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ABSTRACT

Altruism, Cooperation, and Efficiency: Agricultural Production in Polygynous Households*

Altruism among family members can, in some cases, inhibit cooperation by increasing the utility that players expect to receive in a non-cooperative equilibrium. To test this, we examine agricultural productivity in polygynous households in West Africa. We find that cooperation is greater – production is more efficient – among co-wives than among husbands and wives because co-wives are less altruistic towards each other. The results are not driven by scale effects or self-selection into polygyny. Nor can they be explained by greater propensity for cooperation among women generally or by the household head acting as an enforcement mechanism for others' cooperative agreements.

JEL Classification: D13, D70, J12, O13, O55

Keywords: altruism, non-cooperative behavior, household bargaining, polygyny, Africa

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1. Introduction

Altruism towards others is typically thought to facilitate cooperation, as the inter-dependence of utility functions helps to align incentives and reduce transaction costs. Consequently, we should be more likely to observe an efficient allocation of resources among parties who are altruistic towards each other – most obviously, family members (Foster and Rosenzweig, 2001). Pareto efficiency has been confirmed in many studies (Browning and Chiappori, 1998; Chiappori, Fortin, and Lacroix, 2002; Bobonis, 2009), but a growing body of empirical evidence suggests that households fail to achieve efficiency in certain circumstances, particularly in the presence of transaction costs (Duflo and Udry, 2004; Rangel and Thomas, 2005; Goldstein and Udry, 2008; Dubois and Ligon, 2010). However, what is less clear from these studies are the factors that may be inhibiting cooperation.

In this paper, we argue that altruism may, in fact, be the culprit. We consider a game involving three players with differing degrees of altruism towards each other. In this case, stronger altruism can actually inhibit cooperation by increasing the utility that is obtained in the non-cooperative equilibrium and, therefore, reducing both the gains to cooperation and the threat of punishment. The implications of the model are tested using data on monogamous and polygynous households in Burkina Faso. We control for plot characteristics and household-crop-year fixed effects and examine the variation in yields due to the inefficient allocation of inputs across plots controlled by individuals within the same household, planting the same crop in the same year. We find that the difference in yields between husbands and wives is considerably smaller in polygynous households, whereas the difference in yields between household heads and other male cultivators is slightly larger. This suggests greater cooperation among co-wives than among husbands and wives, because wives' productivity increases while the head's productivity declines relative to other cultivators. The results are not driven by scale effects or self-selection into polygyny, nor are they the result of stronger preferences (lower costs) for cooperative behavior among women or of the household head serving as an enforcement mechanism for others' cooperative agreements, except under specific circumstances.

The remainder of the paper is organized as follows. Section 2 discusses the socio-cultural context and household arrangements in Burkina Faso and presents the data used in the empirical analysis. Section 3 presents a game-theoretic model of interactions among members in polygynous households. Section 4 describes the empirical strategy and presents the main results, along with several robustness checks. Section 5 concludes.

2. Burkinabé Households

Intrahousehold dynamics in rural Burkina Faso are quite complex. Households cultivate several rain-fed, primarily subsistence crops on multiple plots, some of which are controlled by the household head and some by other household members. Although norms vary by ethnic group, married Burkinabé women often have access to private plots under their own control (Kevane and Gray, 1999)[1]. Control over plots includes decision-making power over crop choice, quantity and timing of inputs, and ownership of plot output (Guyer, 1986; Udry, 1996). This access does not relieve women of their responsibility to contribute labor to household fields for joint production (Dey, 1997), which typically takes precedence over females' work in their own fields (van Koppen, 1990). While it is usually assumed that rural household heads are responsible for providing staple foods and covering expenditures on medical care and school fees, females often have to supply their own millet or cover expenses in practice. A single household, may include multiple mother-child pairs (Thorson, 2002), but each husband/wife pair is viewed as a separate

[1] Wives' plot locations and sizes are determined by the husband, and they may change each year. Conversely, private fields of other household males are usually more stable and allow the male to accumulate wealth to eventually break off to form his own household (Diallo and Nagy, 1986).

entity (Boye *et al.*, 1991).[2] Wife-child pairs typically live in their own nuclear units, hearthholds, or buildings, and wives are responsible for primary caretaking activities for their own children.[3] Co-wives occupy various positions of power in the household, with the first wife typically holding the most power of the co-wives.

Much of the anthropological literature suggests that co-wife relationships within polygynous households are characterized by conflict. Jankowiak, Sudakov and Wilreker (2005) find this to be true in almost all of the 69 polygynous cultures they reviewed. Despite this near-universal trait, they note the tendency for co-wives to cooperate to achieve pragmatic goals, particularly if females are not as reliant on their husbands for material or emotional support. This scenario was suggested earlier by Becker (1981), who applied his Rotten Kid Theorem to suggest that cooperative behavior could occur in productive activities in polygamous households, while conflict might still occur over distribution. Given that women in Burkina Faso have been found to work significantly more hours per day than male household members (Saito, 1994), cooperation by co-wives could be an important method of managing demands on time and energy. Indeed, in rural areas of the Sahel, polygyny can serve to reduce a co-wife's daily responsibilities by allowing women to engage in labor-sharing activities (Boye *et al.*, 1991). Members of the same household and compound often exchange goods or services through involved agreements that are driven by local norms and customs (Saito, 1994).

Kazianga and Klonner (2009) examine child survival in rural Mali using Demographic and Health Survey data and are unable to reject efficiency in child survival in monogamous

[2] Compounds are the major social unit of organization, overseen by the male lineage head. Inside compounds are one or more households headed by males who have single and married male dependents and numerous hearthholds comprised of widows, wives, away migrants' wives, daughters-in-law and single children (Thorson, 2002).
[3] Other female duties include retrieving water and wood, doing other domestic chores, caring for children, spinning cotton, and selling millet beer or food products (Diallo and Nagy, 1986). In general, each wife would prepare daily meals for her own children, with a rotation system among wives for preparing for the husband.

households and for children of senior wives in bigynous households. However, they find evidence of differential child survival by sex for junior wives and suggest that co-wife competition and the junior wife's weaker bargaining position drive this inefficient result. Similarly, Mammen (2004) finds that some education-related outcomes differ (typically for the worse) for children of junior wives, although she cannot reject a version of the collective model when credit constraints are allowed.

Data used in this paper are from the 1984-85 International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Burkina Faso household survey, which covers 150 households in 6 villages across 3 provinces: Djibo, Yako, and Boromo (see Matlon, 1988 and Udry, 1996 for detailed descriptions of the data). Just over half (50.7 percent) of the households in our sample are polygynous, defined as the household head having two or more wives. Of these households, 56 percent have two wives, 33 percent have three wives, and the remaining 11 percent report 4 or 5 wives.[4] For household heads and other female non-wife cultivators, average yields are considerably lower in polygynous households compared to monogamous households, although average plot size is quite similar (Table 1). For wives and other males, yields are slightly higher and plots are somewhat larger in polygynous households. The percentage of plots planted with a given primary crop is quite different, with wives in polygynous households devoting a larger percentage of plots to millet and sorghum (staple crops) and a smaller percentage to okra and earthpeas/fonio (cash crops). Other cultivators also have a different distribution of crops across monogamous and polygynous households, although it does not differ as clearly between staple

[4] We define polygyny by the number of wives listed in the household roster, because household heads were not asked to report the number of wives directly. Thus, if there are wives of the head living outside the household at the time of the survey, we may mistakenly count the household as monogamous. However, migration of wives appears to be quite rare in Burkina Faso. In our data, only 6 percent (17 out of 275) of economic migrants reported being a wife of the household head and, of these, the vast majority are listed in the household roster. Additionally, we construct both definitions of polygyny (reported versus observed number of wives) using the 1993 Demographic and Health Survey, with a difference of only 2 percentage points in the implied polygyny rate.

and cash crops. This suggests that polygynous households may utilize a different cropping strategy, although some of these differences may be driven by differences in agro-climatic zones that coincide with differences in polygyny rates within the ICRISAT sample.[5]

Several papers test for productive efficiency within the household, but none to date have focused on the distinction between monogamous and polygynous households. Using the 1981-83 ICRISAT data, Udry (1996) finds that, among plots planted with the same crop in the same year within a given household, female-controlled plots achieve significantly lower yields than male-controlled plots, even after controlling for plot characteristics, suggesting a lack of cooperation between husband and wife in the allocation of farm inputs. His analysis also reveals that households distribute inputs inefficiently: there is much less male labor on female-controlled plots, as well as lower manure usage. Households could increase output by approximately 6 percent simply by reallocating inputs across plots. More recently, Rangel and Thomas (2005) have shown that differences in cropping patterns and fallow can explain husband-wife differences in yields. However, these are still endogenous production decisions; the finding that crop and fallow decisions are inefficient does not negate the possibility of non-cooperation in agricultural production. Additionally, Akresh (2008) shows that inefficiencies within the household are muted in the face of adverse shocks, perhaps because the gains to cooperation are larger when household production is closer to the subsistence level. A study by Kazianga and Wahhaj (2012) uses household-crop-year fixed effects and is able to reject Pareto efficiency in household production in Burkina Faso in 1993 and 1994. Kazianga and Wahhaj distinguish

[5] The Djibo region is well-suited to millet and fonio but not white sorghum, and respondents in this region are predominantly Rimaibe with a low incidence of polygyny. The Yako region is well-suited to white sorghum, millet and cotton, and respondents in this region are predominantly Mossi with a high incidence of polygyny. The Boromo region is better suited to sorghum and maize than millet, and respondents are predominantly Dagari and Bwa, both with high incidences of polygyny (see Matlon, 1988).

between the household head, junior males, and females, but do not consider differences across monogamous and polygynous households.

