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Author(s): Christopher Udry
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Gender, Agricultural Production, and the Theory of the Household

Christopher Udry

Northwestern University

Virtually all models of the household assume that the allocation of resources is Pareto efficient. Within many African households, agricultural production occurs on many plots controlled by different members of the household. Pareto efficiency implies that factors should be allocated efficiently across these plots. I find, in contrast, that plots controlled by women are farmed much less intensively than similar plots within the household controlled by men. The estimates imply that about 6 percent of output is lost because of inefficient factor allocation within the household. The paper suggests a new approach to modeling intrahousehold allocation consistent with the empirical results.

I. Introduction

Empirical studies of consumer demand, labor supply, and household production are commonly based on the premise that households behave as though they are single individuals. The assumption of a "unitary household" is convenient and innocuous in many contexts. However, neoclassical economic theory is based on the behavior of individuals, and there is theoretical justification for aggregation into households that behave as though they are individuals only under

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quite restrictive assumptions. Moreover, a growing number of studies (see the review in Strauss and Thomas [1995]) have found strong evidence against the hypothesis that empirical demand systems are generated by households that act as though they are individuals. In particular, it is commonly found that the budget shares of particular goods are significantly related to the shares of (arguably exogenous) income accruing to women in the household. The aggregate demands generated by households, these studies conclude, should be modeled as the outcome of some interaction between household members with diverse preferences and resources.

A number of different models of the interaction that occurs between individuals within the household have been proposed. Cooperative bargaining models have played an influential role in this literature.[1] One assumption of all cooperative bargaining models of the household is that the allocation of resources is Pareto efficient. A variety of other particular assumptions are made concerning the sharing rule within the household and the threat points used as fallback positions by the individuals in the household in the event that a cooperative equilibrium is not achieved. Browning and Chiappori (1994) have suggested that models of intrahousehold allocation dispense with these supplementary assumptions and assume *only* that Pareto efficiency is achieved.

It is not obvious that resource allocation within households must be Pareto efficient. It is a commonplace that noncooperative games need not yield Pareto-efficient outcomes. Moreover, there exists prima facie evidence against Pareto efficiency in households in a number of instances. Most dramatically, the routine practice of domestic violence against women and children (particularly, though not exclusively, in the West African context of this paper) is strong evidence against full-information Pareto efficiency within households.

However, the assumption of Pareto efficiency in the context of household decision making remains attractive for a number of reasons. First, household members are engaged in a long-term, relatively stable relationship with, presumably, good information about each other's actions. After specifying a particular game, one can appeal to Folk theorem arguments that with sufficiently patient players, a Pareto-efficient outcome can be supported as a subgame-perfect Nash equilibrium of the repeated game played by the household members. Alternatively, it is possible to appeal to the noncooperative foun-

[1] Manser and Brown (1980) and McElroy and Horney (1981) are the seminal papers. The theoretical literature is reviewed in Bergstrom (1993). Lundberg and Pollak (1993) provide a recent reinterpretation of the threat points of a cooperative bargaining model of the household.

dations of cooperative bargaining outcomes (Kanbur and Haddad 1994). Finally, Lundberg and Pollak (1993) argue that the actual mechanism used to decide who does what for whom within the household is likely to be exceedingly complex. It may be quite difficult to capture the essence of these interactions within an explicit game form. Citing Shubik (1989), they argue that an axiomatic approach—cooperative bargaining models—may be more fruitful. One axiom, of course, is the Pareto efficiency of the outcome.

It is appropriate, therefore, to begin empirical modeling of household behavior by testing the assumption of Pareto efficiency. The implications of Pareto efficiency for household demands are discussed by Browning and Chiappori (1994), who show that even this limited assumption has testable implications for demand functions. Using Canadian data, the authors reject the unitary household model but cannot reject the hypothesis of Pareto efficiency. Thomas and Chen (1994) implement the first tests of Pareto efficiency within households using data from a developing country (Taiwan). They also reject the unitary model, but not Pareto efficiency.

Agricultural production by farm households in sub-Saharan Africa provides an unusually opportune environment in which to test the implications of Pareto-efficient allocations within the household. The opportunity is provided by the fact that, within many African households, agricultural production is simultaneously carried out on many plots controlled by different members of the household. This paper provides a simple and transparent test of the weak implication of household models that the allocation of resources across these plots is efficient, using an extremely detailed agronomic panel data set from Burkina Faso.

Section II develops the implications of Pareto efficiency of resource allocation within the household for patterns of input use and yields across plots farmed by a single household. Section III provides background information on the farming systems of Burkina Faso and an overview of the data used in the analysis. The central empirical results of the paper are presented in Section IV. I show that yields are substantially lower (on the order of 30 percent) on plots controlled by women than on similar plots controlled by men planted with the same crop, in the same year, in the same household. This contradicts the Pareto efficiency of resource allocation within the household. In Section V, the robustness of the conclusion of inefficiency is examined. As part of this effort, production functions are estimated and the loss due to the apparent misallocation of factors of production within the household is quantified. The paper concludes with suggestions toward a new approach to modeling intrahousehold resource allocation that is consistent with these results.

II. Household Models

The null hypothesis to be tested in this paper is the Pareto efficiency of the allocation of resources within the household. A necessary condition for the efficiency of the allocation is that factors of production are allocated efficiently to the various productive activities of the household. Consider a household with two members (the model generalizes easily to N members). There are K private goods in the economy. The vector $\mathbf{C}_j$ denotes the consumption of these goods by member j, $j \in \{F, M\}$. Aggregate consumption of these goods within the household is $\mathbf{C} = \mathbf{C}_F + \mathbf{C}_M$. The labor supply of person j is N_j. The public goods consumed within the household are denoted by Z. The utility of member j is determined by the function $U_j(\mathbf{C}_F, \mathbf{C}_M, Z, N_F, N_M)$ and therefore may depend on her own consumption and on the consumptions and utility levels of the other members of the household. The household engages in production of at least some goods on the plots controlled by the household. Let i index the plots of the household, A^i be the area of plot i, and $P^k = \{i \mid \text{plot } i \text{ is planted to crop } k\}$. Then the production of good k in the household is

$$Y^k = \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i), \tag{1}$$

where N_F^i and N_M^i are female and male labor used on plot i and $G^k(\cdot)$ is a concave production function. If crop k is planted both on plots controlled by men and on plots controlled by women within the household, then equation (1) embodies the assumption that technology may vary across crops but men and women have access to the same technology $G^k(\cdot)$ for producing crop k.

Public good production within the household is determined by

$$Z = Z(N_F^Z, N_M^Z). \tag{2}$$

There is no labor market in the Burkina Faso villages. (Nothing in this section hinges on this restriction. However, it is a reasonable approximation of the environment [Fafchamps 1993].) So

$$N_F = \sum_i N_F^i + N_F^Z \tag{3}$$

and

$$N_M = \sum_i N_M^i + N_M^Z. \tag{4}$$

The price vector is $\mathbf{p}$, so the budget constraint is

$$\mathbf{p} \cdot \mathbf{C} \leq \mathbf{p} \cdot \mathbf{Y}, \tag{5}$$

where $\mathbf{Y}$ is $(Y^1, Y^2, \ldots, Y^K)$. A Pareto-efficient allocation of resources within the household solves

$$\max_{\mathbf{C}_j, N_j^i, P^k} U_F(\cdot) + \lambda U_M(\cdot), \tag{6}$$

subject to equations (1)–(5), for some $\lambda > 0$. Consider any good k produced on more than one plot in the household. Equation (6) is recursive. If N_{Fk} and N_{Mk} are the aggregate quantities of female and male labor inputs on plots planted with crop k, then (6) implies that the allocation of labor across these plots solves

$$\begin{gathered}\max_{N_F^i, N_M^i} \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i) \\ \text{subject to} \sum N_F^i = N_{Fk}, \quad \sum N_M^i = N_{Mk}, \quad N_F^i, N_M^i \geq 0.\end{gathered} \tag{7}$$

This result is the standard separation result in agricultural household models, where production decisions are independent of preferences, except that this pertains to the allocation of resources *within* rather than across households. If $G^k(N_F^i, N_M^i, A^i)$ is concave, increasing, and strictly increasing in A, then (7) and $A^i = A^j$ imply that $G^k(N_F^i, N_M^i, A^i) = G^k(N_F^j, N_M^j, A^j)$. This is the implication of productive efficiency in the household that forms the basis of the tests in this paper: within the household, variations across plots in output and factor inputs are functions only of variation in plot characteristics. So we can define

$$Q^k(A^i) = \frac{G^k(N_F^i(A^i), N_M^i(A^i), A^i)}{A^i} \quad \forall\, i \in P^k, \tag{8}$$

where $N_F^i(A^i)$ and $N_M^i(A^i)$ are female and male labor inputs on plot i in the solution to (7), and $Q^k(A^i)$ is the yield (output per area) on plot i ($i \in P^k$) in the solution to (7), which depends only on the characteristics of plot i. Let $\overline{A}^k$ be the average area of plots planted to crop k. If A^i is permitted to vary across $i \in P^k$, the first-order Taylor approximation from (8) is

$$Q^k(A^i) - Q^k(\overline{A}) \approx \frac{\partial Q^k(\overline{A})}{\partial A} \cdot (A^i - \overline{A}) \quad \forall\, i \in P^k. \tag{9}$$

The equation to be estimated, therefore, examines the deviation of plot yield from the mean yield as a function of the deviation of plot characteristics from mean plot characteristics within a group of plots planted to the same crop by the members of the same household in a given cropping season—the fixed-effect estimator.

