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GENDER DIFFERENTIALS IN FARM PRODUCTIVITY: IMPLICATIONS FOR HOUSEHOLD EFFICIENCY AND AGRICULTURAL POLICY

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ABSTRACT

Within many African households, agricultural production is simultaneously carried out on many plots controlled by different members of the household. Detailed plot-level agronomic data from Burkina Faso provides striking evidence of inefficiencies in the allocation of factors of production across the plots controlled by different members of the household. Production function estimates imply that the value of household output could be increased by 10 to 20 percent by reallocating currently-used factors of production across plots. This finding contradicts standard models of agricultural households. A richer model of behavior, which recognizes that the individuals who comprise a household compete as well as cooperate, has important implications for the structure of agricultural production and for the design of agricultural policy.

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1. INTRODUCTION

At least since the 1970s (and especially following the start of the UN Decade for Women in 1975), academic interest in the role of rural women in agricultural development has been strong. There is a large and growing literature concerned with gender-based distributional issues and the economic activities of rural women.[1] A great deal of substantive work has been done concerning, for example, the distribution of resources and work within the household (Jones 1986; Kanbur and Haddad 1994); the various roles played by women and men in a variety of farming systems (Carney and Watts 1990, 1991; Aredo 1992; Guyer 1984); the access of women to credit markets (Morris and Meyer 1993); discrimination against women in formal-sector interventions in smallholder agriculture (Bindlish and Evenson 1993; Bowen 1993); and the relative

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[1] See Kandiyoti (1990) for a brief, but valuable, overview.

effects of increases in men's and women's incomes on the health, nutrition, and education of children (Strauss and Thomas 1995).

This large body of work, however, occupies an ambiguous and contested position relative to the main thrust of research in economics and agricultural economics. A building block of virtually all empirical studies in economics is the premise that households behave as though they are single individuals.[2,3] This is a convenient and innocuous assumption in many contexts. However, it can be quite restrictive when investigating the causes and welfare consequences of gender differences in agriculture. In order for the discipline of economics to contribute to an understanding of the role of gender in rural economies, a different and richer theory of household organization is required.

In response to a growing number of econometric studies that have found strong evidence against the hypothesis that households act as if they are individuals (see the review in Haddad, Hoddinott, and Alderman [1994]), a number of different models of the interaction that occurs between individuals within the household have been proposed.[4]

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[2] This includes (not surprisingly, given the time it was written and the issues it engages) *Getting Agriculture Moving*.

[3] It should be noted that economic theory is based on the behavior of individuals. There is theoretical justification for aggregation into households that behave as if they are individuals only, under quite restrictive assumptions (see Samuelson 1956; Becker 1981; McElroy and Horney 1981).

[4] The most robust empirical finding has been that a household's pattern of expenditure depends not only on total resources (as predicted by the unitary household model), but also on the proportion of those resources accruing to different members of the household.

Many of these share with the standard model the assumption that the allocation of resources is Pareto efficient.[5] A variety of alternative 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.

This conception of the household is far richer than the traditional unitary model. It opens the door, in particular, to an analysis of the distribution of resources within the household. It is possible, for example, to analyze a claim such as "policy *X* will reduce living standards of women, while it raises those of men."

However, even this enriched vision of the household is too narrow to address most of the concerns raised by observation of gender differences in agricultural production. The problem is that a minimal implication of the assumption that intrahousehold allocations of *consumption* are Pareto-efficient is that the allocation of resources in *production* is allocatively efficient. This, in turn, implies that while the issues of gender and intrahousehold allocation may have distributional implications, they are unrelated to productive efficiency. For example, discrimination against women in the allocation of credit might weaken the bargaining position of women (and thus lower their welfare), but any credit that reaches any member of a household will be allocated efficiently across the

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[5] This includes the bargaining models of McElroy and Horney (1981) and Manser and Brown (1980), as well as the more general "collective household" models building on Chiappori (1988, 1992). The theoretical literature is reviewed in Haddad, Hoddinott, and Alderman (forthcoming), Dasgupta (1993), and Bergstrom (1993).

productive activities of *all* of the members of the household. Issues of gender, generation, and intrahousehold resource allocation, it seems, need not concern those interested primarily in the determinants of rural output or long-run growth.

