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SUPPLY RESPONSE OF WEST AFRICAN AGRICULTURAL HOUSEHOLDS: IMPLICATIONS OF INTRAHOUSEHOLD PREFERENCE HETEROGENEITY

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ABSTRACT

This paper explores the implications of preference heterogeneity between wives and husbands in nonresource-pooling rural West African households for the effect of crop price changes on agricultural production, i.e., their supply response. A "semi-cooperative" game-theoretic model of household decisionmaking, in which household members make unilateral time and income allocation decisions and negotiate over who controls these resources, is proposed. The model is used to show that Pareto efficiency in both production and consumption do not hold. It is then employed to simulate the supply response to cotton price increases accompanying agricultural sector liberalization in Burkina Faso in the early 1980s. The simulated semi-cooperative model predicts the cotton supply response of (monogamous) Burkinabé households to be 25 percent below that which would ensue in households facing the same production constraints yet whose members have identical preferences. The analysis indicates that in nonresource-pooling agricultural households, preference heterogeneity can be expected to mute supply response and may do so in a quantitatively significant manner. It illustrates how an intrahousehold approach that allows for such heterogeneity and for disaggregation of resource control by gender contributes to a better understanding of price effects.

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Wa nii bi too yensé waari inn.
(Our hands are not long in the cotton money).
—Burkinabé woman from the village of Bwahoun
(Mamboué 1991:79)

1. INTRODUCTION

Traditional "unitary" models of household economic behavior have portrayed households as unified entities in which all members agree, resources are pooled across members, and Pareto efficiency is achieved (Deaton and Muellbauer 1980; Singh, Squire, and Strauss 1986). More recently, households across the world have come to be viewed by economists as consisting of multiple decisionmakers who have possibly differing preferences and, in many cases, control separate sets of resources. This approach has greatly improved understanding of household resource allocation behavior, showing that heterogeneity among members has implications for a variety of individual, household, and economy-wide outcomes (Haddad, Hoddinott, and Alderman 1997; Haddad et al. 1995). Recent research on West African households, in particular, has demonstrated that gender-differentiated resource allocation processes in households result in allocative inefficiencies that reduce overall household production and income (Udry 1996), directly challenging the assumption of Pareto efficiency.

This paper seeks to provide further understanding of the implications of gender-based intrahousehold heterogeneity by asking what role it plays in agricultural price policy impacts. In particular, it asks: What are the implications of differences in women's and men's preferences for semi-subsistence agricultural households' production responses to increased cash crop prices? Price policies intended to give households incentive to increase cash crop production are considered important instruments for accelerating agricultural and economy-wide growth, reducing poverty, and improving rural people's well-being. Development policymakers and researchers therefore have great interest in how households will react to them.

Conventional wisdom is that the supply response of semi-subsistence developing country households is positive but weak. Sitting on the market-nonmarket divide, these households have historically displayed low responsiveness to price incentives and opportunities to adopt productivity-enhancing technologies for cash crop production.

Considerable debate surrounds the underlying causes of this sluggish supply response. A substantivist school of economic anthropology attributes it to "peasant"-specific motives to satisfy only minimum survival needs or ensure "simple reproduction" rather than to maximize income. A countering structuralist explanation posits that labor and food market failures render households dependent on own labor endowments and home-produced food, constraining their abilities to respond to price incentives (de Janvry, Fafchamps, and Sadoulet 1991). Other supply-response-stifling structural constraints are thought to be poor infrastructure and technological development, unavailability of irrigation and productive inputs, missing credit markets, seasonal labor shortages, and lack of "incentive goods" in the form of industrial consumer products to motivate efforts to earn cash income (Barrett 1994; World Bank 1991; de Janvry, Fafchamps, and Sadoulet 1991). The literature on risk and food security stresses that risk averse agricultural households may be unwilling to rely exclusively on purchases of food in volatile markets to meet their food needs (Chavas 1995). The associated exposure to price risk may also weaken supply response (Barrett 1994).

Insights gained from studies of household behavior that take an intrahousehold approach further deepen the supply response debate. They reveal that increases in cash crop prices can alter the opportunity sets of female and male household members differently. Price changes bring with them conflict-laden negotiation over who gains the benefits—in terms of income and the goods it buys—and who bears the costs—in terms of labor—of increased cash crop production (Whitehead 1990a, 1990b) that may play a role in stifling households' supply response. The studies suggest that (1) decisionmaking in households is not necessarily "joint," and individual control over resources is valued by household members; and (2) preference heterogeneity between spouses can have real consequences for changes in households' production, income, and welfare accompanying change in their economic environments.

This paper brings to bear these new insights from the intrahousehold literature to the supply response debate. Section 2 begins with an overview of household decision models in current usage. Section 3 then describes rural West African household decisionmaking in detail to identify a formal model that most accurately captures it. Taking the case of Burkinabé households, a "semi-cooperative" game theoretic model is presented in Section 4. In Section 5 the model is employed to conduct a simulation analysis of the supply response to increased cotton prices accompanying agricultural liberalization in Burkina Faso. The data employed were collected from 1981 to 1985 in southwestern Burkina Faso by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Section 6 contains concluding remarks.

2. MODELS OF HOUSEHOLD DECISIONMAKING

Models of household decisionmaking can be broken up into two main categories, unitary and collective (Haddad, Hoddinott, and Alderman 1997). The unitary model, rooted in the work of Becker (1974) and expanded to the case of agricultural households by Singh, Squire, and Strauss (1986), is the most widely-employed. Its key assumption is that household decisions can be described by the maximization of a "household utility function," whether it represents the common preferences of all members (Samuelson 1956) or those of a benevolent dictator with whom all other household members have an incentive to agree (Becker 1974). Any preference differences are either assumed nonexistent or to be irrelevant. The time and income of all household members are pooled: decisions over their allocation are made with respect to the household's total endowment of resources.

Collective models are distinguished from unitary models in that preferences of household members may differ, i.e., intrahousehold preference heterogeneity is allowed for. Generally described by economists through game-theoretic models, they may be broken up into two types: cooperative and noncooperative. In classical game theory, cooperative and noncooperative games are distinguished on the basis of two criteria: (1) the enforceability of agreements among players, and (2) communication among players. While modern theorists argue that enforceability is the more fundamental of the two criteria (Harsanyi and Selten 1982; Auman 1989), the extent of communication between players is particularly relevant to the understanding of household decisionmaking. In particular, it is useful in distinguishing between decisions made unilaterally by individual household members, in which communication does not take place, and those made jointly by household members in which it does.

The aim of a cooperative game is to resolve players' possibly differing preferences through communication and eventual agreement. In this case enforceability is necessary, for "an ability to negotiate agreements is useful only if the rules of the game make agreements binding and enforceable" (Harsanyi and Selten 1982). The most common cooperative household model is the Nash bargaining model. In the model, resource allocation decisions are taken jointly by household members. The outcome depends on their relative bargaining powers as determined by their "fallback positions." Such a position may be household dissolution (e.g., McElroy and Horney 1981) or some noncooperative equilibrium within marriage (e.g., Lundberg and Pollak 1993). All players have knowledge of all other players' constraints and objectives, i.e., the game is one of complete information (Harsanyi and Selten 1982). Since resource allocation decisions, while bargained, are made with respect to the household's entire endowment of resources, as in the unitary model, all resources are pooled.

In noncooperative games the aim of each player is to maximize their individual utility in expectation of how other players will behave. No communication takes place between players, so agreement is not reached and the enforceability of agreements is therefore not necessary. The players may have restricted knowledge of the constraints the other players face, making the game one of incomplete information (Harsanyi and Selten 1982). In these models bargaining power does not matter. In noncooperative household models (e.g., Ulph 1988) members control separate sets of resources, i.e., they make *unilateral* decisions over the allocation of the resource. Thus, resources are not pooled.

A defining feature of both unitary and cooperative household models is that they imply Pareto optimality in both consumption and production (Doss 1996; Udry 1996). That is, at the optimum, resources cannot be reallocated to make any member better-off without making another worse-off, whether through reallocation of income or time between consumption goods ("Pareto efficiency in consumption") or reallocation of factors of production to increase income ("Pareto efficiency in production"). Pareto efficiency does not hold in noncooperative models due to their unilateral, nonresource-pooling decision structure.

A final class of models are combination cooperative-noncooperative games, which allow for some decisions to be made jointly in a negotiation process and others to be made unilaterally. This type of flexibility accommodates a wide variety of location-specific decisionmaking morés that fall in between the extremes of pure cooperative and noncooperative household models. The premier in this modeling innovation is Carter and Katz's (1997) "Separate Spheres model" which, while based in noncooperatively modeled resource allocation decisions, allows communication and negotiation over transfers of resources among household members.

3. DECISIONMAKING IN RURAL WEST AFRICAN HOUSEHOLDS: "SEPARATENESS AND RELATION"[1]

The models reviewed above differ with respect to assumptions on (1) who makes decisions; (2) preference heterogeneity; and (3) who controls resources. Drawing on a wide literature rooted in studies by anthropologists and economists, this section discusses West African household decisionmaking to determine which assumptions are appropriate to the setting.

SEPARATE SPHERES OF DECISIONMAKING

Broad consensus has been reached that there exists a strong separation within West African households of husbands' and wives' resource allocation processes. Married men and women tend to make day-to-day decisions over the allocation of time, expenditures of income, and allocation of productive resources individually, in "separate spheres" of decisionmaking (Guyer 1981, 1988; Whitehead 1990a; Saul 1989).[2] With respect specifically to agricultural production, such separateness is structured by a widely-

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[1] The term "Separateness and Relation" titles Saul's (1989) work on Bobo households of Burkina Faso.

[2] Indeed, claims Collier (1993), the characteristic gender-based division of households into decision units has put Africa at the forefront of the "new economics of viewing household decisions as a bargaining process" (p. 72).

documented communal-personal dichotomy in income generation. In communal income-generating activities, from which the majority of household income is earned, a male "household head" is the principal decisionmaker and receives any income generated; all household members provide labor, including his wife (or wives). In personal income-generating activities, individual members are the principal decisionmakers and receive the income generated; they are also the main source of labor (Whitehead 1990a; Roberts 1988; Davison 1988).

