ELSEVIER

Agricultural Economics 27 (2002) 23–32

AGRICULTURAL ECONOMICS

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Seasonal labor constraints and intra-household dynamics in the female fields of southern Cameroon

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Received 2 September 1999; received in revised form 8 November 2000; accepted 1 January 2001

Abstract

African agricultural production is modeled as a sequential decision process, with men's labor first allotted to clearing, then women's labor allotted to harvesting. A switching regression is then used to measure the constraints due to clearing labor capacity and harvesting labor capacity. The import of men's clearing labor depends on the valuation of shadow wages. Output appears to be more frequently constrained by husband's clearing labor, and in this situation male labor appears under-utilized. However, output is also significantly constrained by female harvest labor, although the findings imply that female labor is over-utilized at this stage. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Agriculture; Seasonal labor; Gender; Production; Economic development

1. Introduction

Seasonal variation in agricultural production is commonly associated with unevenness in resource requirements and output flows. The exact nature and extent of this problem, however, depend largely on the farm setting. For households in the humid forest zone of Cameroon, the problem of inter-seasonal variability is mitigated by the presence of bimodal rainfall patterns. These rainfall patterns allow for two cropping seasons per calendar year, thus reducing the length of any 'hungry' period. Even with this natural advantage, it remains necessary for households to attempt to ameliorate the effects of variations—at the intra-seasonal if not inter-seasonal levels—in production and resource use potential.

This study examines women's production decisions, given men's labor contributions, and the impact of seasonal household labor scarcity on production in the household's major food crop field—the women's groundnut field. A sequential, multi-period labor input demand problem was modeled conditional on the husband's labor available for field clearing and preparation. We capture the sequential nature of the wife's agricultural production by dividing the cropping cycle into two periods the land preparation and planting period and the harvesting period. Econometric results from the sequential production were used in a switching regression to elicit production response to labor constraints at the different stages of farm production. This multi-season structure will be shown to have important implications for the characterization of household labor decisions as well as agricultural

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PII: S0169-5150(01)00054-8

output. The next section presents the sequential decision model, followed by a discussion of the data and switching regression estimation. The results of the sequential model and switching regression models are presented and finally the conclusion.

2. Theoretical model

2.1. Labor input decision making

To capture the sequential nature of the women's agricultural production, following Antle (1983); Halvorson (1984) and Skofias (1994), we assume the cropping cycle is divided into two periods. In the first period, land preparation and cultivation is carried out using primarily the men's labor for land clearing, followed by female labor for planting. The level of labor and seed input used in this stage is based on the desired or expected output, conditional on available natural resources and the production technology (rainfall, land quality, men's clearing labor, etc.). Output at this stage, which is generally unmeasurable, is the mature crop stand. Allotted labor and seed input will depend on the area of land cleared for cultivation by male labor.

In the second stage, prior information—the mature crop—is used, rather than the initial expectations as women use actual observations of the first stage output to determine the labor input to harvesting. Sequential dependence arises as the decisions made in the first stage affect the second stage; thus, output is modeled on the first stage output and the second stage inputs. That is, using the Cobb-Douglas production function (Antle, 1983), the first stage output is given by

$$Q_1 = \beta_0 L_1^{\beta_1} K^{\beta_2} \mathrm{e}^{\varepsilon_1} \tag{1}$$

and the second stage output is then

$$Q_2 = \gamma_0 Q_1^{\gamma_1} L_2^{\gamma_2} \mathrm{e}^{\varepsilon_2} \tag{2}$$

where Q_i are agricultural outputs at the different stages, L_1 and L_2 are the vectors of the men's and women's labor, K is the vector of quantities assumed predetermined at this stage, such as land, seed, and other family labor, and ε_i the disturbance term associated with the production technology due to weather variability, animals, pests, and other unanticipated events. Combining the two equations by substituting for Q_1 gives

$$Q_2 = \gamma_0 \beta_0^{\gamma_1} L_1^{\beta_1 \gamma_1} K_1^{\beta_2 \gamma_1} L_2^{\gamma_2} \mathrm{e}^{\gamma_1 \varepsilon_1 + \varepsilon_2} \tag{3}$$

The usual assumptions for the production disturbances ε are that they are independently distributed across households such that ε is $N(0, \sigma^2)$.

