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

Richard Akresh
University of Illinois at Urbana-Champaign

Joyce J. Chen*
The Ohio State University

Charity T. Moore
Harvard Kennedy School and Evidence for Policy Design

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Abstract
Altruism towards others can inhibit cooperation by increasing the utility players expect to receive in a non-cooperative equilibrium. To test this, we examine agricultural productivity in West African polygynous households. We find cooperation, as evidenced by more efficient production, is greater among co-wives than among husbands and wives. Using a game-theoretic model, we show this outcome can arise because co-wives are less altruistic towards each other than towards their husbands. We present a variety of robustness checks, which suggest results are not driven by selection into polygyny, greater propensity for cooperation among women, or household heads enforcing others' cooperative agreements.

JEL Codes: D13, D70, J12, O13, O55
Keywords: Altruism; Non-cooperative behavior; Household bargaining; Polygyny; Africa

* Corresponding Author: Department of Agricultural, Environmental and Development Economics, 324 Agricultural Administration Building, 2120 Fyffe Road, Columbus, OH 43210. Email: chen.1276@osu.edu; Phone: (614)292-9813. This work has benefited from comments from two anonymous referees, Ethan Ligon, Steve Wu, Tom Vogl, seminar participants at The Ohio State University, the University of Wisconsin-Madison, IFPRI, IUPUI and participants of the NEUDC Conference, Midwest International Economic Development Conference, and the ASSA Annual Meeting. The authors thank Christopher Udry for graciously sharing his data.

1. Introduction

Altruism towards others is thought to aid cooperation, as the inter-dependence of utility functions helps to align incentives and reduce transaction costs. Thus, we should be more likely to observe an efficient allocation of resources among family members because they are altruistic towards each other (Foster and Rosenzweig, 2001).[1] Pareto efficiency has indeed been confirmed in many studies (Browning and Chiappori, 1998; Chiappori *et al.*, 2002; Bobonis, 2009; Rangel and Thomas, 2012), but a growing body of empirical evidence suggests that households fail to achieve efficiency in production, particularly in the presence of transaction costs (Duflo and Udry, 2004; Goldstein and Udry, 2008; Dubois and Ligon, 2010). However, what is less clear from these studies are the factors that may be inhibiting cooperation.

We argue that altruism may, in fact, be a culprit by both increasing payoffs in the non-cooperative equilibrium (*i.e.*, reducing the gains to cooperation) and limiting the scope for enforcement (*e.g.*, because punishment directly harms the altruist). Building upon an earlier exploratory analysis (Akresh *et al.*, 2012), in this paper we provide a rigorous theoretical explanation for greater inefficiency in monogamous households compared to polygynous households. Furthermore, the analysis helps put into context the literature on failures of efficiency within the household and suggests a more nuanced view that social capital may not always enhance the scope for cooperation. We model a game involving three players with differing degrees of altruism towards each other and show that stronger altruism can actually encourage players to choose a non-cooperative strategy 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.

[1] Foster and Rosenzweig (2001) argue that in environments characterized by imperfect commitment family members can engage in more complete risk-sharing arrangements.

The model has several testable implications that we examine using data on agricultural production 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 in the same household planting the same crop in the same year. Based on the game-theoretic model, we focus on efficiency differences across monogamous and polygamous households because the larger role of shared public goods between husbands and wives, relative to co-wives, also suggests the husband-wife pair has a greater degree of altruism. The empirical evidence supports our model. We find more efficient production, a sign of greater cooperation, among co-wives in polygynous households than among husbands and wives; our point estimates suggest that wives have roughly 80% higher productivity in polygynous households. This finding highlights the possibility that altruism between parties can inhibit cooperation and lead to less efficient outcomes.

Building on the initial findings in Akresh *et al.* (2012), we present an expanded empirical specification, motivated by the theory, as well as a wide variety of robustness checks which allow us to better isolate the role of altruism over alternate explanations.[2] The main empirical concern is that women in polygynous households may be different in terms of unobservable characteristics. However, we provide suggestive evidence to show that potential endogenous selection into polygyny is not likely to be driving the results. Further, a number of robustness checks suggest results are not due to unobserved plot characteristics, endogenous crop choice, stronger preferences (lower costs) for cooperative behavior among women, or the household head serving as an enforcement mechanism for others' cooperative agreements. While our paper focuses on a context, the household, in which altruism is prevalent, altruism can similarly alter

[2] The expanded empirical specification differentiates other household members by gender and robustness checks include a detailed analysis of the underlying household fixed effects, a Tobit analysis of input use, and an analysis of investment choice and dynamic inefficiency.

incentives for cooperation among other parties, such as farmers within a cooperative or members of a rotating savings and credit association. Our findings therefore suggest a more nuanced view of social capital, one in which greater capital may actually lead to worse outcomes, to the extent that it reduces the gains to cooperation and/or weakens the scope for punishment.

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

2. Households in Burkina Faso

Intrahousehold dynamics in rural Burkina Faso are complex. Households cultivate several rain-fed, primarily subsistence crops on multiple plots, with each plot controlled by different household members. Married women often have access to private plots under their own control (Kevane and Gray, 1999).[3] Control over plots includes decision-making power over crop choice, timing and quantity of inputs, and output ownership (Guyer, 1986; Fafchamps, 1993; Udry, 1996). Women's access to land does not relieve them of their responsibility to contribute labor to household fields for joint production (Dey, 1997), which typically takes precedence over females' work on their own fields (van Koppen, 1990). While household heads are assumed to provide staple foods and cover medical expenses and school fees, in practice, females often have to supply their own crops as food or cover expenses. A single household may include multiple mother-child pairs (Thorson, 2002), but each husband/wife pair is viewed as a separate entity

[3] Wives' plot locations and sizes are determined by the husband, often at the time of marriage, while private plots of other household males are usually intended to allow the male to accumulate wealth to eventually break off to form his own household (Diallo and Nagy, 1986).

(Boye *et al.*, 1991).[4] Mother-child pairs typically live in their own nuclear units, and wives are responsible for primary caretaking activities for their own children. In general, each wife prepares daily meals for her own hearth-hold, a norm that suggests cooperation is not the default arrangement in at least some aspects of daily life.[5] Co-wives occupy various positions of power in the household, with the first wife typically holding the most power of the wives.

Much of the anthropological literature suggests that co-wife relationships are characterized by conflict. Jankowiak *et al.* (2005) find this to be true in almost all of the 69 polygynous cultures they review. 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 was suggested earlier by Becker (1981), who applied his Rotten Kid Theorem to polygamous households to suggest that cooperation could occur in productive activities, 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 in polygynous households could be an important method for them to manage demands on time and energy, even if they do not necessarily care about the utility of the other wives. 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 often exchange goods or services through involved agreements that are driven by local norms and customs (Saito, 1994).

[4] 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 hearth-holds comprised of widows, wives, wives of non-resident migrants, daughters-in-law, and single children (Thorson, 2002).

[5] Other female duties include retrieving water and wood, doing domestic chores, and income generating activities such as selling millet beer or food products (Diallo and Nagy, 1986). There is typically a rotation system among wives for preparing food for the husband.

Several papers test for productive efficiency within African households, although none focus on the distinction between monogamous and polygynous households. Peterman *et al.* (2011) find lower productivity on female-controlled plots in Uganda and Nigeria, even after controlling for crop choice, agricultural inputs, socioeconomic background, and household fixed effects. Pareto inefficient outcomes have also been observed in fallow times in Ghana, a result attributed to the role of ambiguous property rights and individual political power (Goldstein and Udry, 2008). Kazianga and Wahhaj (2013) reject Pareto efficiency among the household head, junior males, and females in rural Burkina Faso, but they do not consider differences across monogamous and polygynous households. As households in the region are often organized along gendered production spheres, observation of non-cooperative outcomes is not entirely surprising.

Using International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) data, Udry (1996) finds that, among similar 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. His analysis reveals that households use inputs inefficiently: female-controlled plots use less male labor and manure, suggesting that husband-wife cooperation to reallocate household resources would yield larger output for the family. Akresh (2008) shows that these production inefficiencies within households are muted in the face of adverse shocks, perhaps because the gains to cooperation are larger when household food security is threatened. Nevertheless, when Rangel and Thomas (2012) test whether household consumption decisions are Pareto efficient, they cannot reject efficiency in West African households.

Inefficiency within the household has also been found along other dimensions. Mammen (2009) finds some education-related outcomes are worse for children of junior wives in Cote d'Ivoire, but she cannot reject a collective bargaining model that allows credit constraints.

Finally, in their examination of child survival in Mali, Kazianga and Klonner (2009) cannot reject efficiency in monogamous households. However, they find evidence of differential child survival for junior wives and suggest that co-wife competition and the junior wives' weaker bargaining position drive this inefficient result.

