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The Effect of Land Scarcity on Farm Structure: Empirical Evidence from Mali

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I. Introduction

We find that, even leaving socialist countries aside, collective farms, in the sense of farm units wherein production is collectively carried out on jointly used fields, were more widespread than usually thought, particularly in land-abundant areas. This is attested by their presence in the context of large and complex households in old-day Russia and Serbia or in west Africa, where they have persisted until recent times. In Burkina Faso, Gambia, Senegal, and Mali, for example, extended households managing collective farms remain a characteristic feature of the rural landscape, even though a trend toward granting individual plots of land to family members has been observed during the last decades. Mixed farm structures have thus emerged in which individual plots coexist with the collective family field on which members continue to work as a team. While the output of individual plots entirely accrues to the members, the output of the family field is shared among all the coworkers after the head has retained his own portion. Transfers to the latter from the incomes that have been individually obtained are rarely observed, and while they are theoretically possible, they are hard to enforce, owing to the high cost of monitoring harvests on private plots (especially when crops are harvested at frequent intervals).

An interesting question is how we can account for the emergence of mixed farm structures within households that were used to run large collective fields to the exclusion of any private farming. It is a well-known finding in the development literature that the movement toward increasing individualization of land tenure rules at the community level has been largely driven by land scarcity. We argue in this article that the same force may actually explain the rise of mixed farms in southern Mali. In other words, the growing value of land causes an individualization of both farm units and property rights. To

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make this point, we construct a simple argument based on the idea that integrated collective farms are run by a household head acting as an all-powerful patriarch. This patriarch is confronted with a dilemma that becomes increasingly acute as land becomes scarce: while efficiency is enhanced by the granting of individually farmed plots, the possibility to extract income for himself is exclusively ensured through collective production since the patriarch cannot tax individual production. To the extent that the patriarch must meet reservation utility constraints for the family members, a higher level of land scarcity compels him to pay more attention to efficiency considerations.

The above argument is developed with the help of a simple model that is presented in Section III, after we have reviewed the existing literature in Section II. Sections IV and V are then devoted to testing the central prediction of the model by using firsthand data that we have systematically collected in the Koutiala-San-Sikasso region of Mali. In Section IV, we first provide general information about our sample data. Thereafter, we present descriptive evidence about the farm and family structures encountered in our survey area and proceed by discussing qualitative evidence in support of the main assumptions underlying our model. In Section V, we propose an econometric analysis to test the prediction from our econometric model. We conclude that land scarcity is a key determinant of the presence of private plots. Moreover, when we control for the land area available, we find that not only the size of the workforce but also its composition influence intrahousehold land allocation.

II. Review of the Literature

This article is concerned with the question as to why and under which conditions individual plots of land can coexist with a collective field within a given farm structure. Such an issue has been addressed in three different strands of the economic literature. The first strand deals with agricultural producer cooperatives; the second strand with large-scale feudal-like farms, such as haciendas and plantations; and the third strand with family farms.

By far the most significant, the writings devoted to agricultural producer cooperatives have proposed various lines of argument to explain why cooperative units may choose to have some lands allocated to private production and managed by the member households. Conversely, the question becomes, absent any form of coercion, why would farmers be interested in pooling some of their individually owned lands?

If certain activities are subject to scale economies while others are not, it seems natural for farmers to undertake the former on collective fields while retaining private plots for the latter. This organizational choice was observed in Hungarian cooperatives, where activities intensive in husbandry skill were left for households to conduct on their private plots, whereas activities easy to standardize and monitor remained the province of collective work on the cooperative fields (Swain 1985; Guillaume 1987; see also Chayanov 1991, chap. 13, for Russia).[1] Collective production is often plagued with a moral-hazard-in-team problem when information regarding contributions to collective production is imperfect, forcing the cooperative to pay all workers equally (Holmstrom 1982). Then, collective production is desirable only if this incentive failure is outweighed by the benefits of scale economies or else by the intrinsic motivations of members (Putterman 1981, 1985).[2]

Risk aversion and output uncertainty provide another justification for collective farming. If natural contingencies strike randomly across members, pooling of land and labor may provide an insurance strategy (Putterman and DiGiorgio 1985, 18, 20 n. 32; Chayanov 1991, chap. 11). Michael Carter (1987) centers his analysis on the trade-off between risk sharing and incentives that arises because the insurance that income sharing provides also shelters the individual from the full effect of his or her own slack behavior, thereby inducing lower work effort. Assuming that collective income is shared equally, Carter argues that complete parceling of cooperative land is suboptimal in both static and dynamic terms. He shows that intermediate forms that preserve some degree of risk sharing may prove superior.

[1] For example, Guillaume reports that the raising of piglets until they reach age 1 was collectively carried out in large shelters heated with the help of powerful lamps and placed under the constant surveillance of veterinarians. By contrast, the raising of pigs beyond 1 year was performed by the member households in their private compounds.

[2] Louis Putterman and Marie DiGiorgio (1985) develop a more sophisticated argument based on work incentive considerations but in a context in which individual contributions to collective production are measurable. They assume that the reward function in the collective sector of a cooperative is a combination of two opposite principles: distribution according to needs (equal sharing) and distribution according to effort (the work-point system). The weights given to each system, as well as the allocation of the cooperative land between the collectively farmed field and the private plots, are endogenous variables democratically chosen by the members who are heterogeneous in terms of their income-leisure preferences. While a strict equal-sharing rule is subject to the moral-hazard-in-team problem, a distribution according to work effort may cause a sort of "tragedy of commons": indeed, members seek to earn additional work points bearing average net product returns, although their additional work hours have a low marginal productivity (Putterman 1989, 324). The presence of distribution according to needs mitigates this excessive incentive effect. The authors show that by distributing some revenue according to needs, the cooperative can achieve optimal work incentives (while increasing equality of income distribution). Land is then allocated between private and collective production in such a manner that the marginal product of land in the private plot of the household of median industriousness equals the marginal product of land in joint production (if one of these marginal products would exceed the other over the whole range of possible values of intersectoral allocation of land, land would be allocated wholly to either the collective or the private sector; Putterman 1989, 332). Therefore, both the private and the collective sectors can meaningfully exist, yet only in the presence of some economies of scale (see also Putterman 1987).

The second relevant strand of literature deals with asymmetric farm structures instead of democratic participatory agrarian institutions. In the advantageous position is the landlord or estate owner who enjoys a local monopoly power over land. In deciding how to use his land, he may opt for a combination of two systems: direct cultivation with the help of wage workers on a portion of his property and renting out the remaining portion of the estate land to the same workers. There is typically no money exchange between the tenant and the landlord: the labor services supplied by the workers on the landlord's field (the field supervised and managed by the landlord) constitute the rent due for the use of individualized plots. Such a system has been widely observed, for example, in the post-Carolingian manors of medieval Europe, in American plantations using slave labor, in Russian boyar estates using serf labor (Blum 1961; Kolchin 1987; van Zanden 2009, 56 n. 13), in feudal Japanese farms during the Tokugawa era (Smith 1959), or among estate landlords of Latin America, such as those employing *inquilino* laborers in Chile after the middle of the eighteenth century (Bauer 1975; de Janvry 1981, 111).[3]

An interesting theoretical explanation for the labor-service system has been proposed by Elisabeth Sadoulet (1992). The basic intuition is as follows. In the presence of limited liability—a tenant's liability is limited to his total wealth—the tenant does not bear the full risk of defaulting on his rental payment and thus has incentives to shirk. This decreases the rent the landlord can extract from land rental contracts. In the words of Sadoulet, the landlord "faces a dilemma between reducing the rent charged to lower the occurrence of default and increasing it to capture the full surplus that the tenant can obtain from the utilization of his family labor" (1033). The labor-service contract, that is, the exchange of free labor for use on the landlord's field against free access to a private plot of land for personal use by the tenant, enables the landlord to impose an optimal level of insurance and, thus, efficient resource use on the tenant.

Another justification for the same system lies in risk considerations. In fact, the exchange of free labor services against free access to a piece of land is equivalent to a sharecropping contract that would be applied on the whole farm

[3] In Japan, for example, during the second half of the eighteenth century both land and labor were increasingly transferred by the *oyakata* (landlord) to his *nagos* (clients). Since the *oyakata* was responsible for the livelihood of the *nago*, awarding land to the latter also implied that the burden of his labor services on the former's land be proportionately reduced. The land allocated to the *nago* was now under his own management, and, although he was a tenant rather than a holder, he himself made many of the critical decisions of farming. More important, despite receiving the *oyakata*'s continued protection in times of adversity, the *nago* took many of the risks associated with independent farming (Smith 1959, 134).

area and may therefore be motivated by risk sharing (Allen 1984). Yet, underlying this argument is the assumption that labor effort on the estate owner's field can be monitored at no cost. If monitoring is imperfect, the equivalence result does not hold anymore: granting sharecropping contracts to risk-averse tenants on the whole estate domain is more efficient than a system in which individual plots coexist with the landlord's field. As a result, the functional equivalent of the collective sector in a producer cooperative may not come into existence.

Finally, the third strand of literature has the family farm as its frame of reference. Marcel Fafchamps (2001) has thus proposed a model that attempts to explain the decision of the household head to allocate individual plots to family members. The idea is as follows: because the head is unwilling or unable to commit to reward their work on the family field after the harvest, family members are tempted to relax their labor efforts or to divert them to other income-earning activities. To solve this commitment failure, the head decides to reward his wife and dependents for their labor on the collective field by giving them individual plots of land and the right to freely dispose of the resulting produce. It must be stressed, however, that the commitment problem only exists if the short-term gain of deviating from cooperation (which means here reneging on the promise to reward the workers for their effort on the collective field) exceeds the long-term flow of benefits ensuing from a smooth relationship between the household head and the working members. Fafchamps himself recognizes that this condition appears to be restrictive since the game played within the family is by definition of a long (and indeterminate) duration, and future benefits are not heavily discounted (future cooperation among close relatives matters a lot). In other words, voluntary collaboration should in principle be induced by the threat of future noncooperation. Even assuming that Fafchamps's hypothesis is valid, it remains unclear why there should be a tendency over time for collective farms to transform themselves into mixed farms.

An alternative account of the presence of individual plots is found in Foster and Rosenzweig (2002). They argue that the advantages of collective production arising from scale economies and also from savings associated with the financing of household public goods (which are jointly consumed) may be outweighed by diverging preferences over the household public good. Since conflicts over the provision of this good may increase as a result of increases in income and in within-household inequality, we expect to observe a growing incidence of splits of the stem household into independent units. This argument, however, does not apply well to our context where the rule of joint residence and joint consumption persists when the head awards individual plots to the members: meals continue to be organized at the household level, with married women taking turns in preparing the food.

Overall, we therefore lack a pertinent explanation for the existence of individual plots in the setting of family farms. Is it possible to infer such an explanation from the first two bodies of literature? A first conceivable reason behind the emergence of private plots is the diminishing importance of technological scale economies or the growing significance of husbandry skill-intensive activities that gives rise to the so-called management diseconomies in agriculture. These phenomena are typically observed when land scarcity causes a shift to land-saving and labor-using agricultural techniques. As we have learned from the work of Ester Boserup (1965) and others, a key characteristic of these techniques is that labor quality, which is costly to monitor, becomes a critical input. Given the incentive problems associated with care-intensive activities, more individualized forms of agricultural organization, in which few coworkers (spouses and their children) are residual claimants, appear more efficient (see also Binswanger and Rosenzweig 1986; Binswanger and McIntire 1987; Pingali, Bigot, and Binswanger 1987; Binswanger, McIntire, and Udry 1989; Hayami and Otsuka 1993). Note that Boserup's line of argument has been advanced to explain the splitting of large family farms into smaller units based on the narrow family—the peasant farms—rather than the emergence of mixed structures involving the presence of individual plots of land side by side with a collective field. Another possible explanation is the decreasing need for risk sharing as relatively cheap alternative insurance mechanisms become available, most typically in the form of off-farm income opportunities. Finally, the multiplication of these new income opportunities and the development of rural credit markets might reduce the limited liability problem confronting poor tenants.