If we generalize (9) to accommodate multiple dimensions of plot characteristics and introduce notation to accommodate the existence of different households and time periods, we have

$$Q_{htci} = \mathbf{X}_{htci}\beta + \gamma G_{htci} + \lambda_{htc} + \epsilon_{htci}, \tag{10}$$

where $\mathbf{X}_{htci}$ is a vector of characteristics of plot i planted with crop c at time t by a member of household h ($\mathbf{X}_{htci}$ includes, along with other information, the area of the plot); Q_{htci} is the yield on that plot; G_{htci} is the gender of the individual who controls the plot; λ_{htc} is a household-year-crop fixed effect that in accordance with (9) restricts attention to the variation in yields across plots planted to the same crop, within a single household in a given year; and ϵ_{htci} is an error term (possibly heteroskedastic and correlated within household-year groups) that summarizes the effects of unobserved plot quality variation and plot-specific production shocks on yields.

Equations (8) and (9) imply that $\gamma = 0$; this is the exclusion restriction tested in this paper.[2] Conditional on plot size (and, of course, land quality), are yields equal on plots planted with the same crop in the same year but controlled by different members of a household? It should be noted that in the absence of labor and land markets, (10) imposes no restrictions on relative yields on plots controlled by different households, and with credit and liquidity constraints, (10) may not hold across plots controlled by the same household in different years.

III. The Setting

The data used for this study are drawn from the Burkina Faso farm household survey conducted by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) (Matlon 1988). The survey was a 4-year panel study (1981–85) of 150 households in six villages in three different agro-climatic zones of Burkina Faso. This study uses data from the first three agricultural seasons of the survey (1981–83), during which the most detailed agronomic information was collected. During these three seasons, enumerators visited the sample households approximately every 10 days to collect information on farm operations, inputs, and outputs on each of the household's plots since the previous visit. These three seasons of data collection result in 432 household-years of data on agricultural activities, with usable data on a total of 4,655 cultivated plots. It is common for the household head and at least one of his wives to plant the same

[2] The strict concavity of $G^k(\cdot)$ with respect to variable inputs when A^i is held constant implies that (8) and (9) hold when Q_i is interpreted as input intensity (e.g., female labor hours per hectare). Hence, (10) is also estimated with input intensities as the dependent variable.

crop on their different plots during the same year (on average, there are 1.8 wives per household head). This occurred for more than half (243) of the household-year observations and accounts for almost 40 percent (1,723) of the plot-level observations.

The assignment of individuals to households by the ICRISAT investigators was governed by participation in common production activities and by consumption in common. In ambiguous cases, the investigators relied on the judgment of the household head:

> An entirely unambiguous, consistent, and universal definition of the "household" for use in sampling, data collection and analysis, proved to be elusive. . . . As a working definition we defined the household as the smallest group of persons usually, but not exclusively kin related who form a more or less independent production and consumption unit during the cropping season. To operationalize this definition we set two conditions based on observed group behavior and consistent with farmers' own criteria for defining households: first, that members of the household work jointly on at least one common field under the management of a single decision-maker, and second, that members draw an important share of their staple foodstuffs from one or more granaries which are under the control of that same decision-maker. Because both of these criteria sometimes tended to vary in a continuous rather than discrete manner, for [ambiguous] individuals the final boundaries used to delimit household from non–household members were drawn by the household heads themselves—that is, we included persons whom the head considered as integral parts of the socio-economic unit and under their principal decision-making authority. [Matlon 1988, p. 4]

All of the farmers in the survey are poor, with an average income per capita of less than \$100 (Fafchamps 1993). The farming system is characteristic of rain-fed agriculture in semiarid Africa: each household simultaneously cultivates multiple plots (10 is the median number of plots per household in any year) and many different crops (a median of six different primary crops on the plots farmed by a household in a given year). An important characteristic of the organization of agricultural production in these villages (and in much of sub-Saharan Africa) is that decisions with respect to crop choice and the timing and quantities of inputs on different plots within the household are made by different individuals within the household. The household head makes decisions regarding the "communal" plots of the household, the output from which nominally is used for the basic consumption needs of the household as a whole (Ramaswamy 1991). In addition, each member of the household (including the household head) cultivates individual plots.[3] Individuals do not have absolute autonomy with respect to decision making on their own plots, but a large literature makes it clear that people have substantive control over cultivation decisions on their individual plots (Davison 1988; Ramaswamy 1991; Dey 1993). In surveys in Nigeria and Kenya, Saito, Mekonnen, and Spurling (1994) conclude that "while some men and women do make certain decisions on each other's plots, essentially they each manage their own separate plots" (p. 18). The rhetoric surrounding these individual plots is that the output can be used (with some restrictions, which vary across localities) in accordance with the individual's desires (Jones 1986; Ramaswamy 1991; Saito et al. 1994). It has often been argued (Berry 1993) that rights over the output of various plots are ambiguous and contested. This paper is an attempt to determine whether differences in decision-making authority and nominal control over output from various plots are reflected in the allocation of resources across the plots of the household.

The process through which land is allocated to individual plots is complex, varies across (and within) the five main ethnic groups represented in the survey, and is not well documented in the descriptive literature on Burkina Faso. Davison (1988, p. 18) offers the generalization that "men historically gained access to land largely as lineage members, but in the majority of cases, women gained access as wives" (also see Sanders, Nagy, and Ramaswamy 1990). Members of the household have access to land, generally speaking, through the (male) household head. This says little about the equilibrium allocation of plots, and certainly does not imply that the allocation of plots is simply dictated by the household head. The allocation of plots to particular individuals persists over time in those regions of Africa for which there is information (e.g., von Braun and Webb 1989; Carney and Watts 1991), so it seems that the marriage market must play an important role in the determination of the intrahousehold land allocation.

There are active markets for crop output in these villages, but there is virtually no hiring of labor or rental of land. The absence of these markets is related to the historical abundance of land. As land has become scarce over the past few decades (particularly in the Mossi

[3] The ICRISAT data do not permit me to distinguish between communal plots, which are under the control of the household head, and the individual plots cultivated by the household head. All these plots, therefore, are treated similarly as plots of the household head.

highlands), large variations in cultivated land per adult household member have emerged (Reardon, Delgado, and Matlon 1988); however, neither labor nor land rental markets have emerged to accommodate these variations.

IV. Results

Table 1 presents summary statistics concerning the yields achieved (in terms of the value of output per hectare) and inputs used on men's and women's plots. On average, women achieve much higher values of output per hectare than men, on much smaller plots. Labor inputs by household members who are men and children and by non–household members are higher on plots controlled by men; female labor is more intensively used on plots controlled by women. The higher yields achieved on plots controlled by women reflect, at least in part, the different crops grown by men and women. Table 2 summarizes the primary crops on male- and female-controlled plots.

As summarized in equation (10), there are a variety of possible sources of variation in mean yields between male and female plots. First, land quality may vary systematically across plots controlled by men and women. The survey collected data on the topographical characteristics, location, and local soil names of each plot. Second, crop choice is systematically different by gender; this is a reflection of the well-known gender division of labor in rural Africa. Third, owing to the imperfections in local labor and land markets, there may be variations across households in the shadow prices of factors of production and therefore yield variation. Fourth, the absence of credit markets might induce variations across time in factor shadow prices even within households. The estimates focus, therefore, on yield variations between male and female plots planted to the same crop, in the same household, in the same year.

Column 1 of table 3 reports estimates of equation (10). Plots controlled by women have significantly lower yields than other plots within the household planted to the same crop in the same year, but controlled by men. Moreover, the effect is very large. The mean yield across all plots is under 90,000 FCFA (francs issued by the Communauté Financière Africaine), so the effect of a female cultivator is to reduce yields by over 30 percent of the average yield. This result is strongly inconsistent with the existence of a Pareto-efficient allocation of resources within the household. The household could achieve higher output by reallocating variable factors from plots controlled by men to plots controlled by women or, equivalently, by reallocating land from women to men. This is the central empirical finding of the paper.