Allocative inefficiency in household production has been noted even despite evidence of technical efficiency in production across both genders (Quisumbing 1996). McPeak and Doss (2006) find evidence of non-cooperative behavior (and therefore potential inefficiency) in nomadic pastoralist households' migration and milk marketing activities in northern Kenya. Peterman *et al.* (2010) find signs of lower productivity on female-controlled plots in Uganda and Nigeria, even after controlling for crop choice, agricultural inputs, socioeconomic background, and household fixed effects. They find, however, that gender productivity differentials vary by crops farmed, region, biophysical characteristics of the plot, and whether the gender variable was reported at the household or plot level. Exclusively in West Africa, Pareto inefficient outcomes have been observed in fallow times in Ghana (Goldstein and Udry 2008), although this result is primarily attributed to the roles of ambiguous property rights and individual political power. As households in West Africa are often organized with separate production spheres (Lundberg and Pollak 1993), observation of non-cooperative outcomes is not entirely surprising.

3. Modeling Cooperation in Polygynous Households

The notion that altruism can reduce efficiency was first formally suggested by Bernheim and Stark (1988). They describe two channels through which altruistic preferences may inhibit cooperation and the efficient allocation of resources. First, an altruist may take action to preempt exploitative behavior, in effect committing him/herself to an inefficient allocation so as to provide other household members with better incentives. Second, when altruism improves the static non-cooperative outcome, it also weakens the severity of punishments, making cooperative behavior more difficult to sustain. Our model goes in a slightly different direction, allowing for three players within the same family to have differing degrees of altruism towards each other. The advantage of this formulation is that, when we turn to empirical tests of the model, we can control for other features of the household that may facilitate cooperation, such as capacity for monitoring or expectations about future interactions. We show that, when altruism between two players improves the static non-cooperative outcome, it also reduces the gains to cooperation, encouraging cooperation with a non-altruistic player over an altruistic one when transaction costs are fixed. We also consider how altruism may affect the feasibility and renegotiation-proofness of cooperative equilibria when commitment is imperfect.

3.1 Theoretical Framework

Consider a polygynous household with a husband (h) and his two wives (w_1 and w_2). Each individual has preferences over own consumption of two goods (x and z). Additionally, husbands and wives derive utility from each other's consumption of good z, but co-wives exhibit no altruism towards each other.

$$U_h = U_h(x_h, z_h, z_1, z_2) \text{ and } U_{w_i} = U_{w_i}(x_i, z_i, z_h) \ \forall i \in \{1,2\}$$

Note that our characterization of altruism follows that of Fehr and Schmidt (2006), in which the utility of an individual is increasing in the consumption of another person (other people). Preferences are not functionally interdependent, as each player cares only about the final allocation of resources and not how that allocation was reached or the utility other players actually receive from the allocation.

The feature of the z good that drives the main implications of the model is that the altruist cannot purchase it directly or, more generally, the altruist and the subject face different implicit prices for the same good.[6] Thus, even with interdependent preferences ($U_{j \neq i}$ enters the utility

[6] Alternatively, we could allow both the husband and wife to purchase all z goods directly, but at different prices. Note that, if both players can purchase the public good at the same price and both make strictly positive

function of i), the main implications of the model will still hold, provided the altruist does not fully internalize the effect of his actions on other(s) (*i.e.*, at the point where utility is maximized, $\partial U_i / \partial U_{j \neq i} < \min[\partial U_i / \partial x_i, \partial U_i / \partial z_i]$). This is very similar to the separate spheres assumption in Lundberg and Pollak (1993) and is consistent with many common forms of altruism (*e.g.*, preferences for the utility of one's spouse, parents' preferences for children's future earnings, preferences for the well-being of individuals in another country/class). And, if we think of *z* as child "quality", this assumption is also consistent with anthropological descriptions of Burkinabé households, with wives having ultimate control over the care of their own children. More generally, we could think of *z* as a vector, with some elements being private goods that provide derived utility (aesthetic appearance of one's spouse, cleanliness of the wife's home) and other elements being public goods for the conjugal unit (child quality). Moreover, a subset of the *z*-vector (*e.g.*, meals, childcare) may overlap across family members, including co-wives, with the important distinction that, even where elements of *z* overlap, each individual possesses the ability to purchase that good directly.

On the production side, each individual operates one plot of agricultural land. Farm production utilizes both male labor (N_M) and female labor (N_F), which are imperfect substitutes. Although all individuals have access to the same production technology, they are endowed with plots with different characteristics (*e.g.*, size, soil type, toposequence), denoted *A,* that affect the optimal input mix. Denote each individual's production function as follows:

$$Y_h = Y(N_M, N_F; A_h),\ Y_{w_1} = Y(N_M, N_F; A_{w_1}),\ Y_{w_2} = Y(N_M, N_F; A_{w_2})$$

Farm production is the only source of income, with the price of output normalized to one, and each individual supplies one unit of labor inelastically. Each pair of players may negotiate a

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contributions, an efficient allocation of resources can be achieved even without explicit cooperation among players (Warr, 1983 and Bergstrom et al., 1986).

cooperative agreement for labor-sharing.[7] This agreement stipulates plot-specific labor allocations for each player as well as a (net) payment from *j* to *i*, R_i^j, (with $R_i^j = -R_j^i$). For the moment, we assume that cooperative agreements are fully binding; however we impose a fixed cost of $c \geq 0$, per player, for negotiating each cooperative agreement. Each player may also choose to forgo explicit arrangements for cooperation, in which case he/she will not incur any costs.

3.2 Stage Game with Transaction Costs

Clearly, multiple equilibria are possible in this very general model. What we wish to establish here is that there exists a Nash equilibrium in which co-wives cooperate with each other in each period, but never cooperate with the husband. To see this, note that co-wives will be willing to cooperate with each other as long as the gains to cooperation exceed the cost

$$\left(\hat{Y}_{w_1} + \hat{Y}_{w_2}\right) - (Y'_{w_1} + Y'_{w_2}) \geq 2c \qquad [1]$$

where ^ denotes the allocations that prevail when only the co-wives cooperate and $'$ denotes the allocations that prevail when no cooperative agreements have been reached. However, they will not additionally cooperate with the husband if the marginal benefit, conditional on cooperating with the co-wife, does not exceed the cost

$$2c > \left(Y^*_{w_i} + Y^*_h\right) - \left(\hat{Y}_{w_i} + \hat{Y}_h\right) \; \forall i \in \{1,2\} \qquad [2]$$

where * denotes the allocations that prevail when a wife is cooperating with both her husband and her co-wife. Provided the optimal allocation of female labor on each wife's plot is not equal to the time endowment (*T*), there exist gains from trade, and condition [1] will hold for some arbitrarily small value of *c*. Conversely, the second condition must hold for some arbitrarily large value of *c*. Given that male and female labor are imperfect substitutes in farm production, there

[7] The key implications of the model are unaffected by the existence of markets for labor, provided those markets are imperfect.

exist gains from trade between husbands and wives, even if co-wives are already cooperating, which suggests $c > 0$.