In agriculture, only the final harvest is observed; thus, the estimated model is based on the final output (3). Assuming that the women choose inputs to maximize expected returns, the maximization problem is represented as

$$\operatorname*{Max}_{L_1, L_2} \pi = pQ_2 - w_1 L_1 - w_2 L_2 \tag{4}$$

subject to Eqs. (1) and (2), where p is output price and w_i is the wage rate for the different stages of labor. When L_1 is chosen, in the first stage, it is assumed that the wage rate w_1, the probability distribution of the production disturbance terms ε_i, output prices p, and the second stage wage rate w_2 are known. With first stage information used in the second stage, the labor input in period two is chosen to maximize the second stage expected profits:

$$E[P] = pg_0 Q_1^{g_1} L_2^{g_2} \mathrm{e}^{s_2^2/2} - w_1 L_1 - w_2 L_2 \tag{5}$$

The expectation in (5) is taken only with respect to ε_2 from (2), which is the stochastic error term associated with the second stage production, because both Q_1 and w_2 are known. The optimal level of L_2 is thus obtained as

$$\ln L_2 = \frac{1}{1-\gamma_2}\left[\frac{\sigma_2^2}{2} + \ln \gamma_0 \gamma_2\right] - \frac{1}{1-\gamma_2} \ln \frac{w_2}{p} + \frac{\gamma_1}{1-\gamma_2} \ln Q_1 \tag{6}$$

and L_1 as

$$\ln L_1 = \delta_0 + \delta_1 \ln K_1 + \delta_2 \ln \frac{w_1}{p} + \delta_3 \ln E[L_2] \tag{7}$$

where the δs are functions of the production function parameters, σs. Because the information acquired in the first stage about Q_1 is used to determine the levels of L_2, it is a function of ε_1 through Q_1, and is thus correlated with Q_2. L_1, on the other hand, is based on pre-production information and not a function of ε_1 and ε_2. Therefore, under ideal conditions, we obtain a simultaneous model consisting of (1), (2), (6) and (7). In agriculture, Q_1 is the mature crop stands, and is thus unobservable to the analyst. However, we can substitute (1) into (2) and (6) to obtain L_2 as

$$\ln L_2 = \frac{1}{1-\gamma_2}\left[\frac{\sigma_2^2}{2} + \gamma_1 \ln \beta_0 + \ln \gamma_0\gamma_2\right] - \frac{1}{1-\gamma_2}\ln\frac{w_2}{p} + \frac{\beta_1\gamma_1}{1-\gamma_2}\ln L_1 + \frac{\beta_2\gamma_1}{1-\gamma_2}\ln K_1 + \frac{\gamma_1}{1-\gamma_2}\varepsilon_1 \quad (8)$$

and

$$\ln Q_2 = \ln \gamma_0\beta_0^{\gamma_1} + \beta_1\gamma_1 \ln L_1 + \beta_2\gamma_1 \ln K_1 + \gamma_2 \ln L_2 + \gamma_2\varepsilon_1 + \varepsilon_2 \quad (9)$$

The sequential production relations described above are generally nonlinear. To provide for tractability, therefore, we assume the existence of functional separability between the two production stages, justified by the sequential nature of clearing and harvest labor use in agriculture (Antle, 1983). The resulting additive error terms thus assumed allow for a tractable estimation of Q_2.

2.2. Labor-constrained production

Predicted values of the econometric results from the above sequential labor input decision model (e.g., see Halvorson, 1984) are then used in a two-stage switching regression (Maddala and Nelson, 1974) to allow for constraints on farm output due to land-clearing labor and/or harvesting labor capacity. This technique is employed so as to purge from the production function shocks and other "fixed effects", such as managerial skills, and to elicit production responses to labor constraints at the different stages of farm production, independent of the "noise" effects. Output from the groundnut field is subject to both clearing and harvesting labor, and, using a Cobb-Douglas functional form, the linearized model is presented as

$$\ln Q = \min(\ln Q_1, \ln Q_2),$$
$$\ln Q_1 = \beta_1 \ln L_1 + \beta_1 \ln N_1 + u_1,$$
$$\ln Q_2 = \beta_2 \ln L_2 + \beta_2 \ln N_2 + u_2 \quad (10)$$

where subscripts 1, 2 stand for clearing and harvesting, respectively, and N for all other inputs. Implicit in this representation is the assumption that there is no substitution between the inputs to Q_1 and inputs to Q_2. Although labor is the major input to both production processes, the sequential nature of production ensures that our assumption holds.