In Mali, it is not clear that the rising importance of mixed farm structures is accompanied by technological change, credit market development, or an increased access to insurance opportunities. In fact, agricultural techniques do not appear to have changed in our survey region during the last decades. Credit market failures remain pervasive, as the only way of obtaining loans is through the marketing-cum-credit interlinking provided by the parastatal agency in charge of cotton production and marketing (Compagnie Malienne de Developpement des Textiles). Finally, the opening of new migration possibilities may allow rural households to diversify risks, thereby blurring the effect of land scarcity on farm structure. We come back to this issue when presenting robustness checks in Section V.

In the next section, as an alternative to the above-outlined theoretical frameworks, we propose a new theory of the patriarchal family that has the advantage of bringing explicitly into light the relationship between land scarcity and farm structure. Unlike in the literature on producer cooperatives, decisions about the form of the farm are made by an authority figure, the family or household head, and, unlike what is assumed in Sadoulet's model, the patriarch does not interfere with the family members' allocation of effort. Two key assumptions in our model are (1) a simple sharing of collective output under conditions of unobservable effort and (2) unenforceable transfers of output from the individual plots. We consider the situation of a family farm that is initially integrated (and hence different than feudal or semifeudal estates) and where a hierarchical relationship prevails (and hence different than democratic producer cooperatives).[4]

III. A Simple Model of Family Farm Structure

A. The General Framework

In a companion article, we have developed a general theory of the individualization of the farm-cum-family structures in which the household head may choose not only to grant private plots to members but also to split the stem family into branch families. In this section, we pursue a more limited objective by precluding the possibility of household splitting. This simplification carries an appreciable advantage since it allows us to derive analytical solutions in contrast to the more general model for which we have to largely rely on numerical simulations. The theoretical predictions thus obtained will then be tested against our data from Mali, which are rather rich in details about private plots (but incomplete and often unreliable regarding the incidence of splitting).

A household head has n male family members who live and farm with him. Farm production $f(d, l)$ requires two inputs, land d and labor l, and

[4] It is noteworthy that the transformation we observe from collective to mixed structures implies a process that is exactly the reverse of the process observed in many feudal or semifeudal estates. In the latter instance, indeed, independent tenants have typically become reintegrated into a seigneurial estate when landlords decided to cultivate their land directly in response to favorable market conditions. The ability of estate owners to impose labor obligations on the tenants resulted from the weakened bargaining position of the latter because of either financial crises leading to debt servitude (see, e.g., Sadoulet [1992], 1032, with reference to the Chilean *inquilinos* in the latter half of the eighteenth century; Blum [1961], 241–46, with reference to Russia in the late sixteenth and early seventeenth centuries; or van Zanden [2009], 271–72, for Egypt under the Mamluks) or the concentration of coercive power in the hands of the landlords acting in collusion with state authorities (see Blum [1957, 1961, esp. chaps. 13–14, 21], for Russian serfs during the fifteenth through the nineteenth centuries). Such circumstances obviously affect the constraints set in the theoretical model. In particular, since the worker/tenant does not have any outside option left (if he runs away from his landlord, he will be traced and captured to be returned to his "owner"), no participation constraint can be assumed to exist.

takes the specific form of a Cobb-Douglas function. The total land endowment of the extended family is $A = na$ (where a denotes the average individual endowment), and labor is supplied by male dependents (there are no land or labor markets). An individual's utility is $x - v(l)$, where x is the production that the individual consumes and l the level of labor he exerts. The function $v(l)$ is the disutility of labor and has the usual properties $v'(l) > 0$ and $v''(l) \geq 0$.

The head allocates available land na between a collective field, where the male members work together, and individual fields, where each works individually and for his own benefit. We assume that members receive an equal treatment with respect to both the distribution of the produce of the collective field (hence the existence of a moral-hazard-in-team problem) and the division of the land earmarked for individual farming. Therefore, if the head decides to grant individual plots, each member receives h. The size of the collective field is then $n(a - h)$. Since the equal-sharing rule is not a natural assumption to make, it is important to stress that it overwhelmingly dominates in our survey area: about 90% of the heads explicitly state that they give equal shares to the male members working on the collective field. To the extent that the head measures individual labor effort imperfectly, equal sharing appears as the best rule to follow. Moreover, equal sharing may be appropriate even when individual effort is observable. The reason is that differentiated rewards between members may spark off accusations of unfair discrimination and cause serious intrafamily conflicts, thereby undermining the cooperative spirit that is so important in family production. This argument, which has been mentioned several times in our interviews with household heads, has been occasionally discussed in the economic literature: excessive metering creates a calculative atmosphere that destroys trust and cooperation (Williamson 1985, 1996, chap. 10; Platteau and Nugent 1992). The same sort of considerations come into play when the head gives land away while he is still alive: individual plots of unequal size would trigger tensions and feelings of jealousy that would undermine work incentives in collective production activities.

Another key feature of our model is as follows: members consume the whole production of their individual fields, implying that the father's entire consumption R is obtained from his share of the output produced on the collective field. In keeping with our field observations again (more on this in Sec. IV.C), we thus assume that there is no income transfer from household members to the head.[5] Attention is restricted to pure share contracts where

[5] This assumption is discussed at length in Guirkinger and Platteau (2010).

the head's rent is $R = \alpha f(-)$.[6] When $h = 0$, we say that the farm structure is purely collective, whereas if $h > 0$, it has a mixed form.

One unit of labor, whether applied on the collective field or on the individual plot, causes the same disutility. Moreover, consumption from individual and from collective production is perfectly substitutable. A member's j utility is thus written as $x_j - v(l_j^C + l_j^I)$, where x_j is the sum of the share received from the collective field and the production from his individual plot, l_j^C is the level of effort applied to the collective field, and l_j^I is that applied to the individual field. In the line of the argument proposed by Foster and Rosenzweig (2002), members might be assumed to have a preference for individual consumption. There are two reasons why we refrain from making this effect explicit in the current model. First, since it clearly strengthens the case for individual plots, no new important insight would be gained by modeling it. Second, it bears emphasis that individual consumption is not incompatible with collective production since the head can always decide to remunerate the members, at least in part, in the form of equal cash payments.[7] Therefore, in our framework, the preference for individual consumption alone cannot account for individualization. Finally, members have an outside option that provides them utility $\underline{u}$, giving rise to a participation constraint.

The problem is a two-stage game. In the first stage, the head chooses α and h. In the second stage, members observe these choices and individually decide how much effort to apply to the collective field and how much to their individual plot, if such a plot is available. We restrict our attention to symmetric Nash equilibriums in the second stage. This allows us to solve for a single pair (l^C, l^I) and to write the whole problem as follows:

$$\max_{\alpha,h} R = \alpha f(n(a - h),\ nl^C),$$

such that

[6] We argue elsewhere (Guirkinger and Platteau 2010) that, given the specific context of a family farm, a share system appears as the second-best efficient contract, even when risk considerations are abstracted from. This becomes evident when, following an argument developed by Eswaran and Kotwal (1985), the contract choice problem is viewed as a trade-off between the need to provide tenants with adequate incentive to apply effort, on the one hand, and the need to use the land owner's management skills to the best possible extent, on the other hand. We also show that no Nash equilibrium exists when a remuneration contract with a fixed component is used to distribute the proceeds of collective production in the presence of individual plots.

[7] Our observations actually reveal that the incomes derived from cotton production are sometimes distributed in cash.

$$\{l^C, l^I\} = \arg\max_{l_j^C, l_j^I} \frac{1}{n}\left[(1-\alpha)f\left(n(a-h),\ l_j^C + (n-1)l^C\right)\right]$$
$$+ f\left(h,\ l_j^I\right) - v(l_j^C + l_j^I),$$

$$l^C \geq 0 \quad \text{and} \quad l^I \geq 0,$$

$$\underline{u} \leq \frac{1}{n}[(1-\alpha)f(n(a-h),\ nl^C)] + f(h, l^I) - v(l^C + l^I),$$

$$0 \leq h \leq a.$$

Total labor on the collective field in the incentive compatibility constraint is written $l_j^C + (n-1)l^C$ to stress that each member takes the behavior of others as given when deciding how much effort to apply to that field.

B. The Head's Rent in the Strictly Collective Regime

In the collective regime, $h = 0$, $l^I = 0$, and the members' choice of effort on the collective field is a concave problem with a unique solution. We can therefore represent it by its first-order conditions. The father's rent is the solution of the following program:

$$\max_{\alpha} R = \alpha f(na, nl),$$

such that

$$0 = \frac{1-\alpha}{n} f_L(na, nl) - v'(l),$$

$$\underline{u} \leq \frac{1-\alpha}{n} f(na, nl) - v(l).$$

The moral-hazard-in-team problem is captured by the incentive compatibility constraint: receiving $[(1-\alpha)/n]f_L(na, nl)$ instead of his full marginal product, $f_L(-)$, each member underapplies labor. To explicitly solve for the above problem, we assume that, in addition to the Cobb-Douglas production function, the cost of effort is linear: $f(a, l) = a^{\varepsilon} l^{1-\varepsilon}$, and $v(l) = \omega l$.

Note that our main results do not depend on the choice of the Cobb-Douglas, which implies that returns to scale are constant and the elasticity of substitution between land and labor is unitary. In fact, neither assumption modifies the trade-off that lies at the heart of our theoretical argument or the way it is affected by land scarcity. As pointed out in Section I, this trade-off is between the head's ability to extract rents, which is possible only from the collective field, and productive efficiency, which is highest on the private plots where no incentive problems are encountered. The existence of increasing returns to scale, for example, would simply make collective cultivation relatively more attractive, thus lowering the threshold of land availability below which it becomes profitable to distribute private plots. However, a substitution elasticity higher than 1 would imply that it is relatively easy to substitute labor for scarce land. For one thing, this mitigates the effect of land scarcity on the collective field, yet, for another thing, since labor is used relatively intensely on that field, the moral-hazard-in-team problem becomes more serious. Private plots are therefore expected to remain attractive once a certain degree of land scarcity is reached. As for the assumption of linear cost of effort, it allows us to derive an explicit expression for the head's rent, while it does not modify our central results (since, again, it does not affect the trade-off between productive efficiency and rent capture).

With the above forms for the production and cost functions, the rent of the household head is as follows (see app. A for the proof):

$$\begin{cases} \text{If } a < \left(\dfrac{n\omega\varepsilon}{1-\varepsilon}\right)^{1/\varepsilon} \dfrac{n\underline{u}(1-\varepsilon)}{n\omega-\omega+\omega\varepsilon}, & R = na^{\varepsilon}\left(\dfrac{\underline{u}(1-\varepsilon)}{n\omega-\omega+\omega\varepsilon}\right)^{1-\varepsilon} - \dfrac{n^2\underline{u}}{n-1+\varepsilon} \\ \text{If } a > \left(\dfrac{n\omega\varepsilon}{1-\varepsilon}\right)^{1/\varepsilon} \dfrac{n\underline{u}(1-\varepsilon)}{n\omega-\omega+\omega\varepsilon}, & R = na\varepsilon\left(\dfrac{(1-\varepsilon)^2}{\varepsilon n\omega}\right)^{(1-\varepsilon)/\varepsilon}. \end{cases} \tag{1}$$

We obtain two expressions for the father's rent in that regime, depending on whether the members' participation constraint is binding. If land is abundant, to increase work incentives, the head rewards members beyond their reservation utility, and his rent is independent of $\underline{u}$ (second expression in the above system). Conversely, when land is sufficiently scarce, participation constraints become binding, and the head's rent is a decreasing function of the member's reservation utility.

