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2 authors:

Jean-Louis Arcand
Graduate Institute of International and Development Studies

Tina Rambonilaza
French National Institute for Agriculture, Food, and Environment (INRAE)

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Is Adverse Selection Relevant? Spence-Mirlees Meets the Tunisian Peasant†

Jean-Louis ARCAND* and Mbolatiana RAMBONILAZA**

**CERDI-CNRS, Université d'Auvergne, FRANCE
and Instituto de Saude Coletiva (ISC), Universidade Federal da Bahia (UFBA), BRAZIL*

***CERDI-CNRS, Université d'Auvergne, FRANCE*

Abstract

In the standard problem of mechanism design under adverse selection, it is well known that the transfer function from the principal to the agent will be increasing in the agent's unknown productivity when there exists an incentive compatible mechanism. Cost-sharing contracts in LDC agriculture are a particularly interesting form of such mechanisms. In this paper, we develop a simple model of cost sharing contracts and construct a measure of potentially unobservable household productivity by estimating a plot level production function with household-specific fixed effects, which are then purged of observable household characteristics. We then use the implications of the model and our measure of potentially unobservable tenant productivity to test whether the productivity of tenants is indeed unobservable to landlords. Our empirical results strongly suggest that adverse selection concerns are not empirically important : in the Tunisian village we consider, it would appear that peasants do much better than is expected by Spence and Mirlees.

Keywords : mechanism design, adverse selection, economic development, empirical methods
JEL : O12, C23, D13, D82, O17, Q12, Q15

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Abstract

In the standard problem of mechanism design under adverse selection, it is well known that the transfer function from the principal to the agent will be increasing in the agent's unknown productivity when there exists an incentive compatible mechanism. Cost-sharing contracts in LDC agriculture are a particularly interesting form of such mechanisms. In this paper, we develop a simple model of cost sharing contracts and construct a measure of potentially unobservable household productivity by estimating a plot level production function with household-specific fixed effects, which are then purged of observable household characteristics. We then use the implications of the model and our measure of potentially unobservable tenant productivity to test whether the productivity of tenants is indeed unobservable to landlords. Our empirical results strongly suggest that adverse selection concerns are not empirically important : in the Tunisian village we consider, it would appear that peasants do much better than is expected by Spence and Mirlees.

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1. Introduction

The theory of mechanism design in the presence of adverse selection (unobservable characteristics) provides an elegant characterization of contractual structures that ensure that agents possessing private information as to their type truthfully reveal such information to uninformed principals. The implementation of such mechanisms results, however, in a departure from the allocation associated with the first-best optimum. Asymmetric information is therefore a potential explanation for failures to achieve Pareto optimality. In this paper, we apply the elementary theory of mechanism design to cost-sharing contracts in developing country agriculture. This context provides a particularly rich environment in which to test received theory. Moreover, in developing country agriculture, deviations with respect to the first best optimum can have particularly severe consequences in terms of the welfare of peasant households. Characterizing the informational structure of markets in developing countries can therefore provide insights that are of interest to theorists as well as clues as to those factors that constitute fetters on the development process.

It is probably not unfair to state that opinions regarding the relevance of adverse selection, be it in developed or developing countries, are divided. On the one hand, the theoretical literature concerned with mechanism design has laid heavy emphasis on adverse selection as a potential cause of departures from the first-best optimum. The standard textbooks by Laffont (1990) and Fudenbeg and Tirole (1991) are cases in point. Similarly, substantial effort has been expended in the theoretical development literature on the formulation of screening models that also allow one to account for a number of important stylized facts that characterize tenancy markets in developing countries (Hallagan, 1978, Newberry and Stiglitz, 1979, Basu, 1982, Allen, 1982, 1985); these include (i) the coexistence of sharecropping contracts, despite their purported inefficiency, alongside fixed rental contracts, (ii) the allegedly higher levels of productivity associated with plots farmed under fixed rental contracts (in comparison with plots under sharecropping), (iii) the relative constancy of the output sharing rule (50-50) in sharecropping contracts, and (iv) the progressive disappearance of sharecropping during the development process.

In contrast to the theoretical literature, many development economists, while recognizing that adverse selection may have a role to play, are of the opinion that it has limited relevance in the context of closely-knit village communities, and is therefore neither the basis for a theory of contractual choice nor the most important cause of the alleged departures from Pareto optimality observed in developing areas (see, for example, Bardhan, 1984, or Eswaran and Kotwal, 1985).