3. Data and estimation

The "Implicit Valuation of Resources within the Household" survey, carried out in the International Institute for Tropical Agriculture–Humid Forest Zone benchmark of southern Cameroon (Elad, 1997), provides the source of data used in the seasonal analysis. Production information for the household groundnut field covers two cropping seasons and 115 households (Table 1). The groundnut field is cultivated under

Table 1
Characteristics of the groundnut field[a]

Characteristic	Mean	Mode	Standard deviation
Field size (m^2)	1887.75	1823.79	1041.08
Groundnut yield (kg/ha)	964.34	529.00	1036.51
Total value of yield (CFA)	30089.00	20000.00	24065.00
Share of groundnut yield	0.28	0.35	0.20
Groundnut seed cost (CFA)	8752.00	5000.00	5954.00
Share of seed cost	0.70	1.00	0.38
Share of seed from last season	0.83	1.00	0.38
Cost of fertilizer (CFA)	7.00	0.00	67.00
Cost of pesticides (CFA)	15.00	0.00	126.00
Cost of hired labor (CFA)	350.00	0.00	1655.00

[a] $n = 220$; source: Elad (1997).

a multi-cropping pattern, with an average of seven crops. In addition to being the prestige crop in the female farming system, groundnuts are also the major crop in this field in terms of labor allocation. Production data are multiplied by the share of groundnut output in order to obtain a measure of groundnut production. The harvested groundnut yield in kilograms per hectare (kg/ha) becomes the dependent variable for the output equation. This measure is preferred over the more frequently used measure, which is obtained by extrapolation from field transects, because the former measure is less costly to obtain and provides a more realistic measure of the economic value of production to the household.

Groundnut seed is the greatest production expenditure on the field; however, almost all of seed input comes from the previous season's production. Commercial fertilizer or pesticide use is negligible, even when compared to usage on other household commercial food crop fields. The production system follows traditional patterns of cultivation, in terms of control and management of the field. This is evident in the decision making processes within the households presented in Table 2. It is clear that, in general, men have greater control over the early stages of production up to the planting stage. In the later stages of production, the care and responsibility of the field rests with the women (Figs. 1 and 2).

Field size, seed input and labor are the production variables used, as little or no chemical inputs are employed. With respect to the field characteristics in rain-fed agriculture, it would be expected that more effort would be put into cultivation during the major cropping season. In the same vein, an early start on the field is expected to allow for a longer, and therefore less time-constrained, growing season, as cultivation can be stretched out over a longer period. The age of the person in charge of the field and whether the person responsible for the field supplies most of the agricultural labor reflect managerial skills and, together with other socioeconomic variables, are expected to reveal the intra-household dynamics. The size of the household is expected to be positively correlated with output, given the traditional role of the groundnut field in meeting household food needs, and it is also expected to imply more agricultural labor and hence fewer per capita labor hours. We do not posit as to whom the benefits of this agricultural labor will go—the men or the women. Men's cash contribution to daily consumption is expected to ameliorate women's tasks of meeting food needs, and hence a negative relationship is expected. The variables used and brief descriptions are presented in Table 3. The estimated sequential model, then, consists of the following equations:

$$\begin{aligned}\ln \mathrm{Qf} = {} & a_1 + a_2 \ln K_1 + a_3 \ln K_2 + a_4 \ln L_1 + a_5 \ln L_2 \\ & + a_6 \ln L_3 + a_{10}\,\mathrm{date} + a_{11}\,\mathrm{Fcrop} + a_{12}\,\mathrm{seas} \\ & + a_{13}\,\mathrm{CHusT} + a_{14}\,\mathrm{HHsize} + a_{15}\,\mathrm{WifYr} \\ & + a_{16}\,\mathrm{Lsp} + a_{17}\,\mathrm{fls} + u_1 \end{aligned} \quad (11a)$$