This argument, of course, relies on the assumption that households achieve Pareto efficiency. Agricultural production by farm households in Sub-Saharan Africa provides an unusually opportune environment in which to test this assumption. 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. In Burkina Faso, it is often the case that different members of the household simultaneously cultivate the same crop on different plots. Pareto efficiency in production implies that yields should be the same on all plots planted to the same crop within a household in a given year (controlling, of course, for plot characteristics).

The starting point of this paper is an examination of this condition, using an extremely detailed agronomic data set collected by ICRISAT in Burkina Faso. The data are drawn from a four-year panel study (1981-1985) of 150 households in six villages in three different agroclimatic zones of Burkina Faso.[6] During the first three years of the survey, extremely detailed agronomic information was collected. 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,

[6] See Matlon (1988) for documentation of the survey. These data have seen limited use by economists. See Fafchamps 1993; Reardon, Delgado, and Matlon 1992; Savadogo, Reardon, and Pietola 1994.

yielding usable data on a total of 4,655 cultivated plots. A unique feature of the Burkina Faso ICRISAT data is the extremely rich set of plot characteristics, including area, location, toposequence, and local name for soil (each plot is categorized into one of 89 possible soil types) that it contains. This richly textured plot information permits much finer control for land quality than is generally possible with developing country data.

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 rainfed agriculture in semi-arid 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 farming systems of these villages (and more generally in much of Sub-Saharan Africa) is that decisionmaking authority and nominal control over output on different plots within the household are held by different individuals. Individuals do not have absolute autonomy with respect to decisionmaking on their own plots, but a large literature makes it clear that people have substantive control over cultivation decisions on their own plots (Ramaswamy 1991; Guyer 1984; Dey 1993; Davison 1988; Saito, Mekonnen, and Spurling 1994; Jones 1986; Berry 1993). One goal of this paper is to determine if differences across plots in decisionmaking authority and nominal control over output are reflected in the allocation of resources across those plots.

The next section briefly describes the implications of Pareto efficiency for the allocation of resources across plots within a household. Section 3 presents evidence that plots controlled by women are farmed much less intensively than similar plots simultaneously planted to the same crop but controlled by men in the same household. Taken at face value, these results contradict the hypothesis of Pareto efficiency within the household. If efficiency is violated, total output could be increased by reallocating factors of production between plots within a household. Section 4 presents estimates of production functions that can be used to construct an estimate of the output lost due to the inefficient allocation of resources across plots within households. These estimates imply that, on average, households could increase output of affected crops (those crops grown by both men and women) by about 10 percent, by reallocating labor and manure used on men's plots to women's plots. For a more complete treatment of the econometric issues associated with the results presented in Sections 3 and 4, as well as a more general treatment of economic efficiency within households, see Udry (1994). Section 5 provides suggestions for new theoretical approaches to intrahousehold resource allocation that have important implications for the design and implementation of agricultural policy.

2. EFFICIENCY

The starting point for most household models is the assumption of *first-best Pareto efficiency* of resource allocation within the household. In other words, the models start with the assumption that the equilibrium allocation will be such that it would be impossible to rearrange the total resources at the disposal of the household in such a way that all the members of the household are better off. The households that comprise the

ICRISAT Burkina Faso sample are agricultural households, each engaged in a wide variety of productive activities. A necessary (but not sufficient) condition for Pareto efficiency within the household is that factors of production are allocated efficiently to the various productive activities of the household. Going one step further, a necessary (but not sufficient) condition for the efficiency of the allocation of factors of production across the various activities of the household is that within any one agricultural activity (for example, cultivating sorghum), factors of production are allocated efficiently across the various plots on which it occurs. It is this final condition that is examined in this paper. On the one hand, this is a very weak condition (and thus a rejection is particularly surprising)—the efficiency of factor allocation across plots within a household devoted to a particular crop is a minimal requirement for overall efficiency within the household. On the other hand, the authors are testing for first-best productive efficiency—the null hypothesis presumes no information asymmetries or cultural constraints on the allocation of resources between men and women. It should be emphasized that the null hypothesis is relevant: it is assumed to be true in virtually all extant models of the household in the economics literature.

Suppose that in a given agricultural season, a wife and a husband are growing the same crop on their separate plots. If the two plots are identical in all respects except for the fact that one is controlled by the wife and the other by the husband, then productive efficiency requires that yields and input allocations be identical on the two plots.[7] This is the argument behind the central empirical effort of this paper.