The separate spheres pattern can also be found in a second major activity taking place in households, the reproduction and continued maintenance of the physical well-being of household members. In West Africa, this includes the birthing and care of children, food processing and preparation, gathering fuelwood and water, maintaining cleanliness, purchasing food and medicines, and care of elderly and ill members. Such "well-being provisioning" is structured by a gender division of labor and expenditure responsibilities, with the large majority of the labor being women's (Smith 1995).

Consonant with a separate spheres nature of decisionmaking, field research has revealed that wives and husbands in West African households tend to receive cash income from different sources and to maintain these receipts separately of one another. Thus, they commonly control subsets of total household income individually. Income pooling is not the norm; that is, cash incomes are not generally combined for use in a single household expenditure plan (Guyer 1988; Fapohunda 1988).[3]

While the separateness of West African spouses' decisionmaking processes is now well established in the literature, their *relatedness* has only recently been given attention. Numerous studies have demonstrated substantial flows of income between wives and husbands, many of which are from husbands to wives in compensation for wives' labor in communal income-generating activities managed by their husbands. Evidence of the pervasiveness of these "incentive motivated" transfers, which often arise with the initiation of cash crop production on communal fields, is mounting.[4] For the Massa of Cameroon, Jones (1983a, 1983b) provides statistical evidence of their wage-like nature, finding a significant relationship between husband-wife transfers and the time wives work on communal fields. The study concludes that "a husband's ability to mobilize his wife's labor for rice production is contingent on the remuneration he gives her" (Jones

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[3] The roots of the separate nature of decisionmaking in West African households—and a transactional rather than "pooled" nature of resources—most probably lie in a social organization in which "rights in people" (e.g., women and children), polygyny, and marriage as a resource transaction (marked by bride wealth) are legitimized. These aspects of African social organization are discussed in Guyer (1981). Whitehead (1990a) relates the characteristic separation to pre- "modern transformation" (19th century) patterns in which both conjugal and kinship relations were important economically.

[4] Incentive-motivated transfers are distinguished from consumption-motivated transfers in that the latter are made with the intention of facilitating purchases of goods or services for which the transferee is responsible (Smith 1995). Examples of the occurrence of incentive-motivated transfers in West Africa are given in Venema (1986) for the Wolof of Senegal; Funk (1988) for the Brassa of Guinea-Bissau; Babalola and Dennis (1988) for the Yoruba of Nigeria; Basset (1988) for northern Côte d'Ivoire; Dey (1981), Carney (1988) and von Braun, Puetz, and Webb (1989) for various ethnic groups in The Gambia; Guyer (1988) for the Beti of Cameroon; David (1991) for the Kpelle of Liberia; McMillan (1986) for the Mossi of Burkina Faso; and Lilja et al. (1996) for Malian households. Note that land for women's personal agricultural production is in some cases a form of compensation for women's time in communal production (Lilja et al. 1996).

1983b:143). The presence of such remuneration suggests that, while income pooling is not the norm, neither are spouses' incomes completely separated.[5]

Note that labor and income transactions between spouses are fundamentally shaped by the existence of incomplete markets for labor. In the case of Burkina Faso, Fafchamps (1993) notes the virtual absence of a labor market, making households dependent on their own members for labor.[6]

PREFERENCE HETEROGENEITY AND BARGAINING OVER RESOURCE CONTROL

Husbands and wives in West African households tend to spend income they control differently, corresponding to gender-specific expenditure responsibilities. This pattern of divided expenditure responsibilities is felt to lead spouses to have differing perceptions of their financial obligations and differing allocative priorities (Fapohunda 1988; Bruce and Dwyer 1988). Writes Guyer (1988:160), "men and women have different spending preferences, not necessarily because they hold different values but because they are in structurally different situations." The literature suggests that women's and men's preferences are biased relatively more towards goods falling under their own responsibility. Their preferences are therefore “heterogeneous."

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[5] To understand resource allocation in West African households, a clear distinction between income *receipts*, income *control*, and income *earnings* must be made. A case where income receipts do not correspond to earnings is husbands' receipts of income from communal production, which are earned using not only their own labor, but the labor of other household members as well.

[6] A fair amount of exchange labor has also been reported in Burkina Faso (Smith 1995).

Given individualized income control, preference heterogeneity is manifested in conflict between spouses over who controls income (rather than directly over income allocation) and, consequently, who earns it. Recent studies reveal that the changing income receipts of different household members with the rise of cash cropping in West Africa over the last century have brought with them conflict-laden negotiation between husbands and wives not only over income control, but also over wives' labor contributions to communal production, i.e., control over wives' labor (Whitehead 1990a, 1990b; Guyer 1988, 1989; Roberts 1988). A quote from a women of the village of Bwahoun in Burkina Faso captures the conflict between husbands and wives accompanying the dramatic rise in cotton production there. She says, "We just want to make sure that men don't put too much emphasis on cotton at the expense of food crops. There is too much work on cotton, and we know that *wa nii bi too yensé waari inn*," which has a literal translation of "our hands are not long in the cotton money" (Mamboué 1991:79).

The outcome of conflict-laden negotiations is determined by the negotiating parties' relative "bargaining powers." Bargaining power gives an individual the ability to influence negotiations with others in the person's own interests. A person's bargaining power is influenced by the resources available to them in some "fallback" alternative living situation (Folbre 1988). This is because a person who is not dependent on their relationship with the other negotiating party for access to resources that they need or from which they benefit is less likely to concede in favor of the other party's interests. Studies of power relations in African households claim that, due to mens' greater access to productive resources from outside of their household, men have more bargaining power than women (Stamp 1989). Research showing women working consistently longer hours than men (Brown and Haddad 1996) gives supporting evidence for this supposition. Thus, in the presence of preference heterogeneity, resource control negotiations are likely to be settled in favor of men.

Nevertheless, West African women do appear to have some degree of bargaining power through viable alternatives to their current marriages, as evidenced in the frequency of wife-instigated divorce (Funk 1988; Basset 1988). In Burkina Faso, for example, divorce rates as high as 50 percent (for the Bwaba) and as low as 10 percent (for the Mossi) are reported (Kevane and Gray 1996). The literature on African women "repeatedly testifies to the fragility of marriage, the causes of which include mistreatment, polygyny, abandonment or poverty...women who are unduly deprived are likely to terminate their marriages if they can improve their positions by doing so" (Barnes 1990:259). Empirical support for the role of bargaining power is given by Lilja et al. (1996), who estimate that women in Mali who perceive themselves to have the "right to refuse work" (a proxy for bargaining power) receive a 28 percent higher compensation rate for their labor in communal production than those who do not.

THE FAILURE OF PARETO EFFICIENCY

The character of decisionmaking in rural West African households as described above, not surprisingly, points to the existence of inefficiencies—from the point of view of total household resources—in the allocation of resources, i.e., the failure of Pareto efficiency. Such inefficiency has long been recognized by anthropologists. Writes Lawson (1972:95) quoted in Guyer (1981) of the Ghanian Ewe, "Household expenditure patterns in Battor certainly demonstrate that the household cannot be considered as a single unit in which effort and expenditure are directed towards optimizing welfare." Of the Hausa in Nigeria, Hill (1972:147) quoted in Guyer (1981) similarly writes that "A considerable proportion of the wives of the poorest farmers were not in as serious a predicament as their husbands ... which insulated them to some degree from their husbands' poverty."

More recently, statistical evidence documenting the failure of Pareto efficiency has begun to accumulate. Studies contesting the existence of income pooling in households (recent ones are reviewed in Haddad 1997) have put first-best consumption efficiency into question. Hoddinott and Haddad (1995), for example, find that in Côte d'Ivoire a higher share of cash income to wives leads to higher expenditures on food and lower expenditures on alcohol and cigarettes. Doss (1997), for Ghana, similarly shows that female asset shares are positively associated with food and education expenditures and negatively associated with alcohol, recreation, and tobacco expenditures. While these results are not definitive evidence against the income pooling hypothesis,[7] they are consistent with the existence of non-income-pooling behavior.

With respect to Pareto efficiency in production, the work of Udry (1996) and Udry et al. (1995), using the ICRISAT data employed in this study, clearly demonstrates that productive resources in Burkinabé households are not allocated in a Pareto-efficient manner across agricultural activities. They find that total household output could be increased by from 10-20 percent by reallocating currently employed factors of production across plots controlled by men (including communal plots) and women. This is a violation of household income maximization.

What are the implications of the failure of Pareto efficiency for supply response? While no empirical studies have yet explored this question, preliminary clues can be culled from studies of changes in resource control and labor allocation in West African households that have taken place during periods of commercialization over the last century. They show that increased cash crop production can bring with it (1) reductions in women's income receipts and shifts in the distribution of income control in favor of men (Kennedy and Bouis 1993; Smith 1986) and (2) increased amounts of wives' time being controlled by their husbands for use in agricultural production (Whitehead 1990a; Fleuret and Fleuret 1981; Safilios-Rothschild 1985).[8]

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[7] Female-controlled income and assets may affect expenditures through their influence on female bargaining power. This would be the case regardless of whether income is pooled.

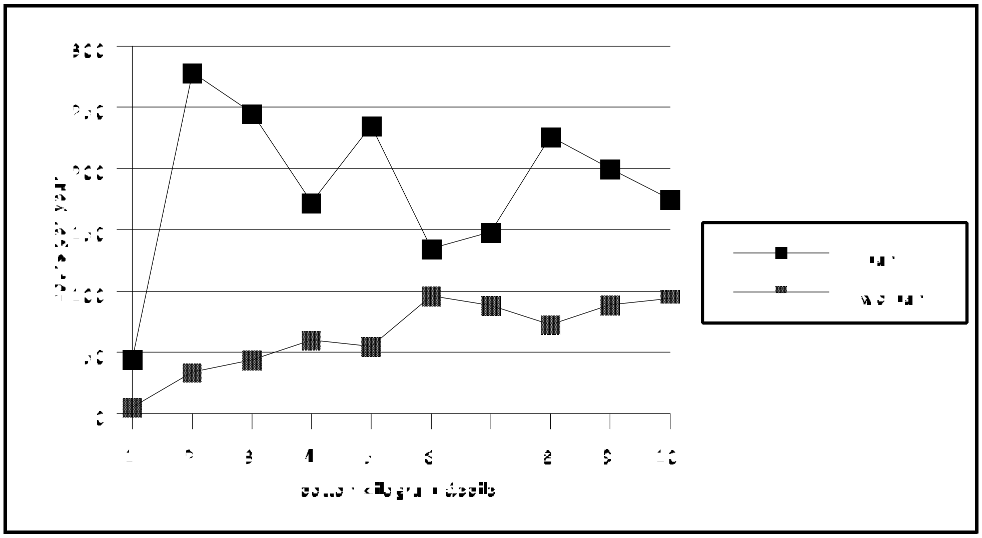
[8] See examples in World Bank (1987) from Burkina Faso, von Braun, Puetz, and Webb (1989) for The Gambia, and Basset (1988) for Côte d'Ivoire.