Regardless of the ambiguity of informed opinions on the topic, what *is* undisputable is that contractual choice models driven by adverse selection have been much less the object of empirical validation than their moral hazard brethren (typical examples of the empirical moral hazard literature include Lafontaine and Bhattacharyya, 1995, in the context of franchising contracts, Shaban, 1987, in the context of sharecropping in India, or Foster and Rosenzweig, 1994, in the case of labor markets in India). We would suggest that this paucity of empirical applications stems from the fact that existing models of contractual choice geared specifically towards adverse selection have few empirically testable hypotheses, at least as these models are presently formulated, although a number of important contributions have appeared in the context of auctions (Laffont, Ossard, and Vuong, 1995), the used-car market (Genesove, 1993), and the market for slaves in mid-19th century America (Pritchett and Chamberlain, 1993).

One notable exception to the preceding characterization of the theoretical literature on contractual choice is provided by the model developed by Allen (1985), which revolves around the problem of default risk by tenants, who are assumed to be able to abscond with the proceeds of their agricultural activities before having paid either their rent or their share of output. In this two-period model, low productivity peasants self-select in the first period into wage contracts through the landlord's restriction of the amount of land offered to potential tenants to a level lower than what would be individually rational for low productivity tenants. High productivity peasants, on the other hand, will find it in their interest to select a tenancy contract. All uncertainty as to the potential tenant's true type is thus resolved in the first period, and the landlord is able to solve the problem of default risk in the second period through the appropriate choice of a fixed rental or sharecropping contract. While Allen's model has testable implications in a context in which there is a steady stream of new potential tenants and in which default risk is important, these assumptions do not square with what is encountered in many villages in developing countries, where there is little if any movement of potential tenants from one village to another, and the risk of default is usually negligible.

It is therefore not surprizing that what little empirical evidence there is on adverse selection in developing countries has focused on markets in which agents are relatively mobile. For example, Foster and Rosenzweig (1993), in a carefully argued paper, examine the casual agricultural labor market in India, the Philippines and Pakistan. They obtain a measure of the productivity of individual workers by focusing on their remuneration when they are employed using piece rates, and use this information to investigate whether the time-rate wages received by the same workers reflect this information. Foster and Rosenzweig find that "while a substantial portion of individual worker skills are rewarded in time-rate wages, the evidence suggests that there is also considerable ignorance among employers about individual differences in worker abilities….".[1] Their results suggest that adverse selection is indeed a problem in casual labor markets in developing countries, but little can be said regarding the quantitative importance of the question. With respect to the presence of adverse selection in village communities, on the other hand, the evidence is mostly anecdotal.

The point of departure of this paper is agnostic as to the relevance of adverse selection in village communities. Indeed, our aim is to ascertain whether adverse selection concerns are significant as determinants of contractual choice, and thus causes of departures from optimality, on the basis of empirical evidence driven by a simple model that corresponds reasonably closely to reality in the field; hence the title. Of course, basic common sense suggests that, in a compact society in which agents are relatively immobile, adverse selection should not be present. The challenge is to see whether a widely-held opinion based on stylized facts and casual observation is not rejected by hard empirical evidence.

The structure of the paper is as follows. In section 2 we develop a simple model of cost-sharing contracts in the absence of asymmetric information and derive hypotheses linking tenant productivity to (i) contractual choice, (ii) the optimal transfer function from landlord to tenant and (iii) the share of the cost of a given factor input borne by the tenant. Given the appropriate data, all three of these hypotheses are readily testable.

In section 3, we develop the corresponding model under asymmetric information, meaning that we consider an environment in which landlords cannot observe tenant productivity. The testable implications that allow one to empirically distinguish between the two cases are then

[1] Foster and Rosenzweig (1993), p. 761. Also see Glaeser (1991) in the context of the US labor market.

contrasted. Essentially, when tenant productivity is observable to landlords, (i) contractual choice (the choice between fixed rental and sharecropping contracts) must be *independent* of tenant productivity, (ii) the transfer from the landlord to the tenant in the context of sharecropping contracts must be *decreasing* in tenant productivity, and (iii) a substantial number of the cost shares (corresponding to the fraction of the cost of a given input that is borne by the tenant) must be *increasing* in tenant productivity. The opposite should be true when landlords cannot observe tenant productivity. Together, these three hypotheses provide a powerful test for the ability of landlords to observe tenant household productivity.

In section 4, we construct our measure of potentially unobservable household productivity. We do so by estimating a plot level production function with household-specific fixed effects, since all households in our sample from a Tunisian village cultivate more than one plot of land. These fixed effects are then purged of the impact of observable household characteristics in order to arrive at our measure of household productivity. Since this measure of household productivity has been orthogonalized with respect to observable household characteristics, it represents a measure of household productivity that, in the case of tenants, is potentially unobservable to landlords.