3. A Model of Altruism and Cooperation

The notion that altruism can reduce efficiency was first formally suggested by Bernheim and Stark (1988). They note that, when altruism improves the static non-cooperative outcome, it also weakens the severity of punishments, making cooperative behavior and the efficient allocation of resources more difficult to sustain, a kind of "Samaritan's dilemma" (Buchanan, 1975). Our model follows this premise but allows 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 empirically test the model, we can control for features of the household that may be correlated with altruism but also facilitate cooperation independently, such as capacity for monitoring/punishment or expectations about future interactions. We show that, when altruism improves the non-cooperative outcome, it also reduces the gains to cooperation *ceteris parabis*. We then show, more importantly, that altruism can reduce the scope for punishment, making cooperative agreements either unsupportable or vulnerable to renegotiation when commitment is imperfect. In Section 3.1, we lay out the basic utility and production functions. We then describe the stage game (Section 3.2) and the repeated game with limited commitment (Section 3.3), as well as alternate forms of player heterogeneity (Section 3.4).

3.1 Theoretical Framework

Consider a game involving three players. In the context of Burkinabé households, we can think of the players as a husband and two wives, and this model provides a framework – the first, to our knowledge – with which to analyze a polygynous agricultural household.[6] Each individual i has preferences over own consumption of two goods (*x* and *z*) and may derive utility from other households members' (*j* and *k*) consumption of *z* as well. The *x* good represents private consumption of a composite good purchased in a perfectly competitive market, while the *z* goods represent unique public goods produced by each member. To abstract from the labor-leisure choice, we assume that each individual is endowed with one unit of labor that he/she supplies inelastically. Labor, therefore, does not enter the utility function.

$$U_i = U_i(x_i, z_i, z_j, z_k) \; \forall i \in \{1,2,3\}$$

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 of the other players. The notion of a good which one has preferences over but no direct control is consistent with many formulations of altruism (*e.g.*, parents' preferences for children's future earnings or preferences for the well-being of individuals in another country/class). This basic framework and implications can, therefore, be applied to a variety of contexts.

On the production side, each individual operates one plot of agricultural land and retains control of all output. All individuals have access to the same production technology but are endowed with heterogeneous plot characteristics (*e.g.*, size, soil type, toposequence), denoted *A,* that affect the optimal input mix, and the labor inputs of other players may be complements or imperfect substitutes for own labor. Denote each individual's production function as follows

$$Y_i = Y(N_i^i, N_j^i, N_k^i; A_i).$$

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[6] Note, however, that this is not a model of polygynous households *per se*. In particular, this model will not apply to polygynous households in which the "separate spheres" assumption, discussed below, does not hold.

where N_i^j represents player i's labor allocated to player j's plot. We assume that each individual has complete control of his/her labor allocation. The z-goods are produced by transforming x-goods at a fixed price that is unaffected by labor allocation choices.[7]

Farm production is the only source of income, and the price of output is normalized to one. Therefore, in the absence of any transfers, the budget constraint for an individual is

$$x_i + p_i z_i = Y_i$$

where *x* is denominated in terms of the agricultural good and p_i denotes the relative price of player i's public good. It is important to note that each *z* good is unique, with a unique "buyer". It is this feature of the *z* good that drives the main implications of the model because it implies that the altruist cannot purchase it directly. More generally, our model is driven by the fact that the altruist and the subject face different prices for the same good, whether implicitly (*i.e.*, one player must purchase it from another) or explicitly (*i.e.*, $p_i \neq p_j$).[8] Thus, even with interdependent preferences ($U_{j\neq i}$ enters the utility 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 others.[9] This is similar to the separate spheres assumption in Lundberg and Pollak (1993) 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 (*e.g.*, aesthetic appearance of spouse) and other elements being

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[7] More realistically, we could specify production functions for the *z* goods as well, which would allow each individual to influence others' public good purchases both directly, via farm income, and indirectly, via changes in the shadow price of the public good. However, given that both effects operate in the same manner, this complication of the model provides little additional insight.

[8] Note that, if both players can purchase the public good at the same price and both make strictly positive contributions, an efficient allocation of resources can be achieved even without explicit cooperation among players (Warr, 1983; Bergstrom *et al*., 1986).

[9] In other words, at the point where utility is maximized, the marginal utility derived from others' consumption is less than the marginal utility derived from own consumption: $\partial U_i / \partial U_{j\neq i} < \min[\partial U_i / \partial x_i , \partial U_i / \partial z_i]$.

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, such that each individual possesses the ability to purchase some, but not all, *z*-goods directly.

3.2 Basic Stage Game

The action space for each player includes own consumption and labor allocations to his/her own plot and other players' plots $\{x_i, z_i, N_i^i, N_i^j, N_i^k\}$ where N_i^j represents player *i*'s labor allocated to player *j*'s plot. Note that we use subscripts to denote ownership and superscripts to denote allocations to other players. Although the action space is continuous, we can define two strategy types: *cooperate* and *do not cooperate*. Cooperation is typified by maximization of a joint objective function (with either 1 or 2 of the other players), while all other actions are deemed non-cooperative. For simplicity, we further limit attention to a single best response non-cooperative strategy that is consistent with maximization of the individual's objective function, taking the actions of others as given. Multiple equilibria are clearly possible with this general set-up, and the feasible equilibria are highly dependent on how payoffs and key parameters are defined, to which we now turn.

When all three players cooperate, they first maximize joint output across all plots.[10]

$$\max_{N_i^i, N_i^j, N_i^k, N_j^i, N_j^j, N_j^k, N_k^i, N_k^j, N_k^k} Y(N_i^i, N_j^i, N_k^i; A_i) + Y(N_i^j, N_j^j, N_k^j; A_j) + Y(N_i^k, N_j^k, N_k^k; A_k) \qquad [1]$$

$$\text{subject to } N_i^i + N_i^j + N_i^k = 1, N_j^i + N_j^j + N_j^k = 1 \text{ and } N_k^i + N_k^j + N_k^k = 1$$

They then maximize a joint utility function, in order to coordinate choices of *z*

$$\max_{x_i, z_i, x_j, z_j, x_k, z_k} \lambda_i U_i(\cdot) + \lambda_j U_j(\cdot) + (1 - \lambda_i - \lambda_j) U_k(\cdot)$$

subject to $x_i + x_j + x_k = Y_i + Y_j + Y_k - p_i z_i - p_j z_j - p_k z_k$, $U_i \geq \widehat{U_i}$, $U_j \geq \widehat{U_j}$ *and* $U_k \geq \widehat{U_k}$

[10] With inelastic labor supply, production and consumption decisions can be treated as separable and sequential.

where ^ denotes the maximum utility each player can obtain outside the cooperative agreement. The λ parameters determine how the gains from cooperation are distributed given the players' outside options. Based on this optimization, the cooperative agreement then stipulates plot-specific labor allocations[11] for each player, as well as quantities of *x* and *z* for each player.

When only two players ($s \in \{i, j\}$) cooperate, the pair again maximizes joint output and a weighted utility function, now treating the labor allocations and consumption choices of the third player (k), denoted by *, as fixed.

$$\max_{N_i^i, N_i^j, N_j^i, N_j^j} Y(N_i^i, N_j^i, N_k^i; A_i) + Y(N_i^j, N_j^j, N_k^j; A_j) \qquad [2]$$

subject to $N_i^i + N_i^j + N_i^k = 1, N_j^i + N_j^j + N_j^k = 1$ and $N_k^s = N_k^{s*}(N_i^k, N_j^k; \mu_k, p_k, A_k)$ for $s = i,j$ where μ represents parameters of the utility function. They then maximize a joint utility function, taking as given the provision of z_k by the third player, in order to coordinate their choices of z [12]

$$\max_{x_i, z_i, x_j, z_j} \lambda U_i(\cdot) + (1 - \lambda)U_j(\cdot)$$

s.t. $x_i + x_j = Y_i + Y_j - p_i z_i - p_j z_j$, $U_i \geq \widehat{U}_i, U_j \geq \widehat{U}_j$ and $z_k = z_k^*(N_i^k, N_j^k, N_k^k; \mu_k, p_k, A_k)$

The cooperative agreement again specifies plot-specific labor allocations for each player as well as quantities of *x* and *z* for each player.

Finally, when a player does not cooperate with any other players, he/she chooses consumption and labor allocations to maximize his/her own utility, subject to the income generated on his/her plot and taking into account the other players' response functions (or cooperative agreements):

[11] Labor-sharing is the primary source of cooperation in our model. However, the model's key implications are unaffected by the existence of labor markets, provided those markets are imperfect, as is likely the case in our empirical setting (Fafchamps, 1993).

[12] Since co-wives have no shared goods and their utility functions are independent, maximization of a joint utility function is equivalent to co-wives separately maximizing their own utility functions.

$$\max_{N_i^j, N_i^k, z_i} U_i(\cdot) \text{ subject to } x_i = Y_i\left(1 - N_i^j - N_i^k, N_j^i, N_k^i; A_i\right) - p_i z_i$$

where $N_s^i = N_s^{i^*}(N_i^s, N_{-s}^s; \mu_s, p_s, A_s)$ and $z_s = z_s^*(N_i^s, N_j^s, N_k^s; \mu_s, p_s, A_s)$ for $s = j, k$

Note that, because labor is supplied inelastically, consumption of *x* is fully determined by the production function and the budget constraint.