The changes in labor allocation and income receipts during cotton price liberalization in Burkina Faso from 1981 to 1985 bear out this pattern. A 60 percent cotton price increase over this period was followed by a 50 percent increase in cotton production and a 136 percent increase in households' cash incomes. Over the same period, the average man's income receipts increased by 57 percent while the average woman's increased by 17 percent (Smith 1995). Figure 1 relates these gender-differentiated changes to the rise of cotton production by comparing female and male labor allocation and income receipts across groups of households producing varying levels of cotton. The figure employs the ICRISAT data on which the simulation exercise below is based. The survey households are divided into cotton production deciles, with cotton production increasing across the deciles to the right. Figure 1a shows that the more cotton produced, the more is women's labor input and, generally, the less is men's. Figure 1b indicates that the more cotton produced, the higher are men's income receipts and the lower are women's. The data do not allow a gender breakdown of income control (although the simulation exercise will).

As discussed in the last section, changes such as those illustrated in Figure 1 have been accompanied by considerable conflict between wives and husbands. Given the nonpooling of income, preference heterogeneity in households creates differing incentives across household members to allocate increased amounts of their time to the production of cash crops whose prices have risen. The incentives depend on who expects to control any increased income generated. "Incentive incompatibilities" (Collier 1990) associated

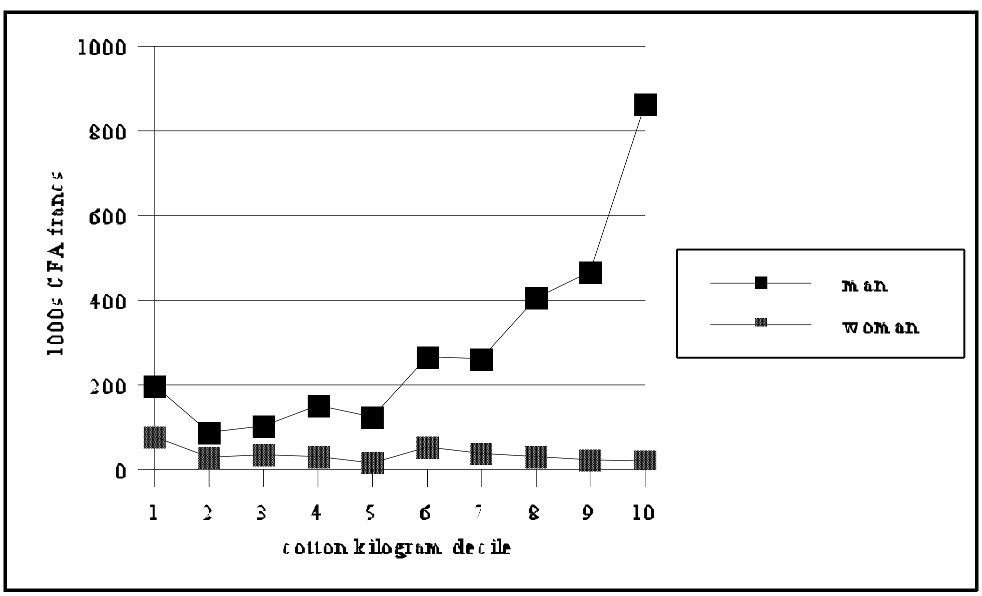
Figure 1 Men's and women's time in communal cotton production and cash income receipts, by cotton production decile in Burkinabé households (early 1980s)

(1a) Time in communal cotton production (1982/83)



Source: ICRISAT survey data.

(1b) Cash income receipts (1984)



Source: ICRISAT survey data.

with shifts in resource control distribution can reduce households' overall abilities to increase cash crop production in response to increased output prices. In particular, women's labor, a critical productive input, is not always forthcoming in response to increased prices of cash crops from which income is received by their husbands (Kabeer 1992; Dey 1997). The failure of Pareto efficiency thus corresponds to an attenuation of households' overall supply response. The attenuation is likely to be more pronounced the stronger the degree of preference heterogeneity is.

4. MODEL FOR WEST AFRICAN AGRICULTURAL HOUSEHOLDS

The above discussion points to several key characteristics of decisionmaking in West African households:

(1) preference heterogeneity between spouses;

(2) individualized time and income control;

(3) separate decisionmaking over how time and income are allocated ("unilateral" decisionmaking over resource allocation);

(4) bargaining over who controls women’s labor and the share of total household income controlled by each spouse ("joint" decisionmaking over resource control). From a practical standpoint, this bargaining is manifested in negotiations over the time wives spend in communal production and the return payments from their husbands; and

(5) the absence of a labor market.[9]

In this section, these characteristics are incorporated into a formal model and the implications for allocative efficiency are examined. The model, which we call a "semi-cooperative" model, is based on the Separate Spheres model of Carter and Katz (1997). This model, as discussed in Section 2, allows for all of the above.

MODEL

While rural West African households are often polygynous and embedded in extended family compound units, in order to clarify the role of preference heterogeneity in resource allocation, a two-decisionmaker household, composed of a woman (agent *f*) and her husband (agent *m*)—the decisionmakers—is assumed.

The household's production technologies are represented by composite functions for communal (*c*) and personal (*p*) production. Communal production takes place of a partially marketed food crop (cereals), Q_{c1}, and a fully marketed cash crop, $Q_{c2,}$ given by

$$Q_{cj} = Q_{cj}[T_{cj}^{f},\ T_{cj}^{m},\ V_{cj}] \quad j=1,2\ , \qquad \textbf{(1)}$$

where $T_{cj}^{\,i}$ is agent *i*'s time allocated to the production of the j^{th} communal crop and V_{cj} is a nonlabor input.[10] Production functions for agents' personal activities, $Q_p^{\,i}$, are given by

[9] The extent to which labor markets are present and functioning varies across West Africa. As mentioned above, labor markets in Burkina Faso, the country on which the empirical portion of this paper focuses, are virtually absent.

[10] All production functions, including W[.] below, are assumed continuously differentiable, increasing in all arguments, and strictly quasi-concave.

$$Q_p^{\,i} = Q_p^i[T_p^{\,i},\; V_p^i] \;\; i = f,m \,, \tag{2}$$

where $T_p^{\,i}$, $i = f,m$ is agent i's time allocated to $Q_p^{\,i}$ production and $V_p^{\,i}$ is a nonlabor input. We assume that the output of all personal production is sold on the market.

The household's well-being provisioning process is given by the function

$$W = W[T_W^f,\; F,\; X_W^f,\; X_W^m], \tag{3}$$

where W is the level of household physical well-being. Note that here, W[.] is modeled as a household production function (Becker 1974). It is not meant to represent a “welfare” function, which is generally measured in utility rather than the output of a product or service. $T_w^{\,f}$ in equation (3) is agent f's time devoted to well-being provisioning, F is cereals consumed, and the $X_w^{\,i}$ are noncereal "well-being inputs" purchased by the agents at prices $p_w^{\,i}$.

The agents' time constraints are given by

$$T_c^{\,i} + T_p^{\,i} + T_w^{\,i} + T_o^{\,i} = T, \quad i = f,m,\;\; T_w^{\,m} = 0 \,, \tag{4}$$

where $T_c^{\,i} = T_{c1}^{\;i} + T_{c2}^{\;i}$ is agent i's time in communal production, $T_o^{\,i}$ is leisure, and T is a time endowment. Let q_{cj} and v_{cj} be the output and input prices associated with Q_{cj}[.], j = 1,2. Let $q_p^{\,i}$ and $v_p^{\,i}$ be the output and input prices associated with $Q_p^{\,i}$[.]. Budget constraints for agent f and agent m, respectively, are then given by

$$p_w^{\,f} X_w^f + p_o^{\,f} X_o^f + \nu_p^f V_p^f = q_p^{\,f} Q_p^f[T_p^f, V_p^f] + E^{\,f} + t \tag{5}$$

$$p_w^{\,m} X_w^m + p_o^{\,m} X_o^m + q_{c1} F + \nu_p^m V_p^{\,m} + \sum_{j=1}^{2} \nu_{cj} V_{cj} = q_p^{\,m} Q_p^{\,m}[T_p^m, V_p^m] + \sum_{j=1}^{2} q_{cj} Q_{cj}[T_{cj}^f, T_{cj}^m, V_{cj}] + E^{\,m} - t \,, \tag{6}$$

where the X_o^i denote "consumption goods" purchased by agent i at prices p_w^i, the E^i are exogenous incomes, and "t" is a (net) transfer of income from agent m to agent f. For convenience, let vectors of prices be given by

$$p^i = (p_w^i, p_o^i) \;\; i = f,m \quad p = (p^f, p^m)$$
$$q_c = (q_{c1}, q_{c2}) \quad q = (q_p^f, q_p^m, q_c)$$
$$\nu = (\nu_c, \nu_p^f, \nu_p^m), \;\; \nu_c = (\nu_{c1}, \nu_{c2}).$$

The decision variables can be categorized into distinct "decision sets" as follows:

$$\xi^f = (T_p^f, T_w^f, T_o^f, X_w^f, X_o^f) \quad \xi^m = (T_{c1}^m, T_{c2}^m, T_p^m, T_o^m, X_w^m, X_o^m, F, T_{c1}^f, T_{c2}^f) \quad \xi^j = (T_c^f, t).$$

The sets ξ^i, $i = f,m$ contain variables over which each agent makes unilateral decisions. The set ξ^j contains "joint" decision variables over which bargaining takes place: the total amount of time agent f spends in communal production (T_c^f) and net income transfer from agent m to agent f (t),[11] which together specify a "resource control distribution."

To allow for preference heterogeneity, a separate utility function is specified for each agent. Preferences are defined over household physical well-being (W), consumption goods (X_o^i), and leisure (T_o^i). They are represented by continuously differentiable, increasing, and quasi-concave utility functions:

$$U^i(W, X_o^f, X_o^m, T_o^f, T_o^m) \quad i = f,m. \qquad \textbf{(7)}$$

[11] Note that, as the decisionmaker for communal production, agent m decides how agent f's time in communal production will be divided between Q_{c1} and Q_{c2} production. Thus T_{c1}^f and T_{c2}^f are included in ξ^m.