Thus, for some intermediate value of $c > 0$, there exists an equilibrium in which co-wives cooperate with each other but not with their husbands, as long as each wife finds cooperating with only her co-wife to be more beneficial than cooperating with only her husband. Because each wife derives utility from her husband's consumption of z, this condition must be expressed in terms of utility rather than income: $\widehat{U}_{w_i} - U'_{w_i} > \widetilde{U}_{w_i} - U'_{w_i}$. Taking a linear approximation,

$$\frac{\partial U_{w_i}}{\partial \hat{x}_i}\frac{dx_i}{d\hat{V}_{w_i}} + \frac{\partial U_{w_i}}{\partial \hat{z}_i}\frac{dz_i}{d\hat{V}_{w_i}} > \frac{\partial U_{w_i}}{\partial \tilde{x}_i}\frac{dx_i}{d\tilde{V}_{w_i}} + \frac{\partial U_{w_i}}{\partial \tilde{z}_i}\frac{dz_i}{d\tilde{V}_{w_i}} + \frac{\partial U_{w_i}}{\partial \tilde{z}_h}\frac{dz_h}{d\tilde{V}_h} \forall i \in \{1,2\} \qquad [3]$$

where $V = Y + R$ are total earnings (recall that R is the net transfer between cooperating players). Then $d\hat{V} = (\hat{V} - V')$ is the net income gain for wife i when co-wives cooperate only with each other, and $d\tilde{V} = (\tilde{V} - V')$ is the net income gain when wife i cooperates only with the husband. To simplify this expression further, note that, at the constrained optimum,

$$\frac{\partial U_{w_i}}{\partial z_i} = \frac{\partial U_{w_i}}{\partial x_i} p_i \, .$$

And, taking into account the budget constraint, we can rewrite condition [3] as follows:

$$\frac{\partial U_{w_i}}{\partial \hat{x}_i} d\hat{V}_{w_i} > \frac{\partial U_{w_i}}{\partial \tilde{x}_i}\left(d\tilde{V}_{w_i} + d\tilde{V}_h\right) - \left(\frac{\partial U_{w_i}}{\partial \tilde{x}_i} - \frac{\partial U_{w_i}}{\partial \tilde{z}_h}\frac{1}{p_h}\right) d\tilde{V}_h - \frac{\partial U_{w_i}}{\partial \tilde{z}_h}\frac{1}{p_h} d\tilde{x}_h$$

$d\tilde{V}_{w_i} + d\tilde{V}_h$ is exactly the total surplus generated by the cooperative agreement between the husband and wife i. Provided the marginal utility of own consumption exceeds that for consumption of others and the utility function is well-behaved,

$$\frac{\partial U_{w_i}}{\partial x_i} > \frac{\partial U_{w_i}}{\partial z_h} \text{ and } \frac{\partial^3 U_{w_i}}{\partial x_i^3} > 0 \, ,$$

a sufficient condition for [3] is to verify that the surplus generated by co-wives cooperating exceeds the surplus generated by each wife cooperating with the husband independently.

$$\left(\hat{Y}_{w_1} + \hat{Y}_{w_2}\right) - \left(Y'_{w_1} + Y'_{w_2}\right) > \left(\tilde{Y}_{w_i} + \tilde{Y}_h\right) - \left(Y'_{w_i} + Y'_h\right) \forall i \in \{1,2\} \qquad [4]$$

Recall that ˜ refers to outcomes when wife *i* cooperates only with the husband. This condition also ensures that the husband cannot entice either wife to cooperate with him by offering her a much larger share of the surplus, because the co-wife can always offer her a slightly larger payment. And, she would be willing to do so because this would allow her to still retain a smaller amount of the cooperative surplus, rather than being excluded entirely.[8]

Condition [4] does not necessarily imply that the total cooperative output generated by the co-wives exceeds the output that could be generated by the husband and wife together. In fact, given that male and female labor are imperfect substitutes, it is more likely that the opposite is true. However, the surplus that is generated, above and beyond the non-cooperative equilibrium, may be greater when co-wives cooperate if, as is suggested in the anthropological literature (Dey 1997), husbands and wives pool some resources even in the absence of an explicit cooperative agreement, whereas co-wives do not. Altruistic preferences make it more probable that husbands and wives engage in some minimal exchange behavior even when no cooperative agreement is reached. Put another way, in the absence of cooperative agreements, each husband-wife pair is closer to the Pareto frontier for agricultural production than is the wife-wife pair.

More formally, assume that each wife chooses x and z to maximize her utility, subject to her husband's choice of z and the income generated on her plot. The husband chooses x and z to

[8] We can ensure that this equilibrium is coalition-proof (Bernheim, Peleg and Whinston, 1987) by assuming that the husband cannot simultaneously offer both wives agreements that dominate the agreement between co-wives

$$\left(\hat{Y}_{w_1} + \hat{Y}_{w_2}\right) - \left(Y'_{w_1} + Y'_{w_2}\right) > \left[\left(\dot{Y}_{w_1} + \dot{Y}_h\right) - \left(Y'_{w_1} + Y'_h\right)\right] + \left[\left(\dot{Y}_{w_2} + \dot{Y}_h\right) - \left(Y'_{w_2} + Y'_h\right)\right]$$

where ˙ denotes the allocations that prevail when both wives cooperate with the husband but not each other. This is a somewhat extreme case. In a repeated game, as we describe below, we can maintain condition [4] and ensure the equilibrium is coalition-proof by assuming that coalitions, once formed, cannot be re-formed for some minimum number of periods such that the gain to deviating is not Pareto-improving for any coalition.

maximize his own utility, subject to his wives' choices of *z* and his own agricultural production. Additionally, the husband chooses how to allocate his labor between his own and his wives' plots, recognizing that an increase in the wives' income will increase their purchases of *z* as well.

$$\max_{N_M^1, N_M^2, z_h} U_h(x_h, z_h, z_1, z_2) \text{ subject to } x_h = Y_h(1 - N_M^1 - N_M^2, N_1^M + N_2^M; A_h) - p_h z_h$$

$$\text{and } z_i = z_i^*(N_M^i, N_1^i + N_2^i, \mu_i, A_i) \text{ for } i = 1{,}2$$

where μ represents parameters of the wives' utility functions, N_M^i represents male labor allocated to wife *i*'s plot and N_i^M represents wife *i*'s labor allocated to the husband's plot. From the first order condition,

$$\frac{\partial U_h}{\partial z_i}\frac{\partial z_i^*}{\partial N_M^i} = \frac{\partial U_h}{\partial x_h}\frac{\partial Y_h}{\partial N_M^i} \text{ for } i = 1{,}2$$

we see that the optimal allocation of labor to wife *i*'s plot is strictly greater than zero, as long as the husband's marginal utility of z_i exceeds his marginal utility of *x* and the wife's choice of *z* is increasing in the labor he allocates to her plot.

Moreover, the husband's allocation of labor in the absence of a cooperative agreement will not be efficient because production and consumption decisions are not separable. To see this more clearly, rewrite the above condition as

$$\frac{\partial U_h}{\partial z_i}\frac{\partial z_i^*}{\partial Y_{w_i}}\left(\frac{\partial Y_{w_i}}{\partial N_M^i} + \frac{\partial Y_{w_i}}{\partial N_i^i}\frac{dN_i^i}{dN_M^i} + \frac{\partial Y_{w_i}}{\partial N_j^i}\frac{dN_j^i}{dN_M^i}\right) = \frac{\partial U_h}{\partial x_h}\frac{\partial Y_h}{\partial N_M^i} \qquad [5]$$

where N_F^i represents wife *i*'s labor on her own plot. In order for the marginal product of the husband's labor to be equalized across plots, the marginal rate of transformation between *x* and *z*, in utility terms, must be equal to one, and both wives' labor allocations to wife *i*'s plot must be independent of the husband's labor allocation. Each wife solves

$$\max_{N_i^M, N_i^j, z_i} U_{w_i}(x_i, z_i, z_h) \text{ subject to } x_i = Y_i\left(N_M^i, (1 - N_i^M - N_i^j) + N_j^i; A_i\right) - p_i z_i$$

$$N_M^i = N_M^{i\,*}(N_i^i, N_j^i, \mu_h, A_i) \text{ and } z_h = z_h^*(1 - N_M^i - N_M^j, N_i^M + N_j^M, \mu_h, A_i)$$

which gives us the following first order condition for N_i^M for an interior solution.

$$\frac{\partial U_{w_i}}{\partial x_i}\left(\frac{\partial Y_i}{\partial N_i^M} + \frac{\partial Y_i}{\partial N_M^i}\frac{\partial N_M^{i\,*}}{\partial N_i^M}\right) + \frac{\partial U_{w_i}}{\partial z_h}\frac{\partial z_h^*}{\partial N_i^M} = 0 \qquad [6]$$

The wife is willing to provide labor on her husband's plot as long as he is willing to provide enough labor to offset the decline in her production, net of the utility gain she receives via the husband's increased consumption of *z*. Both spouses should benefit from this arrangement if, in the absence of labor-sharing, the marginal product of own labor is lower on own plots than on spouses' plots. Note that, when simply maximizing own utility, co-wives will not provide labor on each other's plots because they do not expect reciprocity. However, as long as the husband and wife are at an interior solution, her labor allocation will be responsive to his choices. Thus, although the husband and wife supply labor on each other's plots even in the absence of an explicit cooperative agreement, they do not reach an efficient outcome. This result is, of course, sensitive to the separate spheres assumption and is a result of the husband and wife not being able to purchase each other's *z*-goods directly.