C. *Giving out Individual Plots?*

The question of the distribution of individual plots is not trivial since there are two forces working in opposite directions. On the one hand, unlike the collective field where the workers suffer from the moral-hazard-in-team problem, individual plots are used efficiently. As a consequence, a smaller amount of land has to be dedicated to meeting the members' reservation utility under a mixed system than under a pure collective regime. On the other hand, incentives to work on the collective field are further eroded when there is competition between the family field and private plots. The output obtained on the land wherefrom the father derives his income is therefore lower on a double count: the size of the collective field is reduced, and work incentives on these fields are dampened.

To understand the underlying logic of the model, it is useful to analyze the trade-off faced by the head when he decides to allocate individual plots. We consider the problem in a sequential manner. First, let us define $\alpha^*(h)$, which is the optimal α for a given h. We can then examine how the value function of this degenerate problem varies when h changes. If $(\partial V/\partial h)(\alpha^*(h)) < 0$ for all h such that $0 \leq h < a$, the head will not allocate individual fields. On the contrary, if $(\partial V/\partial h)(\alpha^*(h)) > 0$ over some range, the head may choose to allocate individual fields.

Suppose that h is fixed. When there exist both a collective field and individual plots, we can replace the members' maximization problem by the first-order conditions with respect to l^C and l^I and write the following Lagrangian:

$$\begin{aligned} L(l^C, l^I, \alpha) = {} & \alpha f(n(a-h),\, nl^C) - \lambda\left(v'(l^C + l^I) - \frac{1-\alpha}{n} f_L(n(a-h),\, nl^C)\right) \\ & - \mu(v'(l^C + l^I) - f_L(h,\, l^I)) \\ & - \nu\left(\underline{u} - \frac{1-\alpha}{n} f(n(a-h),\, nl^C) - f(h,\, l^I) + v(l^C + l^I)\right). \end{aligned} \tag{2}$$

In order to analyze the sign of $\partial R/\partial h = \partial V/\partial h$, we apply the envelope theorem and obtain the following expression:

$$\begin{aligned} \frac{\partial V}{\partial h} = \frac{\partial L}{\partial h} = {} & -n\alpha f_A^C - \lambda(1-\alpha) f_{LA}(n(a-h), nl^C) + \mu f_{LA}(h, l^I) \\ & -\nu(1-\alpha) f_A(n(a-h), nl^C) + \nu f_A(h, l^I), \end{aligned} \tag{3}$$

where f_A is the marginal productivity of land and f_{LA} is the cross-partial derivative. The above expression allows us to decompose the impact of larger land availability into distinct effects. As h marginally increases, the size of the collective field decreases (by n), and the first term indicates how, everything else being constant, the family head's rent declines with the size of the field from which it is extracted. The second term captures the lower incentives for male members to work on the collective field as h increases (we show in app. B, sec. 1, that λ is positive). For a given amount of effort, indeed, the marginal product of labor falls when land becomes smaller. The third term reflects the negative impact on R caused by the enlarged size of the individual plots: members have more incentive to spend effort on their individual plot because the marginal productivity of labor has increased for a given amount of effort. As a result, the cost of their effort on the collective field is now higher (we show in app. B, sec. 1, that μ is negative).

The last two terms of equation (3) indicate how a change in h modifies the participation constraint and how this affects the head's utility (bear in mind that ≥ 0 since the head's rent increases if the participation constraint is relaxed). Other things being equal (the distribution of labor efforts being constant), reallocation of land from the collective field to individual plots has the effect of enhancing the ability to produce $\underline{u}$ on the latter and simultaneously decreasing the ability to do so on the former. Measured by the marginal productivity of land in the two locations, this combined effect is positive overall because incentive problems exist on the collective field but not on the individual plots.[8]

Even while using the above functional forms, it is impossible to derive an explicit solution for the optimal size of individual plots or the head's rent in this regime (we derive an expression for $R(h)$ in app. B, sec. 2). In the next section, we nevertheless show that the head's rent is greater in the mixed regime than in the collective regime when land pressure is acute.

D. The Attractiveness of the Mixed Regime When Land Pressure Increases

We are able to show that whether the household head chooses to grant individual plots to members depends on land availability. Furthermore, the portion of the land dedicated to individual production is a decreasing function of land availability. The following proposition states these results, which are proven in appendixes C and D.

PROPOSITION 1.

a) When land is very abundant, the head always prefers a pure collective farm to a mixed structure in which male members have individual plots that they cultivate for their own benefit. As land becomes scarce, however, the mixed structure becomes more attractive. In particular, there exists a level of land endowment, a^I, for which the head is indifferent between a mixed and a collective farm. If the land endowment is greater than this threshold, $a > a^I$, the head chooses a collective farm structure, while if it is below, $a < a^I$, the head chooses a mixed structure.

[8] Indeed, assuming constant returns to scale, we have $f_A(h,\ l^I) > f_A(n(a-h),\ nl^C)$ (a formal proof is in app. C, starting with eq. [C2]). This implies, a fortiori, that $-\nu(1-\alpha)f_A(n(a-h),\ nl^C) + \nu f_A(h,\ l^I) > 0$.

b) The share of farm area dedicated to individual production, h/a, is monotonically decreasing in land availability, a. When the mixed regime dominates, $a < a^I$, a decrease in land endowment causes a strict increase in the share of land dedicated to individual plots.

The intuition behind the results becomes clear once the key role of the participation constraints is understood: the tightening of these constraints under conditions of growing land scarcity induces the family head to put more weight on efficiency considerations. When land is abundant, the head can easily satisfy the participation constraints of the family members, and, consequently, his choice of farm structure is essentially driven by considerations of rent capture. Since his income originates in the collective field, he opts for a collective farm organization. When land becomes more scarce, however, satisfying the needs of members becomes more difficult, and the efficiency cost of collective production starts to weigh. Beyond a certain degree of land scarcity, it becomes profitable for the head to subtract some land from collective cultivation and distribute it to individual members so that they can satisfy part of their needs from their own plots. Of course, the head retains a collective field since he would be entirely deprived of income if all the land were privately allocated.

IV. Land Scarcity and Individual Plots in Mali: Descriptive Evidence

A. The Data

The data used in this article are collected firsthand in Mali during 2006 and 2007. Located in the Sahelian west African region, Mali is among the poorest countries of the world with a purchasing power parity annual income of $1,090 per capita (for 2008). Close to four-fifths of the Malian population earns less than $2 a day, and 70% lives in rural areas (World Bank 2008, 2010). An interesting feature of Mali is that family farms appear to be in a state of flux: traditional collective farms headed by a patriarch are still widespread, although, as pointed out in the introduction, there is an increasing tendency toward more individualized forms of cultivation.

We randomly sampled 50 villages in the three districts of Koutiala, Sikasso, and San, which belong to the old cotton zone of southern Mali. Within each village, we randomly selected 12 households from a complete listing of the local household population. In this article, we restrict attention to the 437 households that count at least one male member above 18 apart from the household head, so that there is at least one male member eligible for an individual plot in the household.[9]

[9] Some robustness checks are run on the complete sample. When we change samples, we mention it.

Our main survey instrument is a questionnaire administered to the household heads. In addition to detailed information on the composition of the household as well as on the size and structure of the associated farm, it includes qualitative queries about the reasons underlying the granting of individual plots and the possible problems that ensued. In order to have a more complete view about the rights and duties of the different participants to the household, we also interviewed a sample of household members who cultivate an individual plot.

B. The Broad Picture

To define households, we follow Matlon (1988; cited from Udry 1996, 1016), for whom a household is a group of individuals who "work jointly on at least one common field under the management of a single decision-maker" and "draw an important share of their staple foodstuffs from one or more granaries which are under the control of that same decision-maker." Traditionally, a west African rural household is large and complex. It extends both vertically (in the sense that married sons continue to live with their father) and horizontally (brothers of the head, their wives, and children are part of the household). It need not be so, however, as recent trends indicate.

Table 1 reports key statistics of our sample of households. It reveals that 50% of household heads live with at least one brother and 51% with at least one married son. Only 20% have neither brothers nor married sons around (strictly speaking, they are nuclear households). In the traditional family organization, married sons stay with their father (patrilocal residence), and their children grow up in the same compound. Family splits typically occur when brothers decide to separate upon adulthood and marriage of their own children with whom they form a common compound. Polygamy concerns

TABLE 1

DESCRIPTIVE STATISTICS OF KEY VARIABLES, HOUSEHOLD (HH) SAMPLE

Variable	Definition	Mean	SD	Min	Max
brother	1 if brother of head in hh	.499	.51	0	1
nbbrother	No. of brothers when brother = 1	1.293	1.142	1	6
marson	1 if married son of head in hh	.511	.500	0	1
nbmsons	No. of married sons if marson = 1	1.718	1.019	1	6
nuclear	marson = 0 and brother = 0	.200	.400	0	1
polygamy	1 if head is polygamous	.589	.492	0	1
hh size	No. of household members	10.635	6.148	2	33
IP	1 if male individual plots on farm	.259	.438	0	1
share_IP	Share of area in IP if IP = 1	.087	.093	.01	.586
share_IP_eq	Same as share_IP in dryland equivalent	.118	.111	.01	.608
IP_past	1 if IP in stem household	.202	.402	0	1

59% of the household heads. On average, the sample households count 10.6 individuals above 12, with a maximum family size of 33.

Mixed farming units coexist with traditional collective farms in our study area. Individual plots are allotted to male members living on the farm in 25.9% of the households. Even more households give individual plots to women (71% of households surveyed in 2007), although women's plots are significantly smaller than men's plots.[10] There are two important differences between men's and women's individual plots. First, women are traditionally expected to use their private plots—called garden plots—mainly to produce ingredients of the collective meals, condiments in particular. As we have pointed out, no such requirement is imposed on the male members who keep their private production for their private use. Second, women owning an individual plot are generally freed from the duty to work on the collective field, so that there is less direct competition in effort allocation between collective and private plots as far as they are concerned. Because the awarding of individual plots to men and women obeys different logic, attention is restricted to men's private activities. When extant, male private plots occupy 8.7% of total farm area on average, with a maximum of 58.6%.[11]

Interestingly, the practice of granting private plots to men seems to be spreading: when asked whether male members had individual plots while they were cultivating under the authority of the former head, current heads answered yes in only 20% of the cases. Also note that in mixed farms all male members above a certain age are typically granted a plot. In the few cases in which the head's brothers have an individual plot while sons do not, the latter tend to be very young.

Land markets are almost nonexistent in the study area: 80% of the parcels were inherited (post- or premortem), 10% were cleared by the owner a few decades ago when there was still land available in the open access zones, and 9% have been borrowed by the interviewed households.[12] Low activity of land

[10] We use the 2007 survey, as in 2006 some enumerators ignored very small garden plots cultivated by women. Women interviewed cultivate on average 0.41 hectares of private land, compared with 0.85 hectares for men.

[11] When we take into account the greater productivity of bottomland compared to dryland (as detailed in Sec. V.B), we obtain that male private plots account for 11.8% of farm area on average, with a maximum of 60.8%.