3. TESTING FOR PRODUCTIVE EFFICIENCY

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 nonhousehold members are higher on plots controlled by men; female labor is more

Table 1—Mean yield, area, and labor inputs per plot, by gender of cultivator (n = 4,655)

	Crop Output *1,000 CFA[a]	Area	Male Labor	Female Labor	Nonfamily Labor	Child Labor	Manure Weight
		(hectare)	(hours per hectare)				(kilograms/ per hectare)
Men's plots	79.9	.740	593	248	106	104	2,993
(Std)	(186)	(1.19)	(1,065)	(501)	(407)	(325)	(11,155)
Women's plots	105.4	.100	128	859	46	53	764
(Std)	(286)	(0.16)	(324)	(1,106)	(185)	(164)	(5,237)
t-statistic H_0: $\mu_m = \mu_w$	-3.27	29.03	22.16	-21.31	6.89	7.08	7.68

[a] In 1982, the exchange rate was approximately US$1 = FCFA 325.

[7] It should be noted that the different technologies used to produce different crops implies that the equality of yields need not hold across plots devoted to different crops in a household, that in the absence of land and labor markets, yields might vary across plots controlled by different households, and that with liquidity constraints, yields might differ across plots controlled by the same household in different years. When agricultural production is risky, the equality holds, on average.

intensively used on plots controlled by women. The higher yields achieved on plots controlled by women reflects, at least in part, the different crops grown by men and women (see Table 2).

Attention is restricted here to comparing yields achieved by men and women in the same household, simultaneously farming the same crop on similar plots, by estimating the following equation:

$$Y_{htci} = X_{htci}\beta + \gamma G_{htci} + \lambda_{htc} + \epsilon_{htci} , \qquad \textbf{(1)}$$

where Y_{htci} is the log yield achieved on plot i of household h in year t planted to crop c and X_{htci} is a vector of characteristics of that plot, including the log of the plot area and dummy

distance from the compound (because closer-in plots mi

intensively). G_{htci} is a dummy variable corresponding to the gender of the plot manager, λ_{htc} is a household-year crop-specific fixed effect and ϵ_{htci} is an error term. This regression explores, therefore, the variation in yields between plots controlled by men and women farming the same crop, within a single household in a given year. Table 3, column 1, reports the results. Plots controlled by women have significantly lower yields than other plots within the household planted to the same crop in the

Table 2—Distribution of primary crops across plots

Primary Crop	Women's Plot	Men's Plot
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	5.1
Cotton	0.7	11.1
Okra	12.4	0.6
Earthpeas/fonio	26.0	2.1
Others	6.0	10.0

Table 3—Ordinary least squares (OLS) estimates of the determinants of crop yield per hectare

Independent Variables	Dependent Variable: Yield per Hectare of ... 1 All Crops	2 Sorghum	3 Vegetables (Fonio/Earthpeas/ Groundnuts/Okra)
Gender (1 = female)	-.18	-.41	-.21
	(-3.36)[a]	(-5.50)	(-2.06)
ln (plot area)	-.17	-.30	-.28
	(-6.27)	(-8.81)	(-2.37)
Number of indicator variables for soil type, toposequence, and plot location	23	21	15
Joint F-statistic	1.69	19.49	11.91
Degrees of freedom	(23,1981)	(21,793)	(15,235)
(Significance = p)	(0.02)	(0.00)	(0.00)
Fixed-effect categories	Household-year-crop	Household-year	Household-year-crop

Note: t-statistics are in parentheses.

[a] t-ratios based on heteroskedastic-consistent estimates of the variance-covariance matrix.

same year, but controlled by men.[8] Moreover, the effect is very large. On average, yields are about 18 percent lower on women's plots than on similar men's plots simultaneously planted to the same crop within the same household. Columns two and three report the results for restricted samples of plots planted to sorghum and the four most important vegetable crops (fonio, earth peas, groundnuts, and okra). In both cases, plots controlled by women have lower yields than plots controlled by men. For sorghum, the decline is striking—about 40 percent. Even for the vegetable crops, in which women tend to specialize, the decline in yields is about 20 percent.