3.3 Repeated Game with Limited Commitment

If transaction costs are reduced or eliminated then, all else equal, a Pareto efficient outcome is feasible, with all three players cooperating and pooling labor. However, we must also consider the possibility that players may renege on established cooperative agreements. Because each player retains control over the output produced on his/her own plot (as is consistent with the anthropological literature from West Africa), it is possible to renege on both the labor allocated to other players' plots and the payment *R*. Clearly, with limited enforcement, cooperation cannot be sustained in a one-shot (or finitely repeated) game. However, if the stage game is repeated infinitely and players are sufficiently forward-looking, then Nash reversion (Friedman, 1971) may be used to sustain cooperative agreements. First, consider the punishment phase in which the players revert to their non-cooperative Nash strategies for a predetermined number of periods. In this equilibrium, altruism between the husband and wife leads to some strictly positive labor-sharing, even though wife *i* does not share labor with her co-wife. Thus, as long as condition [3] above still holds, the gains to cooperating with the co-wife exceed the gains to cooperating with the husband which, in turn, implies that, under Nash reversion, wife *j* can hold wife *i* to a more severe punishment than can her husband.

Next, consider a deviation by player *i* from the equilibrium in which all players behave cooperatively. When deviating from a cooperative agreement with player *j*, player *i* withholds both labor as well as any positive payments owed to player *j* ($R_j^{i^*} < 0$), while the other players continue to provide the agreed-upon payments and/or labor on player *i*'s plot. Total income for player *i*, conditional on reneging on his/her agreement with player *j*, is then

$$\bar{V}_{w_i} = \bar{Y}_{w_i} + \left|R_j^{i^*}\right| + R_i^{k^*}$$

where $\bar{Y}_{w_i}$ is the output player *i* produces by sharing labor with player *k* but not player *j*. This payoff is positively correlated with the surplus that would have been generated by cooperation, because the sum of $\bar{Y}_{w_i}$ and $R_j^{i^*}$ is (weakly) increasing in the quantity of labor to be shared. Condition [4] then implies that the gain to deviating from an agreement with the co-wife should be greater. However, when wife *i* deviates from a cooperative agreement with the husband, she allocates strictly less labor to his plot than she would in the Nash equilibrium. Therefore, the gain in output is greater when deviating against the husband than the co-wife. Moreover, the more labor-sharing there is in the one-shot Nash equilibrium, the greater are the gains in output.

But, when wife i deviates from a cooperative agreement with her husband, towards whom she is altruistic, she is also penalized via a reduction in her husband's consumption of z. However, the optimal deviation, though it involves less labor-sharing than the Nash strategy, will not be to supply zero labor on her husband's plot (recall that labor-sharing with the co-wife is exactly zero under the Nash strategy). In fact, under the optimal deviation, the value of the marginal unit of own labor on wife i's plot just offsets the loss from her husband's reduced consumption of z (see condition [6]).

$$\frac{\partial U_{w_i}}{\partial x_i}\frac{\partial Y_i}{\partial N_i^M} = -\frac{\partial U_{w_i}}{\partial z_h}\frac{\partial {z_h}^*}{\partial N_i^M}$$

Thus, whether wife i deviates against her husband or co-wife, in both cases she is able to fully capture the value of the other's labor to her plot as well as the labor she should have allocated to his/her plot, although she converts the income gains into utility with different bundles of goods. Deviating against the husband will, therefore, yield both greater income and greater utility than deviating against the co-wife, while the threat of punishment from the husband is weaker. Altruism between the husband and wife makes cooperation more difficult to sustain.

Of course, if the husband and wife j can jointly punish wife i for deviating from either agreement, then cooperation among all three players could be sustained. However, joint punishment is not subgame-perfect, as condition [4] implies that wife i can always offer wife j a higher pay-off by deviating from the joint punishment to co-wife cooperation. Alternatively, we can consider a min-max punishment strategy, in which the husband punishes a deviation by wife i by allocating zero labor to her plot until she again plays cooperatively. This would be a more severe punishment than Nash reversion and could be sufficient to sustain cooperation even when Nash reversion cannot, but it is not weakly renegotiation-proof (Abreu, Pearce and Stachetti, 1993). Once in the punishment phase, both the husband and wife i would be better off playing the Nash equilibrium. Because of the altruistic linkage between the two, the husband's utility is increasing in the wife's payoff and, therefore, there does not exist a tit-for-tat punishment that rewards the husband while min-maxing wife *i*. We could consider a tit-for-tat punishment in which the husband receives at least his Nash payoff as well as a side payment from the wife – consisting of his private good, the public good or a combination of the two – at the expense of her own private consumption. However, the wife will be tempted to renege in the punishment phase and, if she were to do so, the strongest punishment the husband could invoke would be the min-max strategy. Thus, this equilibrium too would unravel with renegotiation.

We have shown the existence of an equilibrium in which, within a polygynous household, co-wives cooperate with each other but not with their husband. Altruism between the husband and each wife makes such an equilibrium more likely, for three reasons. First, in the presence of transaction costs, each player may choose to invest only in the single most beneficial cooperative agreement. Because altruism facilitates exchange behavior even in the absence of an explicit agreement, it reduces the gains to cooperation, making cooperative agreements between husbands and wives less likely. Second, altruism can both increase the gains to deviating from a cooperative agreement and reduce the severity of the punishment that may be imposed. Then, in the presence of limited commitment, a non-altruistic party (a co-wife) is better able to prevent deviations from the cooperative agreement and, therefore, better able to sustain cooperation. Note that, in the presence of transaction costs, we could observe wives cooperating with husbands in a monogamous arrangement, but then electing to cooperate with a co-wife *instead* when placed in a polygynous arrangement. Limited commitment could not generate such a result, unless polygyny somehow affects the capacity for binding agreements between husbands and wives. Finally, even when the altruistic party is willing to impose very severe punishments, these will not be renegotiation-proof because altruism makes it impossible to punish the deviating player while rewarding the cooperating player. Thus, payoffs in the punishment phase will be Pareto-dominated by the Nash equilibrium.

These results are sensitive to our separate spheres-type assumption although, based on the anthropological evidence, it seems to be an accurate representation of Burkinabé households. Moreover, the notion of a good over which one has preferences but no direct control is consistent with many formulations of altruism (*e.g.*, parents' preferences for children's future earnings, preferences for the well-being of individuals in another country/class). The basic framework and implications can, therefore, be applied to a variety of contexts, even though they have been derived from the very specific case of polygynous households.

4. Empirical Application

4.1 Testable Implications

To generate testable implications from our theoretical model, recall that cooperation maximizes joint farm production and equalizes the marginal productivity of inputs across plots controlled by the cooperating individuals. This also implies that, controlling for land characteristics, crop choice and shocks to the production process, yields should be equalized across these plots. We estimate plot yield as a function of plot characteristics (area, soil type, toposequence, location) and cultivator characteristics (gender, relation to household head – head, wife, or other), conditional on a household-crop-year fixed effect. That is, we examine the deviation of plot yield from mean yield as a function of the deviation of plot characteristics from mean plot characteristics within a group of plots planted to the same crop by members of the same household in a given calendar year (Udry, 1996). Yield Q for plot i, planted with crop c, in year t, in household h can be expressed as:

$$Q_{htci} = \boldsymbol{X}_{htci}\beta + \gamma_G G_{htci} + \gamma_{OM} OM_{htci} + \gamma_{OF} OF_{htci} + \lambda_{htc} + \varepsilon_{htci}$$

where $\gamma_k = \gamma_k^0 + (Poly_{ht} * \gamma_k^P)$ for k = *G*, *OM*, *OF*. $\boldsymbol{X}$ is a vector of plot characteristics, *G* is gender of the plot cultivator (1=female), *OM* and *OF* are indicators equal to one if the plot cultivator is an "other male" (not the household head) or an "other female" (not a wife of the head), respectively, λ is a household-crop-year fixed effect, and ε is an error-term. Cultivator characteristics (gender and relationship to household head) are allowed to differ for polygynous households via an interaction with an indicator for polygyny (*Poly*).[9] The data, unfortunately, do not link agricultural plots to individual identifiers, so we are unable to identify the specific relationship of the cultivator to the head or to other household members. We are also unable to differentiate senior and junior wives in polygynous households.

The interactions between polygyny and cultivator characteristics tell us how the variation in yields between cultivators differs across monogamous and polygynous households. We can attribute this difference to the causal effect of additional wives in the household as long as the household-crop-year fixed effects account for unobserved characteristics that are correlated with both conjugal status and the *difference* in yields between cultivator types, conditional on planting the same crop, in the same year, in the same household. In Section 4.3, we present several tests of the robustness of this strategy. Given a negative coefficient on gender, then a positive coefficient on the interaction between polygyny and gender indicates that the yield differential between husbands and wives is smaller when the husband has multiple wives. However, this may be indicative of either cooperation among co-wives or (greater) cooperation between husbands and wives. To differentiate these, we need to examine how polygyny affects the yield differential between husbands and other cultivators. A decline in other cultivators' yields, relative to the

[9] Akresh, Chen and Moore (2012) use a similar specification but do not differentiate "other" cultivators by gender.

household head, suggests that the head himself is also able to achieve a more efficient allocation of agricultural inputs in the presence of multiple wives, whereas an increase in other cultivators' yields, again relative to the head, suggests that wives cooperate more with each other (and perhaps with other cultivators) than with the household head.