Decisionmaking is modeled as a two-stage game. In stage one, unilateral resource allocation decisions are made conditional on resource control distribution ξ^j. This stage is modeled as a noncooperative game in which allocational decisions are made, given agents' expectations of the other agent's choices. The noncooperative solution concept employed is a Nash equilibrium. In stage two, the agents bargain over ξ^j itself in a cooperative bargaining process. Specifically, the Nash solution for two person bargaining games with variable threats is employed.[12]

Stage One: Noncooperative Resource Allocation Decisions

The agents maximize utility, given fixed levels (signified by barred variables) of the other agent's choice variables and ξ^j. Agent *f* chooses ξ^f to maximize U^f given fixed ξ^m and ξ^j subject to equations (3), (4, $i = f$), and (5). The Langrangian for her decision problem is

$$\begin{aligned} \mathfrak{L}^f = {} & U^f(W^f[T_w^f, \bar{F}, X_w^f, \bar{X}_w^m], X_o^f, \bar{X}_o^m, T_o^f, \bar{T}_o^m) \\ & + \mu_f^f\,(T - \bar{T}_c^f - T_p^f - T_w^f - T_o^f) \\ & + \lambda_f^f\,(q_p^f Q_p^f[T_p^f, V_p^f] + E^f + \bar{t} - p_w^f X_w^f - p_o^f X_o^f - \nu_p^f V_p^f). \end{aligned} \qquad \textbf{(8)}$$

Agent *m* chooses ξ^m to maximize U^m, given fixed ξ^f and ξ^j and subject to equations (1), (2), (3), (4, $i = m$), (6), and the additional condition that agent *f*'s labor in the two

[12] Note that the separation of choice into a two-stage process for modeling purposes is not meant in a real-time sequential sense (Katz 1992) but instead signifies a distinction between two qualitatively different decision modes. In the real world, household members likely take both types of decisions simultaneously.

communal production activities equal T_c^f, her total time in communal production. The Langrangian for his decision problem is

$$\begin{aligned}\mathcal{L}^m = {} & U^m(W^m[\bar{T}_w^f, F, \bar{X}_w^f, X_w^m], \bar{X}_o^f, X_o^m, \bar{T}_o^f, T_o^m) \\ & + \mu_m^m\,(T - T_{c1}^m - T_{c2}^m - T_p^m - T_o^m) \\ & + \lambda_m^m\,(q_p^m Q_p^m[T_p^m, V_p^m] + \sum_{j=1}^{2} q_{cj} Q_{cj}[T_{cj}^f, T_{cj}^m, V_{cj}] + E^m - \bar{t} - \exp^m) \\ & + \mu_f^m\,(\bar{T}_c^f - T_{c1}^f - T_{c2}^f),\end{aligned} \qquad \textbf{(9)}$$

where $\exp^m$ is the left-hand side of equation (6).

In equations (8) and (9), μ_i^i, λ_i^i, $i = f,m$, and μ_f^m are Lagrange multipliers for the corresponding constraints. The derivatives of (8) with respect to T_o^f and (9) with respect to T_o^m yield first order necessary condition (FONC):

$$\frac{\partial U^i}{\partial T_o^i} = \mu_i^i \quad i = f, m.$$

The μ_i^i can thus be interpreted as the agents' marginal utilities, or "shadow values," of consuming their own time in the form of leisure. From the FONC for consumption goods, the λ_i^i $i = f,m$ can similarly be interpreted as agents' shadow values of income they control:

$$\frac{\dfrac{\partial U^i}{\partial X_o^i}}{p_o^i} = \lambda_i^i, \;\; i = f, m.$$

Finally, from the derivative of (9) with respect to T_{cj}^f j = 1,2, shadow values (agent *m*'s) of agent *f*'s time in communal production can be defined as

$$\lambda^m_m q_{cj} \frac{\partial Q_{cj}}{\partial T^f_{cj}} = \mu^m_f \;\; j=1,2.$$

Since agent *m* receives income from communal production, the shadow values are positively related to his shadow value of income he controls and to the MRP of agent *f*'s labor.

Nash equilibrium values of ξ^m and ξ^f are determined through simultaneous solution of agents' "reaction functions," given by

$$\xi^m = R^m(p^m, q^m_p, q_{c1}, q_{c2}, \nu^m_p, \nu_c, \overline{T}^f_c, E^m - \overline{t} \mid \overline{\xi}^f).$$

$$\xi^f = R^f(p^f, q^f_p, \nu^f_p, T - \overline{T}^f_c, E^f + \overline{t} \mid \overline{\xi}^m).$$

The resulting *conditional* reduced-form equations for the agents' unilateral choice variables give optimal outcomes for each possible (T^f_c, t) combination. They take the form

$$\xi^{i'} = \xi^{i'}(p, q, \nu, \overline{T}^f_c, T - \overline{T}^f_c, E^m - \overline{t}, E^f + \overline{t}) \quad i=f,m. \qquad \textbf{(10)}$$

Stage Two: Cooperative Resource Control Decisions

Indirect utility functions conditional on ξ^j serve as the utility metric for choice of ξ^j. They are derived by substituting equation (10) into the agents' direct utility functions (7), yielding

$$V^i = V^i(p, q, \nu, \overline{T}^f_c, T - \overline{T}^f_c, E^m - \overline{t}, E^f + \overline{t}) \quad i=f,m. \qquad \textbf{(11)}$$

Equation (11) gives the maximum utility each agent can attain at all feasible ξ^j combinations.

Agents f and m jointly choose ξ^j to maximize a Nash objective function

$$N(T_c^f, t) = [V^f(p, q, \nu, T_c^f, T-T_c^f, E^f+t, E^m-t) - \Phi^f(p, q^f, \nu_p^f, E^f, \alpha^f)] * [V^m(p, q, \nu, T_c^f, T-T_c^f, E^f+t, E^m-t) - \Phi^m(p, q^m, q_c, \nu_p^m, \nu_c, E^m, \alpha^m)] \quad \textbf{(12)}$$

subject to

$$(V^i - \Phi^i) > 0 \qquad i = f, m . \quad \textbf{(13)}$$

The Nash objective function is the product of the agents' gains from membership in the joint decisionmaking unit, i.e., the difference between their current (conditional) utilities and some fallback position (or "threat point") Φ^i. The fallback positions are defined as marital dissolution and are functions of the prices agents would face in that event, their exogenous incomes, and nonmonetary variables α^i, $i = f,m$ that affect their maximized utility in the event of divorce. They reflect agents' bargaining powers: the higher is an agent's fallback position, the stronger that agents' preferences influence joint decisionmaking. Equation (13) is an individual rationality constraint specifying that both agents must be made better-off than they would be in divorce.

Reduced-form equations for t and T_c^f are given by

$$T_c^{f^*}(p,q,\nu,E^f,E^m,\alpha^f,\alpha^m) = T_c^f(p,q,\nu,E^f,E^m,\phi^f(p,q_p^f,\nu_p^f,E^f,\alpha^f),\phi^m(p,q_p^m,q_c,\nu_p^m,\nu_c,E^m,\alpha^m)) \quad \textbf{(14)}$$

$$t^*(p,q,\nu,E^f,E^m,\alpha^f,\alpha^m) = t(p,q,\nu,E^f,E^m,\phi^f(p,q_p^f,\nu_p^f,E^f,\alpha^f),\phi^m(p,q_p^m,q_c,\nu_p^m,\nu_c,E^m,\alpha^m)). \quad \textbf{(15)}$$

Final reduced-form equations for agents' unilateral choice variables in ξ^f and ξ^m are derived by substituting (14) and (15) into (10), yielding

$$\xi^{i*}(p, q, \nu, E^f, E^m, \alpha^f, \alpha^m) = \xi^{i*}(p, q, \nu, T_c^{f^*}, T - T_c^{f^*}, E^m - t^*, E^f + t^*). \qquad \textbf{(16)}$$

Equation (16) is an implicit function of agent f's time controlled by each agent (T_c^f for agent m, T - T_c^f for agent f) and of the income controlled by each (E^m - t for agent m, E^f + t for agent f), which are endogenous bargained outcomes. Thus, individual resource control—and the preference heterogeneity and bargaining power divergences that underlie it—are an important intermediate determinant of the levels of the agents' unilateral choice variables, including agricultural inputs and outputs.

ALLOCATIVE EFFICIENCY

In the above model, since agent f's time in communal production is an input into the household's income-generating activities, allocative efficiency in income generation is partially dependent on optimality conditions for resource control. The FONC for ξ^j is given by the derivatives of (12) with respect to t and T_c^f:

$$t: \ \frac{\partial V^f}{\partial t}(V^m - \phi^m) + \frac{\partial V^m}{\partial t}(V^f - \phi^f) = 0 \qquad \textbf{(17)}$$

$$T_c^f: \ \frac{\partial V^f}{\partial T_c^f}(V^m - \phi^m) + \frac{\partial V^m}{\partial T_c^f}(V^f - \phi^f) = 0. \qquad \textbf{(18)}$$

Combined, equations (17) and (18) give the condition for an optimal resource control "contract":

$$\frac{\frac{\partial V^f}{\partial t}}{\frac{\partial V^f}{\partial T_c^f}} = -\frac{(V^f - \phi^f)}{(V^m - \phi^m)} = \frac{\frac{\partial V^m}{\partial t}}{\frac{\partial V^m}{\partial T_c^f}} \quad \left(\frac{\partial V^i}{\partial T_c^f} \neq 0\right). \tag{19}$$

The agents' marginal rates of substitution (MRS) of t for T_c^f are equated. In turn, the MRS's are equated to (the negative of) a ratio of agents' utility gains. Condition (19) depends on (1) agents' individual marginal utilities, i.e., on both agents' preferences, and (2) their fallback positions, which determine the degree to which each agent's preferences influence the joint decisions. The marginal utilities are restricted to the following signs (see Carter and Katz 1997; Smith 1995):

$$\frac{\partial V^m}{\partial T_c^f} \geq 0, \quad \frac{\partial V^m}{\partial t} \leq 0, \quad \frac{\partial V^f}{\partial T_c^f} \leq 0, \quad \frac{\partial V^f}{\partial t} \geq 0. \tag{20}$$

To interpret these conditions, we introduce a specific definition of preference heterogeneity. The degree of preference divergence between agents is defined with respect to the relative values they place on the consumption goods they purchase (i.e., for which they make income allocation decisions) and their leisure time relative to their spouse's.[13] We distinguish among preference *homogeneity*, *heterogeneity*, and *independence.* These are defined at any point $\xi = (\xi^f, \xi^m, \xi^j)$ as follows:

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[13] For the purposes of the present analysis, preference heterogeneity is defined only with respect to the X_o^i and T_o^i and not over well-being itself, in order to avoid making arbitrary assumptions about which agent values well-being more than the other and (for the simulation exercise) by exactly how much. While definitive quantitative evidence is not available, a wide literature suggests that women "care" more about well-being, especially that of their children, than men, whether due to gender-specific socialization or expected future returns (Kabeer 1992; Folbre 1984; Bruce and Dwyer 1988).