TABLE 1

MEAN YIELD, AREA, AND LABOR INPUTS PER PLOT BY GENDER OF CULTIVATOR
(N = 4,655)

	Crop Output per Hectare (1,000 FCFA)*	Area (Hectare)	Male Labor (Hours/ Hectare)	Female Labor (Hours/ Hectare)	Nonfamily Labor (Hours/ Hectare)	Child Labor (Hours/ Hectare)	Manure Weight (kg/ Hectare)
Men's plots	79.9	.740	593	248	106	104	2,993
	(186)	(1.19)	(1,065)	(501)	(407)	(325)	(11,155)
Women's plots	105.4	.100	128	859	46	53	764
	(286)	(.16)	(324)	(1,106)	(185)	(164)	(5,237)
T-statistic	−3.27	29.03	22.16	−21.31	6.89	7.08	7.68
H_0: $\mu_m = \mu_w$							

NOTE.—Standard deviations are in parentheses.
* In 1982, the exchange rate was approximately US$1 = FCFA 325.

TABLE 2

Distribution of Primary Crops across Plots

Primary Crop	Women's Plots	Men's Plots
White sorghum	20.4	20.4
Red sorghum	8.6	8.7
Millet	8.4	22.8
Maize	1.9	19.2
Groundnuts	15.6	5.11
Cotton	.7	11.1
Okra	12.4	.6
Earth peas/fonio	26.0	2.1
Others	6.0	10.0

This result remains unchanged when (10) is estimated using household-year–primary crop–secondary crop fixed effects to control for intercropping mixtures and also when the sample is restricted to plots planted to a series of specific crops (cols. 2–4 of table 3) in order to accommodate the variation across crops in the relationship between yield and plot characteristics. Column 5 reports estimates of (10) if we assume that the production function (1) has the constant elasticity of substitution (CES) form. The central result remains unchanged: plots controlled by women have significantly lower output than other similar plots within the household planted to the same crop in the same year, but controlled by men. The reduction is approximately 20 percent.

A. *Perspective*

There is a large differential between the yields achieved by men and those achieved by women in the same household. However, as can be expected in an economy without well-functioning labor or land markets, the yields achieved by different households simultaneously farming the same crop vary tremendously, even within a village. In this subsection I present the first of two measures of the relative importance of the misallocation of factors across plots within a household and within a village. The present measure is based on the deviation of actual plot yields from the yield that is predicted if factors are allocated efficiently within the household and, alternatively, if factors are allocated efficiently across households in each village. In Section V*B*, production function estimates are used to compare the output lost because of factor misallocation within households and across households within villages.

A baseline case is provided by the maintained hypothesis that the allocation of factors of production across the plots controlled by an *individual* is efficient. Equation (10), therefore, is estimated with λ_{jtc}, an *individual*-crop-year fixed effect, replacing the household-year-crop effect λ_{htc} (G_{htcp} is dropped). Let $\epsilon_{htcp}(j)$ be the error term on this equation. If there were no risk and no unobserved plot characteristics, $\epsilon_{htcp}(j)$ would be identically zero. Of course, there is both risk and unobserved variation in plot characteristics, so figure 1 reports a kernel estimate of the density of $\epsilon_{htcp}(j)$. This is an estimate of the yield variation across apparently identical plots attributable to plot-specific risk and unobserved plot characteristics. Next, equation (10) is estimated with λ_{htc}, the household-year-crop effect, but without G_{htcp}. In this case, $\epsilon_{htcp}(h)$ contains the variation in plot yields due to any inefficiencies in the allocation of factors of production across household members (including any gender effect) as well as the sources of variation in $\epsilon_{htcp}(j)$. Figure 1 also reports a kernel density estimate of $\epsilon_{htcp}(h)$. Finally, (10) is estimated with λ_{vtc}, a village-year-crop effect. In this instance, $\epsilon_{htpc}(v)$ contains the variation in plot yields attributable to factor misallocation across plots controlled by different households within a village as well as those sources of variation included in $\epsilon_{htcp}(h)$. A kernel estimate of the density of $\epsilon_{htpc}(v)$ is presented in figure 1.

There is little detectable difference between the distributions of $\epsilon_{htpc}(j)$ and $\epsilon_{htpc}(h)$; $\epsilon_{htcp}(h)$ is just slightly more diffusely distributed than $\epsilon_{htcp}(j)$. Analogously, albeit less visually, it is not quite possible to reject (at the 5 percent level) the hypothesis that $\lambda_{jtc} = \lambda_{htc}$ for all individuals j who are members of household h.[4] There is little evidence from this exercise that there is any misallocation of resources within the household. Rather, the dispersion of yields across plots within the household is similar to the dispersion of yields across plots controlled by an individual. In contrast, $\epsilon_{htpc}(v)$ has a much more diffuse distribution. Similarly, the hypothesis that $\lambda_{htc} = \lambda_{vtc}$ for all households h that are resident in village v is strongly rejected.[5] Therefore, there is much more variation in yields across similar plots controlled by individuals in different households than there is variation in yields across plots controlled by individuals in the same household.[6] From this analysis, there is little to distinguish factor allocation across plots controlled by different individuals in the same household from factor allocation across plots controlled by the same individual. There

[4] The test statistic is distributed as $F(789, 1{,}192)$ and has a value of 1.11 ($p = .06$).

[5] The test statistic is distributed as $F(2{,}457, 1{,}981)$ and has a value of 5.98 ($p = .00$).

[6] Some of this additional variation may be a consequence of greater unobserved plot quality variation or greater plot-specific production shock variation across plots controlled by different households within a village than across plots within a household. However, the likely importance of this source of variation is mitigated by the fact that the plots controlled by single households are spread throughout the village land, clearly as part of a risk diversification effort.

TABLE 3

OLS Fixed-Effect Estimates of the Determinants of Plot Yield and Ln(Plot Output) (× 1,000 FCFA)

Dependent Variable: Value of Plot Output/Hectare

	Household-Year-Crop Effects: All Crops (1)	Household-Year Effects: Millet Only (2)	Household-Year Effects: White Sorghum (3)	Household-Crop-Year Effects: Vegetables (4)	Household-Crop-Year Effects: All Crops: CES* (5)
Mean of dependent variable	89	31	41	134	1.67
Gender: (1 = female)	−27.70 (−4.61)	−10.36 (−2.53)	−19.38 (−4.43)	−34.27 (−2.21)	−.20 (−3.56)
Plot size:					
1st decile	133.99 (3.50)	−28.35 (−2.67)	−17.90 (−1.92)	237.10 (4.66)	
2d decile	69.10 (4.38)	8.64 (.82)	52.30 (3.16)	63.97 (2.38)	
3d decile	63.45 (5.52)	16.95 (1.81)	47.68 (4.77)	35.87 (1.52)	
4th decile	34.08 (2.88)	9.79 (1.12)	26.73 (3.12)	4.21 (.18)	
6th decile	−2.04 (−.29)	−.99 (−.11)	−6.38 (−1.16)	−6.65 (−.26)	
7th decile	−13.44 (−1.78)	−13.01 (−1.73)	−11.31 (−1.69)	−33.54 (−.90)	
8th decile	−17.23 (−2.59)	−12.97 (−1.34)	−28.58 (−4.82)	31.04 (.73)	
9th decile	−26.68 (−3.81)	−21.50 (−2.65)	−28.65 (−4.98)		
10th decile	−31.52 (−4.49)	−20.56 (−2.55)	−37.70 (−6.03)		
Ln(area)					.78 (29.52)
Toposequence:					
Uppermost	−41.35 (−2.18)	2.50 (.24)	−14.60 (−1.73)	−131.34 (−1.82)	−.46 (−2.71)
Top of slope	−26.35 (−1.27)	9.53 (.96)	−11.27 (−1.47)	−121.05 (−1.85)	−.29 (−1.92)
Mid-slope	−24.38 (−1.19)	5.39 (.64)	−8.62 (−1.15)	−119.68 (−1.88)	−.28 (−1.97)
Near bottom	−21.70 (−.90)	4.48 (.40)	−5.36 (−.71)	−93.96 (−1.30)	−.18 (−1.27)

Soil types:										
11	−32.20	(−.93)	−6.13	(−.92)					−.89	(−2.34)
12	41.82	(1.11)	4.92	(1.18)	47.04	(5.26)			.23	(.74)
13	102.92	(1.10)	7.43	(1.11)	−21.08	(−1.82)			.69	(1.01)
31	1.86	(.36)	10.65	(1.55)	−.00	(−.00)	−36.66	(−.66)	.08	(.83)
32	6.38	(.99)	10.26	(1.23)	−.37	(−.06)	−19.36	(−.38)	.07	(.74)
33	29.42	(2.14)	8.56	(.67)	21.29	(1.52)			.18	(1.14)
37	7.69	(1.37)	6.20	(.80)	−.87	(−.17)	−76.60	(−.49)	.13	(1.36)
45	5.66	(1.03)	7.42	(1.15)	1.36	(.26)	52.92	(.46)	.06	(.67)
46	−17.03	(−1.20)	−25.95	(−1.98)	−7.16	(−.73)			−.32	(−1.16)
51	8.57	(.90)	43.77	(1.72)	−10.35	(−1.20)	12.96	(.26)	.05	(.42)
Location:										
Compound	1.54	(.19)	9.69	(2.67)	−4.98	(−1.04)	32.48	(.38)	.23	(3.02)
Village	−1.82	(−.40)	6.07	(1.45)	−1.68	(−.62)	50.37	(1.58)	.16	(2.35)

NOTE.—*t*-ratios (in parentheses) and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix. The omitted plot size category is the 5th decile. The omitted toposequence is bottom land. The omitted soil type is "all others," and the omitted location is "bush" (far from the village).