[12] Land lending is not synonymous with renting. We carefully asked both borrowers and owners whether there was any type of cash payment or goods and services exchanged for the land, and the answer was always negative. The land is often borrowed over several generations. With increasing land pressure, however, conflicts between owners and borrowers have become more common, frequently because the family that borrowed land a generation ago is reluctant to return it to the owner.

markets persists in spite of rising land pressure resulting in the quick disappearance of idle lands during the last decades. Until quite recently, indeed, land in the region was still rather abundant, and it was possible for new settlers into a village to be given land by local authorities. In addition, the labor market is hardly developed, so that land available per unit of labor is not equalized across farms. In other words, the sample farms are heterogeneous in terms of land-labor endowment.

C. Functioning of the Farm: The Strengths and Limitations of Patriarchal Power

Family farms are ruled by a patriarch who is typically the eldest man in the household. His authority is exerted in both the production and the consumption spheres. The former is most evident on the collective field, where the head has absolute power over all management decisions. Furthermore, to have access to an individual plot of land, the rule is that household members have to seek approval of the head. Justification is twofold: (1) as an authority figurehead, the head can decide "everything," so that not consulting him amounts to a lack of respect (47%), and (2) "free" decisions by members are likely to cause conflicts within the family (30%).[13]

When individual plots exist, management decisions including the choice of crop and supervision of effort belong to the landholding member, yet the allocation of labor time between the collective field and the individual plot is fixed by the head. Our data show that in the rainy season 38% of plot managers are free to work on their own field every day before and after their collective labor duty. The others are allowed to spend only 1–2 days per week on their individual plot. In the dry season, when competition between the collective field and individual plots is less acute, about 90% of plot managers are allowed to work on their plot every day.

It bears emphasis that the ability of the head to set the timetable for work on the collective field does not imply that he can control the allocation of actual labor effort between collective and individual activities. This point was made in the context of Gambia by von Braun and Webb (1989), who stress that competition unavoidably arises between personal interest and cooperation with the rest of the household when effort is allocated between collective and private production. It is revealing that in our study area almost half of the plot managers admit that they tend to give priority to cultivation of their individual plot at the expense of collective production. This is amply con-

[13] The reported percentages correspond to our classification of answers given by household heads to the following open question: "Why do household members need to seek your approval when they wish to cultivate an individual plot?"

firmed by the household heads who complain that family members tend to relax their effort on the collective field, thereby causing yields to fall. For example, one of them said that "more effort is applied to the individual plots and when members work on the collective plot, they are tired." Another one complained that when they work on the collective field, his sons "are prone to keep energy in reserve for their individual plots."[14] This sort of statement suggests that the granting of individual plots exacerbates the problem of moral-hazard-in-team on the collective field.

The existence of incentive problems on the collective field is absolutely crucial to our analytical attempt to explore the relationship between land scarcity and farm structure. We have, therefore, devoted a full paper to establishing it empirically (Goetghebuer, Guirkinger, and Platteau 2011). We show there that yields on individual plots are significantly higher than yields on the collective plot, especially for care-intensive crops (e.g., rice, peanuts). This result holds in a multivariate framework when we compare plots with similar characteristics planted with similar crops within the same household. A moral-hazard-in-team problem is argued to plague collective production, at least when care-intensive crops are grown and especially when there are married male adults among the workforce.

Since in the presence of individual plots the output of the collective field remains jointly consumed in the form of collective meals, it is unlikely that the incentive problems plaguing collective production originate in the consumption sphere. In other words, it is not plausible that individualization of productive activities is caused by conflicts over the ingredients of the jointly consumed meals or the collective organization of the daily meals. Furthermore, the head has the ability to make equal cash payments to remunerate effort on the collective field, so that he does not need to resort to individual plots to overcome consumption conflicts. It is thus telling that as much as 60% of our sample heads distribute part of the proceeds of the collective fields in the form of (equal) individualized allocations. Many of them are actually aware that this mode of remuneration offers the advantage of motivating members to work on the collective field.[15]

While we are thus confident that the presence of individual plots must be explained by incentive problems on the collective field, the precise source of productive inefficiency is not clear. As is evident from the theory proposed in Section III, there are two effects that reinforce each other and that are hard

[14] In French, "ils se réservent."

[15] When asked "How do you motivate members to work on the collective field?" 35% of the household heads spontaneously mentioned these allocations.

to disentangle empirically. First, the head appropriates a share of the collective output, whereas the totality of the output of a private plot accrues to the worker. Second, the collective output net of the head's share is to be divided equally among the members, giving rise to the moral-hazard-in-team problem.

The frequent mention by our respondents of the existence, or the fear, of intrafamily conflicts and jealousies may just reveal pervasive incentive problems. As a matter of fact, suspicions or accusations of misbehavior and exploitation of fellow members inside the family are likely to be rooted in manifestations of labor shirking on the collective field. Likewise, as again revealed by our interviews, tensions between members and the head often involve a disagreement about the excessive share of collective output retained by the head for his private consumption.

The preceding discussion deals with the nature and limitations of patriarchal decision-making power in the production sphere. It remains to be added that such power stretches beyond productive activities. Thus, when asked whether members of their family seek their approval before taking a loan, hardly 6% of the household heads answered no. And when queried about whether in the past they have sometimes opposed such a demand, more than 87% answered yes. In justifying their attitude, the majority argued that they consider themselves responsible for the family, in general, and for repayment of defaulted loans taken by family members, in particular—hence their perceived right to decide whether members may borrow.

A final observation is in order. We observe that the awarding of individual plots to members goes hand in hand with the devolution of nonfood expenditures to them. As compensation for this new burden, the members who have received private plots are not expected to transfer part of their private production to the head. From our interviews with the household heads, it is apparent that only 6% of these members have "helped" the head during the previous year through either cash or crop transfers. The figure is slightly higher when the members themselves were asked the same question, yet both the head and the members agree that when transfers are made the amount involved is typically very small.

D. Descriptive Statistics

The prediction from our theory of the patriarchal family is that individual plots are more likely to be observed in households where land pressure is acute. Before turning to the econometric analysis, we compare the means of key variables between the two types of farms.

Table 2 reveals that land availability per man ("area per cap") is larger in purely collective than in mixed farms, and this difference is driven by dry-

TABLE 2

DESCRIPTIVE STATISTICS OF EXPLANATORY VARIABLES FOR HOUSEHOLDS (HH) WITH AND WITHOUT INDIVIDUAL PLOTS (IP)

		Without IP*		With IP†		
Variable	Definition	Mean	SD	Mean	SD	Difference
area per cap	Hectares of farm area per man	2.727	1.821	2.211	1.201	Significant at 5%
dry area per cap	Hectares of dryland per man	2.586	1.852	2.011	1.196	Significant at 1%
bottom per cap	Hectares of bottomland per man	.147	.323	.201	.307	Significant at 10%
historical area	Hectares per brother when became head	6.300	5.258	6.507	4.479	
area dry (hist)	Hectares of dryland per brother (historical)	5.927	5.156	5.939	4.360	
area bottom (hist)	Hectares of bottomland per brother (historical)	.373	.871	.569	1.078	Significant at 5%
bottom	1 if bottomland on farm	.386	.488	.667	.473	Significant at 5%
share bottom	If bottom = 1: bottom area/total area	.198	.201	.158	.166	
hh size	No. of household members	9.519	5.602	13.837	6.530	Significant at 5%
married men	No. of married men (apart from head) in hh	1.578	1.692	2.721	2.030	Significant at 5%
others	No. of hh members (apart from married men)	6.943	4.328	10.116	5.021	Significant at 5%
dep hist	No. of brothers when became head	1.549	2.181	1.876	2.179	
age hh	Age of hh head	55.259	14.425	59.651	14.079	Significant at 5%
educ hh	1 if head had any formal education	.119	.324	.124	.331	
IP_past	1 if IP existed in stem hh	.141	.348	.372	.485	Significant at 5%
founding	1 if funding lineage	.635	.482	.713	.454	

* $N = 370$.
† $N = 129$.

lands. However, bottomland is more commonly found in mixed farms.[16] It corresponds to plots located in a flood-recession area or irrigable with a well, so that they can be possibly cultivated beyond the rainy season and allow the growing of more water-demanding crops, such as vegetables. Bottomland is present in 39% of households. There is no significant difference in the relative importance of bottomland (when present) across type of farm: bottomland accounts for 19.8% of farm area in mixed farms against 15.8% in farms with no male individual plots.

The variable "historical area" stands for the historical land availability as measured by the following ratio. The numerator is the number of hectares received by the current head when he acceded to that position. The denominator is the number of brothers who stayed with the current head at that moment (a variable labeled "dep hist") plus the head himself. Measuring land availability historically rather than currently inverts the above picture: on average, the land historically available per staying brother is slightly larger in currently mixed farms (6.5 hectares) than in currently collective farms (6.3 hectares).[17]

Turning now to household size ("hh size"), mixed farms count close to 14 members as against 9.5 members in collective farms. A breakdown of families into married men ("married men") and other members ("others") further shows that, in mixed farms, there is about one additional married man and, therefore, one additional conjugal unit. Historically the trend is similar: on an average, 1.5 brothers lived with the head in collective farms against 1.9 in mixed farms.

The average education level of the head does not vary at all between the two types of farms. This level is noticeably low: only 12% of current heads have ever been to school. Unsurprisingly, there is a noticeable continuity in the heads' practice of awarding individual plots: the proportion of current heads who received individual plots when they were under the authority of the previous head is 37% in mixed farms, compared with hardly 14% in collective farms.

Finally, household heads belonging to founding lineages (their ancestors were the first village settlers) are found in 63.5% of the farms with no individual plots and in 71.3% of the farms with individual plots. Since founding lineages typically have higher social status inside their village community, it is an important control in a multivariate setting.

[16] Bottomland is "bas-fond," in French.

[17] Historical land endowment is strictly larger than the current one since the number of brothers is smaller than the total current number of adult men.

V. Land Scarcity and Individual Plots in Mali: Econometric Analysis

From our descriptive statistics, we know that individualization of agricultural production is negatively correlated with current land availability and positively correlated with current family size. There is, however, a need to test these relationships in a multivariate framework where proper controls are introduced. Moreover, in order to be able to determine a causal relationship, we have to address an obvious endogeneity problem, whereby residential choices, and therefore household size, are likely to be directly influenced by land allocation. More precisely, if sons are prone to leave the family farm when no individual plots are awarded by their father, the absence of individual plots would appear, spuriously, to arise from small families and land abundance. Valid instruments susceptible to overcoming this problem are historical indicators of land availability and family size that predate both land allocation decisions by the head and location decisions by the members. Thanks to the availability of such historical information, we are able to avoid the potential problems arising from our abstracting away from household splitting as an alternative response to land scarcity.

In addition, we have seen that the composition of households varies from simple to complex structures. These differences are likely to affect the relationship between land availability and the distribution of individual plots. In particular, there are grounds to suspect that the intensity of the moral-hazard-in-team problem does not depend only on the size of the working team but also on its composition, in particular the number of married couples present in the household.

In what follows, we proceed in two steps. First, we analyze the determinants of the probability that a household head awards individual plots to members, and, second, we examine why the ratio of individualized to total land varies across households. In both cases, primary attention is given to the role of land availability.