By including indicators for the relationship of the cultivator to the household head, we can look more closely at other opportunities and incentives for cooperation among household members. In the previous section, we make the case that a positive coefficient on the interaction between polygyny and gender is the result of greater altruism between husbands and wives than between co-wives. However, we would observe the same result if the cost of cooperation is simply lower among women, not necessarily just co-wives. In this case, the presence of additional women, in the form of polygyny, should facilitate greater cooperation among all women and therefore reduce any difference in yields between wives and other female cultivators. Alternatively, the household head may be able to serve as an enforcement mechanism for cooperative arrangements among other household members. That is, with multiple wives, the head may be able to enforce an optimal allocation of agricultural inputs among their plots, even when he is unable to enforce cooperative arrangements between himself and his wives, because he can act as a third-party monitor/arbitrator. In this case, the head should be able to enforce cooperation between other cultivators within the household as well, resulting in smaller yield differences among other cultivators who are not the household head or wife (wives).

These dynamics, summarized in the table below, allow us to distinguish between alternative explanations for smaller male-female yield differentials in polygynous households. Our altruism story is consistent only with the first row. However, if women prefer to cooperate with each other over men, we will observe a smaller yield differential between wives and other

Hypothesis	Testable Implication
Greater cooperation among co-wives than among husbands and wives	Smaller yield differential between husbands and wives in the presence of multiple wives, and smaller or unchanged yield differential between husbands and other male cultivators $\gamma_G^P > 0$ and $\gamma_{OM}^P \geq 0$
Greater cooperation among women than among men	Smaller yield differential between wives and other female cultivators in the presence of multiple wives (more women) $\gamma_G^P > 0$ and $\gamma_{OF}^P > 0$
Household head serves as low-cost enforcement mechanism for others' cooperative arrangements	Smaller yield differential between other male cultivators and other female cultivators than between husbands and wives $\gamma_G^P > 0$ and $\gamma_{OM} - \gamma_{OF} < 0$

females in polygynous households as well as a smaller yield differential between men and women in polygynous households. Alternatively, if the household head acts as an enforcement mechanism for cooperative arrangements, we should observe smaller yield differentials among other cultivator pairs, in addition to co-wives. And, if co-wives find the head to be less credible as a neutral third-party than do other cultivator pairs, then we should only observe cooperation between co-wives *in conjunction* with cooperation between other cultivator pairs. Given the importance of order and rank in the treatment of co-wives (Boye *et al.*, 1991; Mammen, 2004 and Kazianga and Klonner, 2009), this seems plausible. In this case, the three hypotheses have distinct empirical implications.

4.2 Main Results

Column I of Table 2 replicates the household-crop-year fixed effects specification in Udry (1996), using only data for the years 1984-85.[10] We find a negative and significant effect of cultivator gender on plot yield, but the magnitude is larger than in Udry. This difference is, in part, a result of the ICRISAT survey design. In 1981-83 (the data used in Udry's analysis), detailed information was collected for a selected sample of plots (all cereal, cotton, and root

[10] In addition to including household-crop-year fixed effects, all regressions have controls for plot size (by decile), soil type, toposequence, and location.

crops, but only one plot under the management of the household head and one plot of his senior wife for legume or other garden crops), whereas summary information was collected for all plots in 1984-85 (Matlon 1988). Note that, because we are interested in the yields of other cultivators, particularly senior as well as junior co-wives, and wives devote a greater proportion of plots to legume and garden crops, data from 1981-83 suffer from significant sample selection and are, therefore, excluded from our estimates. In column II, we add indicators for other male and other female cultivators within the household. The coefficient on gender is still statistically significant and similar in magnitude. Other male cultivators are found to have significantly lower yields, relative to the household head, again consistent with findings in Udry (1996), suggesting that inefficiencies in intrahousehold allocation arise along other dimensions, in addition to gender.

In column III of Table 2, we add interactions of cultivator characteristics with an indicator for polygyny, as well as interactions of all plot characteristics with the indicator for polygyny, to allow for differences in technology across household types.[11] Wives in polygynous households have significantly higher yields than wives in monogamous households, relative to the household head, and the same is true for other male cultivators. This is consistent with greater cooperation among co-wives than among husbands and wives. The point estimate for γ_{OF}^{P} is consistent with stronger preferences for cooperation among women but is not statistically significant, and there is no significant difference between wives and other females to begin with. We do not find evidence of the household head acting as an enforcement mechanism; although the point estimates are consistent with this story, we cannot reject the hypothesis that the coefficient on other male is equal to the coefficient on other female (*p-value* = 0.196). Thus,

[11] We easily reject the hypothesis that the interactions of polygyny with plot characteristics are not jointly significant, (F(25, 3323) = 6.55, *p-value* = 0.000), so we include them in all specifications that distinguish monogamous and polygynous households.

while we do not find evidence in favor of these alternative explanations, we cannot yet confidently rule them out.[12]

Limiting the estimation to specific cultivator pairs provides some corroborating evidence to distinguish these hypotheses. Identification in Table 3 relies on variation in yields across plots planted with the same crop, in the same year, within the same household, between only two types of cultivators, rather than all four types. In column I, we see that polygyny reduces the male-female yield differential even when the sample is limited to plots cultivated by the household head and his wife (wives). Focusing on plots cultivated by other males and other females (Table 3, column II) shows that yield differences are nearly identical to those between husbands and wives, providing more conclusive evidence that heads are not enforcing cooperation among other cultivators, in either monogamous or polygynous households.

When the estimation is limited to only male cultivators (column III), we again find that the difference in yields between the head and other males is significantly smaller in polygynous households. Polygyny allows other male cultivators to narrow the gap in yields, relative to the head, which suggests that husbands' yields suffer, rather than benefit, from polygyny.[13] This indicates that cooperation among co-wives is not supplementing cooperation between husbands and wives; rather, arrangements among co-wives appear to be either replacing those between husbands and wives or emerging where husband-wife cooperation is unsustainable. Based on our simple model, this could only occur when there are significant transactions costs associated with cooperation; limited commitment alone is not sufficient to generate this result. That is, if a husband-wife pair was able to sustain cooperation in a monogamous arrangement, that

[12] We discuss column IV in Table 2 after the Table 3 results.

[13] Note that this does not necessarily imply that polygynous household heads are less productive than other male cultivators in the same household, only that they receive fewer inputs relative to other male cultivators, compared to monogamous households.

arrangement should also be sustainable when a second wife is added, unless cooperation is no longer mutually beneficial (*i.e.*, transaction costs erode the gains to cooperation).

However, limiting the estimation to female-cultivated plots still does not allow us to rule out a greater propensity for cooperation among women generally. Yields for other female cultivators are not significantly different from those for wives of the household head, in either monogamous or polygynous households (column IV). To test this more directly, we can look at how the presence of another female cultivator, not a wife of the household head, affects efficiency within the household. In effect, we compare the male-female yield differential across households that do and do not include an "other female" cultivator. We limit this estimation to household heads and their wives to ensure that the coefficients on the female dummy variable and its interactions are not driven by the behavior of the other female cultivators themselves. In column V of Table 3, we see that the presence of an additional female cultivator in the household significantly increases the difference in yields between husbands and wives, and polygyny again eliminates this gap, although the point estimates are imprecise. This is not consistent with stronger preferences for cooperation among all women; rather, the identity of the "additional" woman – wife of the head or other female – determines whether her presence will worsen or improve allocative efficiency within the household.

Our simple model shows that cooperation between altruistic parties can actually be more difficult to sustain than that between purely self-interested parties. We test this by comparing the male-female yield gap across monogamous and polygynous households, where polygyny represents the addition of a potential collaborator with altruistic preferences towards the husband but not the co-wife. However, this contrast between husband-wife and co-wife interaction provides a second testable implication: the likelihood of cooperation should be declining in the degree of altruism between players. If altruism is, at least in part, based in children as a shared public good, then we should see greater cooperation (smaller yield differences) among couples who have fewer children and, therefore, fewer shared goods. Consistent with this, we see that the interaction of number of children of the household head[14] with the indicator for female cultivators is negative and significant (column IV, Table 2), and the direct effect for female cultivators is now not statistically significant. This suggests that there is no statistical difference in yields between husbands and wives when there are no children in the home – *i.e.*, when they do not share public goods, particularly those that tend to fall into separate production spheres.

In polygynous households, the direct effect is also small and not statistically significant, again about one-quarter of the estimate in column III. But the interaction term is positive and statistically significant and almost entirely offsets the effect of children on women's yields in monogamous households. The opposite sign for polygynous households also suggests that this specification is not just picking up some effect of childcare on time allocation and productivity. Women in polygynous households are better able to specialize and optimally distribute childcare and farm duties amongst each other, presumably via cooperative arrangements, but women in monogamous households are unable to do the same with their husbands. We do not wish to rely too heavily on these results, as fertility may be correlated with the degree of efficiency or cooperation within the household. However, this specification does provide some additional suggestive evidence in support of our altruism story, over alternate explanations.