* Dependent variable of col. 5 is ln(value of plot output).

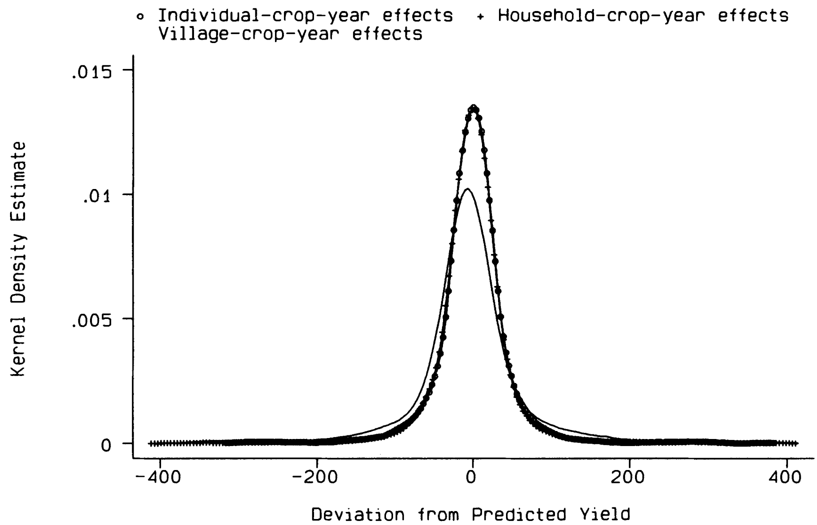

FIG. 1.—Estimates of the densities of yield function error terms

is striking evidence, however, of important inefficiencies in the allocation of factors across plots controlled by different households in the same village. While the results of table 3 provide evidence that efficiency is not achieved within the household, these results indicate that the household operates to bring factor allocation across plots into closer alignment with efficiency than is possible in the village at large.

To prevent confusion, I should note that there is no contradiction between the results reported in table 3, which show dramatic and statistically significant differences in the yield between plots controlled by men and women in the same household, and the results of this subsection, which find no significant evidence of any greater yield dispersion across plots controlled by different individuals in the same households than across plots controlled by a single individual. The former test focuses on a single dimension of possible yield differences: gender. The latter examines all possible dimensions along which there might be factor misallocation and thus is not as powerful against the specific alternative of gender differentials.

B. *Other Results*

In these regressions, the soil type variables generally are jointly significant determinants of yield.[7] However, the primary impact of the

[7] The F-statistics for the joint significance of the soil type variables have p-values of .06, .01, .00, .95 (vegetables, grown on a limited range of soils), and .03 for the regressions reported in cols. 1–5 of table 3.

soil type and location variables runs through the choice of which crop to plant on a given plot. Much of the effect of these characteristics, therefore, is picked up by the household-year-crop effects in the regressions.[8] There is a very strong correlation between both the location and the soil type of a plot and the crop planted on that plot. A χ^2 test of the hypothesis that the distribution of crops across plots is independent of the soil type of the plot has 936 degrees of freedom and a value of over 7,400. Even for similar crops (millet and red and white sorghum), the test has a $\chi^2(100)$ distribution and a value of 1,073. Table 4 is a simplified cross tabulation, with just four major crops and the six most important soil types for those crops.

The results presented in table 3 provide strong evidence of inefficiencies in the allocation of resources within households. There is another puzzle presented by the results in the table. Output per hectare is strongly declining in the size of the plot in each specification. This is *not* the commonly observed inverse relationship between yield and farm size, which occurs across households. The current observation is that *within* a household, larger plots have lower yields than smaller plots. Using a different data set from Burkina Faso, Bindlish, Evenson, and Gbetibouo (1992) find a similar result. There may be a simple technological explanation for this puzzle: a nonhomothetic production function or decreasing returns to scale. The issue of returns to scale is addressed in the production function estimates presented in Section V*D*. However, other explanations are also consistent with this finding, including plot area measurement error, better matching of planting dates to weather on small plots, the "boundary" effect (plants on plot edges have higher yields), fixed transportation costs to the plot, labor monitoring problems, and unobserved variation in land quality.

The strength of the inverse yield–plot size relationship raises the concern that an incorrect parameterization of that relationship lies behind the gender-yield differential. Plots controlled by women, on average, are smaller than plots controlled by men, and I estimate a strongly declining relationship between plot size and yield. If by parameterizing too tightly (e.g., by maintaining that the yield–plot size relationship is the same on male- and female-controlled plots) I have overestimated the slope of the yield–plot size relationship, this could cause an upward bias in the estimated gender differential. This does not appear to be the case. Figure 2 reports the nonparametric regression of yield on the area of the plot (controlling for household-year-crop fixed effects) for plots controlled by men and women.

[8] The location and soil type variables become highly jointly significant ($p < .00001$) when the base regression (table 3, col. 1) is repeated with household-year rather than household-year-crop fixed effects.

TABLE 4

CROSS-TABULATION OF CROP CHOICE AND SOIL TYPE
(Number of Plots; Column Proportion)

	Crop				
Soil Type	Millet	White Sorghum	Red Sorghum	Okra	Total
Loumre	2	29	0	20	51
(13)	.25	3.23	.00	9.48	2.24
Seno	219	0	0	22	241
(21)	27.90	.00	.00	10.43	10.57
Zinka	106	144	38	18	306
(31)	13.50	16.05	9.84	8.53	13.43
Boole	12	51	11	22	96
(37)	1.53	5.69	2.85	10.43	4.21
Ziniare	47	182	9	22	260
(45)	5.99	20.29	2.33	10.43	11.41
Fiaho	35	112	142	7	296
(51)	4.46	12.49	36.79	3.32	12.99
Other	364	379	186	100	1,029
	46.37	42.25	48.19	47.39	45.5
Total	785	897	386	211	2,279
	100.00	100.00	100.00	100.00	100.00

NOTE.—Pearson $\chi^2(18) = 826.36$ ($p = .000$).

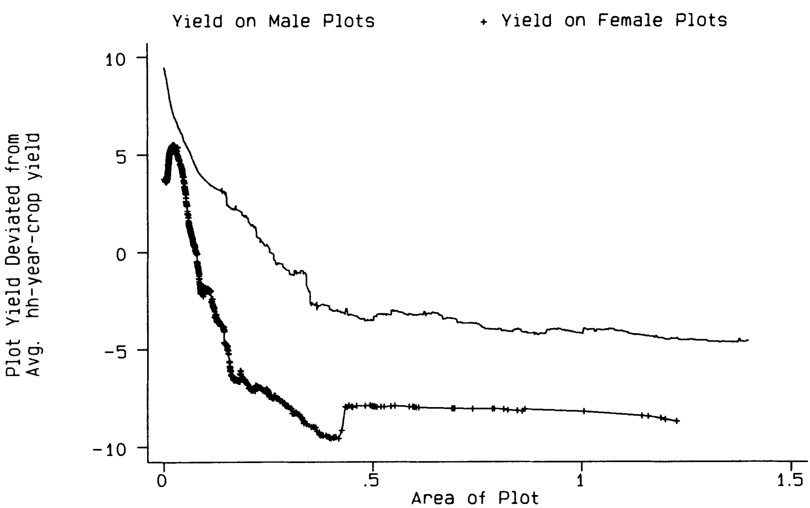

FIG. 2.—Regression of yield on area with household-year-crop effects

Yields are lower on women's plots than on men's plots (in the same household, planted to the same crop in the same year) at all plot sizes. Column 1 of table 5 reports the results of estimating (10) with full gender–plot size interactions. I report only the coefficients on plot size and plot size × gender, but the full set of soil type, toposequence, and location indicators was also included in the regression. Except on the smallest decile of plots, women receive a lower yield than men in the same household planting the same crop in the same year. The difference is statistically significant (at the 10 percent level) for the second through eighth deciles of plot sizes. The test of the joint significance of the gender–plot size interactions is distributed as $F(10, 1{,}964)$ and has a value of 4.39 (p = .00).