Equation (1), of course, is not a production function (which would map inputs to outputs and thus is determined by biology and the technical efficiency with which inputs are used). Instead, equation (1) is a reduced form, which provides a test of the efficiency of the allocation of inputs across the plots controlled by a household. 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 reflect differences in the intensity with which inputs are applied on men's and women's plots. Recognizing the source of the yield difference is a necessary step in the determination of an appropriate policy intervention. Many previous studies (reviewed in Quisumbing [1993]) have indicated differences in output per acre or per person but have failed to isolate the source

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[8] Women have higher output per hectare in Table 1, but lower output per hectare in this regression, for two reasons: women tend to farm higher value crops, and women have smaller plots (that have higher yields than larger plots). When yields of the same crop are compared, and on similar plots, it is found that men have much higher yields than women.

of these differences. Table 4 reports the results of estimating equation (1) with Y_{htcp}, now interpreted as the per-hectare usage of inputs on plot p planted to crop c in year t by household h. In column 1, it can be seen that much less male labor per hectare is devoted to plots controlled by women than to similar plots planted to the same crop but controlled by men. The converse but weaker result appears in column 2: the point estimate indicates that a small amount of more female labor is devoted to plots controlled by women, but the coefficient is not statistically, significantly different from zero. More surprisingly, child labor is devoted more intensively to plots controlled by men than to similar plots controlled by women—moreover, this effect is large relative to average child labor inputs. Similarly, nonhousehold labor (almost entirely unpaid exchange labor) is used more intensively on plots controlled by men.

A particularly striking result emerges with respect to manure inputs (column 5). It is well-documented that the marginal product of fertilizer diminishes.[9] 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 household members.

[9] Experimental data in similar agroclimatic regions confirm this pattern at the levels of organic fertilizer application observed in these data. See McIntire, Bourzat, and Pingali 1992.

Table 4—Determinants of intensity of inputs at the plot-level

Variable	Inputs (Fixed-Effect Tobit Estimates) Hours of Labor (per Hectare) Male	Female	Child	Nonhousehold	Manure
					(kilograms per hectare)
Gender (1 = female)	-679 (-11.95)	42.72 (0.88)	-199 (-2.29)	-451 (1.92)	-13.73 (-2.89)
In (plot area)	-219 (-9.80)	-316 (-8.47)	-112 (-2.46)	-181 (-1.39)	-6.14 (-2.45)
Number of indicator variables for soil type, toposequence, and plot location	20	20	19	19	19
Joint F-statistic Degrees of freedom (Significance = p)	27.67 (20,1984) (0.00)	42.62 (20,1984) (0.00)	74.62 (19,1985) (0.00)	10.01 (19,1985) (0.00)	42.31 (19,1985) (0.00)
Fixed-effect categories	Household-year-crop	Household-year-crop	Household-year-crop	Household-year-crop	Household-year-crop
Mean of dependent variable					
all cases	427	466	86	85	1.70
when dependent variable > 0	507	517	203	213	7.78

Source: ICRISAT village-level data for Burkina Faso.

Note: t-statistics are in parentheses.

4. QUANTIFYING THE LOSS OF OUTPUT

There is econometric evidence that factors of production are not allocated efficiently across plots controlled by different members of the same household. This section presents estimates of the production losses due to the differences across plots within a household in the intensities with which inputs are applied. There is a series of assumptions with respect to the statistical properties of the data that are required to permit the consistent estimation of a production function when price data are lacking.[10] Modified Cobb-Douglas and trans-log agricultural production functions are estimated and used to calculate the loss from the inefficient allocation of inputs across plots within a household. It will be seen that, on average, households could increase output of affected crops (those crops produced by both men and women on separate plots) by approximately 10 percent by allocating variable factors of production evenly across the plots controlled by men and women.

Any estimate of the loss due to factor misallocation must be based on an estimate of a production function. It is useful to reiterate a commonplace observation concerning the difficultly of directly estimating production functions. For simplicity of exposition, suppose that the production function is of the form

$$Q_{htcp} = \alpha_0 + \alpha_1 T_{htcp} + \alpha_2 L_{htcp} + \epsilon_{htcp} , \qquad \textbf{(2)}$$

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[10] Such exercises are common in development economics (Jacoby 1993; Saito, Mekonnen, and Spurling 1994; Moock 1976; Bindlish, Evenson, and Gbetibouo 1992). It is useful to reiterate the strong conditions that must be satisfied if consistent estimates are to be achieved.