4.3 Robustness Checks

To further support our story, we would also like to find differences in input usage that could explain the observed differences in yields among cultivators within the same household. Unfortunately, data on the use of agricultural inputs is quite limited for the years in which we

[14] Includes only children of the head currently living in the household.

have information on all plots cultivated by the household (1984-85). We are unable to compare the use of male and female labor across plots controlled by different cultivators, making it difficult to corroborate directly our hypotheses regarding labor-sharing. Moreover, input data from 1984-85 are subject to significant measurement error, as they are based on recall at the end of each year. Using panel Tobit estimation (Honoré, 1992) and again controlling for household-crop-year fixed effects, we find suggestive evidence that women use inputs less intensively. Coefficients on the indicator for female are negative for labor hours in land improvement (clearing, burning, and bund construction), value of paid labor, manure, and length of fallow, although the point estimates are generally imprecise (columns I-III, Table 4). There are no significant differences for cultivators in polygynous households, although the estimated coefficients are of the opposite sign (except in the case of manure).

We lack data on many other inputs, but the estimates, although not conclusive, are consistent with women in polygynous households being better able to offset less intensive use of paid labor with a more efficient allocation of labor throughout the cropping season, providing some indirect evidence for our labor-sharing hypothesis. However, women also appear to follow shorter cropping cycles (columns IV and V, Table 4), keeping plots fallow for shorter periods of time but also allowing significantly fewer years between fallow periods. This is consistent with findings in Goldstein and Udry (2008) and may be indicative of differences in property rights for men and women. Point estimates are again of the opposite sign for women in polygynous households but not statistically significant. The more frequent fallowing does not appear to be sufficient to offset differences in yields between men and women, which suggests that the intra-household allocation of some other inputs, perhaps including length of fallow, must be sub-optimal as well. These results may also reflect differences in plot history or crop rotation (recall that the fixed effects control only for the current crop) if, for example, women tend to farm crops that are less deleterious to soil quality.

Alternatively, differences in fallow may point to differences in unobserved plot quality, which would pose a significant threat to our identification strategy. It may be the case that wives in polygynous households are endowed with plots of better unobserved quality. Unfortunately, we cannot test for this directly because plot borders change from year to year, making it impossible to identify any time-invariant plot fixed effects. Omitting all plot characteristics (size, toposequence, soil type, location) from our preferred specification decreases the magnitude of the coefficients on both the indicator for female and the interaction of gender with polygyny, leaving the total effect for women in polygynous households essentially unchanged (column I, Table 5). Assuming observed and unobserved plot characteristics are positively correlated, our results are consistent with higher unobserved plot quality for women, but this does not appear to differ across monogamous and polygynous households. Moreover, polygyny is found to increase yields equally for wives and other female cultivators, and it is not clear why other female cultivators in polygynous households would also have higher quality plots even though other male cultivators do not or, put another way, why greater wealth in polygynous households would translate into *differentially* higher quality for all women's plots.

The design of the ICRISAT survey provides a further opportunity to test the robustness of our results. In the 1981-83 years of the study, data on the plots of junior wives were collected only for cotton, cereal, and root crops, which are representative of less than 40 percent of the plots controlled by wives (Table 1). This selection is not necessarily problematic if the behavior of junior and senior wives is comparable. However, with the inclusion of household-crop-year fixed effects, the 1981-83 data only allow us to examine the variation in yields across plots planted with the same crop by the household head and his senior wife, with the exception of cotton, cereal and root crops. In contrast, the 1984-85 data provide variation in yields across plots planted with the same crop by the head and senior wife as well as by the senior and junior wives for all crops.[15] Thus, the beneficial effect of polygyny on women's yields should be much more muted in 1981-83, unless it is driven by unobserved heterogeneity across monogamous and polygynous households. Conversely, if the smaller gender yield differential in polygynous households is the result of greater cooperation between husbands and wives, instead of, or in addition to, greater cooperation between co-wives, then the same effect should be evident when we look predominantly at plots controlled by the head and the senior wife, omitting most of those controlled by the junior wives. Results shown in column II of Table 5 are not consistent with either of these alternate explanations. The coefficient on the interaction between female and polygynous is very small in magnitude and not statistically significant.

Clearly, polygyny could be correlated with unobserved characteristics of the household such as wealth, capital and family size (Jacoby, 1995; Tertilt, 2005). Household-crop-year fixed effects control for any such factors that affect men and women in the same household identically, conditional on planting the same crop, in the same year. However, they will not account for differences in crop choice or in the propensity for cooperation. When we split the data according to cereal and non-cereal crops, it becomes evident that non-cereal crops are driving the main results (columns III and IV, Table 5). For cereal crops, the coefficient on gender is much smaller in magnitude, as is the coefficient on gender interacted with polygyny, and neither is statistically significant. The opposite is true for non-cereal crops. However, wives in polygynous households devote a greater percentage of their plots to cereal crops (38 versus 24 percent, see Table 1), so

[15] For example, in 1981-83, we essentially would not observe variation in yields across plots planted with okra, a predominantly female crop planted on over 20 percent of wives' plots and less than 1 percent of heads' plots.

differences in crop choice attenuate observed differences in cooperative behavior across monogamous and polygynous households.

It is not clear whether the pattern described above is the result of (endogenous) differences in crop choice across monogamous and polygynous households, or whether this simply reflects stronger social norms governing the pooling of resources in the production of staple foods, the majority of which occurs on household communal plots. A complete model of crop choice is beyond the scope of the current paper, but we can utilize an alternative specification to look at within-household yield differences a bit more generally. Using household (rather than household-crop-year) fixed effects allows us to identify gender differences from variation across all plots cultivated by the household, rather than only those planted with the same crop. But, because weather variability and other time-varying factors may differentially affect certain crops, we also include village-crop-year fixed effects to account for aggregate crop-specific shocks. With this specification, we obtain the same qualitative results in terms of sign and significance, although the point estimates are considerably smaller in magnitude (Table 6, panel A). This suggests that the main results cannot be explained, at least not entirely, by differences in crop choice across monogamous and polygynous households.

And, because cultivator characteristics are included as control variables, we can interpret the household fixed effects implied by this specification as a measure of the latent productivity of the household head, net of plot characteristics and aggregate village-crop-year farming conditions. In Panel B of Table 6, we regress the implied household fixed effects on various characteristics of the household, to determine how polygyny is related to the level of production, in addition to the differences between cultivators. Without including any controls, the household fixed effect is not significantly different across monogamous and polygynous households.

Adding controls for village- and time-fixed effects increases the magnitude of the coefficient on polygyny, and the point estimates now indicate a statistically significant difference, with heads in polygynous households having higher latent productivity than those in monogamous households.[16] Thus, greater yields for women in polygynous households appear to be a level effect, and not simply indicative of a reduction in the productivity of polygynous household heads. Comparison of columns I and II suggests that polygynous households are more likely to be located in regions with lower agricultural productivity, consistent with anthropological evidence that polygyny is driven primarily by ethno-cultural traditions, rather than agricultural practices. In contrast, controls for household composition, total cultivated area and capital intensity do not significantly affect the magnitude of the coefficient on polygyny.

To test for the possibility that households that achieve more efficient allocations are more likely to take on additional wives, we compare polygynous households with different numbers of wives. That is, if more efficient households also take on more wives, the positive effects of polygyny should also be more pronounced for households with greater numbers of wives. We find no evidence of this; the point estimates for cultivator characteristics interacted with polygyny are not significantly different when we restrict the definition of polygyny to exactly two wives or more than two wives, respectively (columns I and II of Table 7). Of course, we cannot rule out the possibility of a non-monotonic relationship between number of wives and efficiency or preferences for cooperation (*e.g.*, a threshold effect around exactly two wives).

Although we have shown that the effect of polygyny is not simply a scale effect – that is, the addition of an "other" female cultivator is not equivalent to the addition of a wife – it may still be the case that polygyny affects production decisions in another manner unrelated to cooperation. For example, perhaps multiple wives are able to meet labor requirements on

[16] Quantile regressions at the 10th, 25th, 50th, 75th, and 90th percentiles yield similar results and are not shown here.

communal plots more quickly or efficiently, leaving more time for own cultivation. Alternatively, perhaps the household head is required to devote a fixed minimum amount of labor to his wives' plots and polygyny, therefore, reduces the time available for his own cultivation. To check for these possibilities, we split the sample into two different types of households, with access to different mechanisms for contract enforcement. In vertically-extended households (head with adult children), the head is also the patriarch, and social norms may allow him to exert more influence over other household members and therefore enforce greater cooperation. Power dynamics are considerably more complex in horizontally-extended households (head with adult siblings), and the influence of the head may be undermined by coalitions among other household members. If polygyny causes changes in productive arrangements that are not the result of cooperative arrangements, then we should observe the same effects for both household types. However, in our model, polygyny should provide greater benefits for households with more limited scope for cooperation.