A. The Determinants of the Probability of Granting Individual Plots to Members

We estimate a linear model for the probability that individual plots exist on the farm. The specification below (featuring land per capita and family size on the right-hand side) is in strict accordance with our theoretical prediction as stated under proposition 1.

$$\mathrm{IP}_{iv} = \alpha + \beta' \mathrm{Land}_{iv} + \gamma' \mathrm{HHComp}_{iv} + \delta' \mathrm{Controls}_{iv} + \mu' \mathrm{Villages} + \varepsilon.$$

The dependent variable IP_{iv} is a binary variable equal to 1 when at least one male member of household i in village v cultivates an individual plot. Independent variables are grouped into four vectors, the composition of which varies across specifications. Land availability (vector Land) cannot be measured by a single variable, owing to quality heterogeneity. In all the specifications, we control for the presence of bottomland through a discrete variable. Current land availability as such is measured continuously as the total land area (dry and bottom) per man above 12 years old.

Regarding household composition (vector HHComp), we first use the total number of members above 12 and then proceed by decomposing this number into two categories: the number of married men ("married men"), which stands for the number of nuclei inside the family, and the number of dependents (above 12; "others"). The controls included in the fourth vector (Controls) are as follows. First, the past history of private plots in the family is captured by a binary variable ("IP past") equal to 1 when the current head received an individual plot when he was under the authority of the previous head. Second, "age hh" and "educ hh" measure the age and the education, respectively, of the household head. Finally, we include village fixed effects (vector Villages) to control for local variations in land quality. This implies that the estimation of coefficients on the other explanatory variables relies on variations across households within the same village. Because we believe that allowing for fixed effects is important, we prefer to use the linear probability model rather than a logit or a probit model.

As suggested above, the identification of the effects of land pressure and household composition on land allocation has to account for the potential endogeneity of current land availability and household size. Fortunately, because we know all past transfers, we are able to construct a variable measuring the land area that the current household head held upon accession to headship. We also have available a historical indicator of the extent of horizontal extension of the family. More precisely, we know the number of brothers of the head who participated in the household at the time of the latter's accession to headship. Of course, the two historical variables are well correlated with current land area and family size, yet what matters for our purpose is that they were measured before members could receive individual plots. One could object that household members anticipate whether they would receive individual plots in the light of the practice prevailing in the previous generation, and, therefore, their decision of whether to remain in the household would be based on that anticipation. In order to address this problem, we control for the historical existence of private plots through the variable IP past. As instruments in two-stage least squares estimation procedures, we use the historical farmland per man and the number of brothers who stayed with the head when he acceded to headship.

We present our main results in columns 2–4 in table 3 (first stages are in table 4). In column 1 we show the result for the benchmark case of a simple ordinary least squares estimate carried out without any instrumentation. In column 2 both land availability and family size are instrumented. In column 3 we look at the differentiated effect of married men and other members. As we do not have separate instruments for these two measures of household size, the results reported have been obtained after instrumenting only for land availability. In column 4, we drop the other members' variable, while married men is instrumented with the historical number of brothers (area is again instrumented by historical area). Furthermore, we want to test for the possibility that household composition affects the relationship between land availability and the distribution of private plots. This is done in columns 5 and 6 by introducing

TABLE 3
LINEAR PROBABILITY MODEL: PRESENCE OF MALE INDIVIDUAL PLOTS

	No IV (1)	IV: area and hh size (2)	IV: area (3)	IV: area and married (4)	With Interaction (5)	(6)
area per cap	−.0207*	−.0836**	−.0648**	−.0766*		
	(.0120)	(.0394)	(.0297)	(.0415)		
historical area					.0033	−.0003
					(.0085)	(.0060)
bottom	.2122***	.1952***	.2099***	.1932***	.2114***	.2077***
	(.0569)	(.0528)	(.0523)	(.0549)	(.0579)	(.0586)
hh size	.0184***	.0229***			.0274***	
	(.0043)	(.0072)			(.0066)	
married men			.0450***	.0893***		.0741***
			(.0144)	(.0285)		(.0198)
others			.0067			.0124*
			(.0072)			(.0073)
hh size × hist area					−.0009*	
					(.0005)	
married × hist area						−.0034***
						(.0011)
age hh	.0013	−.0003	.0002	−.0014	.0020	.0015
	(.0011)	(.0017)	(.0013)	(.0020)	(.0012)	(.0013)
educ hh	−.0041	.0022	.0072	.0246	−.0115	.0016
	(.0676)	(.0676)	(.0673)	(.0672)	(.0664)	(.0680)
IP past	.2200***	.2323***	.2300***	.2338***	.2118***	.2115***
	(.0535)	(.0518)	(.0514)	(.0525)	(.0534)	(.0531)
founding family	.0671*	.0774*	.0825**	.0862**	.0631*	.0669*
	(.0369)	(.0404)	(.0386)	(.0393)	(.0372)	(.0355)
Village fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Cragg-Donald						
F-statistic		14.77	85.13	15.73		
Stock and Yogo 10%		7.03	16.38	7.03		

Note. Clustered robust standard errors (at the village level) in parentheses. IV = instrumental variable; $N = 499$.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

TABLE 4
FIRST STAGE OF REGRESSIONS REPORTED IN TABLE 3

	hh size (2)	area per cap (2)	area per cap (3)	married men (4)	area per cap (4)
historical area	.5774***	.1204***	.1393***	.1386***	.1204***
	(.0578)	(.0265)	(.0271)	(.0249)	(.0265)
dep hist	1.5145***	.0275		.3863***	.0275
	(.2527)	(.0332)		(.0640)	(.0332)
married men			.0315		
			(.0412)		
others			−.1188***		
			(.0238)		
bottom	1.4638**	−.1829	−.0165	.4118**	−.1829
	(.6520)	(.1944)	(.1766)	(.1744)	(.1944)
age hh	.0856***	−.0268***	−.0227**	.0369***	−.0268***
	(.0233)	(.0098)	(.0084)	(.0059)	(.0098)
educ hh	−.1839	.1613	.1719	−.3103*	.1613
	(.7120)	(.2650)	(.2385)	(.1815)	(.2650)
IP_past	.1110	.1725	.1712	−.0018	.1725
	(.7551)	(.1802)	(.1770)	(.2182)	(.1802)
founding	.2072	.1364	.2050	−.0564	.1364
	(.5251)	(.1418)	(.1262)	(.1613)	(.1418)

Note. Column headings specify variable instrumented, with column numbers from table 3. Clustered robust standard errors (at the village level) in parentheses.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

appropriate interaction terms. Testing such interaction effects is particularly difficult because of the multiplication of endogenous variables that need to be instrumented. The easiest route, which consists of interacting the instruments used for the separate variables, fails to provide reliable estimates in our particular setting (our set of instruments is particularly weak).[18] In the light of this problem, we choose to measure land availability directly through the historical variable and to interact it with family composition variables. The difference between columns 5 and 6 hinges on whether the historical land availability variable is interacted with the total family size or the number of married men.

The naive regression displayed in column 1 shows that the effects of land availability and family size are according to expectation: the household head is more likely to distribute private plots to male members when land per man is lower and when the family is larger. Regarding the latter, the implication of the theory must be borne in mind: when the size of the workforce on the collective field is larger, the scope of the moral-hazard-in-team problem increases, which enhances the relative attractiveness of private plots where no efficiency

[18] This is not actually surprising given that the interaction of historical land availability per capita and the historical number of brothers is in fact roughly equivalent to historical farm size.

problem arises. Instrumenting the two variables of key interest in the aforementioned way has been successful: as displayed in the last rows of table 3, the Cragg-Donald Wald test statistic is well above the Stock and Yogo critical values at 10%, indicating that our instruments reduce by 90% the bias of ordinary least squares estimates and are thus strong.

As is evident from column 2 the effects of land availability and family size are confirmed. Whereas the coefficient and the statistical significance of the family size variable prove remarkably stable between these first two regressions, this is not true of the land availability variable. Indeed, not only does the significance of its coefficient improve (from 90% to 95% confidence level), but its size has considerably increased (it is multiplied by four). A reduction of the land available per man of 1 hectare causes the probability to distribute private plots to increase by 8 percentage points. However, an increase by one unit of the family size increases the same probability by 2.4 percentage points.[19]

Table 3, column 3, reveals another interesting result. When the family is decomposed into married men and other members, only the first category appears to have a significant influence on private plot allocation. The effect is strongly significant. The regression presented in column 4, in which the two key variables (land availability and married men) are instrumented, shows that the effect of the number of nuclei in the family is confirmed (the level of statistical significance remains at 99%), and the size of this effect is more than doubled. An increase of one unit in the number of married men increases the probability of individual plots by almost 10 percentage points.

This additional result suggests that the standard moral-hazard-in-team argument needs to be refined. As usually stated, this argument implies that the magnitude of the efficiency loss increases with the number of team members considered as equivalent units. Our result shows that the assumption of an undifferentiated impact of group size is not applicable to the context of an extended or complex family. More precisely, free riding on other members' efforts on the collective field is observed when several married men work together. In our theoretical framework, this implies that n should be interpreted as the number of conjugal units rather than as that of individual members.

Two types of explanations come to mind regarding the role of married couples. First, being strangers, daughters- or sisters-in-law bring heterogeneity into the household: they are not tied to the household by the same solidarity links and loyalty feelings as their husbands. Second, and perhaps most convincingly, when the families of married men are of unequal size, the sharing

[19] The results prove robust to an alternative specification that separately tests the effect of land availability aggregated at the family level and family size (results not shown).

rule is bound to look arbitrary to a category of parents. Thus, if the sharing rule provides for equal incomes to all married adults regardless of the size of their family, parents with more children feel discriminated against. Whereas, if shares are proportional to family size, parents with fewer children feel exploited because they work partly for the benefit of larger conjugal units. These two weaknesses of complex households often have been pointed out to us in the field, and they are also stressed in anthropological and historical literature (see, e.g., Worobec 1995, 81, for pre-Communist Russia).

The implication of the above is that productive efficiency should be lower in complex households, so that the effect of land availability on farm structure should be stronger in those households. This prediction is tested in table 3, columns 5 and 6, through the introduction of an interaction term between land availability and a measure of family size. The coefficient of the interaction term is negative and statistically significant in both regressions. Significance is stronger when land availability is interacted with the number of married men as seen in the last regression. In this regression, we also find that the number of other members now has a statistically significant (at 95%) positive effect on the distribution of private plots.[20]

It is noticeable that across all six regressions, the coefficient of the bottomland dummy is stable, positive, and highly significant (at 99% level). Its size indicates that households with bottomland have a 20-percentage-point-higher probability to distribute private plots. As pointed out earlier, thanks to their better access to water, bottomlands allow for crops that are often of comparatively high value and require more care-intensive efforts. These two characteristics imply that incentive problems are more serious on bottomlands than on drylands. On the one hand, because of the higher value of the crops, the monetary cost of inefficiency is higher on bottomlands. On the other hand, labor-shirking problems are more important when quality of effort matters. Both arguments can be found in the literature. The first has actually been used to explain why regions suitable for the cultivation of high-value crops experienced an earlier individualization of land tenure rules at the community level (Baland and Platteau 1998; Platteau 2000, chap 3). The second argument is discussed by Binswanger and Rosenzweig (1986) and by Hayami and Otsuka (1993, chap. 1), who stress the existence of management diseconomies when land-saving and labor-using techniques are used. In our sample, we thus find that the proportion of bottomland parcels that are individualized is much higher (17% on average) than the proportion of individualized dryland par-

[20] If we distinguish between dryland and bottomland, only the interaction with dryland is significant.

cels (2% on average). The proportions are 44% and 8%, respectively, if we limit our attention to households that have given private plots to male members. In our regressions, this effect is reflected in the positive relationship between the presence of bottomland and the incidence of private plots at the household level.