where Q_{htcp} is the logarithm of output on plot p devoted to crop c at time t by household h, L_{htcp} and T_{htcp} are the logarithms of labor and land on that plot, and ϵ_{htcp} is a random variable with mean zero. Consider the nature of ϵ_{htcp}. It is generally argued that ϵ_{htcp} represents the large set of unobserved inputs into the production process. If Q, T, and L are observed, and ϵ is uncorrelated with T and L, then ordinary least squares (OLS) estimates of the parameters of equation (2) are consistent. How reasonable is it to assume that factor inputs are uncorrelated with the error term in equation (2)? The answer, of course, is that it is not reasonable at all. T and L are *chosen* by the farmer, not randomly allocated across plots. If the farmer knows something about ϵ (for instance, how good the soil is on the plot, or some details about the weather [Fafchamps 1993]), she will accordingly adjust her factor input decisions. ϵ will be correlated with T, L, or both and OLS parameter estimates will be biased. As a general practice, therefore, it is prudent to be skeptical of direct production function estimates. An appropriate estimation strategy would be to use instruments, typically prices, that influence factor allocation decisions and yet are uncorrelated with ϵ_{htcp} (for example, Jacoby 1993). This method, unfortunately is not available in this instance. There is no information on key factor prices because of the virtually complete absence of factor markets in the surveyed villages.

Nevertheless, there is reason for hope that sensible production function estimates can be constructed with these data. First, it is possible to control for fine variations in plot characteristics, thus mitigating the general problem of bias due to the correlation of inputs with unobserved land quality. Secondly, following Mundlak (1961), it is possible to remove much of the remaining unobserved variation in land quality by using fixed effects procedures. In particular, equation (2) is estimated conditional on household-year-crop fixed effects, depending on variation in input choices across plots within household-year-crop groups to identify α. This procedure eliminates the omitted variables bias that would otherwise arise from any unobserved variables that are constant within a household-year-crop group (such as household-year-level weather shocks, and farm-level soil quality).[11] The production function that is actually estimated, therefore, is of the form:

$$Q_{htcp} = X_{htcp}\alpha + \gamma G_{htcp} + \lambda_{htc} + \epsilon_{htcp} \ , \qquad \textbf{(3)}$$

where Q_{htcp} and ϵ_{htcp} are defined as above, X_{htcp} is a vector of inputs discussed more fully below, G_{htcp} is the gender of the cultivator, and λ_{htc} is the household-year-crop fixed effect.

Table 5 presents selected parameter estimates from the more flexible translog specification. However, since this functional form requires a large number of parameters, a restricted form of it—the Cobb-Douglas (C-D) production function—is used for individual crops. Column 1 of Table 6 presents estimates of the C-D production function for the entire sample (for comparison with Table 5), and columns 2 and 3 present estimates for sorghum and vegetables separately.

[11] This conclusion is dependent on a functional form assumption that the unobserved attributes (like the observed inputs) enter the production function linearly.

Table 5—Production function estimates: Translog function; log of yield per hectare, all crops

Dependent Variable-Ln (yield)	Translog: All Crops Estimate	t^a
Gender (1 = female)	-.01	-0.14
Plot area	.11	1.10
Squared	-.01	-1.26
Male labor	.40	4.24
Squared	.02	2.88
Female labor	.55	6.19
Squared	-.02	-2.21
Child labor	.06	1.07
Squared	-.003	-0.60
Nonhousehold labor	-.04	-0.70
Squared	.01	2.51
Animal hours	-.10	-1.73
Squared	-.01	-1.27
Manure	.18	2.22
Squared	-.01	-1.65
Fertilizer	.03	0.46
Interactions		
Male labor x		
Female labor	-.06	-6.26
Child labor	-.01	-1.37
Nonhousehold	-.001	-0.19
Animal hours	.02	2.56
Manure	-.01	-1.60
Fertilizer	-.02	-1.78
Female labor x		
Child labor	.001	0.22
Nonhousehold	.01	1.66
Animal hours	-.003	-0.54
Manure	.000	0.14
Fertilizer	.005	0.72
Manure x		
Child labor	.003	0.89
Nonhousehold	-.001	-0.23
Animal hours	.004	1.00
Fertilizer	-.002	-0.47
	F	p
Indicator variables for soil type, toposequence, and plot location	1.71 (23,1942)	0.02
Fixed effect categories	Household-year-crop	
Average gain from equalizing inputs per hectare within household-year-crop groups:	Mean	Std.
Δyield - average over plots	10%	(.32)
Δoutput - average over groups	12%	(.14)

[a] Does not account for sampling error in parameter estimates.