Column 2 of table 5 provides evidence that intrahousehold yield differentials occur across generations as well as genders. Plots cultivated by women are excluded, and yields are compared across plots cultivated by the household head and other males in the household (mostly sons). The household head achieves a significantly higher

TABLE 5

OLS Fixed-Effect Estimates of the Determinants of Plot-Level Yield (× 1,000 FCFA)

	All Crops, with Full Gender–Plot Size Interactions (Household-Year-Crop Effects) (1)				All Crops, Only Male-Controlled Plots (Household-Year-Crop Effects) (2)	
	Base Effect		Additional Effect for Women's Plots			
"Generation" (1 = household head, 0 = other males)					16.42	(1.96)
Plot size:						
1st decile	122.84	(1.99)	12.01	(.20)	142.15	(2.10)
2d decile	101.47	(2.99)	−76.19	(−2.29)	118.26	(3.04)
3d decile	61.27	(2.95)	−25.02	(−1.29)	85.02	(3.16)
4th decile	55.85	(1.95)	−65.72	(−2.19)	62.23	(1.88)
5th decile			−26.68	(−1.79)		
6th decile	−5.28	(−.37)	−20.34	(−2.51)	6.39	(.34)
7th decile	−16.62	(−1.20)	−17.44	(−2.71)	−7.71	(−.43)
8th decile	−18.03	(−1.49)	−18.62	(−2.86)	−15.16	(−.95)
9th decile	−27.28	(−2.23)	−3.16	(−.65)	−21.55	(−1.31)
10th decile	−29.93	(−2.47)	−28.83	(−1.07)	−21.87	(−1.32)
Indicator variables for soil type, toposequence, and location	$F(16, 1{,}971) = 1.67, p = .05$				$F(16, 1{,}062) = 1.83, p = .02$	

Note.—t-ratios (in parentheses) and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix.

yield than other men in the household: the gap is about 18 percent of average yields.

It should be noted that there is significant diversity in the size of the gender-yield differential across regions and ethnic groups in Burkina Faso. There is no significant differential in the Sahelian region, which is the poorest region of the country, but there are strong gender differentials in the Sudanic and North Guinean regions. Similarly, no gender differentials are found in households identifying themselves as Rimaibe (who live predominantly in the Sahel), but strong differentials are found in Mossi, Fulse/Kurumba, and Bwa households.

C. *The Sources of the Gender-Productivity Differential*

The equations estimated thus far, of course, are not production functions. The finding that there are large gender differences in yield, therefore, does *not* imply that women are less efficient cultivators than men. The yield differences might be caused by differences in input intensity. Table 6 provides estimates of the intensity with which various inputs are used on plots controlled by men and women. Column 1 indicates that *much* less household male labor is devoted to a hectare of land controlled by a woman than to a similar hectare (planted to a similar crop in the same year) controlled by a man in the same household. It should be noted that *some* male labor is used on most plots (58 percent) controlled by women. The converse, but weaker, result is shown in column 2. Somewhat more household female labor per hectare is devoted to plots controlled by women than to plots controlled by men. The coefficient is significantly different from zero at only the 85 percent level. The absolute value of the point estimate is much less than the corresponding estimate for male labor, despite the fact that female labor, on average, is used somewhat more intensively than male labor. Perhaps most surprisingly, the labor of the household's children is used less intensively on plots controlled by women than on plots controlled by men (col. 3). The effect is statistically significant and substantial relative to the average intensity of child labor utilization. Similarly, nonhousehold labor (which is mostly unpaid exchange labor) is used more intensively on plots controlled by men (col. 4). This coefficient is only marginally statistically significant, but the point estimate is large relative to the average utilization of this form of labor.

A particularly striking result emerges with respect to fertilizer (manure) inputs (col. 5). It is well documented that the marginal product of fertilizer diminishes (McIntire, Bourzat, and Pingali 1992). However, virtually all fertilizer is concentrated on the plots controlled by men. Household output could be increased by the simple expedient of moving some fertilizer from plots controlled by men to similar plots planted to the same crop controlled by women in the household.

The estimated yield functions and input intensity functions are mutually consistent. They provide clear evidence that in these data, plots controlled by women are farmed less intensively than similar plots simultaneously planted with the same crop but controlled by men in the same household. The law of diminishing returns implies that a reallocation of the land, labor, and fertilizer used by a household for the production of a specific crop in a given year could increase household production of that crop.

V. Reconciliation with Efficiency

A. *Unobserved Variation in Plot Characteristics*

There are a number of potential econometric problems with the results presented thus far. Perhaps the most obvious and worrisome is the possibility that there are systematic differences in the quality of land farmed by men and women. The regressions include measures of the topography of the plot, its location, and a categorization by local soil type. This is a rich description of the plot, far richer than is available in most studies of agricultural production in poor countries. Nevertheless, it is clear that there remains some unobserved variation in plot characteristics. If it is the case that women are systematically allocated poorer-quality land than men, then the gender differentials in yield and input intensities might be consistent with an efficient allocation of factors across plots within households. Ideally, an instrumental variables procedure would be used to obtain consistent estimates of the gender differential. Unfortunately, it is difficult to make the case for the existence of a variable that is correlated with the gender of the individual who controls a plot but uncorrelated with any unobserved characteristics of the plot.[9] Nevertheless, one can construct an indirect argument that unobserved variation in plot characteristics is not the cause of the gender differential in yields.

If measures of plot characteristics are dropped from the regression, then the gender-yield differential gets smaller. Column 1 of table 7 shows that if all plot characteristics are dropped, so that the estimate is simply a comparison of the yields on men's and women's plots within household-year-crop groups, then the entire gender differ-

[9] Alternatively, one could use observations of the same plot controlled by different people at different times to eliminate any unobserved plot heterogeneity. Unfortunately, it is not possible to track plots over time in these data; even if this were possible, the ethnographic literature indicates that control over plots rarely changes.

TABLE 6

Least-Squares Tobit Fixed-Effect Estimates of the Determinants of Plot Input Intensities

	Household-Year-Crop Effects									
	Male Labor per Hectare (1)		Female Labor per Hectare (2)		Child Labor per Hectare (3)		Nonhousehold Labor per Hectare (4)		Manure (1,000 kg per Hectare) (5)	
Gender (1 = female)	−668.47	(−9.60)	70.23	(1.53)	−195.46	(−2.34)	−428.41	(−1.70)	−16.33	(−2.54)
Plot size:										
1st decile	1,209.72	(2.53)	1,462.21	(5.71)	740.80	(1.17)	193.35	(.43)	24.79	(2.42)
2d decile	417.18	(3.25)	1,131.01	(5.82)	143.12	(1.11)	487.39	(1.28)	7.99	(.96)
3d decile	245.94	(2.74)	799.12	(6.72)	133.16	(1.53)	689.39	(1.27)	2.58	(.48)
4th decile	96.53	(1.71)	407.87	(5.02)	72.51	(.68)	378.18	(1.07)	−6.18	(−1.12)
6th decile	−.55	(−.01)	−69.25	(−1.36)	−72.15	(−.98)	57.48	(.80)	−2.14	(−.33)
7th decile	−153.12	(−2.97)	−306.51	(−5.96)	−59.53	(−.60)	65.51	(.64)	−11.08	(−1.54)
8th decile	−375.53	(−6.23)	−386.78	(−6.61)	−184.61	(−1.61)	−43.81	(−.30)	−11.01	(−1.61)
9th decile	−413.36	(−6.79)	−373.57	(−5.16)	−269.99	(−1.83)	−255.15	(−.87)	−11.64	(−1.80)
10th decile	−490.11	(−7.72)	−418.06	(−6.08)	−219.27	(−1.86)	−220.64	(−1.07)	−16.41	(−2.45)
Toposequence:										
Uppermost	41.62	(.35)	−1.92	(−.02)	−55.52	(−.51)	20.20	(.12)	−9.22	(−.62)
Top of slope	29.36	(.30)	91.02	(1.07)	35.15	(.38)	144.02	(.83)	.26	(.02)
Mid-slope	36.08	(.38)	.57	(.01)	.10	(.00)	−15.45	(−.11)	1.14	(.11)
Near bottom	16.42	(.18)	75.94	(.86)	−98.03	(−1.05)	23.27	(.17)	2.88	(.27)

Soil Types:										
3	103.49	(.60)	−31.68	(−.23)	235.74	(.86)	175.29	(.50)	−11.80	(−1.18)
7	−65.79	(−.85)	−30.39	(−.28)	21.88	(.44)	66.04	(.47)	−.07	(−.01)
11	−28.77	(−.09)	−52.06	(−.34)	−778.86	(−4.36)	262.71	(.70)	−.70	(−.08)
12	1,051.98	(.82)	367.34	(1.63)	62.36	(.44)	368.47	(1.13)	16.32	(1.48)
13	274.48	(1.33)	−38.50	(−.29)			−187.07	(−.89)		
21	196.37	(.95)	−43.41	(−.49)	−42.87	(−.35)	37.73	(.27)	2.86	(.18)
31	83.16	(1.59)	68.24	(.92)	205.90	(2.29)	115.56	(1.00)	6.43	(1.29)
32	24.77	(.50)	−10.36	(−.15)	173.14	(1.07)	−51.08	(−.44)	.73	(.12)
33	250.40	(2.57)	163.76	(1.36)	206.68	(.78)	−113.92	(−.37)	17.28	(1.61)
35	179.46	(1.50)	303.86	(1.90)	248.38	(2.60)	195.14	(.58)	−12.75	(−.94)
37	82.49	(.70)	50.84	(.30)	114.53	(1.19)	31.14	(.20)	8.34	(1.44)
45	78.13	(1.34)	−8.33	(−.10)	79.85	(1.02)	41.90	(.25)	8.00	(1.83)
46	−187.14	(−1.84)	141.73	(.76)	42.70	(.09)	223.23	(1.27)	−15.45	(−.79)
51	95.73	(1.83)	−27.01	(−.33)	2.93	(.05)	126.70	(1.05)	.80	(.17)
Location:										
Compound	35.35	(.78)	37.16	(.90)	−18.82	(−.31)	−162.88	(−1.38)	.99	(.24)
Village	19.69	(.70)	12.18	(.45)	42.92	(.93)	25.80	(.30)	5.86	(1.60)
Mean of dependent variable	427.39		466.18		85.55		84.88		1.70	
when >0	506.62		517.17		202.88		213.11		7.78	

NOTE.—This is the least-squares implementation of Honoré's (1992) fixed-effect Tobit estimator. t-ratios are in parentheses.