Ideally, we would like to break down total land availability into dryland and bottomland, measured continuously. The problem nevertheless arises that instrumentation then becomes difficult.

Finally, it is striking yet not surprising that in all the regressions, the history of the household influences the current farm structure. When private plots were present in the stem household, they are more likely to be observed today, and this relationship is strongly significant. It is not clear to us what is the exact mechanism behind the persistence of the practice of individual plots. It is all the more important, therefore, to check whether our results hold when we remove this independent variable. Reassuringly, our main results continue to hold (results not shown).

B. The Determinants of the Share of Individual Plots in Total Farm Area

In what follows, we want to measure the influence of the same determinants as those used above on the share of the total farm area allotted to individual production. Our econometric model needs to account for the fractional nature of the dependent variable. Being a proportion, it is bounded by zero and one, and, in our sample, there is also a large proportion of zeros. We use the strategy proposed by Papke and Wooldridge (1996) to handle proportion models with zeros or ones. Formally, we assume that the expected value of the share of farmland dedicated to individual plots conditional on our control variables is such that

$$E(\text{ShareIP}_i|\text{Land}_i,\ \text{HHComp}_i,\ \text{Controls}_i) \\ = G(\alpha + \beta'\,\text{Land}_i + \gamma'\text{HHComp}_i + \eta'\text{Controls}_i),$$

where G is a logistic function. To estimate the parameters, we use Bernoulli quasi-maximum likelihood estimators recommended by the authors. We control for village fixed effects by introducing the village mean for all explanatory variables as suggested by Papke and Wooldridge (2008). In order to instrument our key variables, we use their predicted values as yielded by the first-stage regressions, and we bootstrap the second stage to obtain valid standard errors.

In table 5, we present six different specifications. The first four correspond to the first four models presented in table 3. In the last two columns, we

TABLE 5

PROPORTION PANEL MODEL: SHARE OF LAND IN MALE INDIVIDUAL PLOTS

	No IV (1)	IV: area and hh size (2)		IV: area (3)	IV: area and married (4)		IV: area and hh size, Weighting bottom (5)	IV: hh size, Weighting bottom (6)
area per cap	−.1314	−.4423*	−.0046	−.4021	−.4212*	−.0091	−.4814**	
	(.1149)	(.2425)		(.3382)	(.2215)		(.1909)	
area dry (hist)								−.0734**
								(.0295)
bottom	.9966***	.9326***	.0096***	1.0653***	.9467***	.0205***	1.5356***	
	(.3209)	(.2963)		(.3162)	(.2677)		(.2745)	
area bottom (hist)								.2236***
								(.0856)
hh size	.0796***	.1083***	.0011				.1287***	.1250***
	(.0162)	(.0287)					(.0338)	(.0324)
married men				.1827**	.4087***	.0088		
				(.0929)	(.1199)			
others				.0607				
				(.0406)				
age hh	.0039	−.0019	−.0000	−.0052	−.0072	−.0002	−.0117	.0053
	(.0107)	(.0098)		(.0111)	(.0102)		(.0114)	(.0116)
educ hh	.0481	−.0555	−.0006	.1395	.0396	.0009	−.0309	−.0773
	(.4096)	(.3644)		(.4325)	(.5206)		(.2521)	(.3918)
IP past	.8730***	.8617***	.0089	.8777***	.8475***	.0183	.8377***	.9495***
	(.2098)	(.1805)		(.2350)	(.2173)		(.2052)	(.2979)
founding family	.3569	.4857	.0050	.4153	.5292	.0114	.3850	.3105
	(.2698)	(.2997)		(.2567)	(.3292)		(.2596)	(.3213)
Village "fixed effects"	Yes	Yes		Yes	Yes		Yes	Yes
No. of observations	499	499		499	499		499	499

Note. Standard errors in parenthesis are bootstrapped and are clustered at the village level. IV = instrumental variable.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

no longer define the dependent variable as the ratio of the unweighted area under individual plots to the unweighted total farm area. Since bottomlands are more productive than drylands (see above) and also more likely to be cultivated individually, the correct measure of the dependent variable requires that we compute it by associating a greater weight to bottomland. We are fortunate to have a rather precise estimate of the relative productive potential of the two types of land in our sample (see Goetghebuer et al. 2011): when proper controls are introduced, 1 hectare of bottomland is about three times as productive as 1 hectare of dryland. In column 5, for the sake of consistency, the area per capita independent variable is adjusted accordingly.[21] In column 6, we break down the land availability variable into two continuous variables, the area of dryland per man and the area of bottomland per man. We are again reluctant to instrument for three endogenous variables in the same equation, and we directly use historical variables instead (the per capita areas of dryland and bottomland controlled by the head upon accession to headship).

We do not report the regressions with interaction terms since the corresponding coefficients are statistically insignificant. Finally, along with raw parameter estimates and their significance, we report marginal effects for specifications 2 and 4. These marginal effects appear small, but this is related to the fact that a large number of households have no individual plots.

While in the naive regression family size has the expected positive effect on the share of land allocated to private plots, there is no perceptible effect of land availability. However, when we instrument these two independent variables, they both turn out to have a significant influence in the direction predicted by the theory (see table 5, col. 2).[22] When the family size variable is decomposed, it appears that the number of married men significantly increases the share of private plots (col. 3). When the married men variable is instrumented, and the other members variable is concomitantly dropped, the positive effect of the former is confirmed, and the level of statistical significance is very high (see col. 4). If we modify the dependent variable and the land

[21] With this definition, the mean (standard deviation) of farm area (per man) is 3.027 (0.100) for the whole sample and 2.613 (0.125) for households with individual plots. Note that our results hold when we use alternative weights (between 1 and 5).

[22] It could be argued that the negative correlation between total land area per capita and the share dedicated to private plots is the result of something other than the need to provide incentives. The idea is that, if there exists a minimum threshold in plot size, the negative relationship between these two variables would be purely mechanical: when the area per capita is small, because the minimum plot size is unchanged, the share variable would be larger. We nevertheless believe that this alternative explanation is not relevant in our study area where agriculture uses rudimentary techniques that are not subject to scale economies or indivisibilities. In fact individual plots are often quite small and often revealingly called "garden plots."

availability variable in such a way as to give greater weight to bottomland, the results are reinforced (col. 5). Results in column 6 also bear out the theory: the share of individual plot area in the household farm increases as the bottomland area is larger and the dryland area is smaller. The effect of family size is unaffected by the use of continuous variables to measure the two types of land available.[23]

When the presence of bottomland is measured by a binary variable, its coefficient is always highly significant and remarkably stable. The same can be said of the historical presence of private plots in the household. Note that the effect of land scarcity and family composition hold when this variable is not included (results not shown).

VI. Conclusion

The article has yielded both an expected and an unexpected result. On the one hand, our prediction that increasing land scarcity should prompt household heads to give individual plots of land to (male) members is borne out by the evidence adduced on the basis of firsthand data collected in Mali. The intuition is that, when land becomes more scarce, the head has to give more weight to efficiency considerations compared to his rent-capturing ability. This is because he has to satisfy the members' participation constraints under harsher conditions than before. On the other hand, for a given amount of land, an increase in the number of nuclei present inside the household (as measured by the number of married men) raises the probability that private plots are awarded to (male) members. The latter result suggests that the intensity of the moral-hazard-in-team problem that plagues production on the collective or family fields is not simply a function of the size of workforce involved, but it also varies with the composition of this workforce. Incentive problems thus appear to be especially acute when the component units of the household are more heterogeneous owing to the presence of in-laws.

It could be objected that intrafamily conflicts in the presence of married couples may well arise from circumstances independent of productive inefficiencies and directly lead to the individualization of production activities. If tensions make common life unbearable, an obvious solution consists indeed of providing maximal physical distance between the locations of the members' activities. In the case of our study area, however, this line of interpretation is not very convincing because members, even when granted individual plots, continue to work on the collective field. Furthermore, it is hard to imagine

[23] The results prove robust to an alternative specification that separately tests the effect of land availability aggregated at the family level and family size (results not shown).

how intrafamily tensions could increase with land scarcity without being manifested in incentive problems on the level of production. It is true that they could also result in conflicts over consumption choices, especially if the sizes of conjugal units differ. It is nevertheless noticeable that in our study area consumption remains largely collective in spite of rising land scarcity.

Of course, we cannot rule out other possible responses to land scarcity by household heads. They include migration and the breakup of the original (stem) household accompanied by a (partial) splitting of the family land assets. Future research efforts should therefore be directed at estimating simultaneously the effect of land scarcity on these response mechanisms. Interestingly, in our sample the incidence of private plots is larger among bigger and more complex households, suggesting that the awarding of such plots is a substitute for household splitting.

Appendix A
Optimization in the Collective Regime

With a Cobb-Douglas production function, $f(a, l) = a^{\varepsilon} l^{1-\varepsilon}$, and the linear cost of effort, $v(l) = \omega l$, the head's rent is $R = \alpha(na)^{\varepsilon}(nl)^{1-\varepsilon}$, where l is the solution to

$$\frac{1-\alpha}{n} f_L(na, nl) = v'(l) \tag{A1}$$

$$\Leftrightarrow (1-\varepsilon)\frac{1-\alpha}{n}(na)^{\varepsilon}(nl)^{-\varepsilon} = \omega 1 \tag{A2}$$

$$\Leftrightarrow a\left(\frac{(1-\alpha)(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon} = l. \tag{A3}$$

The production on the collective field is $f^C = na((1-\alpha)(1-\varepsilon)/n\omega)^{(1-\varepsilon)/\varepsilon}$, and the head's rent is $R = \alpha na((1-\alpha)(1-\varepsilon)/n\omega)^{(1-\varepsilon)/\varepsilon}$. This function is maximized for $\hat{\alpha} = \varepsilon$, but $\hat{\alpha}$ can only be chosen by the head if the participation constraint of the members is satisfied. The participation constraint defines the maximal share the father may extract, α^M.

$$\underline{u} = \frac{1-\alpha^M}{n} f(na, nl) - \omega l.$$

$$\underline{u} = \frac{1-\alpha^M}{n}(na)\left(\frac{(1-\alpha^M)(1-\varepsilon)}{n\omega}\right)^{(1-\varepsilon)/\varepsilon} - \omega a\left(\frac{(1-\alpha^M)(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon}.$$

$$\underline{u} = (1 - \alpha^M)^{1/\varepsilon} a \left(\frac{1-\varepsilon}{n\omega}\right)^{1/\varepsilon} \left(\frac{n\omega}{1-\varepsilon} - \omega\right).$$

$$\alpha^M = 1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\underline{u}(1-\varepsilon)}{a(n\omega - \omega + \omega\varepsilon)}\right)^{\varepsilon}.$$

If $\alpha^M < \hat{\alpha}$, then $\alpha^* = \alpha^M$; otherwise, $\alpha^* = \hat{\alpha}$. The inequality $\alpha^M < \hat{\alpha}$ is equivalent to $a < (n\omega\varepsilon/(1-\varepsilon))^{1/\varepsilon} n\underline{u}(1-\varepsilon)/(n\omega - \omega + \omega\varepsilon)$. Thus, if

$$a < \left(\frac{n\omega\varepsilon}{1-\varepsilon}\right)^{1/\varepsilon} \frac{n\underline{u}(1-\varepsilon)}{n\omega - \omega + \omega\varepsilon},$$

we have that

$$R = \left(1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\underline{u}(1-\varepsilon)}{a(n\omega - \omega + \omega\varepsilon)}\right)^{\varepsilon}\right) na \left(\frac{\underline{u}n(1-\varepsilon)}{na(n\omega - \omega + \omega\varepsilon)}\right)^{1-\varepsilon}$$
$$= na^{\varepsilon}\left(\frac{\underline{u}(1-\varepsilon)}{n\omega - \omega + \omega\varepsilon}\right)^{1-\varepsilon} - \frac{n^2\underline{u}}{n-1+\varepsilon}.$$