Before discussing possible equilibria, we highlight the ways in which altruism affects both payoffs and the range of credible punishments that may be used to enforce cooperation.

Proposition 1. The gains to cooperation for player *i* are decreasing in the degree of altruism player(s) $j \neq i$ has (have) toward player *i*, all else equal.

Corollary 1. An altruistic player will engage in a greater degree of labor sharing even in the absence of a cooperative agreement, all else equal.

Proof. See Online Technical Appendix. ▪

To see the intuition behind this corollary, consider an individual *i*'s maximization problem in the absence of a cooperative agreement:

$$\max_{N_i^j, N_i^k, z_i} U_i(x_i, z_i, z_j, z_k) \text{ subject to } x_i = Y_i\left(1 - N_i^j - N_i^k, N_j^i, N_k^i; A_i\right) - p_i z_i$$

where $N_s^i = N_s^{i^*}(N_i^s, N_{-s}^s; \mu_s, p_s, A_s)$ and $z_s = z_s^*\left(N_i^s, N_j^s, N_k^s; \mu_s, p_s, A_s\right)$ for $s = j, k$

with first order conditions

$$\frac{\partial U_i}{\partial z_s}\frac{dz_s^*}{dN_i^s} - \frac{\partial U_i}{\partial x_i}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_s^i}\frac{dN_s^{i^*}}{dN_i^s}\right) = 0 \text{ for } s = j, k \text{ and } \frac{\partial U_i}{\partial z_i} - p_i\frac{\partial U_i}{\partial x_i} = 0$$

To consider differing degrees of altruism, we define a scalar $\theta \in [0,1]$ to represent the value of others' consumption relative to own consumption as follows.

$$\frac{\partial U_i}{\partial z_s} = \theta_s \frac{\partial U_i}{\partial z_i} \text{ for } s = j, k$$

Combining this with the first order conditions yields

$$\theta_s = \frac{1}{p_i}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_s^i}\frac{dN_s^{i^*}}{dN_i^s}\right)\Big/\frac{dz_s^*}{dN_i^s} \text{ for } s = j, k \qquad [3]$$

With a declining marginal product of labor, stronger altruism – a larger value of θ – implies a smaller amount of own labor used for own production (higher marginal product).[13] Moreover, with z_s increasing in N_i^s, a larger amount of labor will be given to player s (N_i^s) in order to equalize marginal utilities, *even in the absence of explicit cooperation*. This is consistent with the anthropological literature (Dey 1997), which finds that husbands and wives, who would tend to have stronger altruism, pool some resources even in the absence of an explicit cooperative agreement whereas co-wives do not. Altruistic players derive utility from the consumption of others, and they can increase the consumption of others through exchange.

Corollary 2. Even with labor sharing, agricultural production will not be efficient in the absence of explicit cooperation.

Proof. See Online Technical Appendix. ▪

Corollary 2 is a direct result of the separate spheres assumption, which prevents each player from directly purchasing the public goods within the other players' "spheres" of influence. Thus, although labor sharing is mutually beneficial, purchases of the sphere-specific *z*-goods cannot be coordinated. Consequently, in the absence of explicit cooperation, gains in productivity cannot be fully translated into utility gains, and there will be too little labor-sharing in equilibrium.

Proof of Proposition 1. From Corollary 2, we see that altruism of player *j* for player *i* induces *j* to share labor with *i* even in the absence of cooperation, and the degree of labor sharing is increasing in the degree of altruism. However, from Corollary 2, we also know that labor sharing remains too low in the absence of a cooperative agreement – *i.e.*, there are additional gains to

[13] Note that, if player *s* is also altruistic towards player *i*, he/she will provide a larger amount of labor to player *i* (N_s^i) as well, sustaining even greater labor-sharing.

cooperation. Note that the gains to cooperation, the surplus generated above and beyond the non-cooperative equilibrium, are less than the gains to labor-sharing, which may occur with or without explicit cooperation. By holding constant the total gains to labor-sharing, we can see that greater altruism, via greater labor-sharing in the absence of cooperation, in fact reduces the quantity of labor that will be reallocated under a cooperative agreement. To close the proof, we show that, if all goods are separable in utility, then the quantity of z_j is independent of the altruism j feels toward i, in both the cooperative and non-cooperative equilibriums (see Online Technical Appendix for details). Therefore, altruism from player j does not provide player i with any additional consumption of z_j, and the gains to cooperation for i are unambiguously lower when he/she is interacting with an altruistic player. ▪

3.3 Repeated Game with Limited Commitment

In the absence of transaction costs, a Pareto efficient outcome is feasible, with all three players cooperating and pooling labor. However, 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 the labor allocated to others' plots as well as any implicit transfers needed to achieve the agreed upon quantities of x and z for each player. Clearly, with limited enforcement, cooperation cannot be sustained in a one-shot (or finitely repeated) game. But, if the stage game is repeated infinitely and players are sufficiently forward-looking, then a trigger strategy may be used to sustain cooperative agreements. However, altruism will make such an equilibrium more difficult to sustain by limiting the scope for punishment and increasing the gains to deviating from the cooperative equilibrium.

Proposition 2. Altruism of player i towards other player(s) $j \neq i$ reduces the severity of punishments that can be invoked by player i to sustain cooperation, all else equal.

Proof of Proposition 2. First, consider the case of Nash reversion (Friedman, 1971), in which players revert to their non-cooperative Nash strategies for a predetermined number of periods during the punishment phase. Proposition 1 shows that, in the Nash equilibrium (*i.e.*, in the absence of explicit cooperation), the amount of labor provided by player *i* to player *j* is increasing in *i*'s altruism towards *j*. Then, under Nash reversion, the severity of the punishment (*i.e.*, the amount of labor withheld) imposed by player *i* is decreasing in the degree of altruism towards player *j*.

Alternatively, we can consider a min-max punishment strategy, in which a deviation by player *j* against player *i* is punished by setting player *i*'s labor allocation to player *j*'s plot equal to zero until player *j* again behaves cooperatively. If player *i* is altruistic towards player *j*, this involves less labor-sharing and will be a more severe punishment than Nash reversion. However, min-max punishment is not weakly renegotiation-proof (Abreu *et al*. 1993) because the payoff for player *i* during the punishment phase will be less than the payoff in the Nash equilibrium. To see this, first recall Corollary 1, which shows that, for an altruistic player, it is optimal to share labor with others, even in the absence of a cooperative agreement. Thus, the punishment imposed by player *i* (zero labor sharing) results in a utility loss, even if player *j* continued to play the Nash equilibrium strategy. However, the punishment both reduces the income of player *j* and removes any incentive for *j* to internalize the externalities associated with his/her public good consumption, leading to a lower level of z_j, relative to the Nash equilibrium. This further reduces player *i*'s utility, precisely because he/she is altruistic towards the other player.

Once in the punishment phase, both players would be better off playing the Nash equilibrium.[14] Because of the altruistic linkage between the two, the punishing player's utility is

[14] As a result of this temptation to renegotiate, the husband also cannot achieve a cooperative outcome by "delegating" the enforcement of cooperative agreements to a non-altruistic third party.

increasing in the deviating player's payoff and, therefore, there does not exist a tit-for-tat punishment that rewards one player while min-maxing the other. We could, instead, consider a tit-for-tat punishment in which player *i* receives at least his/her Nash payoff, including the quantity of z_j that would have been obtained in the Nash equilibrium. This would come at the expense of player *j*'s own private consumption, so he/she will be tempted to renege in the punishment phase. But, if he/she were to do so, the strongest punishment that could be invoked would be the min-max strategy, at which point both players would again prefer to renegotiate. Thus, this equilibrium would also unravel with renegotiation.[15] ▪

Proposition 3. Over the range of feasible parameter values, players with stronger altruistic preferences will be less likely to cooperate than those with weaker altruistic preferences.