$$\begin{aligned}\ln L_1 = {} & b_1 + b_2 \ln K_1 + b_5 \ln L_2 + b_6 \ln L_3 \\ & + b_7 \ln w_1 + b_8 \ln r_2 + b_{10}\,\mathrm{date} + b_{11}\,\mathrm{Fcrop} \\ & + b_{12}\,\mathrm{seas} + b_{13}\,\mathrm{CHusT} + b_{14}\,\mathrm{HHsize} \\ & + b_{15}\,\mathrm{WifYr} + b_{16}\,\mathrm{Lsp} + b_{17}\,\mathrm{fls} + u_2 \end{aligned} \quad (11b)$$

Table 2
Women's control over decision making in the groundnut field, by percentage of total respondents[a]

Activity	Full control	Partial control	Joint control	Little control	No control
Field location	39.52	2.96	22.70	2.22	32.59
Field size	45.19	3.70	15.50	5.08	30.53
Timing of field clearing	10.37	1.48	6.61	10.67	70.87
Timing of tilling	33.37	2.22	14.81	3.70	45.89
Timing of planting	85.20	4.43	3.70	0.00	6.67
Choice of crops	66.67	10.37	7.41	8.15	7.41
Timing of weeding	89.89	0.74	2.95	0.00	6.42
Timing of harvesting	70.63	9.15	9.89	2.96	7.37
Control of market surplus	78.52	2.90	12.65	0.74	5.19
Control of crop revenue	65.19	2.02	28.69	0.00	4.10

[a] Number of households = 135; source: Elad (1997).

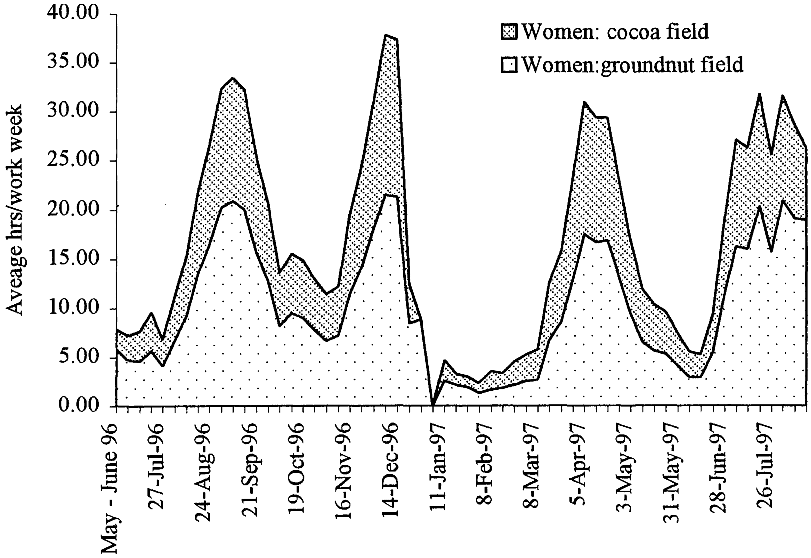

Fig. 1. Women's labor allocation to major household fields (hours per week).

$$\ln L_3 = c_1 + c_2 \ln K_1 + c_4 \ln L_1 + c_5 \ln L_2 + c_8 \ln r_2 + c_9 \ln w_3 + c_{10}\,\text{date} + c_{11}\,\text{Fcrop} + c_{12}\,\text{seas} + c_{13}\,\text{CHusT} + c_{14}\,\text{HHsize} + c_{15}\,\text{WifYr} + c_{16}\,\text{Lsp} + c_{17}\,\text{fls} + u_3 \quad (11c)$$

For the switching regression, the dependent variable for both the clearing labor-constrained production equation and the harvest labor-constrained production equation is the predicted output from the sequential production model. Similarly, the predicted values for