TABLE 7

SPECIFICATION TESTS: CORRELATION OF GENDER AND OBSERVED PLOT CHARACTERISTICS: OLS FIXED-EFFECT ESTIMATES OF THE DETERMINANTS OF PLOT YIELD (× 1,000 FCFA)

	HOUSEHOLD-CROP-YEAR EFFECTS					
	All Crops (1)		All Crops (2)		Original Specification All Crops (3)	
Gender (1 = female)	−.89	(−.22)	−28.53	(−4.74)	−27.70	(−4.61)
Plot size:						
1st decile			133.30	(3.48)	133.99	(3.50)
2d decile			69.61	(4.42)	69.10	(4.38)
3d decile			64.08	(5.63)	63.45	(5.52)
4th decile			34.17	(2.99)	34.08	(2.88)
6th decile			−1.96	(−.27)	−2.04	(−.29)
7th decile			−13.48	(−1.79)	−13.44	(−1.78)
8th decile			−18.00	(−2.69)	−17.23	(−2.59)
9th decile			−26.89	(−3.93)	−26.68	(−3.81)
10th decile			−33.17	(−4.74)	−31.52	(−4.49)
Toposequence:						
Uppermost					−41.35	(−2.18)
Top of slope					−26.35	(−1.27)
Mid-slope					−24.38	(−1.19)
Near bottom					−21.70	(−.90)
Soil types:						
11					−32.20	(−.93)
12					41.82	(1.11)
13					102.92	(1.10)
31					1.86	(.36)
32					6.38	(.99)
33					29.42	(2.14)
37					7.69	(1.37)
45					5.66	(1.03)
46					−17.03	(−1.20)
51					8.57	(.90)
Location:						
Compound					1.54	(.19)
Village					−1.82	(−.40)

NOTE.—*t*-ratios (in parentheses) and test statistics reported in the text are based on heteroskedastic-consistent estimates of the variance-covariance matrix.

ence in yields disappears. This implies that *along the dimensions we observe,* women have *higher*-yielding plots than men.[10]

[10] This argument might be taken one step further. Recall that observable variation in soil quality has the most dramatic effect on crop choice. By dropping the crop element of the household-year-crop fixed effect, one can uncover a greater proportion of the impact of soil quality variation on yields. The regression is now a simple comparison of yields on men's and women's plots within a given household-year group. The coefficient on gender is now strongly positive: 33.1 (with a *t*-ratio of 3.21). This can be interpreted as further evidence that women have better plots, which therefore are

Column 2 provides the results of a less drastic experiment. This regression controls for plot size, but not other plot characteristics. The size of the gender differential is essentially the same as that in the full model, providing no evidence that along these dimensions, men's and women's plots have significantly different quality. This set of results implies that along the dimensions of plot quality we observe, the quality of women's plots is higher than (plot size) or similar to (toposequence and soil type) that of men's plots. This need not be a surprise. Village (and therefore house) location may be determined by the availability of particularly good land, and women tend to farm plots close to home because of their additional household responsibilities.

These results do *not* disprove the hypothesis that a correlation between unobserved plot characteristics and the gender of the cultivator lies behind the gender differential in yields and input intensities.[11] However, the plausibility of this explanation is diminished by the finding that the observed variation in land quality is either uncorrelated with (soil type and toposequence) or positively correlated with (plot size) control of the plot by a woman.

B. *Joint Production of Crops and Household Public Goods*

It is possible that the technology, equations (1) and (2), is misspecified, so that the low intensity of cultivation on plots controlled by women is compatible with economic efficiency. Can the fact that women often combine cultivation activities with care for their children reconcile the gender differential in cultivation intensity with efficiency?

Suppose that both child rearing labor (N_F^Z) and women's agricultural labor (N_F^i) affect both agricultural output (eq. [1]) and child care (eq. [2]). Efficiency still implies separation (i.e., [7], but with the functions $G^k(\cdot)$ including N_F^Z). Equation (8) remains true, and efficiency *still* requires that similar plots within the household be farmed with similar intensities. In order to reconcile efficiency and the gen-

planted to higher-yielding crops. There are explanations for the gender division of labor with respect to crop other than the quality of the plots controlled by men and women (see, e.g., Jones 1986); I do not explore them in this paper.

[11] Indeed, one can construct a model of intrahousehold land allocation in which only unobserved plot characteristics are correlated with gender and that reconciles these results with efficiency. Suppose that land is allocated in the marriage market and that future wives (and, more important, their families) have incomplete information about the characteristics of the plots offered to them by suitors. Suppose in particular that their information matches my own. If men have complete information about the quality of the land they control, then they will offer potential wives land that looks fine but in fact has poor characteristics along those dimensions not observed by potential wives.

der differential in the intensity with which similar plots are cultivated, it is necessary to introduce the land cultivated by the women into the child rearing production function. That is,

$$Z = Z(N_M^Z, N_F^Z, \{N_F^i\}, \{A^i\}_{i \in P^F}), \tag{2'}$$

where $P^F = \{i \mid \text{plot } i \text{ is controlled by the female}\}$. This is not a priori unreasonable. It is possible that the mother has the primary responsibility for teaching her children about farming, which will be the future occupation of most. If this is so, the land cultivated by the mother might serve as a school as well as a farm. Now the apparently low intensity with which women's plots are cultivated can be reconciled with efficiency because that land produces not only the output measured in the data but also better children. This explanation, however, leads to another puzzle. One would expect that child labor inputs on the plot on which they are trained would also contribute to Z. However, as was shown in table 6, child labor is used *less* intensively on plots controlled by women than on similar plots controlled by men. Moreover, I find no relationship between the demographic structure of the household and the differential intensity with which plots are cultivated.

C. *Nonconvex Production Technology*

The tests of household efficiency presented in this paper rely on the assumption that crops are produced with convex technologies. If this assumption is relaxed, it could be efficient to allocate factors differently across identical plots planted to the same crop. In Burkina Faso, nonconvexities could arise as a consequence of fixed travel costs to providing labor on a plot. Households' plots are scattered around the village, with about 10 percent of plots located more than 2.5 kilometers from home. Workers travel to these plots by foot, so there may be a significant fixed travel cost to providing labor on the more distant plots. If T^i is the fixed cost of beginning to work on plot i, then (7) becomes

$$\max_{N_F^i, N_M^i} \sum_{i \in P^k} G^k(N_F^i, N_M^i, A^i)$$

$$\begin{aligned} \text{subject to} \sum_{i \in P^k} N_F^i + \sum_{i \in P^k} T^i \cdot I(N_F^i > 0) &= N_{Fk}, \\ \sum_{i \in P^k} N_M^i + \sum_{i \in P^k} T^i \cdot I(N_M^i > 0) &= N_{Mk}, \\ N_F^i, N_M^i &\geq 0. \end{aligned} \tag{7'}$$

It may be optimal on some plots (particularly small plots with high T^i) to set one of the labor inputs to zero to avoid the fixed transportation cost. Optimality does not require that inputs or output be the same on two identical plots if a nonnegativity constraint is binding for at least one type of labor on at least one of the plots.[12] However, if we consider any two identical plots with small transportation costs (so that the nonnegativity constraints on labor inputs never bind on these two plots), then (7′) implies that output is the same on these two plots, even if there are other plots controlled by the household with large transportation costs on which the nonnegativity constraint binds. Hence, (8) and (9) continue to hold for the set of plots with small fixed transportation costs. If the gender differential in yields is a consequence of a nonconvexity in the production function generated by the fixed travel cost of providing labor on distant plots, then the differential should be eliminated if attention is restricted to plots not subject to significant travel costs.

Table 8, therefore, reports the results of estimating equation (10) for subsamples of plots located close to home. Column 1 reports the gender-yield differential for the full sample of plots (from col. 1 of table 3). Columns 2–6 report the same statistic for progressively smaller samples of plots closer to home. The standard errors of the estimates rise as the sample size falls, but there is no evidence of a diminution of the gender-yield differential on plots located close to home. Even when attention is restricted to plots within 100 meters of the households' residences, where it is not plausible that there is a significant travel cost, plots of women have significantly lower output than similar plots within the household planted to the same crop but controlled by men. There is no evidence, therefore, that the nonconvexity in the production technology generated by fixed travel costs underlies the gender-yield differential.