Preference Homogeneity

$$\frac{\dfrac{\partial U^f}{\partial X_o^f}}{\dfrac{\partial U^f}{\partial X_o^m}} = \frac{\dfrac{\partial U^m}{\partial X_o^f}}{\dfrac{\partial U^m}{\partial X_o^m}}, \quad \frac{\dfrac{\partial U^f}{\partial T_o^f}}{\dfrac{\partial U^f}{\partial T_o^m}} = \frac{\dfrac{\partial U^m}{\partial T_o^f}}{\dfrac{\partial U^m}{\partial T_o^m}}, \quad \frac{\dfrac{\partial U^f}{\partial T_o^i}}{\dfrac{\partial U^f}{\partial X_o^k}} = \frac{\dfrac{\partial U^m}{\partial T_o^i}}{\dfrac{\partial U^m}{\partial X_o^k}} \quad k \neq i,\ i = f, m;\ k = f, m \tag{21}$$

Preference Heterogeneity

$$\frac{\dfrac{\partial U^f}{\partial X_o^f}}{\dfrac{\partial U^f}{\partial X_o^m}} > \frac{\dfrac{\partial U^m}{\partial X_o^f}}{\dfrac{\partial U^m}{\partial X_o^m}}, \quad \frac{\dfrac{\partial U^f}{\partial T_o^f}}{\dfrac{\partial U^f}{\partial T_o^m}} > \frac{\dfrac{\partial U^m}{\partial T_o^f}}{\dfrac{\partial U^m}{\partial T_o^m}}, \quad \frac{\dfrac{\partial U^f}{\partial T_o^i}}{\dfrac{\partial U^f}{\partial X_o^k}} > \frac{\dfrac{\partial U^m}{\partial T_o^i}}{\dfrac{\partial U^m}{\partial X_o^k}} \quad k \neq i,\ i = f, m;\ k = f, m \tag{22}$$

Preference Independence

$$\frac{\partial U^i}{\partial X_o^k} = 0 \quad \frac{\partial U^i}{\partial T_o^k} = 0 \quad i \neq k. \tag{23}$$

Under preference homogeneity, agents fully agree with one another; their MRS's are identical. In this case, all signs in equation (20) are zero: the agents are best-off where the utility of further increments in t and T_c^f can yield them no greater benefit. Conditions (17) and (18) are met trivially, condition (19) is undefined, and agents' fallback positions do not influence the choice of ξ^j, with the intuitively appealing result that bargaining power is not a factor in resource control decisions when preferences are homogeneous.

Under preference heterogeneity (22) and independence (23), agents value the consumption goods they purchase and their own leisure time more than the other agent's.

In these cases, all signs in equation (20) are strictly non-zero. Since agent *m* values goods and leisure time falling into his decision set (requiring resources controlled by him) more than those falling into agent *f*'s, he prefers that income transfers be reduced and agent *f*'s time in communal production be increased. The opposite holds for agent *f*. In this case, the levels of *t* and T_c^f that equation (19) implies are dependent on the agents' bargaining powers: the higher is agent *m*'s fallback position relative to agent *f*'s, the greater will be T_c^f and the lesser will be *t*.

Additional conditions for allocative efficiency in income generation are derived from equations (8) and (9), the Langrangians for the agents' stage-one problems. For agent *f*'s labor in personal production (from the FONC for T_p^f in [8]), the condition is

$$q_p^f \frac{\partial Q_p^f}{\partial T_p^f} = \frac{\mu_f^f}{\lambda_f^f}. \qquad \textbf{(24)}$$

The marginal revenue production (MRP) of her time is equated to a ratio of her shadow value of her time and income she controls. For the allocation of her labor between the communal production activities (from FONCs for T_{c1}^f and T_{c2}^f in [9]), the condition is

$$q_{c1} \frac{\partial Q_{c1}}{\partial T_{c1}^f} = q_{c2} \frac{\partial Q_{c2}}{\partial T_{c2}^f} = \frac{\mu_f^m}{\lambda_m^m} \ s.t. \quad \sum_{j=1}^{2} T_{cj}^f = \overline{T}_c^f. \qquad \textbf{(25)}$$

Here the MRP of her labor is equated across the activities. They must also be equated to a ratio of agent *m*'s shadow value of agent *f*'s labor to his shadow value of income he controls.

From the FONCs for T_{cj}^{m}, j = 1,2 and T_{p}^{m} (from [9]), optimal allocation of agent m's labor across the communally produced food crop, pure cash crop, and his personal production activity takes place where the MRP of his labor is equated across the activities:

$$q_{c1}\frac{\partial Q_{c1}}{\partial T_{c1}^{m}} = q_{c2}\frac{\partial Q_{c2}}{\partial T_{c2}^{m}} = q_{p}^{m}\frac{\partial Q_{p}^{m}}{\partial T_{p}^{m}} = \frac{\mu_{m}^{m}}{\lambda_{m}^{m}}\ . \tag{26}$$

They are equated to a ratio of agent m's shadow values of (his) time and income he controls. The efficiency conditions for the allocation of nonlabor inputs are

$$q_{c1}\frac{\partial Q_{c1}}{\partial V_{c1}} = q_{c2}\frac{\partial Q_{c2}}{\partial V_{c2}} = q_{p}^{m}\frac{\partial Q_{p}^{m}}{\partial V_{p}^{m}}; \qquad q_{p}^{f}\frac{\partial Q_{p}^{f}}{\partial V_{p}^{f}} = \nu_{p}^{f}. \tag{27}$$

Together, equation (19)—for resource control—and equations (24) through (27)—for resource allocation—sum up the efficiency conditions for income generation of the semi-cooperative model. Conditions (24) through (27) emphasize the separate nature of resource allocation decisions, which are governed by the marginal trade-offs felt by agents individually. Lack of communication and coordination between agents lead to lower efficiency than the Pareto efficiency that could be achieved if resources are pooled and allocated in accordance with a single utility function. Condition (19) emphasizes that allocative efficiency depends centrally on (is endogenously determined by) the degree of heterogeneity in agents' preferences and, if agents' preferences are heterogeneous, on their relative bargaining powers. In the simulation analysis of the next section, the implications of this preference heterogeneity for supply response will be explored.

5. SIMULATION OF AGRICULTURAL PRICE LIBERALIZATION IN BURKINA FASO

Employing the semi-cooperative model above, this section undertakes a simulation analysis of the production impact of increases in cotton and fertilizer prices that took place in Burkina Faso from 1982 to 1985 as part of an agricultural price liberalization program. Over the period, the price of cotton increased by 60 percent (from 62 to 100 CFA francs). The price of imported chemical fertilizer increased by 120 percent (from 45 to 100 CFA francs).[14] Cotton is Burkina Faso's principal cash crop, and it is produced largely as a communal crop (Smith 1995). The simulation thus examines the impacts of increases in q_{c2} and υ_{c2} in equation (6).

SIMULATION MODEL AND SOLUTION METHODOLOGY[15]

Equations (1) through (6) are parameterized, where possible, using data collected by the International Crops Research Institute of the Semi-Arid Tropics (ICRISAT) from 50 households in the cotton belt (the Savanna Guinean agro-climatic zone) of Burkina Faso (Matlon 1988). Some parameters that could not be estimated from these data are chosen, based on the best information available from secondary sources.

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[14] Despite the large increase in fertilizer price, the price changes greatly enhanced the profitability of cotton production. See Savadogo and Wetta (1992) for a full description of the liberalization program. CFA francs are those issued by the Communauté Financière Africaine. The 1982 exchange rate was 325 CFA per US$1.

[15] This section gives a broad overview of the parameterization of the simulation model and of the simulation methodology. A full description can be found in Smith (1995).

To allow variation in preference heterogeneity, a direct utility function approach is taken; the utility functions (corresponding to equations [7]) employed are Stone-Geary (Chung 1994), taking the form:

$$U^f = \alpha_w^f \ln(W - \gamma_w) + \sum_{i=f,m} (\alpha_{xi}^f \ln(X_o^i - \gamma_{xoi}) + \alpha_{Ti}^f \ln(T_o^i - \gamma_{Toi})) \tag{28}$$

$$U^m = \alpha_w^m \ln(W - \gamma_w) + \sum_{i=f,m} (\alpha_{xi}^m \ln(X_o^i - \gamma_{xoi}) + \alpha_{Ti}^m \ln(T_o^i - \gamma_{Toi})). \tag{29}$$

The γ's in equations (30) and (31) can be interpreted as minimum subsistence requirements for physical well-being, consumption goods, and leisure time, satisfying

$$\gamma_w > 0 \quad \gamma_{xoi} > 0 \quad \gamma_{Toi} > 0 \quad i = f,m \tag{30}$$

$$(W - \gamma_w) > 0 \quad (X_o^i - \gamma_{xoi}) > 0 \quad (T_o^i - \gamma_{Toi}) > 0 \quad i = f,m, \tag{31}$$

and the α^i are "marginal full-income shares" (Smith 1995). Concavity of the utility functions is ensured by the following conditions:

$$0 \le \alpha_w^i < 1 \quad 0 \le \alpha_{li}^f < 1 \quad 0 \le \alpha_{li}^m < 1 \quad l = x,T \quad i = f,m \tag{32}$$

$$\alpha_w^f + \sum_{l=x,T} \sum_{i=f,m} \alpha_{li}^f = 1, \quad \alpha_w^m + \sum_{l=x,T} \sum_{i=f,m} \alpha_{li}^m = 1. \tag{33}$$