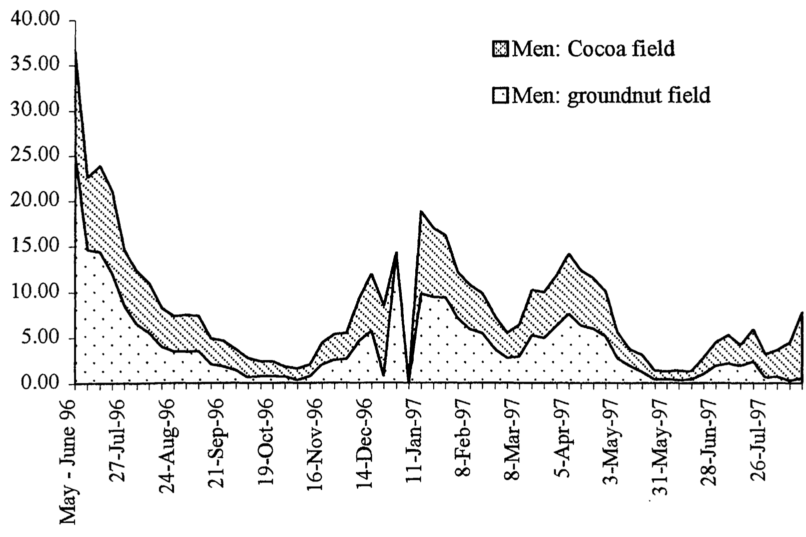

Fig. 2. Men's labor allocation to major household fields (hours per week).

Table 3
Description of variables used to estimate seasonal labor allocation to groundnut production

Short name	Variables	Type of variable
Sequential decision model		
ln Qf	Log of Groundnut yield	Dependent
$\ln L_1$	Log of men's labor hours for clearing	Dependent
$\ln L_3$	Log of women's labor hours for harvesting	Dependent
$\ln K_1$	Log of field size	Production
$\ln K_2$	Log of quantity of groundnut seed	Production
$\ln L_2$	Log of women's labor hours for weeding	Production
$\ln w_1$	Log of normalized men's wage rate	Production
$\ln r_2$	Log of normalized seed input price	Production
$\ln w_3$	Log of normalized women's wage rate	Production
Date	Relative start of clearing season	Farm characteristic
Fcrop	Number of crops planted—proxy for cropping density	Farm characteristic
Seas	Position in annual cycle-1 = February–July season	Farm characteristic
ChusT	Husband's contribution to daily consumption	Socioeconomic
HHSize	Number of residents within household	Socioeconomic
WifYr	Age of wife—owner of the field	Socioeconomic
LSP	Household has land to sell—land surplus environment	Socioeconomic
FLS	Woman supplies most of the labor to her fields	Socioeconomic
Switching regression model		
$\ln Q_i$	Predicted log of groundnut yield ($i = 1, 2$)	Dependent
$\ln K_1$	Log of field size	Production
$\ln K_2$	Log of quantity of groundnut seed input	Production
$\ln L_1$	Predicted log of men's labor hours for clearing	Production
$\ln L_2$	Log of women's labor hours for weeding	Production
$\ln L_3$	Predicted log of women's labor hours for harvesting	Production
ChusT	Husband's contribution to daily consumption	Socioeconomic
WifYr	Age of wife—owner of the field	Socioeconomic
LSP	Household has land to sell—land surplus environment	Socioeconomic
FLS	Woman supplies most of the labor to her fields	Socioeconomic

land-clearing labor and field harvesting labor are used as explanatory variables in the respective models. Other input variables include the women's weeding labor, size of groundnut field, quantity of seed input, and other household decision variables—husband's contribution to daily cash consumption, age of field owner (wife), perceived land scarcity, and perceived female labor contribution to output (Table 3). The estimated model is thus specified:

$$\ln \hat{Q}_1 = a_1 + a_2 \ln K_1 + a_3 \ln K_2 + a_4 \ln \hat{L}_1 + a_5 \ln L_2 + a_6 \,\mathrm{CHusT} + a_7 \,\mathrm{HHsize} + a_8 \,\mathrm{WifYr} + a_9 \,\mathrm{Lsp} + a_{10} \,\mathrm{fls} + u_1 \quad (12a)$$

$$\ln \hat{Q}_2 = b_1 + b_2 \ln K_1 + b_3 \ln K_2 + b_4 \ln \hat{L}_3 + b_5 \ln L_2 + b_6 \,\mathrm{CHusT} + b_7 \,\mathrm{HHsize} + b_8 \,\mathrm{WifYr} + b_9 \,\mathrm{Lsp} + b_{10} \,\mathrm{fls} + u_2 \quad (12b)$$