D. The Assumption of a Common Technology

I have assumed that men and women in the same household farming the same crop use identical production technologies. Suppose, however, that they farm differently. In this case, production of good k becomes

[12] The terms N_F^i, N_M^i, N_{Fk}, and N_{Mk} can be interpreted as vectors of daily labor inputs, in which case it might be optimal to avoid work on plot i on some days in order to avoid incurring the daily fixed transportation cost T^i. If this is the case, then labor inputs and yields optimally might not be equated on identical plots even when there are positive *seasonal* levels of both male and female labor on the plot, as long as the nonnegativity constraint is binding for one type of labor on some days.

TABLE 8

Specification Tests: Gender-Yield Differential on Plots Close to Home: OLS Fixed-Effect Estimates of the Determinants of Plot Yield (× 1,000 FCFA)

	Distance of Plot from Home					
	All Plots (1)	Within 1,000 Meters (2)	Within 500 Meters (3)	Within 200 Meters (4)	Within 100 Meters (5)	Within 50 Meters (6)
Gender	−27.70 (−4.61)	−32.77 (−3.82)	−27.03 (−2.38)	−21.80 (−2.02)	−34.46 (−2.47)	−49.61 (−1.89)

Note.—The specification and sample in col. 1 are identical to those reported in col. 1 of table 3. In the remaining columns, the specification of the regression is identical to that reported in col. 1 of table 3, with the exception that the indicator variables for location are excluded. The sample in these remaining columns is limited to plots within the specified distance of the households' home. All the regressions include household-year-crop effects and indicators of plot size, toposequence, and soil type. The t-ratios (in parentheses) are based on heteroskedastic-consistent estimates of the covariance matrix.

$$Y^k = \sum_{i \in P^k} G^{kj}(N_F^i, N_M^i, A^i), \quad j \in \{F, M\}. \tag{1'}$$

Efficiency no longer implies equal yields on similar plots controlled by different individuals.

Production function estimates can be used to test the restriction that $G^{kj}(\cdot) = G^k(\cdot)$; this is the primary goal of this subsection. In addition, however, production function estimates permit the calculation of the loss in output resulting from any inefficiency in the allocation of factors of production. This loss is calculated with respect to the allocation of factors both across plots within households and across plots controlled by different households in each village.

1. Production Function Estimation

Suppose that output on plot i (devoted to crop c in year t by household h) is a CES function of land and labor inputs:

$$Q_{htci} = \epsilon_{htci}[(1 - \delta)(T_{htci})^{-\rho} + \delta(N_{htci})^{-\rho}]^{-v/\rho}, \tag{11}$$

where $\epsilon_{htci} = \lambda_{htc} \cdot \omega_{htci}$; λ_{htc} summarizes the influence of any unobserved variables that are constant within household-year-crop groups, most important, household-crop-year weather shocks; and ω_{htci} is a plot-specific shock, which includes most importantly plot-level variation in rainfall. I assume that the labor input N is itself a CES aggregate of male, female, child, and nonhousehold labor inputs:

$$N = [\delta_M(N_M)^{-\pi} + \delta_F(N_F)^{-\pi} + \delta_C(N_C)^{-\pi} + (1 - \delta_M - \delta_F - \delta_C)(N_{NH})^{-\pi}]^{-1/\pi};$$

I have dropped the *htci* subscripts to improve legibility. The CES functional form has the important advantage of allowing positive output when some inputs are zero (an advantage not shared by most linear [in parameters] models). The land input is an aggregate of land area (modified by plot characteristics) and fertilizer inputs (aggregated from organic and commercial fertilizer inputs). So $T = A^* \cdot [1 + \phi(M^*/A^*)^{\Phi}]$, where A^* is (quality-adjusted) plot area and M^* is an aggregate of fertilizer inputs. In turn, $A^* = A \cdot (1 + \mathbf{Z}\boldsymbol{\gamma})$, where $\mathbf{Z}$ is a vector of plot characteristics (toposequence, soil type, and location). Finally, $M^* = \eta M + F$, where M is manure and F is commercial fertilizer.[13]

It is prudent to be skeptical of direct estimates of this production

[13] This parsimonious form for the land input is chosen because it makes raw land area essential for the land input, while allowing manure and fertilizer to augment the productivity of land with diminishing marginal returns.

function. The labor, manure, and fertilizer inputs are chosen by the farmer, not randomly allocated across plots. To the extent that the farmer has any knowledge of λ_{htc} or ω_{htci}, his or her production decisions will reflect that knowledge, these inputs will be correlated with the error term, and the estimates will be inconsistent. In order to mitigate this classic simultaneity problem, I follow Mundlak (1961); hence a fixed-effects procedure is used to eliminate λ_{htc} from equation (11). Nevertheless, factor inputs are potentially correlated with the plot-level shock ω_{htci}: Fafchamps (1993) provides evidence that this correlation exists. An instrumental variables procedure could overcome this problem, but no variables are available that are correlated with the deviation of plot-level inputs from household-crop-year average inputs and uncorrelated with ω_{htci}.[14]

Nonlinear least-squares fixed-effect estimates of (11) are presented in table 9.[15] It is not possible to reject the hypothesis that the technology is identical across plots controlled by men and women. A test of the hypothesis that the interaction effects are jointly zero is distributed as $F(23, 4{,}199)$ and has a value of 1.30 ($p = .154$). The gender differential in yields on similar plots is not a consequence of access to different technologies; rather, it reflects the different intensities with which inputs are applied on men's and women's plots.

The production function estimates imply strongly (and statistically significant) diminishing returns to scale. There is a great deal of substitutability between land and labor, and among the different types of labor (elasticities of substitution of 2.1 and 2.3, respectively). Male, female, and nonhousehold labor hours are approximately equally productive, and child labor is much less productive. The point estimate indicates strongly diminishing returns to fertilizer application,

[14] It is not possible to track plots over time. Hence lagged plot-level inputs are not available as instruments, even if the case could be made that they are uncorrelated with ω_{htci}. Nor do household-level variables exist that are significantly correlated with the deviation of plot-level inputs from average inputs.

[15] Taking logs of (11) and differencing any two plots i and j within a household-year-crop group gives

$$\begin{aligned}\ln(Q_{htci}) - \ln(Q_{htcj}) = -\frac{v}{\rho}\cdot\{&\ln[(1-\delta)(T_{htci})^{-\rho} + \delta(N_{htci})^{-\rho}] \\ &- \ln[(1-\delta)(T_{htcj})^{-\rho} + \delta(N_{htcj})^{-\rho}]\} \\ &+ \ln(\omega_{htci}) - \ln(\omega_{htcj}),\end{aligned}$$

with the fixed effect eliminated. This is estimated for all pairs of the n_{htc} plots within each household-year-crop group by weighted nonlinear least squares, with weights equal to

$$\frac{1}{n_{htc}-1}\cdot\frac{n_{htc}!}{2\times(n_{htc}-2)!}.$$

TABLE 9

NONLINEAR LEAST-SQUARES ESTIMATES OF THE CES PRODUCTION FUNCTION
(Full Sample, Household-Year-Crop Fixed Effects)

Dependent Variable: Ln(Plot Output × 1,000 FCFA)

	Base Production Function Estimates (1)		Gender-Specific Production Function Estimates (2): Base Estimates		Gender-Specific Production Function Estimates (2): Interactions: Additional Effect on Women's Plots	
Main production function parameters:						
Returns to scale (v)	.87	(71.38)	.86	(61.10)	−.10	(−1.71)
Substitution (ρ)	−.54	(−7.54)	−.46	(−5.89)	.03	(.27)
Distribution (δ)	.08	(3.00)	.12	(3.15)	−.05	(−1.25)
Labor aggregate:						
Substitution (π)	−.57	(−15.84)	−.46	(−11.34)	−.06	(−1.65)
N_F distribution (δ_F)	.31	(15.71)	.31	(11.74)	.08	(1.77)
N_M distribution (δ_M)	.31	(16.76)	.35	(10.50)	−.05	(−1.04)
N_C distribution (δ_C)	.07	(2.55)	.05	(1.78)	−.01	(−.49)
Fertilizer aggregate:						
Manure share (η)	.01	(1.15)	.01	(1.26)	.00	(−1.04)
Elasticity (Φ)	.80	(3.62)	.84	(3.22)	.10	(.15)
Share (ϕ)	.01	(.76)	.01	(.65)	.00	(−.07)
Land aggregate:						
Toposequence:						
Uppermost	−.59	(−5.85)	−.48	(−3.44)	−.22	(−1.45)
Top of slope	−.45	(−4.11)	−.32	(−2.25)	−.20	(−1.25)
Mid-slope	−.29	(−2.30)	−.22	(−1.39)	−.19	(−1.09)
Near bottom	−.35	(−2.80)	−.31	(−2.08)	−.05	(−.22)
Soil types:						
11	−.56	(−3.95)	−.62	(−3.70)		
12	.73	(2.07)	.82	(2.06)	−.02	(−.03)
13	.13	(.25)	.16	(.30)		
31	.28	(2.18)	.10	(.76)	.40	(1.93)
32	.26	(1.91)	.13	(.84)	.30	(1.50)
33	.57	(1.75)	.68	(1.60)	−.23	(−.50)
37	.34	(1.67)	.35	(1.29)	−.02	(−.07)
45	.25	(1.84)	.09	(.59)	.33	(1.75)
46	.05	(.16)	.10	(.34)		
51	−.10	(−1.28)	.02	(.17)	−.16	(−1.31)
Location:						
Compound plot	.33	(3.13)	.32	(2.77)	.01	(.06)
Village plot	.12	(2.09)	.17	(2.20)	−.10	(−1.08)

NOTE.—t-ratios are in parentheses.

but the coefficient is not significantly different from one. The results with respect to toposequence and plot location correspond to expectations.