The simulation exercise compares 36 alternative decisionmaking scenarios that differ along two dimensions: (1) the extent of preference divergence between the agents and (2) the extent of inequality in their bargaining powers. A continuum of six preference divergence cases are considered, denoted "one" (for preference homogeneity), "two," "three," "four," and "five" (for cases of increasing preference heterogeneity) and "six" (for preference independence). The preference divergence definitions given in equations (21), (22), and (23) are operationalized through parametric restrictions on the α^i as follows:

Preference Homogeneity

$$\alpha_w^f = \alpha_w^m \quad \alpha_{li}^f = \alpha_{li}^m \quad l = x,T \;\; i = f,m. \qquad \textbf{(34)}$$

Preference Heterogeneity

$$\alpha_w^f = \alpha_w^m \quad \alpha_{lf}^f > \alpha_{lm}^f \quad \alpha_{lm}^m > \alpha_{lf}^m \quad l = x,T. \qquad \textbf{(35)}$$

Preference Independence

$$\alpha_{lm}^f = \alpha_{lf}^m = 0 \quad l = x,T. \qquad \textbf{(36)}$$

Secondary data from West Africa on household-level expenditure shares, income elasticities, and time allocation are used to estimate full-income shares of physical well-being (W), consumption goods ($X_o^f + X_o^m$), and leisure time ($T_o^f + T_o^m$). These full-income shares are used to calculate approximate marginal full-income shares for the aggregated categories. Agents f and m are assumed to have the same aggregate marginal shares as follows:

$$\alpha_w^i = 0.2 \quad \alpha_{xf}^i + \alpha_{xm}^i = 0.3 \quad \alpha_{Tf}^i + \alpha_{Tm}^i = 0.5\,.$$

The preference divergence cases "one" through "six" are then based on varying values for agent f's and agent m's marginal full-income shares of consumption goods and leisure falling in their and the other agent's decision set. These are given in Table 1.[16]

[16] The agents' marginal full-income shares for well-being are assumed to be equal (see footnote 13).

Table 1 Marginal full-income shares for agents' Stone-Geary utility functions across preference divergence cases

	Preference homogeneity	Preference heterogeneity				Preference independence
	one	two	three	four	five	six
	i=f, i=m	i=f, i=m	i=f, i=m	i=f, i=m	i=f, i=m	i=f, i=m
α_w^i	.2 , .2	.2 , .2	.2 , .2	.2 , .2	.2 , .2	.2 , .2
α_{xf}^i	.15 , .15	.18 , .12	.21 , .09	.24 , .06	.27 , .03	.3 , 0
α_{xm}^i	.15 , .15	.12 , .18	.09 , .21	.06 , .24	.03 , .27	0 , .3
α_{Tf}^i	.25 , .25	.3 , .2	.35 , .15	.4 , .1	.45 , .05	.5 , 0
α_{Tm}^i	.25 , .25	.2 , .3	.15 , .35	.1 , .4	.05 , .45	0 , .5

Within each of the preference divergence cases are embedded six relative bargaining power (BP) cases, denoted "a," "b," "c," "d," "e," and "f." In case a, agent *m* has much greater BP than agent *f*. In cases b through e, BP gradually becomes more equal. In case f, the agents' bargaining powers are approximately equal. The BP cases are operationalized through simulating the agents' fallback optimization problems.[17]

In sum, the scenarios range from "(one,a)," in which agents' preferences are homogeneous and BP is greatly in favor of agent *m*, to "(six,f)," in which preference independence prevails and agents have relatively equal BP. The only difference across the scenarios is the parameterization of the utility functions and the agents' fallback utility

[17] For case “six," the fallback positions were calculated for each preference divergence case by manipulating the fallback problem of each agent to yield them a fallback utility level approximately 20 percent below the actual utility outcomes of the semi-cooperative model. The manipulated parameters were agent *m*’s fallback endowments of labor (which he may receive, for example, from other wives, his siblings or his brother’s wives) and both agents’ fallback exogenous incomes. For the other cases, agent *m*’s fallback utility level was held constant, and agent *f*’s fallback utility was allowed to decrease progressively until it reached her subsistence minimum level in case “a."

levels. The agricultural production functions, well-being provisioning function, and constraints on time and income for each scenario are identical.

For the communal production activities, Cobb-Douglas food (Q_{c1}) and cotton (Q_{c2}) production functions are estimated using the ICRISAT survey data. A food production function is estimated for 470 plots of millet, red sorghum and white sorghum using ordinary least squares estimation and inputs of land (A_{c1}) and labor (T_{c1}). The estimated function is (t-statistics are in parentheses)

$$\ln(Q_{c1}) = \underset{}{2.96} + \underset{(7.4)}{0.457 \ln(T_{c1})} + \underset{(7.1)\,.}{0.424 \ln(A_{c1})} \qquad R^2 = 0.589$$

Constant returns to scale is imposed for simulation purposes, giving a labor coefficient of 0.472 and a land coefficient of 0.528.

It is not possible to estimate a cotton production function directly from the ICRISAT data due to lack of plot-level data on cotton output. Instead, Cobb-Douglas coefficients on labor (T_{c2}), land (A_{c2}), and chemical fertilizer (F_{c2}) (the latter used almost exclusively in cotton production), are estimated employing efficiency conditions for communal production (see equations [28], [30] and [31]) and average input-output ratios for food and cotton estimated from the ICRISAT data. The function is modified to allow for both positive and negative marginal returns to chemical fertilizer. The resulting cotton production function is estimated as

$$\ln(Q_{c2}) = 2.18 + 0.59 \ln(T_{c2}) + 0.29 \ln(A_{c2}) + 0.12 \ln(F_{c2}) - 0.0045 \ln(F_{c2})^2.$$

Male and female labor are assumed to be perfect substitutes in both food and cotton production.[18]

The well-being provisioning function [3] is specified as Stone-Geary in order to allow for subsistence minimums. It is

$$\ln(W) \;=\; 0.1 + 0.3\ln(T_w^f - \;{}_1) + 0.3\ln(F - \;{}_2) + 0.2\,\ln(X_w^f - \;{}_3) + 0.2\,\ln(X_w^m - \;{}_4).$$

The subsistence minimums (s) for cereals and time are established using World Health Organization standards and women's time allocation data collected in Burkina Faso.

The simulation model allows for four pervasive features of the semi-arid Sahelian West African production environment. These are seasonality in income-generating activities, precautionary cereal market reliance and a "cereal code of honor" sanctifying the use of home-produced cereals for home consumption (McCorkle 1989), and cereal and cash income savings and flows across years. In order to capture the resource allocation behavior of a two-decisionmaker unit, the base cases of the 36 scenarios are targeted as closely as possible to the resource availabilities and production behaviors of the monogamous households participating in the ICRISAT survey.[19] Table 2 presents an

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[18] Udry (1996), using a larger set of the ICRISAT data, estimates a Constant Elasticity of Substitution production function containing female and male labor as inputs. He finds them to be equally productive.

[19] Due to limitations on the number of equations in the nonlinear model being simulated and to the diverse mix of personal production activities in which both men and women engage in Burkina Faso, it was neither possible nor desirable to estimate aggregated personal production functions for each agent. Instead, each agent's time in personal production is assumed to be remunerated at an exogenous hourly rate. These rates were the only unknown parameter in the system of estimating equations to be simulated. Thus they were chosen using controlled experiments to conform to the profile laid out in Table 2 (Smith 1995).

agricultural production profile of these households, which make up 36 percent of the survey households.

Table 2 Features of monogamous Burkinabé households' production behavior targeted for base cases

	Output-land ratio	Output-labor ratio	Labor-land ratio	Fertilizer
	(kg/ha)	(kg/hrs)	(hrs/ha)	(kgs)
Food	435.9	.726	600	-
Cotton	813.8	.644	1264	124
Market reliance for food: 17.5 percent				

Source: ICRISAT data, average of 1982 and 1983 survey rounds.

The simulations are undertaken using the nonlinear mathematical programming solver MINOS in GAMS. The first stage noncooperative resource allocation game, in which t and T_c^f are held fixed, is programmed using an iterative algorithm. Specifically, within each agent's unilateral choice problem, the variables falling in their decision sets are chosen to maximize utility, holding those falling into the other agent's decision set fixed. Upon solution of an agent's optimization problem, the optimal values of their choice variables replace the fixed levels in the other agent's problem, which is then solved for that agent's choice variables. The process is repeated until convergence, when agent f's and agent m's problems yield consistent choices. The solution for the entire two-stage game is found through a grid search over the noncooperative outcomes associated with fixed levels of t and T_c^f for that (t, T_c^f) combination yielding the maximum Nash product.[20] At this point (1) agents' unilateral choice problems (mimicking the crossing of their reaction functions) are consistent with one another, and (2) the Nash cooperative bargaining solution for t and T_c^f is reached, thus solving the semi-cooperative game for all endogenous variables.

A base case validation exercise finds that, within the behavioral framework assumed, scenario (six,d), a scenario of high preference heterogeneity and in which agent f has a fairly high degree of bargaining power (yet lower than agent m's) lies closest to the reality of monogamous households in Burkina Faso. The criteria used are consistency with the targeted production data in Table 2 and with ratios of women's to men's time in communal production, leisure time and income receipts.

PRE-LIBERALIZATION RESOURCE ALLOCATION AND CONTROL

First consider optimal base case resource control distribution across the 36 scenarios. Pre-price-change levels of agent f's time in communal production (T_c^f) and income transfers (t) are reported in Table 3. In the BP cases for which relative BP is greatly in favor of agent m (a to d), as we move across preference divergence cases "one" through "six," T_c^f tends to increase. Where relative BP is more balanced (e and f), it generally decreases as preference heterogeneity increases. The optimal income transfer decreases monotonically as preference heterogeneity increases for all BP cases.

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[20] A wide range of combinations of the variables T_c^f (in units of 5 hours) and t (in units of 500 CFA) are considered.