Proof of Proposition 3. From Proposition 1, we know that altruism from others reduces the gains to cooperation and, from Proposition 2, we know that altruism towards others reduces the scope for punishing non-cooperative behavior. Thus, for any payoff values, the necessary conditions for a cooperative equilibrium are less likely to be satisfied for pairs with stronger altruistic preferences. Note also that mutual altruism is not required to sustain this result; either altruism from or towards the other player is sufficient. ▪

Although altruism can align incentives, facilitate repeat interactions, and improve monitoring/enforcement mechanisms, it also increases exchange behavior in the non-cooperative equilibrium. As a result, the gains to cooperation are not strictly increasing with altruism, and we obtain the above Proposition 3. This stands in contrast with Foster and Rosenzweig (2001), which finds that altruism increases cooperation. To reconcile this with our results, note that they assume the Nash equilibrium involves zero sharing at low levels of altruism. Therefore, in this

[15] Note that these results do not depend on mutual altruism, but only on the altruism of the punishing player towards the deviating player.

range, payoffs in both the non-cooperative equilibrium and the punishment phase are independent of altruism, and both the gains to cooperation and the ability to enforce cooperation are increasing in the degree of altruism. Moreover, this assumption allows them to consider a weaker form of cooperative behavior in which exchange behavior exceeds what would be obtained in the non-cooperative equilibrium but still falls short of the first-best efficient outcome.[16] In contrast, in our model, some exchange will always occur in equilibrium, even in the absence of explicit cooperation, for any non-zero value of altruism. Therefore, the gains to cooperation and the severity of the punishment may be decreasing in the degree of altruism, making it more difficult for altruists to enforce cooperation. Note that, in both models, sharing increases with the players' ability to commit to labor/income sharing arrangements, consistent with our Corollary 1. However, the key difference between our model and that of Foster and Rosenzweig is the effect of altruism on the ability to enforce cooperative agreements.[17]

In summary, altruism – both from and towards others – reduces the set of parameter values for which cooperation is a stable equilibrium, as outlined in Propositions 2 and 3. First, altruism from others facilitates exchange even in the absence of an explicit agreement, which reduces the gains to cooperation. Second, altruism towards others reduces the severity of any punishment that may be imposed. Thus, in the presence of limited commitment, a non-altruistic party is better able to prevent deviations from the cooperative agreement and, therefore, better able to sustain cooperation. Moreover, even if a player is willing to impose severe punishments,

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[16] Additionally, Foster and Rosenzweig (2001) model altruism as preferences over the other player's utility, whereas we model it as preferences over the other player's consumption. The former allows the altruist to directly influence the good he/she derives utility from whereas, in the latter formulation, the altruist's ability to do the same is mediated by the other player's preferences. Thus, in Foster and Rosenzweig, the altruist is better able to internalize his actions, leading to greater gains to cooperation even in the presence of altruism.

[17] Note that sharing differs from cooperation; sharing entails voluntarily providing labor on plots cultivated by other player(s), whereas cooperation entails maximization of a joint objective function. And, because there are "separate spheres" such that players cannot contribute directly to all public goods, sharing and cooperation will only be equivalent if each player is fully altruistic – i.e., values other players' utility equally with her/her own consumption.

these will not be renegotiation-proof because altruism makes it impossible to punish the deviating player while rewarding the cooperating player. Consequently, payoffs in the punishment phase will be Pareto-dominated by the Nash equilibrium. Thus far, our results may also be applied without qualification to the two player case. In order to establish an equilibrium in the three player case, we must consider the formation of coalitions in establishing equilibria.

Proposition 4. If players i and j have weaker altruistic preferences towards each other than towards player *k*, then there exists an equilibrium in which players i and j cooperate with each other but do not cooperate with player *k*.

Proof of Proposition 4. It follows from Proposition 1 that, because the altruism of player *j* towards player *i* is weaker than the altruism of player *k* towards player *i*, the gains to player *i* from cooperating with player *j* will be greater than the gains from cooperating with player *k*. Additionally, from Proposition 2, we know that stronger altruism between players *i* and *k* and players *j* and *k*, respectively, reduces the range of credible punishments player *k* may use to enforce cooperative agreements. Therefore, there exist production technologies and utility functions such that

$$\left(\hat{V}_s - V_s'\right) > \left(\tilde{V}_s - V_s'\right), \hat{V}_s > \widehat{D}_s + \beta V_s' \ and \ V_s^* \leq D_s^* + \beta \hat{V}_s \ for \ s = i, j$$

where *V* represents the continuation payoff, ^ denotes cooperation between i and j, ˜ denotes cooperation between *s* and *k*, ′ denotes the fully non-cooperative equilibrium, * denotes the fully cooperative equilibrium, *D* denotes the one-shot gains to deviating, and *β* is the discount rate. The first equation indicates that neither player i nor j would prefer to cooperate with only player k instead. The second equation states that the payoff received when players i and j cooperate exceeds the payoff to deviating and then being punished[18], and the third equation indicates that, while there may be gains to cooperating additionally with player *k*, they do not exceed the gains to deviating from such an agreement. Players *i* and *j* cannot receive a higher payoff by cooperating with only player *k* instead, and player *k* cannot receive a higher payoff by cooperating with either *i* or *j*, given that both will renege. For the discussion of coalition-proofness, please see the Online Technical Appendix. ▪

Note that the equilibrium conditions above refer to the gains to cooperating with player *k*, conditional on cooperation between players *i* and *j*. It is possible that the cooperation between *i* and *j* reduces the marginal benefit of cooperating with player *k*, crowding out a cooperative agreement that would otherwise have been feasible. However, this result is still fundamentally driven by altruism, as it is the weaker altruism between players *i* and *j* that induces cooperation of *i* with *j* over player *k*, and vice versa. Returning to the case of polygyny, if the altruism between husbands and wives is stronger than that between co-wives, then there exists an equilibrium in which co-wives cooperate with each other but not with their husband. This result is sensitive to our separate spheres-type assumption that, based on the anthropological evidence discussed above, appears to be an accurate representation of Burkinabé households.

3.4 Alternate Forms of Heterogeneity

Here we consider other types of heterogeneity among players that can generate the same equilibria – *i.e.*, cooperation among some but not all players. First, players may face heterogeneous costs associated with cooperation, independent of the degree of altruism. In lab experiments, women display more socially-oriented behavior than men (Eckel and Grossman, 2008) suggesting they face lower costs (or, symmetrically, higher returns) to cooperating. In the

[18] To present the most stringent equilibrium conditions (and for ease of notation), we have assumed that the punishment phase lasts indefinitely. However, the proposed equilibria could still exist, albeit for a more limited range of parameter values, with a punishment phase lasting only a predetermined number of periods.

context of our model, this would be represented as a fixed cost/benefit associated with cooperation. Then, holding altruism constant, co-wives would be more likely to cooperate than husbands and wives. But, in this case, we would expect greater cooperation among all women in the household. In contrast, our model predicts greater cooperation among co-wives specifically because they have weaker altruism than husbands and wives while also benefiting from the features of conjugal relationships that tend to facilitate cooperation (*e.g.*, repeat interaction, lower cost monitoring).

Alternatively, the household head (husband) may be able to act as an enforcement mechanism, effectively eliminating commitment problems. If, however, he can only do so for others' cooperative agreements then, holding altruism constant, we would again observe greater cooperation among co-wives than among husbands and wives. To see this in the context of our model, we can consider one player as the household head, who both has limited ability to commit and faces other players with limited commitment, and the other two players as household members who can fully and costlessly commit to each other. However, with this formulation, we would expect to observe greater cooperation among other household members as well, to the extent that the head can enforce contracts for those parties.

Finally, we consider heterogeneity in production functions such that cooperation yields larger gains for some player pairs than others. For example, with heterogeneous labor inputs, certain pairs may enjoy stronger production complementarities. However, note that in the specific context of polygyny, the highly gendered division of farm tasks suggests that labor inputs from opposite gender players will be more productive than those from same gender players. This would tend to lead to greater cooperation among husbands and wives than among co-wives, while our altruism hypothesis predicts the opposite.

Our model shows that cooperation between altruistic parties can be more difficult to sustain than that between purely self-interested parties. We test this using detailed plot-level data on agricultural production, which allows us to estimate productive efficiency and infer cooperation and coordination of inputs across plots controlled by different players. Polygyny represents an additional potential collaborator in the household with stronger altruistic preferences towards the husband than the co-wife, and our model predicts that the husband-wife yield gap will be lower in polygynous households than in monogamous households, as summarized in the following proposition.

Proposition 5. When players cooperate, inputs are allocated efficiently across plots, and cultivator characteristics have no effect on yield conditional on technology, plot characteristics, and production shocks. Then, if altruism between husbands and wives is stronger than between co-wives, the husband-wife yield differential will be smaller in polygynous households than in monogamous households.

Proof of Proposition 5. By definition, cooperation leads to an efficient allocation of the inputs controlled by cooperating players across the plots cultivated by those players (see equations [1] and [2]), and the efficient allocation of inputs requires marginal products to be equalized across plots. Then, when all players have access to the same technology, marginal products must be independent of cultivator characteristics, all else equal (see Udry, 1996). If husbands, wives and co-wives are all cooperating, then we should observe no yield differential between husbands and wives. Alternatively, if no spouses are cooperating, we should observe the same or perhaps larger husband-wife yield differential in polygynous households. And finally, if the likelihood of cooperation is decreasing in the degree of altruism and co-wives are less altruistic towards each other than are husbands and wives, then co-wives will be more likely to cooperate with each other than with the husband. We would, therefore, observe an improvement in wives' yields relative to the husband, resulting in a smaller husband-wife differential in polygynous households than in monogamous households. ▪

4. Empirical Application

We estimate plot yield as a function of plot 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.[19] 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 with the same crop by members of the same household in a given year. Yield Q for plot i, planted with crop c, in year t, in household h is 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 $\boldsymbol{X}$ 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)[20] are allowed to differ for polygynous households via an interaction with an indicator for polygyny (*Poly*), with $\gamma_k = \gamma_k^0 + (Poly_{ht} * \gamma_k^P)$ for $k = G, OM, OF$.[21] Note that our empirical tests focus on *efficiency* within the household rather than productivity. Clearly, monogamous and polygynous households, as well as individual cultivators within those households, may differ in

[19] Toposequence refers to the plots' location and topography, indicating if the specific plots are located on the uppermost portion of a hill, adjacent to the uppermost portion, on the mid-slope, or adjacent to a swamp.
[20] Unfortunately, the data do not link agricultural plots to individual identifiers, so we are unable to identify specific characteristics about a plot's cultivator (age, senior/junior wife status, or specific relationship to the head or to other household members).
[21] Akresh *et al.* (2012) use a similar specification but do not differentiate "other" cultivators by gender.

their *levels* of productivity, but the degree of cooperation will be evidenced by the efficiency with which inputs are allocated, given household-specific constraints.