If

$$a > \left(\frac{n\omega\varepsilon}{1-\varepsilon}\right)^{1/\varepsilon} \frac{n\underline{u}(1-\varepsilon)}{n\omega - \omega + \omega\varepsilon},$$

then

$$R = na\varepsilon\left(\frac{(1-\varepsilon)^2}{\varepsilon n\omega}\right)^{(1-\varepsilon)/\varepsilon}.$$

Appendix B

Optimization in the Mixed Regime

1. Signs of the Lagrangian Multipliers

We start by showing that if the participation constraint does not bind, then $\partial V/\partial A^I < 0$, so that unless the participation constraint binds, it is always optimal for the father to decrease the size of the individual plots or to increase the size of the collective field. This implies that the mixed regime can only arise if the participation constraint binds. In what follows, to simplify notations, we use the superscript C for the production function on the collective field and I to designate the production function on individual plots, and we ignore the arguments of the production and disutility of effort functions. If the participation constraint does not bind, $= 0$, and the first-order conditions (FOC) are

$$\frac{\partial L}{\partial \alpha} = f^C - \frac{\lambda}{n} f_L^C = 0. \tag{B1}$$

$$\frac{\partial L}{\partial l^C} = \alpha n f_L^C - \lambda\left(v'' - (1-\alpha) f_{LL}^C\right) - \mu v'' = 0. \tag{B2}$$

$$\frac{\partial L}{\partial l^I} = -\lambda v'' - \mu\left(v'' - f_{LL}^I\right) = 0. \tag{B3}$$

The first equation implies $\lambda = nf^C/f_L^C$. Substituting λ in the last equation yields $\mu = -v''\left(nf^C/f_L^C\right)/\left(v'' - f_{LL}^I\right)$. Since λ is unambiguously positive while μ is unambiguously negative, $\partial V/\partial h = -\alpha n f_A^C - \lambda(1-\alpha/n) f_{LA}^C + \mu(1/n) f_{LA}^C$ is negative.

If the participation constraint is binding, the FOC of the maximization problem are

$$\frac{\partial L}{\partial \alpha} = f^C - \lambda \frac{1}{n} f_L^C - \nu \frac{1}{n} f^C = 0. \tag{B4}$$

$$\frac{\partial L}{\partial l^C} = \alpha n f_L^C - \lambda\left(v'' - (1-\alpha) f_{LL}^C\right) - \mu v'' - \nu\left(-(1-\alpha) f_L^C + v'\right) = 0. \tag{B5}$$

$$\frac{\partial L}{\partial l^I} = -\lambda v'' - \mu\left(v'' - f_{LL}^I\right) - \nu\left(-f_L^I + v'\right) = 0. \tag{B6}$$

Equation (B6) implies $\mu = -\lambda\left(v''/\left(v'' - f_{LL}^I\right)\right)$ since $-f_L(A^I, l^I) + v'(l^C + l^I) = 0$. Equation (B4) implies

$$\nu = n - \lambda \frac{f_L^C}{f^C}. \tag{B7}$$

Replacing μ and ν in equation (B5) by these expressions yields

$$\alpha n f_L^C - \lambda(v'' - (1-\alpha) f_{LL}^C) + \lambda \frac{v''^2}{v'' - f_{LL}^I} - n(-(1-\alpha) f_L^C + v') + \lambda \frac{f_L^C}{f^C}(-(1-\alpha) f_L^C + v') = 0$$

$$\Leftrightarrow \alpha n f_L^C + (n-1)(1-\alpha) f_L^C$$

$$+ \lambda\left(-v'' + (1-\alpha) f_{LL}^C + \frac{v''^2}{v'' - f_{LL}^I} + \frac{(f_L^C)^2}{f^C}(1-\alpha)\left(-1 + \frac{1}{n}\right)\right) = 0$$

$$\Leftrightarrow \lambda = -\frac{(n-1-\alpha) f_L^C}{-v'' + (1-\alpha) f_{LL}^C + \left(v''^2/\left(v'' - f_{LL}^I\right)\right) + \left((f_L^C)^2/f^C\right)(1-\alpha)(-1 + (1/n))}$$

$$\Leftrightarrow \lambda = -\frac{(n-1-\alpha) f_L^C}{(1-\alpha) f_{LL}^C + \left(v'' f_{LL}^I/\left(v'' - f_{LL}^I\right)\right) + \left((f_L^C)^2/f^C\right)(1-\alpha)(-1 + (1/n))}.$$

This implies that $\lambda > 0$, and, as a result, $\mu < 0$.

2. *The Head's Rent for a Given H*

The first-order conditions of the members' utility maximization problem yield explicit expressions for the labor efforts on the collective field and individual plots:

$$l^C = (a - h)\left(\frac{(1-\alpha)(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon}. \quad \text{(B8)}$$

$$l^I = h\left(\frac{1-\varepsilon}{\omega}\right)^{1/\varepsilon}. \quad \text{(B9)}$$

From the participation constraint we may now extract an expression of α as a function of h. We have

$$\underline{u} = \frac{1-\alpha}{n} f((a-h)n,\ nl^C) + f(h,\ l^I) - v(l^C + l^I). \quad \text{(B10)}$$

$$\underline{u} = \frac{1-\alpha}{n}((a-h)n)\left(\frac{(1-\alpha)(1-\varepsilon)}{n\omega}\right)^{(1-\varepsilon)/\varepsilon} - \omega(a-h)\left(\frac{(1-\alpha)(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon}$$
$$+ h\left(\frac{1-\varepsilon}{\omega}\right)^{(1-\varepsilon)/\varepsilon} - \omega h\left(\frac{1-\varepsilon}{\omega}\right)^{1/\varepsilon}. \quad \text{(B11)}$$

$$\underline{u} = (a-h)\left(\frac{(1-\varepsilon)(1-\alpha)}{n\omega}\right)^{1/\varepsilon}\left(\frac{n\omega}{1-\varepsilon} - \omega\right) + \omega h\left(\frac{1-\varepsilon}{\omega}\right)^{1/\varepsilon}\frac{\varepsilon}{1-\varepsilon}. \quad \text{(B12)}$$

$$\alpha = 1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\left(\underline{u} - h((1-\varepsilon)/\omega)^{1/\varepsilon}\omega\varepsilon/(1-\varepsilon)\right)(1-\varepsilon)}{(a-h)(n\omega - \omega + \omega\varepsilon)}\right)^{\varepsilon}. \tag{B13}$$

Therefore,

$$\begin{aligned} R = {} & \left(1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\left(\underline{u} - h((1-\varepsilon)/\omega)^{1/\varepsilon}\omega\varepsilon/(1-\varepsilon)\right)(1-\varepsilon)}{(a-h)(n\omega - \omega + \omega\varepsilon)}\right)^{\varepsilon}\right) \\ & \times \ (a-h)n\left(\frac{\left(\underline{u} - h((1-\varepsilon)/\omega)^{1/\varepsilon}\omega\varepsilon/(1-\varepsilon)\right)(1-\varepsilon)}{(a-h)(n\omega - \omega + \omega\varepsilon)}\right)^{1-\varepsilon} \\ = {} & (a-h)^{\varepsilon} n\left(\underline{u} - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{1-\varepsilon}\left(\frac{(1-\varepsilon)}{n\omega - \omega + \omega\varepsilon}\right)^{1-\varepsilon} \\ & - \left(\underline{u} - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)\frac{n^2}{n-1+\varepsilon}. \end{aligned}$$

Appendix C

Proof of Proposition 1a

We proceed in three steps. First, we note that in both regimes the head's rent is monotonically increasing in a, and it tends toward infinity. We then show that a marginal increase in land endowment has a greater impact on the head's rent in the collective than in the mixed regime, which implies that the head's rent moves "faster" to infinity in the collective regime than in the mixed regime. Finally, we show that for very small land endowments the head prefers the mixed regime. This implies that there exists a level of land endowment for which the head is indifferent between the two regimes. Above this threshold, he opts for the collective regime, and, below it, he opts for the mixed regime.

Monotonicity of $R(a)$ in Both Regimes

To examine the impact of a on the head's rent in both regimes, we apply the envelope theorem. Let us begin by defining the Lagrangian in the collective regime:

$$\begin{aligned} L(l,\alpha) = {} & \alpha f(na, nl) - \lambda^{C}\left(v'(l) - \frac{1-\alpha}{n} f_L(na, nl)\right) \\ & - \nu^{C}\left(\underline{u} - \frac{1-\alpha}{n} f(na, nl) + v(l)\right). \end{aligned}$$

The envelope theorem implies

$$\frac{\partial R}{\partial a} = \frac{\partial L}{\partial a} = n\alpha f_A(na, nl) + \lambda^C(1-\alpha)f_{LA}(na, nl) + \nu^C(1-\alpha)f_A(na, nl).$$

To find an expression for λ^C and ν^C, we write the FOC of the maximization problem:

$$\frac{\partial L}{\partial \alpha} = f(na, nl) - \lambda^C \frac{1}{n} f_L(na, nl) - \nu^C \frac{1}{n} f(na, nl) = 0.$$

$$\frac{\partial L}{\partial l} = \alpha n f_L(na, nl) - \lambda^C(v''(l) - (1-\alpha)f_{LL}(na, nl)) - \nu^C(-(1-\alpha)f_L(na,\ nl) + v'(l)) = 0.$$

We need to distinguish two cases: $\nu^C = 0$ (unbinding participation constraint) and $\nu^C > 0$ (binding participation constraint). In the first case, we have $\lambda^C = nf/f_L$, and

$$\frac{\partial R}{\partial a} = n\alpha f_A + (1-\alpha)\frac{nf}{f_L} f_{LA} = n\alpha f_A + (1-\alpha) n f_A \tau_{LA},$$

where $\tau_{LA} = ff_{LA}/f_A f_L$ is the elasticity of substitution between land and labor. Because $\tau_{LA} = 1$ in the case of the Cobb-Douglas function, the above expression reduces to

$$\frac{\partial R}{\partial a} = nf_A.$$

In the second case where $\nu^C > 0$, we have $\nu^C = n - \lambda^C(f_L/f)$, so that

$$\frac{\partial R}{\partial a} = n\alpha f_A + \lambda^C(1-\alpha)f_{LA} + (1-\alpha)\left(n - \lambda^C\frac{f_L}{f}\right)f_A = nf_A + \lambda^C(1-\alpha)f_{LA}\left(1 - \frac{1}{\tau_{LA}}\right).$$

Since $\tau_{LA} = 1$, the above expression reduces to

$$\frac{\partial R}{\partial a} = nf_A.$$

Whether or not the participation constraint binds, the head's rent is monotonically increasing in a, and in both cases the impact of a marginal increase in land endowment on the rent is simply equal to the product of the number of members and the marginal productivity of land (nf_A). Note also that the limit of $R(a)$ when a tends to infinity is infinity.