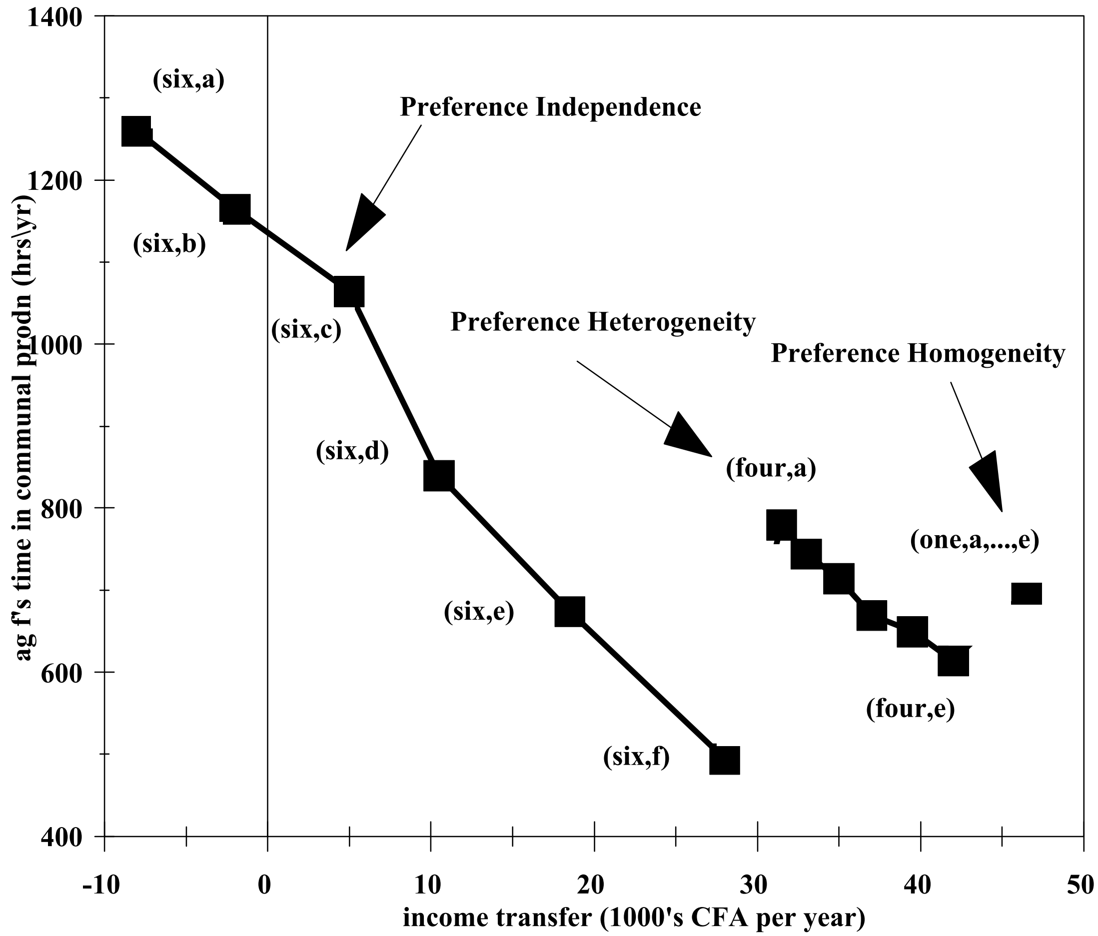
Table 3 Base case levels of agent *f*'s time in communal production (t_c^f) and income transfers (*t*) across scenarios

Bargaining power (BP)		Preference homogeneity	Preference heterogeneity				Preference independence
		one	two	three	four	five	six
			T_c^f (hours per year)				
BP greatly favors *m*	(a)	710	690	700	780	936	1,260
BP moderately favors *m*	(b)	700	685	700	745	880	1,165
	(c)	705	680	680	715	815	1,065
	(d)	705	670	655	670	750	840
	(e)	685	650	635	650	695	675
BP about equal	(f)	690	640	615	615	605	495
			t (1,000s of CFA)				
BP greatly favors *m*	(a)	46	42.5	38.5	31.5	17.5	-8
BP moderately favors *m*	(b)	46.5	43.5	39.5	33	21	-2
	(c)	46.5	43.5	41	35	25	5
	(d)	47	44.5	41.5	37	29	10.5
	(e)	46	44.5	42.5	39.5	34	18.5
BP about equal	(f)	47	45	44	42	38.5	28

Holding the degree of preference heterogeneity constant, as relative BP ranges from being greatly in favor of agent *m* (case a) to relatively equal (case f) T_c^f declines and *t* increases, illustrating the greater control agent *f* has over her time and household income as her fallback position is improved. Figure 2 traces out the optimal levels of *t* (horizontal axis) and T_c^f (vertical axis)—the optimal resource control contract—for the scenarios. Under preference independence the contract varies greatly depending on the agents' BPs. Under preference homogeneity, it is essentially the same no matter what the agents' BPs are.

Simulated base case levels of cotton production, associated inputs, and income levels (receipts and control, by agent) for BP case d, the case most likely to resemble

Figure 2 Simulated base-case contract curves for labor and income transfers in Burkinabé households, alternative scenarios



Source: Simulation results.

spouses' relative bargaining power in Burkinabé households, are given in Table 4. Cotton production tends to increase slightly as preference heterogeneity increases. This increase is associated with an overall increase in agent *f*'s labor (and an overall decline in agent *m*'s), reflecting the greater value agent *m* places on agent *f*'s labor in income generation (rather than her leisure) as preferences diverge.

Agent *f*'s income control declines as preference heterogeneity increases, while agent *m*'s increases. Total household income decreases across the preference divergence cases, indicating that the deviation from Pareto efficiency in income generation caused by the nonpooling of resources increases as preference heterogeneity increases. Case six—that producing the least error when judged against actual behavioral patterns in monogamous Burkinabé households—represents a 16,200 CFA reduction in income over case one, in which the preferences of household members are assumed identical. In other words, total resources controlled within the household could potentially be reallocated to increase its income by 9 percent.[21]

SIMULATED SUPPLY RESPONSE RESULTS

Table 5 reports the predicted effects of the price increases on cotton production for preference divergence cases "one" through "six," relative bargaining power case d.

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[21] This number can be compared with the 10-20 percent increase in output that could be achieved in Burkinabé households by reallocating existing factors of production estimated by Udry et al. (1996). These numbers are not strictly comparable because that estimated in this paper refers to total household income whereas the Udry et al. number refers to agricultural production only. Additionally, the results in this paper are based on monogamous households only while those in the Udry et al. analysis are based on all household types.

Table 4 Base-case cotton production and income, preference divergence cases "one" to "six," bargaining power moderately in favor of agent *m* (case "d")

	Preference homogeneity	Preference heterogeneity				Preference independence
	one	two	three	four	five	six
Cotton (kilograms)	1,071	1,099	1,119	1,132	1,138	1,131
labor (hours)	1,305	1,336	1,358	1,373	1,379	1,371
agent *f*	299	292	291	302	340	378
agent *m*	421	441	452	448	413	371
land (hectares)	1.24	1.29	1.32	1.34	1.35	1.34
fertilizer (kilograms)	133	135	137	139	139	139
Income (1,000s CFA)	193.8	192.7	191.1	188.3	182.7	177.6
f: receipts	11.0	12.0	13.3	15.3	18.9	28.6
f: control	58.0	56.5	54.8	52.3	47.9	39.1
m: receipts	117.5	115.5	113.5	110.8	106.7	96.2
m: control	70.5	71.0	72.0	73.8	77.7	85.7

Note: Total labor in cotton production includes the labor of other household members and nonhousehold exchange labor. Total income includes cash income plus the value of food produced and consumed in the household, while individual agents' incomes refer only to cash income.

Table 5 Impact of price increases on cotton production and income, preference divergence cases "one" to "six," bargaining power moderately favoring agent *m* (case "d") (percent change over base)

	Preference homogeneity	Preference heterogeneity				Preference independence
	one	two	three	four	five	six
Cotton (kilograms)	56.7	52.0	48.9	43.4	41.5	40.3
labor (hours)	73	67	62	57	54	53
land (hectares)	45	41	38	34	33	32
fertilizer (kilograms)	24	20	17	14	13	12
Income (1,000 CFA)	40	39	37	35	39	42
f: receipts	-100	-100	-100	-88	-60	-35
f: control	45	43	39	24	29	23
m: receipts	53	53	53	51	50	54
m: control	35	35	34	35	36	38

Cotton production is predicted to increase in all cases. However, the percentage increase declines from 56.7 percent under preference homogeneity to 40.3 percent under preference independence. Underlying this decline are reductions in the percentage increase in labor (from 73 percent in case "one" to 53 percent in "six") and all other inputs. The simulation model thus predicts that supply response *decreases* as preference heterogeneity *increases*. The increase in cotton production over the four years under scenario (six, d) is 456.2 kilograms; the increase under scenario (one, d) is 607.5 kilograms. Thus, the simulation model predicts the cotton supply response under preference heterogeneity of monogamous Burkinabé households to be 25 percent below that for households employing the same technology and facing the same resource limitations but whose members have identical preferences.[22]

Table 5 also reports the effects of the price increases on income. Cash income received by agent *f* declines to zero in cases one through three, i.e., agent *f* no longer engages in personal income generation after the price change.[23] As preferences diverge more, her personal income receipts decline more slowly: agent *f* continues to engage in activities from which she receives income, even though communal production has become more remunerative. With respect to income control, as preferences diverge more,

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[22] Note that the case of preference homogeneity is not equivalent to the unitary household model since the models' underlying structures are different. In particular, despite the fact that the spouses may agree with each other, their unilateral decisionmaking restricts them from reaching the type of cooperative solution that could be obtained in a traditional unitary (or even cooperative game-theoretic) model.

[23] See Smith and Chavas (1997) for treatment of how the balance of women's time between well-being provisioning and income-generating activities is affected by the price changes.

the percentage increase in income controlled by agent *f* declines. Thus, the greater is preference heterogeneity, the more income control distribution shifts in favor of agent *m*, and the less is agent *f*'s incentive to increase her time in communal production. These trends illustrate how preference divergences drive incentive incompatibilities between spouses, in turn reducing households' overall supply response.[24]

Figure 3 maps out the predicted increase in cotton production across all 36 scenarios. The highest percentage increase occurs under preference homogeneity; the lowest occurs in scenario (six, f), in which preference independence prevails and agents' BPs are relatively equal. Note that, as for the base-case resource control contract, bargaining power matters little for price impacts when agents' preferences are homogenous; its influence becomes more pronounced as preferences diverge.[25]

Figure 4 shows how cotton production is predicted to evolve over time under each of the six preference divergence cases as prices are progressively increased (in equal amounts) over the four years of the study period. Each line gives the average of the BP cases making up each preference divergence case. Figure 5 links the increases in cotton

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[24] Udry (1996) proposes that the roots of the inefficient allocation of resources in Burkinabé households lies in a number of impediments to mutually advantageous trades between members. The first set of impediments is imperfect labor, land, and asset rental markets. The second set of impediments are (intrahousehold) labor market "transactions costs" associated with imperfect information and conflicts over the extent of wives' contributions to husbands' activities. The latter, as pointed out in this paper, is itself rooted in substantial differences in the preferences of husbands and wives. Footnote 3 gives further insight into why inefficiencies persist in the fact of gains from alternative arrangements.