We define horizontally-extended households as those that include a brother of the household head and vertically-extended households as those that do not. When we split the sample along these lines (columns III and IV of Table 7), we observe significant effects of polygyny only in horizontally-extended households. Because the same effects are not evident in vertically-extended households, where there is already greater scope for cooperation, our main results do not seem to be explained by a reorganization of productive activities outside of cooperative arrangements among cultivators, or a lack thereof. Interestingly, among vertically-extended households, we observe no significant yield differences across conjugal status or cultivator type, and the point estimates are generally small in magnitude, consistent with (but not proof of) efficiency in production. This suggests that, where the household head is able to enforce cooperation among other cultivators, he does so among all cultivators, without preference for certain types or pairs. Of course, to the extent that production in vertically-extended households is already efficient, our falsification test may lack power in that there are no gains to be realized from polygyny. However, this seems to beg the question of why productive efficiency is related to the composition of the household and the relationships among members.

4.4 Dynamic Inefficiency

The degree of cooperation within a household clearly affects the efficiency of both production and consumption decisions. It can also have implications for growth if the scope for cooperation affects investment choice. Investments requiring large fixed costs will have higher returns when they can be used across plots controlled by more than one cultivator. Conversely, where there is little opportunity for cooperation, individuals may choose to invest in smaller capital goods or higher quality variable inputs that have both lower fixed costs and lower returns. In our final specification, we look at a household's expenditure on large capital investments (plows, scarifiers, weeders, ridgers, line tracers, seeders, sprayers, carts, tractors and draft animals). To help control for the fact that larger and wealthier households are more likely to undertake such investments, we look at the expenditure on large capital investments as a percentage of the household's total expenditure on agricultural inputs. We also control for household demographic composition and land holdings, treating the latter, as well as polygyny, as endogenous. Because both the outcome of interest and the regressor of interest are now at the household level, we can no longer include household fixed effects and must instead rely on the use of instrumental variables. As instruments, we use (1) the quantity of land that was acquired via inheritance and (2) the ethnic group of the household.

Although land tenure and property rights in Burkina Faso tend to follow a more informal "customary" system, inherited land is granted to the household for permanent cultivation (Stamm, 1994). The instrument should, therefore, isolate the variation in land area (wealth) that arises from the household's relative position within the lineage, excluding differences due to heterogeneity in skill that are unobserved by the researcher but known to the head of the lineage. With regard to the second set of instruments, anthropologists note that polygyny has strong foundations in ethno-cultural traditions (Omariba and Boyle, 2007), while farming practices tended to be quite similar across ethnic groups, at least until very recently (Kevane and Grey, 1999). However, because ethnic groups tend to be geographically concentrated and, therefore, in differing agro-climatic zones, we also include either village- and year- or village-year fixed effects, to account for regional and temporal differences. Our key identifying assumptions are that the percentage of spending on farm inputs devoted to large capital investments is not directly affected by either the long-term land allocation decisions of the lineage or the ethnic group of the household, conditional on household composition and village and year fixed effects.

Without using instrumental variables, we find that household wealth, in the form of landholdings, has a significant positive effect on the percentage of expenditure on agricultural inputs that is devoted to large capital goods, while polygyny has essentially no effect (column I, Table 8). When estimating the IV regression, the coefficient on land holdings is close to zero and is no longer statistically significant. This suggests that asset accumulation, in both land and large capital investments, is driven by some unobserved third factor, such as ability or endowments. Conversely, the coefficient on polygyny increases in magnitude and becomes statistically significant after instrumental variables are included, suggesting that households who self-select into polygyny are, in fact, less likely to utilize a capital-intensive production process. This is consistent with Tertilt (2005), which suggests that wives may serve as an alternate form of capital accumulation. Our second-stage estimates indicate that polygynous households spend more on large capital goods, as a percentage of their total expenditure on agricultural inputs, which are also goods for which the economic returns are increasing in the scope for cooperative behavior. Tests of over-identification lend support to the validity of our instruments, and the difference between the IV and OLS estimates are as expected. However, we cannot rule out the possibility of a weak instruments problem and, therefore, do not wish to rely too heavily on these estimates. Nonetheless, this exercise provides additional suggestive evidence to support to our altruism hypothesis as, all else equal, we would have expected more intensive use of indivisible goods to be associated with greater inefficiency in the allocation of farm inputs.

5. Conclusion

Polygyny creates opportunities for both cooperation and competition. We find that co-wives are more likely to cooperate with one another than with their husband, and this is the result of selfish behavior rather than altruism. Because of the altruism between husbands and wives, the non-cooperative equilibrium does not differ much from the cooperative equilibrium, making the gains to cooperation greater for co-wives than for husband-wife pairs. Other female cultivators also seem to benefit from polygyny, suggesting that women, as a group, may have stronger preferences (lower costs) for cooperation. However, wives of the household head have significantly lower yields when there is another female cultivator present in the household. That is, cooperation among women appears to be influenced by identity/relationship as well as gender. We do not find evidence of the household head acting as a third-party enforcement mechanism for others' cooperative agreements, except perhaps in the context of vertically-extended households, in which the head may have greater influence on other cultivators.

Our results do not appear to be driven by differences in crop choice or the propensity for cooperation between monogamous and polygynous households. Moreover, when junior wives' plots are excluded from the estimation, we do not observe the same pattern, suggesting that the results are driven by interaction among co-wives, rather than fixed characteristics of polygynous households. We cannot definitively rule out the possibility of unobserved plot characteristics that are correlated with women's yields in polygynous households. However, we do not observe differences in women's fallow decisions across the two household types, and the positive effect of polygyny on other female cultivators rules out a simple story about better plot quality for subsequent wives.

Altruism can facilitate cooperation by reducing transaction costs, improving information flows and ensuring repeat interaction. However, we show that altruism can also inhibit cooperation by increasing payoffs in the non-cooperative equilibrium and/or limiting the scope for (credible) punishment. Although we use the unique case of polygynous households to test this hypothesis, there are many situations in which our findings may be relevant. For example, trade agreements between countries that have historically contentious relationships may be more generous than those between friendly countries because shared political interests ensure amicable trade negotiations, even in the absence of an explicit agreement, and create a degree of altruism. The old adage about never mixing business with family/friends also seems to be rooted in the problems created specifically by altruistic linkages. Our findings also imply that there may be some notion of optimal social distance – perhaps policy makers could achieve better outcomes by targeting groups of individuals who belong to the same social network but are not directly connected (*e.g.*, joint liability groups for microcredit, early adopters of new technologies, peer groups in school and the workplace).

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Table 1. Yield, Area and Primary Crop, by Plot, Household Type and Cultivator

	Monogamous				Polygynous			
	Household Head	Wife of Head	Other Male	Other Female	Household Head	Wife of Head	Other Male	Other Female
Yield (1000 FCFA)	126.29	49.15	142.93	124.82	85.47	59.50	145.51	71.57
	(651.6)	(267.0)	(498.2)	(434.7)	(341.3)	(208.4)	(358.6)	(250.6)
Average Plot Size	0.748	0.075	0.318	0.069	0.756	0.099	0.385	0.074
(hectare)	(1.24)	(0.13)	(0.54)	(0.12)	(1.14)	(0.14)	(0.48)	(0.10)
Observations	743	425	172	319	1156	1305	407	699
Percentage of Plots Planted with a Given Primary Crop								
Millet	27.05	9.18	25.00	7.52	18.94	11.42	13.51	6.58
White Sorghum	20.46	8.71	19.77	10.66	22.92	21.30	29.73	12.45
Red Sorghum	8.48	4.00	4.65	6.58	10.73	3.60	5.65	4.15
Maize	17.50	2.35	8.72	0.94	15.57	2.15	8.60	3.72
Groundnuts	4.44	18.35	8.72	-	6.14	18.62	10.32	-
Okra	0.81	21.65	1.74	18.18	0.35	15.33	-	17.02
Cotton	7.67	1.65	17.44	1.57	9.95	1.00	22.60	1.86
Earthpeas/Fonio	1.62	28.23	2.32	36.05	1.04	19.08	1.72	45.21
Others	11.97	5.89	11.62	18.48	14.38	7.51	7.88	9.01

Note: Standard deviations in parentheses. Data source: 1984-85 ICRISAT Burkina Faso survey. During 1984-85, the average exchange rate was approximately US $1 = 441 FCFA.

Table 2. Fixed Effects Estimates of the
Effect of Cultivator Characteristics on Plot Yield[a]

	(I)	(II)	(III)[b]	(IV)[b]
Gender (1=female)	-74.51 ***	-87.69 ***	-202.21 ***	-45.46
	(15.39)	(18.14)	(34.14)	(50.68)
Other Male		-40.49 **	-97.18 **	
		(20.41)	(39.38)	
Other Female		-12.77	-31.96	
		(15.37)	(31.39)	
Gender*No. of Kids				-23.28 **
				(10.27)
Gender*Polygynous			168.94 ***	41.94
			(40.09)	(64.85)
Other Male*Poly			86.50 *	
			(45.82)	
Other Female*Poly			28.71	
			(35.81)	
Gender*Poly*No. of Kids				22.15 *
				(11.62)
Observations	5230	5230	5230	4701

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include household-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence and location. Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a]Calculated as value of plot output per hectare.