Table 6—Production function estimates: Cobb-Douglas (C-D); log of yield per hectare

Dependent Variable/Yield	C-D All Crops		C-D Sorghum		C-D Vegetables (Fonio/Grountnut/ Earthpeas/Okra	
Gender (1 = female)	-.08		-.27		-.17	
	(-1.18)[a]		(-3.12)		(-1.14)	
Plot area	-.19		-.28		-.17	
	(-8.61)		(-9.51)		(-1.63)	
Male labor	.11		.08		.11	
	(6.05)		(3.85)		(2.06)	
Female labor	.24		.19		.47	
	(13.62)		(7.32)		(8.05)	
Child labor	.03		.03		-.02	
	(2.43)		(2.17)		(-0.44)	
Nonhousehold labor	.05		.07		.02	
	(4.42)		(4.87)		(0.69)	
Animal hours	.02		.01		.02	
	(1.94)		(0.49)		(0.39)	
Manure	.02		.05		.18	
	(1.93)		(3.63)		(1.68)	
Fertilizer	.02		.03		-.12	
	(1.83)		(1.79)		(-0.83)	
Number of indicator variables for soil type, toposequence, and plot location	23		21		16	
Joint F-statistic	1.79		1.01		1.28	
Degrees of freedom	(23,1976)		(21,788)		(16,228)	
(Significance = p)	0.01		0.45		0.21	
Fixed effect categories	Household-year-crop		Household-year		Household-year-crop	
Average gain from equalizing inputs per hectare within household-year-crop groups:	Mean	std.	Mean	std.	Mean	std.
Δyield-average over plots	11%	(.28)	18%	(.29)	4%	(.26)
Δoutput-average over groups	16%	(.15)[a]	20%	(.12)[a]	9%	(.17)[a]

Note: t-statistics are in parentheses.

[a] Does not account for sampling error in parameter estimates.

Some comments on the estimates in Tables 5 and 6 are appropriate before moving to their implications for the size of the output loss due to the variation in input intensities across plots controlled by men and women in the same household. First, output per hectare is strongly declining in the size of the plot. It should be noted that this is *not* the commonly-observed inverse relation between farm size and yield across households. Rather, this reflects lower yields on larger plots within a household. The simple imperfect labor market explanation commonly used to rationalize the farm size-yield relationship is not relevant to this case. The inverse plot size-yield relationship has been observed in other African data (Bindlish and Evenson 1993; Carter 1994; Blarel et al. 1992) without satisfactory explanation.[12] Second, female labor is much more productive than male labor in each specification, and particularly so in the case of vegetable crops (women tend to specialize in the production of these crops). This result stands in contrast to production function estimates from Asia and Latin America (for example, Jacoby 1992), but is similar to findings in some other regions of Africa (Saito, Mekonnen, and Spurling 1994). The coefficient on gender is smaller than the corresponding coefficient in Table 3 and is now insignificant except in the case of the sorghum regression. The gender yield differential, apparently, is caused by the difference in the intensity with which measured inputs of labor, manure, and fertilizer are applied on plots controlled by

[12] There are a variety of potential explanations: plot area measurement error, better matching of planting dates to weather on small plots (this interacts with labor market imperfections), the "boundary" effect (plants on plot edges have higher yields), fixed transportation costs to the plot, labor monitoring problems, and unobserved variation in plot quality. These possibilities are left for exploration in future work.

men and women rather than by differences in the efficiency with which these inputs are used.

The final rows of Tables 5 and 6 provide evidence of the percentage of output lost due to the apparent misallocation of inputs across plots controlled by men and women. The counterfactual exercise was conducted as follows. The estimated parameters are used to predict yield on each plot. This is compared with the predicted yield on that plot generated by reallocating the inputs used in each household-year-crop group evenly across the plots controlled by men and women in that group. The first of these rows is that difference, and thus is the mean percentage gain in yields across all plots generated by the redistribution.

The bottom line is represented in the final rows of Tables 5 and 6. These rows report the average (across household-year-crop groups) percentage increase in the total value of output (not yield) generated by equalizing factor inputs over plots within household-year-crop groups. This is calculated by multiplying the change in yield on each plot associated with the factor reallocation by the size of the plot, summing these changes over plots within each household-year-crop group and then averaging over all household-year-crop groups that contain plots controlled by both men and women.[13] These production function estimates, if taken at face value, imply that output could be

[13] In this case, the standard deviation for sampling error in the parameter estimates has not been corrected.

increased by between 10 and 20 percent by reallocating actually-used factors of production between plots controlled by men and women in the same household.