The interaction of polygyny and cultivator characteristics indicates how the variation in yields between cultivators differs across monogamous and polygynous households. For a negative coefficient on gender, a positive coefficient on the interaction of polygyny and gender then indicates that the husband-wife yield differential is smaller for husbands with multiple wives. We can attribute this difference to the causal effect of additional wives 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 Sections 4.3-4.5, we test the robustness of this approach by considering selection into polygyny, unobserved differences in plot quality, and crop choice.

4.1 Data and Main Results

We use the 1984-85 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). Of the households, 50.7 percent are polygynous, defined as the household head having two or more wives. Of these households, 56% have two wives, 33% have three wives, and 11% have four or five wives.[22] For household heads and other female non-wife cultivators, average yields are lower in polygynous households, although average plot size is similar (Table 1). For wives and other males, yields are slightly higher and plots somewhat larger

[22] We classify households as polygynous based on the number of wives in the household roster because household heads were not asked about marital status. If there are wives of the head living outside the household at the time of the survey, we could mistakenly classify the household. However, migration of wives is rare. In our data, only 6% of migrants are wives and, of these, the majority are listed in the household roster. In addition, we use the 1993 Demographic and Health Survey to construct both definitions of polygyny (reported and observed number of wives) and find only a 2 percentage point difference in the implied polygyny rate, further suggesting that our classification is accurate.

in polygynous households. The percentage of plots planted with a given crop differs, with polygynous wives devoting a larger fraction of plots to millet and sorghum (staple crops) and a smaller percentage to okra and earthpeas/fonio. This suggests polygynous households may use a different cropping strategy, although some of the difference may be due to agro-climatic variation that coincides with differences in polygyny rates across Burkina Faso.[23]

Column I of Table 2 replicates the household-crop-year fixed effects specification in Udry (1996) using only 1984-85 data.[24] We find a negative and significant effect of cultivator gender on plot yield, but the magnitude is larger than in Udry. In part, the difference is due to the ICRISAT survey design. In 1981-83 (the data used in Udry's analysis), detailed information was collected for a sub-sample of plots (all cereal, cotton, and root crops, but only one plot of the household head and senior wife for legumes/garden crops), but information for all plots was collected in 1984-85 (Matlon 1988). Because we are interested in the yields of other cultivators, particularly co-wives, and wives devote a greater share of plots to legumes/garden crops, the 1981-83 data suffer from significant sample selection and are therefore excluded from our analysis. In column II, we add indicators for other male and other female cultivators within the household to isolate the yield differential between husbands and wives. The coefficient on gender is still statistically significant and similar in magnitude. Other male cultivators have significantly lower yields relative to the household head, suggesting inefficiencies in intrahousehold allocation arise along dimensions other than gender. In column III, we add interactions of polygyny with cultivator characteristics and, to allow for potential differences in

[23] 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).

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

technology across household types, with all plot characteristics.[25] Relative to the head, wives in polygynous households have significantly higher yields than wives in monogamous households, consistent with greater cooperation among co-wives than among husbands and wives.

Our model predicts that the likelihood of cooperation is decreasing in the degree of altruism between players. Thus far, we have used wife-wife and husband-wife relationships to represent differing degrees of altruism. However, if altruism is, at least in part, based on children as a shared public good, then we should also see greater cooperation (smaller yield differences) among couples who have fewer children and, therefore, fewer shared goods. Consistent with this, the interaction of gender and the number of children of the head currently living in the household is negative and significant (column IV), 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 of gender is also small and not significant. But the triple interaction term is positive and statistically significant and offsets the negative effect of children on women's yields in monogamous households. The opposite sign for polygynous households suggests the 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 cannot do the same with their husbands. This specification provides additional suggestive evidence supporting the altruism story over other explanations. However, we do not rely too heavily on these results, as fertility

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

may be correlated with efficiency or cooperation in the household, and social norms may constrain the amount of childcare that men perform.

4.2 Alternate Hypotheses

The ideal test of our model would be to directly compare yield differentials between co-wives with those between husbands and wives. Unfortunately, our data do not allow us to identify cultivator characteristics beyond relationship to the household head and, while a smaller yield differential between husbands and wives is consistent with greater cooperation among co-wives, this pattern could arise for other reasons as well. To explore the alternate hypotheses discussed in Section 3.4, we can look at yield differences between the household head and other (non-wife) cultivators. First, if women face a lower cost for (receive greater utility from) cooperation, then the presence of additional women, due to polygyny, should facilitate greater cooperation among all women and reduce differences in yields between not only husbands and wives but also between wives and other female cultivators. Alternatively, if cooperation among co-wives is due to the ability of the household head to act as a third-party monitor/arbitrator of cooperative agreements, then we should observe smaller yield differences between not only husbands and wives but also between other cultivators in the household.

We face one additional challenge in interpreting our results, given our inability to directly test for efficiency among co-wives. Namely, a smaller husband-wife yield differential may be indicative of either greater cooperation between co-wives or greater cooperation between husbands and wives. That is, polygyny could introduce an equilibrium (*e.g.*, by relaxing the total labor constraint) in which husbands cooperate with each wife but co-wives do not cooperate with each other. In this case, husbands and wives would both exhibit an increase in yields with polygyny, but a significant husband-wife yield differential would still be evident as a result of non-cooperation among co-wives (*i.e.*, husbands have exploited all available opportunities for cooperation with spouses whereas wives have not). However, in this case, we should observe not only a smaller yield differential between husbands and wives but also higher yields for the husband relative to other cultivators. Conversely, an improvement in other cultivators' yields, relative to the household head, suggests that wives cooperate more with each other than with the head, and the head himself does not enjoy any efficiency gain with polygyny.

Returning to Table 2, in column III we see that polygyny significantly improves the yields of other male cultivators relative to the household head, suggesting that the smaller husband-wife differential is not driven by an increase in efficiency for the household head. 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 that story, we cannot reject the hypothesis that the coefficients on other male and other female are equal (*p-value* = 0.196).

To provide additional evidence to distinguish these hypotheses, we limit estimation in Table 3 to specific cultivator pairs. Identification relies on variation in yields across plots planted with the same crop, in the same year, in the same household, between only two types of cultivators, rather than all four types. In column I, polygyny reduces the male-female differential even when the sample is limited to plots cultivated by the head and his wife (wives). Focusing on plots cultivated by other males and other females (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. Limiting the estimation 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, relative to the head, which suggests that husbands' yields do not benefit (disproportionately) from polygyny.[26]

However, limiting the analysis to female plots still does not 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 head, in either type of household (column IV). To test this more directly, we look at how the presence of another female cultivator, not a wife of the head, affects efficiency in the household. In effect, we compare the male-female yield differential across households that do and do not have an "other female" cultivator. We limit this estimation to household heads and wives to ensure the coefficients on the gender variable and its interactions are not driven by the behavior of the other female cultivators themselves. In column V, we see that the presence of an additional female cultivator significantly increases the difference in yields between husbands and wives, and polygyny again eliminates this gap, although the point estimates are imprecise. There may be multiple explanations for this, and the presence of an additional female cultivator may not be exogenous, even conditional on the household-crop-year fixed effect. Nonetheless, the results are not inconsistent with equal preferences for cooperation among men and 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 (*i.e.*, whether other women will cooperate with her).

4.3 Selection into Polygyny

[26] 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.

Polygyny is likely correlated with household characteristics such as wealth, capital, and family size (Jacoby, 1995; Tertilt, 2005). Household-crop-year fixed effects control for factors that are constant across people in the same household planting the same crop in the same year, but they do not control for factors that are different between husbands and wives, such as propensities for cooperation or varying relative demand for male/female labor. To explore this issue, we take advantage of the ICRISAT survey design. In 1981-83, data on the plots of junior wives were collected only for cotton, cereals, and root crops, which are representative of less than 40 percent of wives' plots. Thus, with the inclusion of household-crop-year fixed effects, the 1981-83 data allow us to examine yield variation on plots planted with the same crop in the same year by the head and his senior wife for all crops but restrict the analysis for junior wives to cotton, cereals, and root crops. In contrast, the 1984-85 data allow us to examine yield variation across all plots, irrespective of crop, planted by the head, senior wife, and junior wives. Thus, if the smaller gender yield differential in polygynous households is driven by either unobserved heterogeneity across household types or greater cooperation between husbands and wives (rather than among co-wives), the effect should still be evident when using 1981-83 data, even when the junior wives' plots are largely omitted. We find no evidence of this (column I, Table 4); the coefficient on the interaction between female and polygynous is small in magnitude and not statistically significant when we limit the data to 1981-83.