[b]Includes interactions of all plot characteristics with the indicator for polygyny.

Table 3. Fixed Effects Estimates of the
Effect of Cultivator Characteristics on Plot Yield[a], Pairwise Groupings

	Head and Wives (I)	Other Cultivators (II)	Men Only (III)	Women Only (IV)	Head and Wives (V)
Gender (1=female)	-151.97 ***	-160.72 ***			-63.60
	(40.47)	(54.01)			(66.14)
Gender*Add'l Female[b]					-132.29 *
					(78.33)
Other Male			-74.78 **		
			(36.06)		
Other Female				18.16	
				(20.77)	
Gender*Polygynous	118.52 **	131.04 **			33.67
	(47.32)	(61.80)			(75.20)
Gender* Poly*Add'l Female					126.61
					(88.86)
Other Male*Poly			69.99 *		
			(42.05)		
Other Female*Poly				-18.87	
				(23.23)	
Observations	3629	1597	2478	2748	5230

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include household-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence, location and interactions with polygyny.
Data source: 1984-85 ICRISAT Burkina Faso Survey.
[a]Calculated as value of plot output per hectare.
[b]Additional Female equal to one if there is an other female cultivator present in the household.

Table 4. Panel Tobit Fixed Effects Estimates of Input Choice

Dependent Variable	Hours in Land Improvement[a] (Per Hectare) (I)	Paid Labor (1000 FCFA Per Hectare) (II)	Manure (1000 Kg Per Hectare) (III)	Length of Fallow[b] (IV)	Years Since Fallow (V)
Gender (1=female)	-12.89	-2.27	-2.69	-3.82 ***	-6.73 ***
	(26.20)	(2.29)	(3.79)	(1.04)	(2.20)
Other Male	-10.82	-5.97	-5.57	-2.12 *	-9.48 **
	(27.43)	(5.01)	(5.32)	(1.20)	(3.99)
Other Female	14.78	-10.03	15.45	-0.25	2.73
	(33.66)	(6.11)	(25.12)	(1.08)	(2.14)
Gender*Polygynous	24.99	2.25	-4.04	1.79	1.31
	(28.17)	(3.15)	(5.46)	(1.15)	(2.32)
Other Male*Poly	-34.60	0.39	-3.03	1.50	2.34
	(33.34)	(5.49)	(6.17)	(1.35)	(4.03)
Other Female*Poly	-90.97 *	8.99	-21.45	0.26	-3.21
	(48.54)	(6.53)	(25.91)	(1.20)	(2.33)
Mean	6.94	0.85	1.17	10.24	11.15
Mean if >0	62.74	5.30	9.30		14.58
Observations	5172	5230	5172	3076	4356

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include household-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence, location and interactions with polygyny.

Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a]Land improvement refers to clearing, burning and bund construction.

[b]Linear regression with fixed effects, as values are recorded conditional on fallowing.

Table 5. Fixed Effects Estimates of the Effect of Cultivator Characteristics on Plot Yield[a], Alternate Specifications

	No Plot Chars. (I)		1981-83 Only (II)		Cereals (III)		Non-Cereals (IV)	
Gender (1=female)	-125.67	***	-35.13	***	-51.61		-482.87	***
	(31.15)		(12.48)		(32.91)		(74.50)	
Other Male	-8.52		-30.30	**	-92.94	**	-83.43	
	(36.98)		(12.58)		(37.39)		(82.15)	
Other Female	-3.58		2.74		-70.15	*	-23.15	
	(31.80)		(15.60)		(36.17)		(51.06)	
Gender*Polygynous	128.65	***	1.66		10.01		452.14	***
	(35.90)		(14.88)		(38.45)		(86.90)	
Other Male*Poly	21.09		17.15		84.15	*	63.75	
	(43.12)		(15.25)		(43.47)		(95.29)	
Other Female*Poly	6.01		-23.77		68.88		17.24	
	(36.33)		(18.53)		(42.36)		(57.24)	
Observations	5230		4198		2923		2307	

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include household-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence, location and interactions with polygyny. Data source: 1984-85 ICRISAT Burkina Faso Survey.
[a]Calculated as value of plot output per hectare.

Table 6. Household Fixed Effects Estimates

	A. Plot Yield[a]			
Gender (1=female)	-84.00 ***			
	(25.04)			
Other Male	-10.51			
	(29.44)			
Other Female	38.79			
	(24.98)			
Gender*Polygynous	65.90 **			
	(28.59)			
Other Male*Poly	2.42			
	(34.90)			
Other Female*Poly	-43.90			
	(29.48)			
Observations	5230			

	B. Household Fixed Effect[b]			
Polygynous	3.76	12.11 *	15.96 **	15.40 **
	(4.00)	(6.30)	(7.60)	(7.66)
Total Hh Plot Area			0.50	1.00
			(1.05)	(1.10)
Capital Intensity[c]				-0.86
				(12.86)
Village/Time Fixed Effects	N	Y	Y	Y
Controls for Hh Composition[d]	N	N	Y	Y
Observations	268	238	238	231

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. Panel A includes household fixed effects, village-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence, location and interactions with polygyny.

Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a]Calculated as value of plot output per hectare.

[b]Estimated from specification presented in Panel A.

[c]Defined as share of total expenditure on agricultural inputs devoted to large capital goods (plows, scarifiers, weeders, ridgers, line tracers, seeders, sprayers, carts, tractors, draft animals).

[d]Number of individuals in nine age-sex categories, excluding females age 17-54.

Table 7. Fixed Effects Estimates of the Effect of Cultivator Characteristcs on Plot Yield[a], by Household Structure

	Polygynous =2 Wives (I)	Polygynous >2 Wives (II)	Vertical[b] (III)	Horizontal[c] (IV)
Gender (1=female)	-155.14 ***	-155.14 ***	-8.43	-516.33 ***
	(40.11)	(39.01)	(21.02)	(111.29)
Other Male	-56.35	-56.35	-18.55	-237.79 **
	(47.21)	(45.91)	(25.80)	(109.52)
Other Female	-16.02	-16.02	-22.94	-5.00
	(36.50)	(35.49)	(20.73)	(74.17)
Gender*Polygynous	136.33 **	154.32 ***	-9.68	518.79 ***
	(53.59)	(53.01)	(26.50)	(117.88)
Other Male*Poly	72.42	45.40	8.06	251.77 **
	(62.19)	(62.09)	(34.52)	(116.05)
Other Female*Poly	14.76	13.91	20.62	2.30
	(48.07)	(44.86)	(27.05)	(78.45)
Observations	3112	3142	2878	1823

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include household-crop-year fixed effects and controls for plot size (by decile), soil type, toposequence, location, and interactions with polygyny. Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a]Calculated as value of plot output per hectare.

[b]Excludes households that contain a brother of the household head.

[c]Includes only households that contain a brother of the household head.

Table 8. Share of Large Capital Investments in Total Agricultural Input Expenditures[a]

	Village, Year Fixed Effects (I)	IV with Village, Year Fixed Effects[b] (II)		IV with Village*Year Fixed Effects[b] (III)	
Polygynous	0.018	0.590**		0.592**	
	(0.044)	(0.209)		(0.209)	
Total Hh Plot Area	0.023 ***	0.008		0.008	
	(0.006)	(0.017)		(0.017)	
Observations	231	231		231	
First Stage		Polygynous	Total Area	Polygynous	Total Area
Dagari-Djula		0.707 ***	0.820	0.708 ***	0.841
		(0.188)	(1.175)	(0.190)	(1.172)
Bwa		0.201	4.138 ***	0.201	4.140 ***
		(0.146)	(0.912)	(0.147)	(0.909)
Other Ethnic Group		0.100	0.648	0.096	0.648
		(0.193)	(1.209)	(0.195)	(1.208)
Inherited Area		0.004	0.257 ***	0.004	0.260 ***
		(0.008)	(0.050)	(0.008)	(0.050)
Sargan Test of Overidentification		0.24		0.27	
(p-value)		(0.89)		(0.87)	
Cragg-Donald Statistic[c]		4.09		4.01	

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively. All specifications include controls for household composition.
Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a] Includes plows, scarifiers, weeders, ridgers, line tracers, seeders, sprayers, carts, tractors and draft animals.

[b] Polygynyous and total household plot area treated as endogenous. Instruments include ethnic group ("other" includes Rimaibe, Fulani/Peulh, Fulse/Kurumba, Mossi and Dafing/Marka; "Southern" Fulani/Peulh Mossi is the excluded category) and hectares of inherited land.

[c] Based on Stock and Yogo (2005).