2. Quantifying the Loss Attributable to Intrahousehold Allocative Inefficiency

It is possible to calculate the additional output that could be gained by reallocating factors of production across plots planted to the same crop controlled by different members of the same household. I sum the factors of production used on plots within household-year-crop groups that contain plots controlled by both men and women, and I compare the expected output on those plots given the actual allocation of labor and fertilizer with the output that could be achieved by the optimal allocation of factors using the base production function estimates from table 9. On average, household output of these crops could be increased by 5.89 percent (standard deviation 4.7 percent) by the expedient of simply reallocating already committed factors of production across the plots controlled by different individuals within these household-year-crop groups.

In Section IV*A* it was shown that there is more variation in yields across similar plots controlled by different households than there is across similar plots controlled by different individuals in the same village. There is a correspondingly greater loss of output from the apparent misallocation of factors across plots controlled by different households than there is across plots within a household. On average, *village* output could be increased by 13 percent (standard deviation 6 percent) by reallocating factors of production across plots planted to the same crop but controlled by different households in the village. Factors of production are not allocated efficiently across plots controlled by different individuals in a household, but the household does succeed in reducing the output losses attributable to misallocation in the village at large.

VI. Conclusion: Toward a Model of Intrahousehold Resource Allocation

I have argued that the allocation of resources across productive enterprises within these households is not Pareto efficient. If correct, this implies that the conventional pooling model of household resource allocation is false and that both cooperative bargaining models and the more general model of efficient household allocations are inadequate for describing the allocation of resources across productive activities in households. In addition, it implies that there is an impediment to apparently mutually advantageous trades between members of the household.

A model of intrahousehold resource allocation that is consistent with these findings should also accommodate two other essential features of the data: control over land is individualized (rather than located in the household as a unit), and yields and input intensities are even more variable across similar plots controlled by members of different households than they are across plots controlled by different individuals within a household.

A. *Individual Control over Plots*

Land is allocated between the husband and wife in the context of the marriage market. In effect, the allocation of fixed assets to a woman in the marriage market is a means of committing a certain flow of utility to that woman. In the context of the Lundberg-Pollak (1993) "separate spheres" bargaining model of household allocation, the allocation of plots to the new wife at marriage is a means of committing to a certain transfer, which in turn affects the division of the surplus between the husband and wife in the marriage. Individualized tenure provides the incentive conflict that causes other imperfections, discussed below, to lead to an inefficient pattern of resource allocation. The descriptive literature from Africanists on this is abundant and decisive: both men and women in African households care more about output on their own plots (see Davison [1988] or Dey [1993] for recent statements).

The marginal product of land controlled by a woman is less than that of similar land controlled by her husband. A reallocation of land from a woman to her husband could increase total output with no change in labor supplies to each individual's land. Higher agricultural output could be achieved, therefore, if the husband could replace some of the land given to the wife in the course of the marriage contract with another asset. The husband, for example, could offer his wife a financial asset that yielded a return equivalent to the implicit rent she earns from a particular plot of land.[16] However, no such financial asset is available. Moreover, other asset rental markets are thin and imperfect, and interhousehold labor markets are virtually nonexistent. The assets that are included in the portfolios of these households (in addition to land, these assets include livestock and stocks of goods for trading), therefore, require household labor inputs to yield a return. The problem is simply generalized from one

[16] This implicit rent depends on the particular structure of the game that divides the surplus of the marriage between husband and wife.

of allocating labor across plots controlled by different household members to one of allocating labor across a broader variety of assets controlled by different household members.

B. Yield Dispersion across Households

The large dispersion of yields and input intensities across similar plots planted to the same crop by members of different households in a village reflects the virtual absence of functioning land rental and labor markets in rural Burkina Faso (Fafchamps 1993). The absence of land rental markets, in turn, is a consequence of tenure insecurity. The literature on land tenure in Burkina Faso (Saul 1993) indicates that a household's control over land extends only to usufructuary rights. Moreover, a household is secure in its tenure only to the extent that it exercises its right to use the land. If one household farms a plot nominally controlled by another (by "borrowing" the land), a payment is made to acknowledge the latter household's nominal control over the land. However, the payment is trivial and only symbolic in nature. Moreover, if the "borrowing" is repeated over a number of years, the original household's claim over the plot gradually diminishes until the land is under the control of the borrower (Bruce 1993). Hence long-term rental contracts are extremely rare.

The virtual absence of labor transactions (except for piece-rate labor during harvest in some of the villages) is likely a consequence of moral hazard. Foster and Rosenzweig (1994) provide striking evidence of the quantitative importance of moral hazard in labor contracts in village India. Collier (1983) and Binswanger and McIntire (1987) argue that moral hazard has inhibited the development of rural labor markets in Africa. This argument is consistent with the observed predominance of share and piece-rate contracts (Robertson 1987) in which labor transactions do occur. In Burkina Faso, the dispersion of household production on many small plots would raise the cost of monitoring hired labor, and the strong gender division of labor with respect to task would raise the cost, in particular, of monitoring labor contracts between men and women.

C. Yield Dispersion within Households

The same features of the economic environment that generate yield and input intensity dispersion across similar plots controlled by individuals in different households induce a lesser degree of yield and input intensity dispersion across similar plots controlled by different individuals within a household. Suppose that endowments of labor relative to land vary across the members of a household. I have found no account in the ethnographic literature on Burkina Faso concerning intrahousehold land rental markets, but it is doubtful that individual tenure within households is more secure than land tenure in general. Perchonock (1985) argues that in northern Nigeria, women's land rights are particularly insecure and are under pressure from male relatives. I hypothesize that a process similar to that described with respect to land rental across households also occurs within households. If a woman continually "rented" land to her husband, she might lose her control over that land.

As with interhousehold transactions, imperfect information can inhibit intrahousehold trade in labor that could otherwise equalize marginal products. Hemmings-Gapihan (1985), Jones (1986), and Dey (1993) cite evidence of informal compensation by husbands for wives' labor in case studies in Burkina Faso, Nigeria, Guinea-Bissau, Sierra Leone, and Cameroon. In each case, however, there is conflict within the household concerning the extent of the contribution by the wife to her husband's activities; indeed there is evidence that these conflicts result in violence within the household (Aluko and Alfa 1985). Moreover, there are *no* reports of compensation from a wife to a husband for his labor on her plots: his labor is claimed to be voluntary assistance. The broad conclusion of this literature is that it is not possible for a woman to hire her husband and that there are significant transaction costs associated with men hiring their wives.

If information asymmetries and other transaction costs are similar in intrahousehold and interhousehold labor transactions, then the existence of either household public goods or a degree of altruism among household members can account for the smaller degree of dispersion of input intensity and yield across plots within households than across households. To take an extreme example, consider a model in which husbands and wives voluntarily allocate labor to their own and each other's plots. Suppose in addition that each gets utility from consumption of private and household public goods and that the allocation of private consumption goods within the household is determined by, for example, the Lundberg-Pollak separate spheres model (where the threat point of a Nash bargaining solution is determined by output on an individual's plots). Then each individual will voluntarily supply labor to the other's plots, because each has a stake (via production of the public good) in the welfare of the other, hence reducing (but not eliminating) the dispersion in yields and input intensities that would otherwise exist.[17]

[17] There is nothing special about the Lundberg-Pollak model for this result; the result that individuals in the household will volunteer to help each other even with severe information asymmetries holds in most noncooperative household models. See Udry (1994) and Udry et al. (1995) for details.

A large number of empirical studies have cast doubt on the unitary household model. By now, it is clear that whenever matters substantially related to intrahousehold distribution are under investigation, the unitary household model must be discarded. The dominant alternative interpretation of the household is based on cooperative bargaining within the household. More recently, a generalization of this approach that assumes only that the allocation of resources within the household is Pareto efficient has become attractive to many researchers. The results of this paper, if confirmed in a wider variety of settings, imply that even this more general approach to intrahousehold allocations can be misleading. Farming households in Burkina Faso do not achieve a Pareto-efficient allocation of resources across the production activities of the different individuals who make up the household.

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