As a further test, we compare polygynous households with different numbers of wives to explore the possibility that households that achieve more efficient allocations are more likely to take on additional wives, in which case the positive effects of polygyny should be larger for households with more wives. We find no evidence of this; the point estimates for cultivator characteristics interacted with polygyny are not significantly different across households with different numbers of wives (columns II and III, Table 4). Despite this, 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 show above 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 – polygyny may affect production decisions in ways unrelated to cooperation. For example, multiple wives may be able to meet labor requirements on communal plots more quickly or efficiently, leaving more time for own cultivation. Alternatively, polygyny may increase demands on the husband's time via spousal, familial, or social obligations and reduce the time available for his own cultivation. To examine these possibilities, we split the sample into vertically and horizontally-extended households, each with access to different mechanisms for contract enforcement. We define horizontally-extended households as those that include a brother of the household head and vertically-extended households as those that do not.[27] In vertically-extended households (head with adult children), the head is also the patriarch, and social norms allow him to exert more influence over other household members and enforce greater cooperation. Power dynamics are 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 agreements, then we should observe the same effects in both vertical and horizontal households. Conversely, in our model, polygyny provides greater benefits for households with more limited scope for cooperation (horizontally-extended). While household structure/composition may be

[27] Unfortunately, while we know the composition of the household, we do not know the identity of the cultivators beyond the classification of "head", "wife", "other male", or "other female" and therefore cannot identify the relationship of the head to specific "other" cultivators. Vertically-extended households have more wives, sons, daughters, and daughters-in-law, while horizontally-extended households have substantially more brothers, nephews, sisters-in-law, nieces, and other non-relatives.

endogenous, we can still use this comparison to determine whether there is a common (set of) unobserved characteristic(s) driving male-female yield differentials and selection into polygyny.

When we split the sample this way (columns IV and V, Table 4), 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. 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 head is able to enforce cooperation among other cultivators, he does so among all cultivators, without preference for certain types or pairs. To the extent production in vertically-extended households is already efficient, our falsification test may lack power as there are no gains to be realized from polygyny. However, this begs the question of why productive efficiency is related to the composition of the household and the relationships among members.

Finally, to examine the possibility that husband-wife yield differentials are driven by endogenous productivity differences between monogamous and polygynous households, we estimate the effect of polygyny on the level of productivity controlling not for household-crop-year fixed effects, but a combination of household fixed effects and village-crop-year fixed effects. We then regress the household fixed effects on household characteristics.[28] These fixed effects can be interpreted as a measure of the latent productivity of the household, net of plot characteristics and aggregate village-crop-year conditions. Without any controls, the household

[28] Although identification of the direct effect of polygyny is based on a small sample of 155 plots farmed by only four households that switch from monogamous to polygynous during the survey period, we estimate the household fixed effects using the entire sample.

fixed effect is not significantly different for monogamous and polygynous households or for households that become polygynous (Table 5). Adding village and time fixed effects increases the magnitude of the polygyny coefficient, and it is now statistically significant, with polygynous households having *lower* latent productivity than monogamous households. Differences in latent productivity are also negative but not statistically significant at the time households become polygynous, suggesting the differences arise over time, rather than being intrinsic. Adding controls for household composition and total cultivated area increases the magnitude of the polygyny coefficient but including capital intensity has no effect (columns III and IV). In summary, we find no evidence of higher latent productivity in polygynous households and suggestive evidence that differences in productivity arise over time, perhaps as cooperative arrangements among members develop.

4.4 Input Use and Unobserved Plot Quality

If the altruism explanation is correct, we should also find differences in input usage that could explain the observed yield differences among cultivators within a household. Unfortunately, for the years in which we have yield data on all plots cultivated by the household (1984-85), the data on agricultural inputs is limited. Therefore, we are unable to compare male and female labor inputs across the plots of different cultivators, making it difficult to corroborate directly the labor-sharing hypotheses. Using panel Tobit estimation (Honoré, 1992) and controlling for household-crop-year fixed effects, we find weak evidence in Table 6, columns I-III, that women use inputs less intensively. The gender coefficient is negative for labor hours in land improvement (clearing, burning, and bund construction), value of paid labor, and manure, but the point estimates are imprecise.[29] There are no significant differences for polygynous households.

[29] Input data may be subject to significant measurement error as they are based on recall at the end of each year.

However, women keep plots fallow for less time and allow fewer years between fallows (columns IV and V, Table 6). Point estimates are of the opposite sign for women in polygynous households but are not statistically significant.[30] Fallow differences may point to differences in unobserved plot quality, which would pose a significant threat to our identification strategy. We cannot test directly for differences in unobserved plot quality because plot borders change from year to year, making it impossible to include 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 female indicator and the interaction with polygyny, leaving the total effect for women in polygynous households essentially unchanged (column I, Table 7). If we assume observed and unobserved plot characteristics are positively correlated, these results are consistent with higher unobserved plot quality for women, but this does not differ across household types. Moreover, our main results show that polygyny increases yields equally for wives and other female cultivators, but it is not clear why other female cultivators in polygynous households would also have higher quality plots even though other male cultivators do not.

4.5. Endogenous Crop Choice

As seen in the descriptive statistics (Table 1), cropping patterns differ across monogamous and polygynous households, and since household-crop-year fixed effects cannot account for this, it is possible the results could be driven by endogenous planting decisions. To check for this, we first split the data by cereal and non-cereal crops, and it is evident that non-cereal crops are driving the main results (columns II and III, Table 7). For cereal crops, the coefficients on gender and gender interacted with polygyny are smaller in magnitude and neither is statistically significant,

[30] 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.

while the opposite is true for non-cereal crops. This may reflect stronger social norms governing the pooling of resources in the production of staple foods. However, wives in polygynous households devote a greater share of plots to cereal crops (38 versus 24 percent), so differences in crop choice would tend to attenuate observed differences in cooperative behavior across monogamous and polygynous households.

We also use an alternative specification (household-year, rather than household-crop-year, fixed effects) to identify gender yield differences from variation across all plots cultivated by the household, rather than only those planted with the same crop. But, because factors such as weather variability 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 smaller in magnitude (column IV, Table 7). This suggests that the main results cannot be entirely explained by differences in crop choice across monogamous and polygynous households.

4.6 Dynamic Inefficiency

The degree of cooperation in a household affects efficiency, but it can also affect growth via investment choice. Investments with large fixed costs will have higher returns if they can be used across plots controlled by multiple cultivators. Conversely, where there is little opportunity for cooperation, individuals may invest in smaller capital goods or variable inputs that have lower fixed costs and lower returns. We examine household expenditure on large capital investments (plows, scarifiers, weeders, ridgers, line tracers, seeders, sprayers, carts, tractors, and draft animals). Because larger and wealthier households are more likely to undertake such investments, we look at investment expenditures as a percent of the household's total expenditure on agricultural inputs. We control for household demographics and land holdings, treating land holdings and polygyny as endogenous. Because both capital investments and polygyny 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 Burkinabé land tenure and property rights follow an 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 lineage head. Regarding the second instrument, 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 (Kevane and Grey, 1999). Since ethnic groups tend to be geographically concentrated and, therefore, in differing agro-climatic zones, we also include village- and year- or village-year fixed effects to account for regional and temporal differences. Our key identifying assumption is that expenditures on large capital investments, as a percentage of total farm inputs, are not directly affected by 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 landholdings have a significant positive effect on the percentage of agricultural expenditures devoted to large capital goods, while polygyny has no effect (column I, Table 8). In the IV specifications (columns II and III), the coefficient on land holdings is small and not statistically significant. This suggests that asset accumulation, in both land and large capital investments, is driven by unobserved factors, such as ability or endowments. Conversely, the coefficient on polygyny increases in magnitude and becomes statistically significant when instrumental variables are used, suggesting that households who select into polygyny are, in fact, less likely to utilize a capital-intensive production process. This is consistent with Tertilt (2005), who suggests that wives may be an alternate form of capital accumulation. Our 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 rely too heavily on these estimates. Nonetheless, these results provide additional suggestive evidence to support the altruism hypothesis as, all else equal, we would expect more intensive use of lumpy goods, which are more difficult to sub-divide and share, to be associated with greater inefficiency in input allocation.

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 our model shows how this can result from 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 benefit from polygyny, but cooperation among women is influenced by identity/relationship as well as gender. We do not find evidence of household heads acting as a third-party enforcement mechanism for others' cooperative agreements, except in the context of vertically-extended households, where the head may have greater influence.