4. Empirical results

An advantage of specifying the function as log linear is that the estimated parameters are equivalent to the percentage change relationship between the dependent and explanatory variables, or elasticities. The equations described above employ shadow wages first estimated at the household level (Elad et al., 1998) in which the scale of analysis is the total of all field production. The sequential model, consisting of a system of one output equation and two input demand equations, is estimated as a non-linear system employing the sysnlin procedure in SAS and three stage least squares (3SLS) method. Estimation of the switching regression is then undertaken using the Limdep econometric software version 7. The results of the sequential decision framework estimation will be discussed first, followed by the

Table 4
Parameter estimates for the labor demand equations in the sequential production model

Variable	Clearing labor parameter estimates[a]		Harvest labor parameter estimates[a]	
Constant	4.69**	(1.84)	−3.03	(3.73)
Log of field size	−0.42**	(0.12)	0.06	(0.34)
Log of weeding labor	0.02	(0.17)	0.50**	(0.19)
Log of clearing labor	–	–	−0.19	(0.77)
Log of clearing wage rate	0.57***	(0.23)	–	–
Log of harvesting labor	0.41	(0.35)	–	–
Log of harvest wage rate	–	–	0.27	(0.29)
Log of seed input price	−0.52*	(0.29)	−0.95**	(0.48)
Clearing date	0.03	(0.05)	−0.08	(0.07)
Cropping density	0.06	(0.04)	0.01	(0.07)
Cropping season	−0.18	(0.16)	0.24	(0.20)
Husband's contribution	−1.85E−04	(3.69E−03)	6.41E−03	(4.22E−03)
Household size	−0.02	(0.03)	−0.01	(0.04)
Owner's age	3.57E−03	(0.01)	7.74E−03	(1.04E−02)
Land surplus	0.14	(0.23)	−0.52**	(0.27)
Owner supplies most labor	−0.10	(0.18)	0.24	(0.26)

[a] Standard errors in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

estimation and implications of the switching regression analysis.

4.1. Sequential production model

Field size relates to the amount of clearing labor (Table 4). This relationship is quite plausible under the present extensive farming system in the humid forest zone. That is, larger fields generally require more time to clear from forest or fallow. The most frequent cultural practice, burning first, reduces the labor required to clear the groundnut field considerably, thus allowing more time spent clearing cocoa fields or the men's own food crop fields. Higher seed prices would imply a reduction in the quantity planted and smaller surface area to be cultivated. The inverse relationship between seed price and clearing labor would thus be expected. Fields cultivated during the major cropping season of February–June are likely to receive less clearing labor than fields cultivated in the minor season of July–December. During the major cropping season, households are expected to cultivate larger field sizes. Given that larger field sizes are associated with less clearing labor demand, the negative relationship between cropping season and clearing labor would, therefore, be credible. It has also been observed that cropping density is associated with intensification of production; that is, the villages with lowest resource pressure also have the lowest crop mix. Households located in the villages higher in resource use intensity spend more time in agricultural activities, as verified by the estimated parameter for cropping density.

At the harvesting stage, seed input price and weeding labor supplied to the field are the only factor inputs that significantly influence the allocation of labor to the female fields. In this stage of production, harvest labor is based on the amount of inputs previously invested in the field. Thus, a direct association would be expected between the outlay of weeding labor and the harvest labor. Despite the fact that weeding takes place during the period when there are the fewest conflicts on female labor, it is still an important activity in the farming process. If harvest labor can be considered as an indirect measure of output, a 1% increase in weeding labor is associated with approximately a 0.5% increase in harvest labor demanded. Unlike the clearing labor (male) shadow wage, the harvest labor (female) shadow wage is not significant. This relative lack of importance concurs with results from other studies, which have found the marginal value of female agricultural labor to be relatively lower than that of men (Tshibaka, 1992; Singh, 1988).