5. INTERPRETATIONS AND POLICY IMPLICATIONS

The evidence presented here demonstrates the existence of substantial inefficiencies in agricultural production. These may be indicative of a system of production in which resources are neither pooled nor traded among household members. In turn, this suggests that a more complex model of household behavior is necessary, not only to make sense of findings such as these, but also to improve policy towards agriculture in Sub-Saharan Africa.

It is important to note that the allocation of factors of production across plots is not the only aspect of agricultural production that can be affected by intrahousehold decision processes. An understanding of these dynamics internal to the household has implications, for example, for the design of policies to improve crop technology. Jones (1986) examined attempts to increase rice production among women farmers in Cameroon. In her study area, rice was considered to be a male crop. Any income generated from it would have been controlled by men, even if the crop was produced by women. Consequently, few women entered into rice cultivation. Instead, they continued to grow sorghum, the product of which they controlled, despite its lower returns. Similarly, in Zambia, households were encouraged to intercrop maize, a male-controlled crop, with beans, a women's crop (Poats 1991). Intercropping would have been welfareenhancing in two ways: there are well-known complementary benefits from consuming these two crops; and the amount of weeding time would have been diminished. However, women refused to adopt this change because if beans were planted on land normally allocated to maize, they lost ownership of the beans. By contrast, a project in Togo to encourage soybean production succeeded precisely because it took into account the collective nature of household behavior (Dankelman and Davidson 1986). At the outset, the project was targeted towards women, via exchange visits and workshops organized in women's homes. Also, soybeans were not introduced as a cash crop, which would have changed their status within the household. Instead, they were promoted as legumes that could be used to make sauces. The result was that the crop remained in the hands of women who, in some cases, were allocated small plots of land for its cultivation.

Studies such as these reinforce the claim that an analytical framework that takes these problems seriously may have payoffs for policy. However, it is important to note that there is not a single alternative to models that treat the household as a unitary entity. Rather, there are a set of "collective" models. These can be divided into two broad types, noncooperative and cooperative.

The noncooperative approach (Ulph 1988; Kanbur 1991; Carter and Katz 1992; Lundberg and Pollak 1993) relies on the assumption that individuals cannot enter into binding and enforceable contracts with each other. Instead, individuals' actions are conditional on the actions of others. For example, in Carter and Katz's "reciprocal claims" model, the household is "depicted as a site of largely separate gender-specific economies linked by reciprocal claims on members' income, land, goods, and labor." A wife's budget is delinked from her husband's; wives respond to changes in their husbands' allocation of his labor solely according to their own needs. Similarly, in Lundberg and Pollak's model, "each spouse makes decisions within his or her own sphere" (p. 994) and responds to the other's decisions by altering the level of voluntary contribution to shared goods.

In cooperative models, it is assumed that household decisions are always Pareto efficient. One approach within this framework involves making no a priori assumptions about how resources are distributed within households (Browning et al. 1994). The second imposes structure by representing household decisions as the outcome of some specific bargaining process and applying the tools of game theory to this framework. The distribution of resources depends on the "fallback" or "threat point" of each member. These are a function of what McElroy (1990, 1992) describes as extra-environmental parameters, that is demographic, legal, and other macroeconomic conditions external to the household. These include sex ratios in marriage markets, laws and conventions regarding divorce, the ability of women to return to their natal homes, and prohibitions on women working outside the home. Note that these different approaches are not mutually exclusive. Lundberg and Pollak (1993) model individuals within a household following a cooperative model, with individuals' fallback positions reflecting a noncooperative equilibrium.

The evidence presented in Jones (1986) and Poats (1991), while not constituting a formal test of the cooperative model, provides support for the view that in some contexts, noncooperative models are more in keeping with the evidence. The results of this paper directly contradict one of the assumptions of the cooperative model (the assumption of Pareto efficiency), and thus imply that noncooperative models are more appropriate in the Burkinabe context.

These models have a particular bearing on strategies to support agriculture. Even under the standard model that treats agricultural households as optimizing firms, it is recognized that missing markets—for labor supervision, for credit, for insurance, and so forth—have an effect on the structure of production (Binswanger and McIntire 1987). Here it is noted that any market imperfections are amplified by the fact that households do not allocate what labor and fertilizer they do obtain with internal efficiency. Conversely, improvements in input and credit markets can alleviate some of the internal allocation inefficiency, as individuals (in particular, women) could then purchase inputs up to optimal levels, regardless of what levels men allocate to their own fields. Attention to issues of intrahousehold allocation, therefore, underscores the importance of improving factor market efficiency, and may help in designing such improvements.