[25] Recall that the price increases lead to an increase in agent *m*'s fallback position and leave agent *f*'s unchanged (see equation [12]). Thus after the price change, the balance of bargaining power shifts in favor of agent *m* across the five cases of preference heterogeneity. Smith (1998) shows how this shift affects the price impacts separately from their direct feasibility effects.

Figure 3 Simulated cotton supply response of Burkinabé households, alternative scenarios

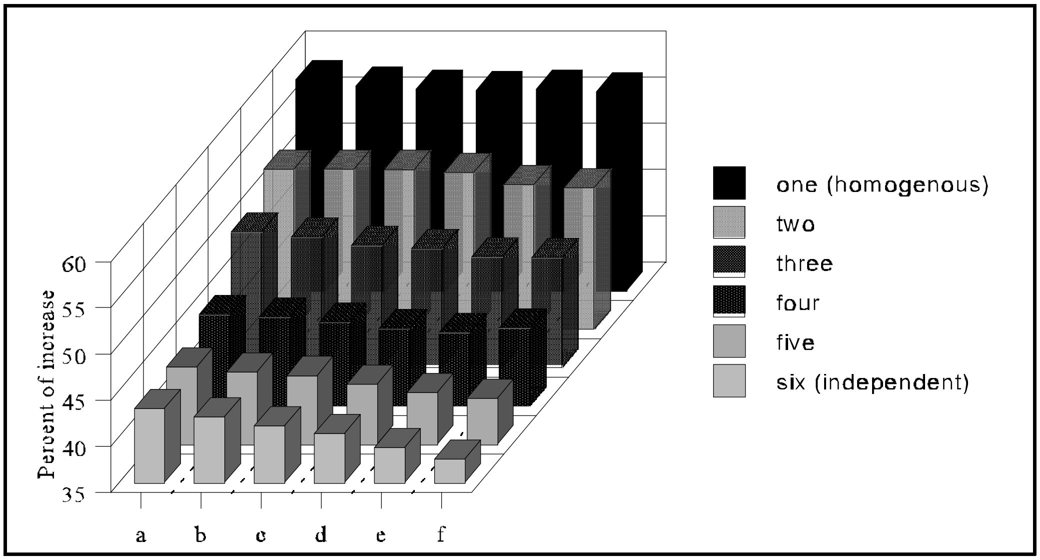


Figure 4 Simulated impact of price increases on cotton production in Burkinabé households, 1981 1985, alternative scenarios

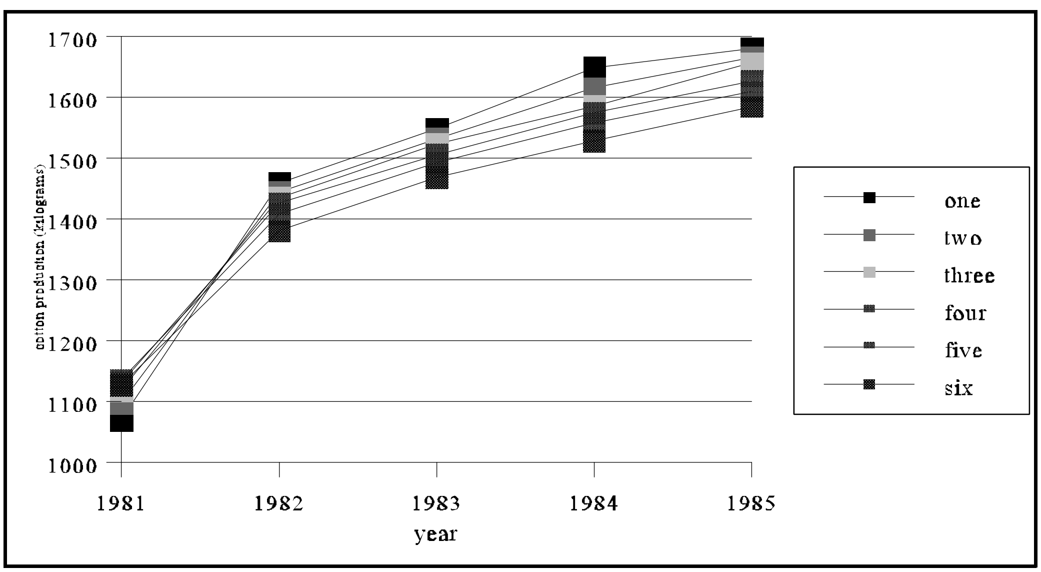
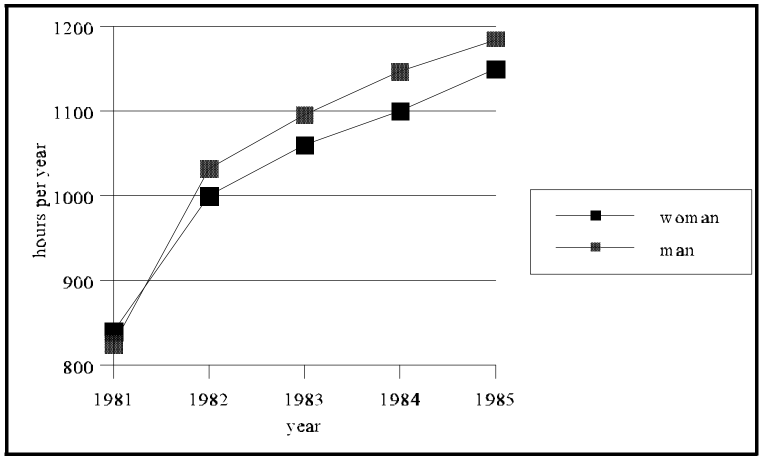
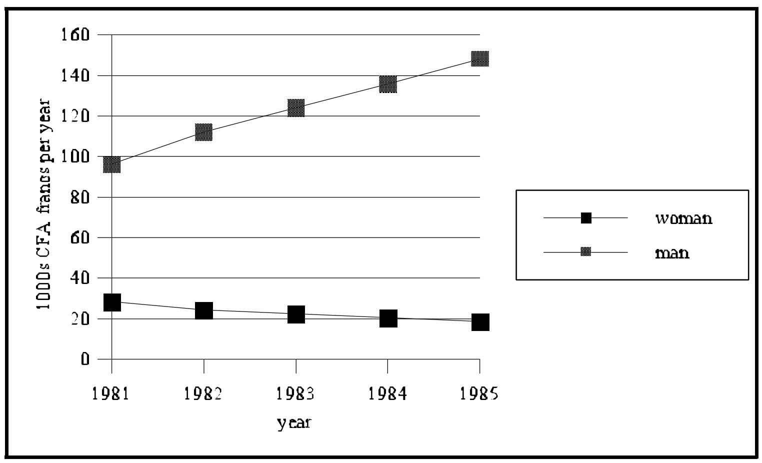


Figure 5 Simulated price-induced changes in labor and income control in Burkinabé households, 1981 1985

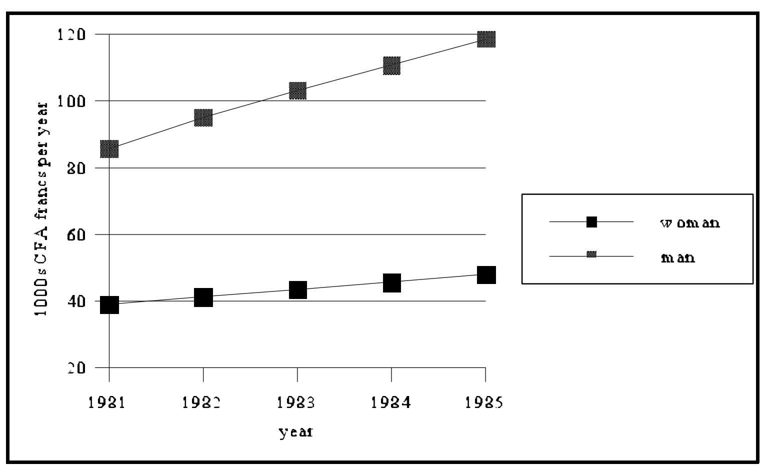
a. Labor in communal production



b. Income receipts



c. Income control



production with changes in resource control distribution in households. While both wives' and husbands' time in communal production increases over the four years (Figure 5a), husbands' income receipts are predicted to increase while wives' are predicted to decrease (Figure 5b). Figure 5c shows husbands' income control increasing at a faster rate than wives, consistent with the studies claiming that increased cash crop production leads to increased inequality in income control distribution within households.

6. CONCLUSION

The principal conclusion of this paper is that in nonresource pooling, West African agricultural households preference heterogeneity between women and men mutes supply response. For preference heterogeneous monogamous households of Burkina Faso, the simulation analysis predicts a 25 percent lower cotton supply response than would be the case if household members' preferences were identical, suggesting that the effect of intrahousehold preference heterogeneity may be quite significant quantitatively. It can thus be added to the list—along with market failures, poor infrastructure, and risk aversion—of potential "structural" constraints to agricultural supply response in West Africa.

The paper illustrates how an intrahousehold approach can contribute to a better understanding of microeconomic allocation decisions and policy impacts. For the West African setting in particular, it has shown that price policy impacts depend on the manner in which individuals in households—rather than households as a whole—respond to price changes. This response in turn depends on how the changes are likely to affect resource control distribution within households, which is influenced by individuals' ability to bargain with other household members over the benefit (and cost) streams flowing from the changes. We hope that by taking these realities into account, policies designed to improve supply response will be both more effective at reaching this goal and more beneficial to households and all individuals in them. We also hope that this research will stimulate further exploration of intrahousehold behavior and its implications for empirical analysis and policy prescriptions.

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