and cash-flow constraints are relaxed through income generating activities off the farm, particularly in the case of a peri-urban setting where off-farm returns tend to be larger than farm returns. Indeed of total household income for the sample (9,837 dalassis), 72% is obtained from self-employment, wage employment, and remittances. Given low estimates of allocative efficiency, our results suggest both significant barriers to nonfarm employment for many households, and the presence of financial market imperfections that increase the liquidity-enhancing benefits of off-farm employment for farm production.

Finally, note that none of the land-tenure variables are found to have a significant effect on allocative efficiency. In other words, for technically efficient households, we find no evidence that local land tenure institutions impede the maximization of household revenue or the responsiveness of household decisions to output markets.

Scale Efficiency

The Tobit results for scale efficiency (SE) are reported in table 7 (pooled analysis) and table 8 for farm households that are "too small" (IRTS) versus "too large" (DRTS). The results in table 7 suggest that the right to sell variable (secure tenure) increases scale efficiency by 17%. Remittances have a negative and significant, yet small effect. A high child/adult dependency ratio shows scale efficiency gains of 10% through either reducing the number of dependents or increasing labor supply.

Table 8 provides a more refined analysis: it shows the factors affecting scale efficiency separately under increasing returns to scale and decreasing returns to scale (DRTS).[24] Households that are "too large" (DRTS) (e.g., in terms of land or labor) might either lease-out surplus land (if tenure is secure), or reduce labor unemployment by investing in skills, or sending unemployed family members away to neighbors or kin. Neither option, however, is necessarily feasible or costless. As illustrated in table 8, households with a high dependency (child/adult) ratio cannot easily overcome the burden of having too many children: the child/adult ratio has a negative and significant impact on scale efficiency. Note that none of the variables related to financial access or land tenure are statistically significant, indicating that neither is important in the evaluation of scale efficiency on larger farms.

Household's that are "too small" (IRTS) face a different set of options. They may try to

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[23] Udry also investigated allocative efficiencies in farming intensities between plots controlled by women and men within the same household. He found that households could raise output by reallocating variable factors from male-controlled plots to female-controlled plots.

[24] Households with constant returns to scale (CRTS) were included in both IRTS and DRTS subsamples so as to increase the degrees of freedom in each Tobit regression.

Table 7. Tobit Analysis of Scale Efficiency (SE)

Variable	SE—Household	Marginal Effects
Intercept	0.916*** (0.159)	
Gender	0.131 (0.112)	0.0838
Founding	0.127 (0.078)	0.0813
Herder	−0.218** (0.107)	−0.1402
Migrant	0.026 (0.113)	0.0169
Food insecure	−0.095 (0.085)	−0.0611
Female/male adult ratio	0.015 (0.031)	0.0094
Child/adult ratio	−0.148*** (0.052)	−0.0956
Kafo	0.110 (0.090)	0.0709
Osusu loans/withdrawals	0.013 (0.099)	0.0087
Remittances	−0.000025* (0.000015)	0.0000
Off-farm earnings	−0.0649 (0.095)	−0.0417
Simpson	−0.087 (0.138)	−0.0557
Sell with authorization	0.271* (0.139)	0.1741
Sell without authorization	−0.055 (0.079)	−0.0354
Borrowed land	0.097 (0.093)	0.0623
Land loss	−0.031 (0.102)	−0.0198

Notes: Standard errors are reported in parentheses. Statistical significance is indicated by stars: * for the 10% significance level, ** for the 5% significance level, and *** for the 1% significance level.

Table 8. Tobit Analysis of Scale Efficiency (SE) under IRTS vs. DRTS

Variable	SE—Household under IRTS	Marginal Effects	SE–Household under DRTS	Marginal Effects
Intercept	1.080*** (0.258)		1.068*** (0.193)	
Gender	0.130 (0.170)	0.0605	0.089 (0.149)	0.0435
Founding	0.079 (0.113)	0.0367	0.170 (0.108)	0.0823
Herder			−0.327*** (0.122)	−0.1584
Migrant	−0.138 (0.162)	−0.0640	0.172 (0.152)	0.0833
Food insecure	−0.223 (0.138)	−0.1037	−0.0089 (0.104)	−0.0043
Female/male adult ratio	0.0038 (0.0474)	0.0018	0.0397 (0.0467)	0.0193
Child/adult ratio	−0.182** (0.075)	−0.0846	−0.119* (0.0717)	−0.0578
Kafo	0.178 (0.154)	0.0826	0.117 (0.100)	0.0569
Osusu loans/withdrawals	−0.019 (0.179)	−0.0088	−0.0969 (0.119)	−0.0469
Remittances	0.00024 (0.00015)	0.0001	−0.00003 (0.00002)	0.0000
Off-farm earnings	0.011 (0.145)	0.0051	−0.0853 (0.125)	−0.0413
Simpson	−0.138 (0.227)	−0.0641	−0.208 (0.158)	−0.1007
Sell with authorization	0.345 (0.212)	0.1603	0.240 (0.174)	0.1165
Sell without authorization	−0.058 (0.115)	−0.0268	−0.0953 (0.104)	−0.0462
Borrowed land	0.0898 (0.136)	0.0417	0.0959 (0.118)	0.0464
Land loss	−0.237* (0.142)	−0.1102	0.0404 (0.231)	0.0196

Notes: Standard errors are reported in parentheses below the parameter estimates. Statistical significance is indicated by stars: * for the 10% significance level, ** for the 5% significance level, and *** for the 1% significance level.

rent more land, increase the utilization of family labor, or hire in wage labor. Few variables in table 8 are statistically significant. Again, the dependency (child/adult) ratio is found to have a negative and significant effect on scale efficiency, most likely underscoring the significance of binding labor constraints within the household in the presence of a poorly functioning labor market. The only other variable that is significant is land loss: for smaller farms, it shows a negative and significant effect on SE. It suggests that, under labor market imperfections, households with few resources find it difficult to take care of their land and generate high off-farm income at the same time.