The demand for harvest labor increases with a decrease in seed input price. Similar to the clearing labor response to seed price, a negative association here is plausible, implying them greater the production costs, the lower the production rate. The magnitude of this harvest labor response to seed price changes is noteworthy, however, as a 1% decrease in seed price is associated with an almost 1% increase in harvest labor. Of course, the converse would also be true, whereby higher seed prices (or values of retained seed) would lower harvest labor demands and the concomitant output implications. The husband's contribution to the household's cash consumption was hypothesized to relax the woman's labor constraint, as fewer work hours would be required to meet household consumptive needs. The parameter estimate of that impact on harvest labor, however, indicates there is no significant relationship.

Field cultivation characteristics, such as cropping season and clearing date, further confirm that the labor demands for harvesting during the major cropping season are greater than during the minor season. The model results also confirm that waiting later in the cropping season to start cultivating tends to lower harvest expectations and harvest labor demand. For fields cultivated by households with perceived land surplus, the demand for harvest labor is significantly lower than the harvest labor allocated by women in households with relatively less land.

4.2. *Seasonal labor-constrained production*

Seasonal labor-constrained production is estimated first with the assumption of no correlation between clearing labor-constrained and harvesting labor-constrained production, then with the assumption of correlation between both constrained production equations. The correlation factor for both equations is significant throughout, and only the results of the model in the presence of correlation are reported. This would also be the acceptable model, given the assumption that the nature of the economic production in this case area could be characterized as "an economy of affection" (Hyden, 1986).

The switching regression likelihood function can be viewed as a disequilibrium likelihood function that allocates sample observations to different regimes based on their likelihood of occurrence within the particular regime (Portes and Winter, 1980). Thus, if one regime dominates another in a particular scenario (model), then the alternative regime is, in effect, estimated on a small subset of the observations. After obtaining the maximum likelihood estimates, the probability that clearing labor is a constraint to output on the groundnut field is calculated for each observation. This is simply the probability that the observed output belongs to the clearing labor-constrained production model and is given by (17). In evaluating the results of the labor-constrained production model, we start by allocating the probability associated with each observation on output to either the clearing labor-constrained production or the harvest labor-constrained production. On the entry criterion of $\pi < 0.5$ indicating the observation belongs to the clearing labor-constrained production equation, production is observed to be constrained by clearing labor on 179 fields (81.4% of the sample).

4.3. *Clearing labor-constrained production*

By definition of the switching regression process, negative parameter estimates imply that the corresponding variables are "over-employed" in the particular regime. Conversely, the positively signed parameters correspond to variables that are "under-employed" (Halvorson, 1984). It is, therefore, not surprising that the clearing labor is under-employed in the clearing labor-constrained production regime. The highly elastic output response to clearing labor (supplied by the men) supports the fact that the men have more control and flexibility over the use of their labor (Table 5). It could also be said that the amount of male clearing labor employed in the women's fields is such that each additional unit provided results in more than a proportionate increase in output. Field size is directly related to clearing labor; therefore, the parameter estimate for field size demonstrates a similar impact on output as did that of clearing labor. The results also demonstrate that, under clearing labor-constrained output, weeding labor and seed input are "over-employed".

With respect to the household decision variables, the husband's contribution to daily consumption, as expected, was inversely related to output, reflecting

Table 5
Parameter estimates for labor-constrained production from the switching regression model

Variable	Maximum likelihood parameter estimates[a]	
Clearing labor-constrained production		
Constant	−8.59***	(1.22)
Log of field size	1.12***	(0.10)
Log of seed input	−0.38***	(0.14)
Log of clearing labor	2.57***	(0.15)
Log of weeding labor	−0.50***	(0.06)
Husband's contribution	−1.13E−02***	(1.97E−03)
Owner's age	−3.17E−02***	(5.75E−03)
Land surplus	0.48***	(0.14)
Owner supplies most labor	0.16	(0.15)
Sigma(1)—clearing	0.57***	(0.07)
Harvest labor-constrained production		
Constant	8.06***	(2.10)
Log of field size	−0.36***	(0.15)
Log of seed input	1.16***	(0.22)
Log of harvest labor	−0.80***	(0.15)
Log of weeding labor	0.19*	(0.11)
Husband's contribution	−5.67E−03**	(2.47E−03)
Owner's age	1.24E−02	(8.65E−03)
Land surplus	−0.62***	(0.18)
Owner supplies most labor	0.02	(0.15)
Sigma(2)—harvest	0.70***	(0.05)
RHO	−1.00***	
Log-likelihood	−153.05	

[a] Standard errors in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

the competing demands on men's clearing labor. Substitution of male children's labor for male adults' labor tends to occur as the women (men) get older. This seems to be associated with a negative effect on output in the clearing labor regime. The parameter estimates associated with perception of land surplus reveal a positive shift effect on output; that is, when output is constrained by clearing labor, households in a perceived land surplus environment could increase output by increasing the clearing labor. Given that land surplus is associated with low resource use, this result is to be expected, as men are less likely to feel the need to intensify production.