Let us now consider the situation under the mixed regime. For a given h, we have

$$\frac{\partial R}{\partial a} = \frac{\partial L}{\partial a} = \alpha n f_A^C + \lambda \frac{1-\alpha}{n} f_{LA}^C + \nu \frac{1-\alpha}{n} f_A^C.$$

Since again $\nu = n - \lambda\left(f_L^C/f^C\right)$, we can write

$$\begin{aligned}\frac{\partial R}{\partial a} &= \alpha n f_A^C + \lambda \frac{1-\alpha}{n} f_{LA}^C + \left(n - \lambda \frac{f_L^C}{f^C}\right)\frac{1-\alpha}{n} f_A^C \\ &= n f_A^C + \lambda \frac{1-\alpha}{N} f_{LA}^C \left(1 - \frac{1}{\tau_{LA}}\right) \\ &= n f_A^C.\end{aligned}$$

When h is fixed, the head's rent is monotonically increasing in a. Therefore, when the head can adjust the size of the individual field, he will a fortiori benefit from an increase in a. For a given h, the explicit expression we obtained for the father's rent clearly implies that it tends to infinity when a tends to infinity. An a fortiori argument can be used when the head is allowed to adjust the size of the individual plots.

Comparison of $\partial R/\partial a$ across Regimes

Let us show that a marginal increase in a has a greater impact on the head's rent in the collective regime than in the mixed regime, when h is fixed. We will then argue that even if h is allowed to vary, the result holds. Bearing in mind that the superscripts *col* and *mix* refer to the optimal values of the parameters and functions in the collective regime and the mixed regime, respectively, we first want to show that

$$\left(\frac{\partial R}{\partial a}\right)^{\text{col}} > \left(\frac{\partial R}{\partial a}\right)^{\text{mix}} \tag{C1}$$

$$\Leftrightarrow (f_A)^{\text{col}} > \left(f_A^C\right)^{\text{mix}}. \tag{C2}$$

With our Cobb-Douglas specification, this inequality is equivalent to

$$\left(\varepsilon\left(\frac{nl}{na}\right)^{1-\varepsilon}\right)^{\text{col}} > \left(\varepsilon\left(\frac{nl^C}{n(a-h)}\right)^{1-\varepsilon}\right)^{\text{mix}}$$
$$\Leftrightarrow \left(\frac{l}{a}\right)^{\text{col}} > \left(\frac{l^C}{(a-h)}\right)^{\text{mix}}.$$

Using the expressions for the level of effort applied on the collective field in both regimes (eqq. [A3] and [B8]), we can rewrite the previous inequality:

$$\left(\frac{(1-\alpha^{\text{col}})(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon} > \left(\frac{(1-\alpha^{\text{mix}})(1-\varepsilon)}{n\omega}\right)^{1/\varepsilon}$$

$$\Leftrightarrow \alpha^{\text{col}} < \alpha^{\text{mix}}.$$

As argued in appendix A, we have

$$\alpha^{\text{col}} \leq 1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\underline{u}(1-\varepsilon)}{a(n\omega-\omega+\omega\varepsilon)}\right)^{\varepsilon}.$$

Furthermore, equation (B13) establishes

$$\alpha^{\text{mix}} = 1 - \frac{n\omega}{1-\varepsilon}\left(\frac{\left(\underline{u} - h((1-\varepsilon)/\omega)^{1/\varepsilon}\omega\varepsilon/(1-\varepsilon)\right)(1-\varepsilon)}{(a-h)(n\omega-\omega+\omega\varepsilon)}\right)^{\varepsilon}.$$

Finally,

$$\alpha^{\text{col}} < \alpha^{\text{mix}} \tag{C3}$$

$$\Leftarrow \frac{\left(\underline{u} - h((1-\varepsilon)/\omega)^{1/\varepsilon}\omega\varepsilon/(1-\varepsilon)\right)}{a-h} < \frac{\underline{u}}{a} \tag{C4}$$

$$\Leftarrow \underline{u} < a\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}. \tag{C5}$$

We know that this last inequality is verified: the right-hand-side expression corresponds to the utility that would be obtained by a member if he would produce individually on a field of size a. Indeed $a^{\varepsilon}l^{1-\varepsilon} - \omega l$, where $l = a((1-\varepsilon)/\omega)^{1/\varepsilon}$ is equivalent to $a((1-\varepsilon)/\omega)^{(1-\varepsilon)/\varepsilon} - \omega a((1-\varepsilon)/\omega)^{1/\varepsilon}$, which is itself equal to $\varepsilon a((1-\varepsilon)/\omega)^{(1/\varepsilon)-1}$ and corresponds to the maximum utility achievable with a per capita level of land endowment of a. It is necessarily greater than $\underline{u}$ since the problem would not yield any solution if this were not the case.

Finally, $\alpha^{col} < \alpha^{mix}$ and $(\partial R/\partial a)^{col} > (\partial R/\partial a)^{mix}$ for a given h. If h is allowed to vary, could the head's rent increase to a greater extent in the mixed regime? The answer is negative because a marginal increase in a has a greater impact on the head's rent in the collective than in the mixed regime for all h.[24]

The Dominance of the Mixed Regime for Very Small *a*

Suppose that $\underline{a}$ is such that the father's rent is null in the collective regime; that is, $\underline{a}$ is such that when the farm is collectively cultivated, the production is just enough to meet the reservation utilities of the members leaving nothing for the head. If $\underline{a}$ would instead be dedicated to individual plots, we know that each member would obtain a utility greater than $\underline{u}$ since the first best level of effort would be applied. As a consequence, the income net of effort cost would be greater than under collective production. Thus, there exists $\underline{h} < \underline{a}$ so that members can just achieve $\underline{u}$ from their individual plot only and, by allocating $n(\underline{a} - \underline{h})$ to collective production, the head would obtain a positive rent. (The optimal h is actually smaller than $\underline{h}$.) We may therefore conclude that, for some small values of a, the head prefers the mixed regime.

The Succession of Regimes When *a* Goes from 0 to $+\infty$

Finally, we know that for small values of a the head prefers the mixed regime. As a increases, the head's rent increases monotonically toward infinity in both regimes, but it increases faster in the collective regime (since $\partial R/\partial a$ is greater in that regime). This implies that, as a goes from 0 to $+\infty$, the mixed regime first dominates, but, once a certain threshold is reached, the collective regime becomes superior.

Appendix D

Proof of Proposition 1b

We want to prove that $d(h/a)/da < 0$.

$$\frac{d\left(\frac{h}{a}\right)}{da} = -\frac{1}{a^2}h + \frac{1\partial h}{a\partial a}.$$

[24] To see this, consider a marginal increase in a from a_1 to a_2. Call $h^*(a)$ the optimal size of individual plots when total land endowment is a, $R^{col}(a)$ the head's rent in the collective regime, and $R^{mix}(a, h^*(a))$ his rent in the mixed regime. We know that $R^{mix}(a_2, h^*(a_2)) - R^{mix}(a_1, h^*(a_2)) < R^{col}(a_2) - R^{col}(a_1)$. By definition, it is also true that $R^{mix}(a_2, h^*(a_2)) - R^{mix}(a_1, h^*(a_1)) < R^{mix}(a_2, h^*(a_2)) - R^{mix}(a_1, h^*(a_2))$. It follows that $R^{mix}(a_2, h^*(a_2)) - R^{mix}(a_1, h^*(a_1)) < R^{col}(a_2) - R^{col}(a_1)$. Even when the father adjusts h in the mixed regime, therefore, his rent does not increase as much as in the collective regime.

We will show that $\partial h/\partial a < 0$, which implies that $d(h/a)/da < 0$. To derive an expression for $\partial h/\partial a$, we apply the implicit function theorem to $G(h^*, a) = \partial R/\partial h = 0$, which defines the optimal size of individual plots, $h^*(a)$.

$$\frac{\partial h}{\partial a} = -\frac{\partial G/\partial a}{\partial G/\partial h}.$$

Let us first derive an expression for $G(h,\ a)$, using the explicit definition of $R(h)$ under the mixed regime:

$$\begin{aligned}
G(h,\ a) &= \frac{\partial R}{\partial h} \\
&= -\varepsilon(a-h)^{\varepsilon-1}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{1-\varepsilon}\left(\frac{1-\varepsilon}{n\omega-\omega+\varepsilon\omega}\right)^{1-\varepsilon} n \\
&\quad - (1-\varepsilon)\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon}(a-h)^{\varepsilon}\left(\frac{1-\varepsilon}{n\omega-\omega+\varepsilon\omega}\right)^{1-\varepsilon} n \\
&\quad + \varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\frac{n^2}{n-1+\varepsilon} = 0.
\end{aligned}$$

We first show that $\partial G/\partial a$ is negative. To simplify the mathematical expressions, we set $K = ((1-\varepsilon)/(n\omega-\omega+\varepsilon\omega))^{1-\varepsilon} n$.

$$\begin{aligned}
\frac{\partial G}{\partial a} &= -K\varepsilon(\varepsilon-1)(a-h)^{\varepsilon-2}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{1-\varepsilon} \\
&\quad -K\varepsilon^2(a-h)^{\varepsilon-1}(1-\varepsilon)\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon} \\
&= K\varepsilon(1-\varepsilon)(a-h)^{\varepsilon-2}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon} \\
&\quad \times \left[u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1} - \varepsilon(a-h)\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right] \\
&= K\varepsilon(1-\varepsilon)(a-h)^{\varepsilon-2}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon} \\
&\quad \times \left[u - \varepsilon a\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right].
\end{aligned}$$

The term $u - h\varepsilon((1-\varepsilon)/\omega)^{(1/\varepsilon)-1}$, which is equal to $u - \omega h((1-\varepsilon)/\omega)^{1/\varepsilon}(\varepsilon/(1-\varepsilon))$, represents the part of the reservation utility obtained from working on the collective field (as can be verified from eq. [B12]), and it is positive. The sign of $\partial G/\partial a$ is thus the same as the sign of the expression in square brackets. This expression is negative, as established by equation (C5). Consequently, the above expression between square brackets must be negative.

We now check that $\partial G/\partial h = \partial^2 R/\partial h^2$ is negative.

$$
\begin{aligned}
\frac{\partial G}{\partial h} &= K\varepsilon(\varepsilon-1)(a-h)^{\varepsilon-2}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{1-\varepsilon} \\
&\quad + K\varepsilon^2\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}(1-\varepsilon)\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon}(a-h)^{\varepsilon-1} \\
&\quad - K\varepsilon^3(1-\varepsilon)\left(\frac{1-\varepsilon}{\omega}\right)^{(2/\varepsilon)-2}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon-1}(a-h)^{\varepsilon} \\
&\quad + K\varepsilon^2(a-h)^{\varepsilon-1}(1-\varepsilon)\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon} \\
&= -K\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon-1}(a-h)^{\varepsilon-2}\varepsilon(1-\varepsilon) \\
&\quad \times \left[\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^2 + \varepsilon^2(a-h)^2\left(\frac{1-\varepsilon}{\omega}\right)^{(2/\varepsilon)-2}\right. \\
&\quad \left. -2\varepsilon(a-h)\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)\right] \\
&= -K\left(u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}\right)^{-\varepsilon-1}(a-h)^{\varepsilon-2}\varepsilon(1-\varepsilon) \\
&\quad \times \left[u - h\varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1} - \varepsilon\left(\frac{1-\varepsilon}{\omega}\right)^{(1/\varepsilon)-1}(a-h)\right]^2.
\end{aligned}
$$

Since all the terms comprising the above expression are positive, including the term $u - h\varepsilon((1-\varepsilon)/\omega)^{(1/\varepsilon)-1}$, and the expression is preceded by a minus sign, it is unambiguously negative. We have therefore established that $\partial h/\partial a < 0$, so that $d(h/a)/da < 0$. In words, the portion of the family farm area allotted to individual production declines as a increases.

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