Our results do not appear to be driven by selection into polygyny. When junior wives' plots are excluded from the estimation, we do not observe the same production pattern, suggesting the results are driven by interaction among co-wives, rather than fixed characteristics of polygynous households. Analysis of latent productivity measures further reveal that polygynous men tend to have lower latent productivity, and this difference is not intrinsic but arises over time. Moreover, we show that the positive effects of polygyny on efficiency are evident only in a subset of households (horizontally-extended), which suggests our results cannot be explained by other impediments to cooperation, such as social norms or administrative obligations. Additional robustness checks suggest our results are not driven by differences in crop choice or the propensity for cooperation between monogamous and polygynous households. We cannot definitively rule out the possibility of unobserved plot characteristics being correlated with women's yields in polygynous households. But 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.

Still, as Rangel and Thomas (2012) note, even if endogeneity and measurement issues have been properly accounted for, differences in yields could still be caused by non-convexities in the production process, making non-cooperation even more difficult to confirm. However, since our empirical strategy relies on a comparison of monogamous and polygynous households, it is sufficient to note that these other unobserved factors cannot be driving our results unless they differ across monogamous and polygynous households. Given the diversity of household structure in Burkina Faso and our finding that co-wives are able to minimize yield differentials more than any other cultivator pair, it seems unlikely that *only* polygynous households would have access to the markets, technologies, and strategies that reduce yield differentials, and that these mechanisms are available *only* to the female cultivators in the household.

Altruism can facilitate cooperation by reducing transaction costs, improving information flows, and ensuring repeat interaction. However, we show that, all else equal, 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 contentious relationships may be more generous than those between friendly countries because shared political interests (a type of altruism) ensure amicable negotiations, even in the absence of an explicit agreement. The adage about never mixing business with family also seems to be rooted in the problems created specifically by altruistic linkages. Our findings imply that there may be some optimal social distance that could be leveraged to improve program 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*Number of Kids				-23.28 **
				(10.27)
Gender*Polygynous			168.94 ***	41.94
			(40.09)	(64.85)
Other Male*Polygynous			86.50 *	
			(45.82)	
Other Female*Polygynous			28.71	
			(35.81)	
Gender*Polygynous*Number 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*Polygynous			69.99 *		
			(42.05)		
Other Female*Polygynous				-18.87	
				(23.23)	
Observations	3629	1597	2478	2748	3629

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 (not wife) cultivator present in the household.

Table 4. Fixed Effects Estimates of the Effect of
Cultivator Characteristcs on Plot Yield[a], Alternate Samples

	1981-83 Only (I)	Polygynous =2 Wives (II)	Polygynous >2 Wives (III)	Vertical[b] (IV)	Horizontal[c] (V)
Gender (1=female)	-35.13 ***	-155.14 ***	-155.14 ***	-8.43	-516.33 ***
	(12.48)	(40.11)	(39.01)	(21.02)	(111.29)
Other Male	-30.30 **	-56.35	-56.35	-18.55	-237.79 **
	(12.58)	(47.21)	(45.91)	(25.80)	(109.52)
Other Female	2.74	-16.02	-16.02	-22.94	-5.00
	(15.60)	(36.50)	(35.49)	(20.73)	(74.17)
Gender*Polygynous	1.66	136.33 **	154.32 ***	-9.68	518.79 ***
	(14.88)	(53.59)	(53.01)	(26.50)	(117.88)
Other Male*Polygynous	17.15	72.42	45.40	8.06	251.77 **
	(15.25)	(62.19)	(62.09)	(34.52)	(116.05)
Other Female*Polygynous	-23.77	14.76	13.91	20.62	2.30
	(18.53)	(48.07)	(44.86)	(27.05)	(78.45)
Observations	4198	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: 1981-85 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 5. Correlates of Latent Household Productivity[a]

	(I)	(II)	(III)	(IV)
Switch to Polygynous	-27.79	-15.99	-22.69	-30.98
	(57.21)	(55.22)	(47.73)	(49.66)
Always Polygynous	-18.51	-33.71 *	-67.79 ***	-67.78 ***
	(13.87)	(19.82)	(20.34)	(20.49)
Total Hh Plot Area			8.109 ***	7.790 ***
			(2.698)	(2.752)
Capital Intensity[b]				30.21
				(37.21)
Village-Crop-Year Fixed Effects	N	Y	Y	Y
Controls for Hh Composition[c]	N	N	Y	Y
Observations	136	136	122	120

Notes: Standard errors in parentheses. (***), (**) and (*) denote significance at the 1%, 5% and 10% levels, respectively.

Data source: 1984-85 ICRISAT Burkina Faso Survey.

[a]Dependent variable is the implied household fixed effect, estimated from a regression of plot yields on cultivator characteristics, plot size (by decile), soil type, toposequence, location and interactions with polygyny.

[b]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).

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

Table 6. Panel Tobit Fixed Effects Estimates of Input Choice

Dependent Variable	Hours in Land Improvement[a] (Per Hectare)	Paid Labor (1000 FCFA Per Hectare)	Manure (1000 Kg Per Hectare)	Length of Fallow[b]	Years Since Fallow
	(I)	(II)	(III)	(IV)	(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*Polygynous	-34.60	0.39	-3.03	1.50	2.34
	(33.34)	(5.49)	(6.17)	(1.35)	(4.03)
Other Female*Polygynous	-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 7. Fixed Effects Estimates of the Effect of Cultivator Characteristics on Plot Yield[a], Alternate Specifications

	No Plot Chars. (I)		Cereals (II)		Non-Cereals (III)		Hh-Year Fixed Effects[b] (IV)	
Gender (1=female)	-125.67	***	-51.61		-482.87	***	-108.12	***
	(31.15)		(32.91)		(74.50)		(25.97)	
Other Male	-8.52		-92.94	**	-83.43		-58.48	*
	(36.98)		(37.39)		(82.15)		(31.45)	
Other Female	-3.58		-70.15	*	-23.15		-13.57	
	(31.80)		(36.17)		(51.06)		(26.85)	
Gender*Polygynous	128.65	***	10.01		452.14	***	74.53	**
	(35.90)		(38.45)		(86.90)		(29.84)	
Other Male*Polygynous	21.09		84.15	*	63.75		35.70	
	(43.12)		(43.47)		(95.29)		(37.09)	
Other Female*Polygynous	6.01		68.88		17.24		5.470	
	(36.33)		(42.36)		(57.24)		(31.37)	
Observations	5230		2923		2307		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 (unless otherwise noted) 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]Also includes village-crop-year fixed effects.

Table 8. Instrumental Variables Estimates of the Effect of Polygyny on Capital Intensity

	A. Large Capital Goods as % of Total Farm Input Expenditure[a]		
	Village, Year Fixed Effects	IV with Village, Year Fixed Effects[b]	IV with Village*Year Fixed Effects[b]
	(I)	(II)	(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

	B. 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 (Dagari-Djula; Bwa; and "other", which includes Rimaibe, Fulani/Peulh, Fulse/Kurumba, Mossi and Dafing/Marka; "Southern" Fulani/Peulh Mossi is excluded) and hectares of inherited land.

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

Online Technical Appendix (not for publication)

Section 1. Individual's Maximization Problem in the Absence of Cooperation

$$\max_{N_i^j, N_i^k, z_i} U_i(x_i, z_i, z_j, z_k) \text{ subject to } x_i = Y_i\left(1 - N_i^j - N_i^k, N_j^i, N_k^i; A_i\right) - p_i z_i$$

$$\text{where } N_s^i = N_s^{i^*}(N_i^s, N_{-s}^s; \mu_s, p_s, A_s) \text{ and } z_s = z_s^*\left(N_i^s, N_j^s, N_k^s; \mu_s, p_s, A_s\right) \text{ for } s = j, k$$

First order conditions:

$$\frac{\partial U_i}{\partial z_s}\frac{dz_s^*}{dN_i^s} - \frac{\partial U_i}{\partial x_i}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_s^i}\frac{dN_s^{i^*}}{dN_i^s}\right) = 0 \text{ for } s = j, k \text{ and } \frac{\partial U_i}{\partial z_i} - p_i\frac{\partial U_i}{\partial x_i} = 0$$

Let *D* denote the determinant of the Hessian, and define its elements as

$$s_{11} = \frac{\partial U_i}{\partial x_i}\left[\frac{\partial^2 Y_i}{\partial {N_i^i}^2} + \frac{\partial^2 Y_i}{\partial {N_j^i}^2}\left(\frac{dN_j^{i^*}}{dN_i^j}\right)^2\right]$$

$$s_{12} = \frac{\partial^2 U_i}{\partial z_j \partial z_k}\frac{dz_j^*}{dN_i^j}\frac{dz_j^*}{dN_i^k} + \frac{\partial U_i}{\partial x_i}\left[\frac{\partial^2 Y_i}{\partial {N_i^i}^2} + \frac{\partial^2 Y_i}{\partial N_i^j \partial N_i^k}\frac{dN_j^{i^*}}{dN_i^j}\frac{dN_k^{i^*}}{dN_i^k}\right]$$

$$s_{13} = \frac{\partial^2 U_i}{\partial z_j \partial z_i}\frac{dz_j^*}{dN_i^j} - \frac{\partial^2 U_i}{\partial x_i \partial z_j}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_j^i}\frac{dN_j^{i^*}}{dN_i^j}\right)$$

$$s_{22} = \frac{\partial U_i}{\partial x_i}\left[\frac{\partial^2 Y_i}{\partial {N_i^i}^2} + \frac{\partial^2 Y_i}{\partial {N_k^i}^2}\left(\frac{dN_k^{i^*}}{dN_i^k}\right)^2\right] < 0$$

$$s_{23} = \frac{\partial^2 U_i}{\partial z_k \partial z_i}\frac{dz_k^*}{dN_i^k} - \frac{\partial^2 U_i}{\partial x_i \partial z_k}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_k^i}\frac{dN_k^{i^*}}{dN_i^k}\right)$$

$$s_{33} = \frac{\partial^2 U_i}{\partial {z_i}^2} - p_i\frac{\partial^2 U_i}{\partial x_i \partial z_i}$$