There are two additional considerations to be borne in mind. First, the choice of collective model matters because certain types of interventions are only effective under certain model regimes. Second, the efficacy of interventions may be heavily dependent on the type of intervention chosen.

Haddad and Kanbur (1992) outline the following model. Within a household, there are two individuals, each of whom produces output as the result of two tasks. There is comparative advantage in the tasks, so it pays to cooperate and specialize in tasks. But how are the gains from cooperation to be divided? Suppose that the fallback option for each individual is identified with the outcome of working alone. Now, suppose that the government introduces a scheme that guarantees better access for all to common property resources (CPRs) (such as common grazing land). How will this affect intrahousehold inequality, and, in particular, the well-being of the individual with poorer preintervention access? If the income generated from improved access is higher than what the women could previously earn on their own, but is still less than the income from cooperation, then, even though the common property is not actually used, more equitable access actually improves intrahousehold equality. What is particularly remarkable is that the scheme equalizes intrahousehold allocation by altering outside options, despite those options not being taken up.

There are several other features of this example worth noting. The credibility of the guaranteed access is at the heart of the matter, and this brings the issue back to some of the policy debates on the extent of access to CPRs. If rationing limits the ability of women to raise their fallback utility, then there will not be an impact on intrahousehold allocation. Second, their results hold for a number of other policy interventions, such as Maharashtra's employment guarantee program, if the guarantee of employment acts as an unalienable property right.

Haddad and Kanbur's work also illustrates the importance of distinguishing among different classes of collective models—the nature of the allocation process affects the predicted outcomes of such a scheme. The Chiappori (1992) cooperative model, with its minimalist assumptions, makes no a priori predictions regarding the effectiveness of such a scheme. A cooperative solution based on bargaining, as proposed by McElroy, may imply no effect if improved access is only guaranteed for married women, because the position outside the marriage is unaffected. Here, only changes in CPRs for women outside as well as inside marriage will alter intrahousehold resource allocation. By contrast, if households are operating in a noncooperative setup, changing married women's access to CPRs will be sufficient to affect the position of women within the household.

The effectiveness of interventions will also depend on the manner in which all individuals, not just women, respond to policy changes. Consider the study by von Braun and Webb (1989) in The Gambia. In the early 1980s, rice irrigation was introduced to an area of swamp rice production in order to raise yields, commercialize the product, and raise women's share of household income. However, an initiative intended to raise female-income shares ended up reducing them. Previously, women were the rice growers. Yield increases transformed the status of rice from a private crop under the control of women into a communal crop under the control of men.

In the Burkinabe example considered here, suppose the intervention took the form of the construction of new wells, thereby reducing the amount of time spent by women collecting water. (This can be thought of as increasing women's available labor endowment, or equivalently as relaxing their time constraint.) Ceteris paribus, this could increase the amount of labor expended on women's plots, thus reducing the inefficiency observed here. But this assumes that husband's supply of labor would remain unchanged. If they reduced their labor input on their wives plots', the net result of this intervention might be an increase in husbands' leisure time! The intended impact of policy interventions may also be thwarted by longer-term actions. Suppose a fertilizer subsidy, targeted towards women, was introduced. This should increase output from women's plots. However, these plots are allocated on marriage as a means of guaranteeing women a certain flow of utility. In the longer term, increased productivity of women's plots might cause husbands to reduce the amount of land allocated at marriage. Essentially, this intervention only affects marriages in existence at the time of the policy change. For subsequent generations of marriages, adjustments in prenuptial transfers of land will exactly offset the shift generated by the changed policy. (See Lundberg and Pollak [1993] for a discussion of this in a different context.)

Thus, although adopting a collective, rather than unitary, model of the household enables an understanding of why certain inefficiencies occur and why certain policies fail, recognizing that households do not act "as one" is not sufficient for the design of better policy. As important is recognition that changing the incentives or constraints faced by one household member may induce other members to change their behavior in ways that frustrate the intention of the policy intervention inefficiencies in agricultural production. These may be indicative of a system of production in which resources are not pooled or traded among household members. In turn, this suggests that a more complex model of household behavior is necessary, not only to make sense of findings such as these, but also to improve policy towards agriculture in Sub-Saharan Africa.

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