Concluding Remarks

This article has presented an economic analysis of production efficiency among farm households, where off-farm activities generate a large part of household income. We argued that a farm-level analysis requires separability between farm profit and off-farm earnings, which would hold only if (*a*) the opportunity cost of farm labor is the wage rate; and (*b*) there is nonjointness in the technologies underlying farm and nonfarm activities. This article has relied on a household-level analysis, where such conditions are not required. Nonparametric methods are used to estimate the technical, allocative and scale efficiency of production involving joint evaluation of both farm and off-farm activities. The empirical evidence suggests that labor market imperfections are driving a wedge between the opportunity cost of labor in the farm and nonfarm sector, and that jointness of technology is evident through at least the substitution of off-farm earnings for financial capital.

The analysis reports evidence of both technical inefficiency (where households do not make use of the best available technology) as well as scale inefficiency (where household resources are either "too large" or "too small"). However, the cost of these inefficiencies is modest: on average, 5% for technical efficiency, and 12% for scale efficiency. The greatest source of inefficiency is due to allocative inefficiency, representing a failure to respond to price and resource scarcity in household decision making. For an average household, the cost of allocative inefficiency amounts to 43% of household income. We find that a significant part of this cost comes from inefficiency in labor allocation between farm and nonfarm activities. This stresses the importance of conducting the analysis at the household level (rather than the farm level).

Why do these states of inefficiency exist? Our econometric analysis suggests that imperfections in labor and capital markets contribute to reduced productivity and lower efficiency of the Gambian-farm households. In the presence of weak capital markets, off-farm activities act to relax cash flow and liquidity constraints. In turn, households with low-food security and poverty status are least able to use labor and output markets to produce efficiently. We find that food insecurity has a particularly strong and negative effect on allocative efficiency. We also find indirect evidence of poorly functioning labor markets. The inability to ease these labor constraints may reflect situations where household labor time must be spent caring for children, or where market imperfections or liquidity constraints preclude labor hiring. Finally, we uncover evidence that the shift in labor time by male adults to off-farm employment is creating economic efficiency through failure to shift control of farm-level decision making and land resources to women. Institutional constraints causing rigidities in the allocation of access rights to resources between men and women within the household are thus producing significant income losses.

What policy interventions would be appropriate to increase efficiency at the farm and household level? The analysis of technical efficiency indicates that access to technology is not the most important factor constraining the welfare of rural households in The Gambia. While a large number of farm households are scale inefficient, the cost of scale inefficiencies is modest. However, the econometric results point to sizable negative effects on allocative efficiency caused by imperfections in factor markets. The analysis indicates significant potential for institutional reforms to improve the functioning of land, labor, and capital markets, and to increase the welfare of low-income households in the peri-urban areas of The Gambia.

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Appendix

An alternative characterization of scale efficiency can be obtained by considering the technology $X_c = \{(x, \mathbf{F}, H, \mathbf{L}; \mathbf{y}, N) : (k \cdot x, k \cdot \mathbf{F}, k \cdot \mathrm{H}, k \cdot \mathbf{L}; \mathbf{y}, N) \in X, \text{for all } k \geq 0\}$, where X_c exhibits CRTS and satisfies $X \subset X_c$. Note that $\mathrm{AR}(x, \mathbf{F}, H, \mathbf{L}, X)$ can be alternatively expressed as

$$\begin{aligned}
&\mathrm{AR}(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X)\\
&\quad = \sup_{\mathbf{y},N,k} \{(\mathbf{p}'\mathbf{y})/k + N/k : (k \cdot x, k \cdot \mathbf{F},\\
&\qquad k \cdot H, k \cdot \mathbf{L}; \mathbf{y}, N) \in X, k > 0\}\\
&\quad = \sup_{\mathbf{Y},N,k} \{\mathbf{p}'\mathbf{Y} + N : (k \cdot x, k \cdot \mathbf{F},\\
&\qquad k \cdot H, k \cdot \mathbf{L}; \mathbf{Y}, N) \in X, k > 0\}\\
&\qquad\qquad \text{where } \mathbf{y} = k \cdot \mathbf{Y}, N = k \cdot N,\\
&\quad = \sup_{\mathbf{Y},N} \{\mathbf{p}'\mathbf{Y} + N : (x, \mathbf{F}, H, \mathbf{L}; \mathbf{Y}, N) \in X_c\} \cdot\\
&\quad = R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X_c)
\end{aligned}$$

It follows that the scale efficiency index SE in equation (A.1) can be alternatively written as

$$\text{(A.1)} \quad \mathrm{SE}(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) = R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X) / R(\mathbf{p}, x, \mathbf{F}, H, \mathbf{L}, X_c).$$