Corollary 1. Altruistic players will engage in a greater degree of exchange behavior even when no cooperative agreement is reached, all else equal

Define $\frac{\partial U_i}{\partial z_s} = \theta_s \frac{\partial U_i}{\partial z_i}$. Then for $\theta_s > 0$,

$$\frac{dN_i^j}{d\theta_j} = -\frac{1}{D}\frac{\partial U_i}{\partial z_i}\frac{dz_j^*}{dN_i^j}(s_{22}s_{33} - {s_{23}}^2) > 0 \; and \; \frac{dN_i^k}{d\theta_k} = -\frac{1}{D}\frac{\partial U_i}{\partial z_i}\frac{dz_k^*}{dN_i^k}(s_{11}s_{33} - {s_{13}}^2) > 0$$

If all goods are separable in utility, then

$$\frac{dz_i}{d\theta_j} = -\frac{1}{D}\frac{\partial U_i}{\partial z_i}\frac{dz_j^*}{dN_i^j}(s_{12}s_{23} - s_{13}s_{22}) = 0 \; and \; \frac{dz_i}{d\theta_k} = \frac{1}{D}\frac{\partial U_i}{\partial z_i}\frac{dz_k^*}{dN_i^k}(s_{11}s_{23} - s_{12}s_{13}) = 0$$

In the absence of explicit cooperation, labor allocations to other players are increasing in the degree of altruism.

For $\theta_s = 0$, $\partial U_i/\partial z_s = 0$ and, since player *s* derives no utility from z_i, he/she has no incentive to reciprocate any labor sharing. Therefore, $dN_s^{i^*}/dN_i^s = 0$. When both of the these conditions hold, first order condition becomes

$$\frac{\partial U_i}{\partial x_i}\frac{\partial Y_i}{\partial N_i^i} = 0$$

Clearly, no interior solution exists, and therefore it must be the case that $N_i^s = 0$ when $\theta_s = 0$. ▪

Corollary 2. Even with labor sharing between players, the allocation of their labor inputs will not be efficient in the absence of explicit cooperation.

To consider the case of altruistic preferences, rewrite the first order condition as

$$\frac{\partial U_i}{\partial z_s}\frac{dz_s^*}{dY_s}\left(\frac{\partial Y_s}{\partial N_i^s} + \frac{\partial Y_s}{\partial N_s^s}\frac{dN_s^s}{dN_i^s} + \frac{\partial Y_s}{\partial N_{-s}^s}\frac{dN_{-s}^s}{dN_i^s}\right) = \frac{\partial U_i}{\partial x_i}\left(\frac{\partial Y_i}{\partial N_i^i} - \frac{\partial Y_i}{\partial N_s^i}\frac{dN_s^{i^*}}{dN_i^s}\right)$$

Rearranging terms yields

$$\frac{\partial Y_i}{\partial N_i^i} = \left(\frac{\partial U_i}{\partial z_s}\frac{dz_s^*}{dY_s}\Big/\frac{\partial U_i}{\partial x_i}\right)\left(\frac{\partial Y_s}{\partial N_i^s} + \frac{\partial Y_s}{\partial N_s^s}\frac{dN_s^s}{dN_i^s} + \frac{\partial Y_s}{\partial N_{-s}^s}\frac{dN_{-s}^s}{dN_i^s}\right) + \frac{\partial Y_i}{\partial N_s^i}\frac{dN_s^{i^*}}{dN_i^s}.$$

In order for the marginal product of player *i*'s labor to be equalized across plots such that

$$\frac{\partial Y_i}{\partial N_i^i} = \frac{\partial Y_s}{\partial N_i^s},$$

several conditions must hold:

(i) the marginal rate of transformation between *x* and *z*, in utility terms, must be equal to one

$$\frac{\partial U_i}{\partial z_s}\frac{dz_s^*}{dY_s} = \frac{\partial U_i}{\partial x_i}$$

(ii) both other players' labor allocations to player *s*'s plot must be independent of player *i*'s labor allocation

$$\frac{dN_s^s}{dN_i^s} = \frac{dN_{-s}^s}{dN_i^s} = 0$$

(iii) player *s*'s labor allocation to player *i* must also be independent of player *i*'s labor allocation to her plot.

$$\frac{dN_s^{i^*}}{dN_i^s} = 0$$

However, from Corollary 1, we know that player *s* will provide labor on player *i*'s plot as long as there is some degree of altruism $\frac{\partial U_s}{\partial z_i} > 0$. Therefore, the allocation of player *i*'s labor cannot be efficient. ▪

Section 2. Cooperative Agreement between Players i and j

Production decisions are separable, so labor allocations are determined independent of the utility maximization problem. For simplicity, assume that the participation constraints are not binding for both players such that the joint maximization problem becomes:

$$\max_{x_j, z_i, z_j} \lambda U_i(\cdot) + (1-\lambda) U_j(\cdot) \quad \text{where } x_i = Y_i + Y_j - p_i z_i - p_j z_j - x_j$$

with first order conditions

$$(1-\lambda)\frac{\partial U_j}{\partial x_j} - \lambda \frac{\partial U_i}{\partial x_i} = 0$$
$$\lambda \frac{\partial U_i}{\partial z_i} + (1-\lambda)\frac{\partial U_j}{\partial z_i} - \lambda \frac{\partial U_i}{\partial x_i} p_i = 0$$
$$\lambda \frac{\partial U_i}{\partial z_j} + (1-\lambda)\frac{\partial U_j}{\partial z_j} - \lambda \frac{\partial U_i}{\partial x_i} p_j = 0$$

Let *D* denote the determinant of the Hessian, and define its elements as

$$s_{11} = (1-\lambda)\frac{\partial^2 U_j}{\partial {x_j}^2}$$
$$s_{12} = (1-\lambda)\frac{\partial^2 U_j}{\partial x_j \partial z_i} - \lambda \frac{\partial^2 U_i}{\partial x_i \partial z_i}$$
$$s_{13} = (1-\lambda)\frac{\partial^2 U_j}{\partial x_j \partial z_j} - \lambda \frac{\partial^2 U_i}{\partial x_i \partial z_j}$$
$$s_{22} = \lambda \frac{\partial^2 U_i}{\partial {z_i}^2} + (1-\lambda)\frac{\partial^2 U_j}{\partial {z_i}^2} - \lambda \frac{\partial^2 U_i}{\partial x_i \partial z_i} p_i$$
$$s_{23} = \lambda \frac{\partial^2 U_i}{\partial z_i \partial z_j} + (1-\lambda)\frac{\partial^2 U_j}{\partial z_i \partial z_j} - \lambda \frac{\partial^2 U_i}{\partial x_i \partial z_j} p_i$$
$$s_{33} = \lambda \frac{\partial^2 U_i}{\partial {z_j}^2} + (1-\lambda)\frac{\partial^2 U_j}{\partial {z_j}^2} - \lambda \frac{\partial^2 U_i}{\partial x_i \partial z_j} p_j$$

Define $\frac{\partial U_i}{\partial z_j} = \theta_i \frac{\partial U_i}{\partial z_i}$. Then for $\theta > 0$ and all goods are separable in utility,

$$\frac{dz_i}{d\theta_i} = \frac{1}{D}\lambda \frac{\partial U_j}{\partial z_j}(s_{11}s_{23} - s_{12}s_{13}) = 0 \; and \; \frac{dx_j}{d\theta_i} = -\frac{dx_i}{d\theta_i} = -\frac{1}{D}\lambda \frac{\partial U_j}{\partial z_j}(s_{12}s_{23} - s_{13}s_{22}) = 0$$

Section 3. Coalition-Proofness

The equilibrium is coalition-proof (Bernheim, Peleg and Whinston, 1987) if 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. Additionally, the following condition must hold, where ^ denotes cooperation between *i* and *j*, ′ denotes the fully non-cooperative outcome, and ˜ denotes cooperation between *i* and *k* and between *j* and *k*, respectively.

$$(\hat{V}_i - V_i') + (\hat{V}_j - V_j') > [(\tilde{V}_i - V_i') + (\tilde{V}_k - V_k')] + [(\tilde{V}_j - V_j') + (\tilde{V}_k - V_k')]$$

This ensures that the husband cannot simultaneously offer both wives cooperative agreements that dominate the agreement between co-wives.