4.4. *Harvest labor-constrained production*

The negative sign of the field size parameter implies that this variable is "over-employed" (or larger than the woman can effectively harvest) in the harvest labor-constrained regime. Output response to harvest labor is, however, of great interest. The fact that the harvest labor-constrained production regime presents the impact of the explanatory variables when harvest labor is limiting would imply that harvest labor is under-employed in this regime. All the same, the negative and highly significant response of output to harvest labor indicates that, despite the fact that output is limited by the amount of harvest labor available for production, harvest labor is being used up to the point where its marginal benefit—the value of output—is less than the marginal cost—the marginal value of harvest labor. This finding has major import to the implications of seasonality, labor productivity and the food production capacity of the household. In light of the above findings on female labor availability during the harvest season, the response of output to the perception of land surplus serves to reinforce our findings. That is, for households living in a perceived land surplus environment, harvest labor is a tighter constraint than clearing labor, especially when considered at the household level.

5. Conclusions

The sequential modeling of agricultural production in the groundnut field yields evidence that variables typically excluded from household production analyses, such as the gender-based sequencing of agricultural activities and intra-household resource allocation patterns, are in fact crucial determinants of household economic activity. These same variables, and in particular the sequential application of household agricultural labor, represent features of the household most likely to be influenced by economic change. The issue of seasonality and food production capacity of the household is similar to that of the chicken-and-the-egg. From an economic point of view, it is difficult to put a high price on a person's time when it is rather obvious that it is not very valuable. Nonetheless, it is necessary to respect human time and potential if it is to be nurtured through investments to foster economic development. Our findings demonstrate that such nurturing should start with investments in labor-saving technologies tailored towards the production systems of rural households, especially in land clearing and harvesting and post-harvesting technologies. These technologies, when targeted towards improving the returns to seasonal labor as well as efficient use of other inputs, would go far towards increasing the productivity of all household members' agricultural labor.

The mention of investments always brings up the question of who pays for what. However, increasing agricultural productivity is integral to overall economic growth. Different households have different production technologies, and different needs and capabilities with respect to modifying their farming practices. An advantage of the benchmark survey approach is that it provides a one-shot view of the gradual effects of increasing resource intensification. By taking advantage of observable resource management domains, the benchmark offers a relatively inexpensive method of identifying and streamlining technologies to those that have both immediate and long-term benefits.

These technologies would not necessarily be attractive to agricultural households, if there were no means for them to recover the benefits from increased productivity. The challenge for policy makers in the short run, therefore, is to stimulate the household's sales (and production) of food crops. Our multi-season structure provides significant insight into the household dynamics surrounding the allocation of household agricultural labor and the resultant effects on production. Important implications for the design of policies include, in addition to a greater need for access to capital inputs, a more realistic measure of the household's response to these policies, especially when considering that gender roles impart serious rigidities on the total deployment of family labor.

The underlying strengths of this study are also its major limiting factors. The benefit of using primary data for our empirical estimations cannot be overstated. However, with no comparable data set available, it is difficult to make judgements as to the statistical consistency of the data. Much of the analysis in this study hinged on the estimated shadow wage of labor. However, shadow wages are sensitive to the method of estimation and should be handled with care. At the same time, this sensitivity is also reflective of the variability in households' responses. Our study can serve as a point of departure in this area. Applying and adapting such an age and gender-oriented understanding of the household to concrete research settings offers the possibility of generating new insights into the complex processes that underlie the household economy. In turn, a better understanding of the impacts of institutional and economic policies can now be demonstrated over diverse cultural backgrounds.

Acknowledgements

The field research for this study was conducted with the support and supervision of the International Institute for Tropical Agriculture, Ibadan, Nigeria.

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