In section 5, we test the theoretical propositions derived in sections 2 and 3 ; we find that (i) contractual choice is independent of our measure of tenant household productivity, (ii) the transfer from landlords to tenants is decreasing in tenant household productivity, and (iii) none of the cost shares are decreasing in tenant household productivity. These results provide compelling evidence that landlords do in fact observe the productivity of the tenant households they face and that adverse selection is therefore not a feature of the market for tenancies in this village. We also consider the robustness of our measures of household productivity. In particular, we show that the decision of a landlord to rent out her land rather than cultivating it herself as an owner operator is a decreasing function of our measure of household productivity as it applies to *landlords*, as is predicted by our theoretical model. Furthermore, since our empirical results indicate that adverse selection is not present in the village, we consider whether contractual choice is independent of our scalar measure of observable household characteristics (given by that portion of the household-specific fixed effect that is predicted by observable household characteristics), as well as the household-specific fixed effect as a whole. This is a particularly strong implication of our model in the absence of asymmetric information and, remarkably, it appears to be supported by the data.

Section 6, which concludes the paper, begins by going out on a limb and attempts to characterize the functioning of the land rental market in the village by investigating the empirical relevance of different assumptions regarding matching procedures between landlords and tenants. On the basis of measures of the productivity of the *potential* tenant available to landlords (for plots that landlords decided to cultivate themselves as owner operators), we find that an assumption of limited perfect matching in which landlords base their choice on the best among those tenants with whom they do in fact engage in contractual relationships appears to be the most consistent with the data in the sense that the probability of renting out (versus cultivating the plot as an owner-operator) is an increasing function of actual (for those plots under tenancy contracts) and potential (for those plots under owner-operatorship) tenant characteristics. Thus, on the one hand, landlords do observe the productivity of their potential tenants, and adverse selection is not relevant. On the other hand, landlord behavior would appear to be consistent with a relatively limited pool of potential tenants. The limited nature of the choice sets used by landlords might therefore preclude more profitable matches that could, potentially, increase the aggregate agricultural output of the village.

Finally, given that tenant productivity does not appear to be a significant determinant of contractual choice, we attempt to provide some clues as to what might be. First, we offer some evidence that the size of plots that are rented out is not a choice variable available to landlords: if plot size were a choice variable, one would expect, at the very least, that landlords would attempt to equate the marginal productivity of land across plots under owner-operatorship and plots under tenancy contracts. The size of plots that are rented out is, however, a decreasing function of observable (productivity enhancing) tenant characteristics, contrary to what one would expect if the landlord were attempting to equate the marginal productivity of land across plots that are rented out and plots that she cultivates herself (it is also independent of the productivity of landlords). This result suggest that it is indeed appropriate to take plot size as being exogenously determined, especially since it was found to be statistically insignificant in the contractual choice equation, thus casting doubt on its potential role as a sorting mechanism as would be posited in the model developed by Allen (1985).

Second, using limited information regarding the repeated nature of the tenancy relationship linking a given landlord with a given tenant, we find, somewhat unexpectedly, that the probability of a contract being a renewal of the previous year's arrangement is *decreasing* in the productivity of the tenant or, in other words, that short-term contracts appear to be associated with higher productivity tenants. This finding is potentially explained by what we refer to as the "dumb cousin conjecture". We also suggest an alternative explanation, based on nutrient depletion, that might explain why low productivity tenants would be more likely to be renewed by landlords.

Third, and at an even finer level of disaggregation, we find, on plots under tenancy contracts which do not constitute renewals, that the predicted value of the household-specific fixed effect (that is, that portion of the fixed effect that can be predicted by observable household characteristics) decreases the probability that the contract in question will be a sharecropping contract. For contracts that do represent a renewal, on the other hand, contractual choice is independent of both components of the tenant's household-specific fixed effect. Since contractual choice remains, in all cases, independent of tenant household productivity, our basic conclusion that adverse selection does not obtain in the village is upheld.

Finally, given that repeated interaction was the sole variable found to be a statistically significant determinant of contractual choice, we consider whether our results on contractual choice might be driven by a problem of simultaneity bias. We therefore estimate a system of three probit equations by full information maximum likelihood, where the three equations are given by a contractual choice equation, a contract renewal equation and, in order to take transaction costs arguments into account, an equation that seeks to explain why a contract is either written or oral. Again, and within a framework in which contract renewal is allowed to be an endogenous variable in the contractual choice equation, the productivity of the tenant is statistically insignificant (in the contractual choice equation). All of these results indicate that our main finding that adverse selection is not present in contractual relations in this village is extremely robust to changes in specification.

2. THE FIRST-BEST OPTIMUM

Preliminaries

Consider a standard sharecropping[2] contract with cost-sharing in which the landlord's objective function is given by

$$\Pi = \frac{1}{2} F(q, x) - (1 - b)x,$$

while the tenant's objective function is

$$Y = \frac{1}{2} F(q, x) - bx,$$

where $F(q, x)$ represents the production technology, x the physical input, b the share of production costs borne by the peasant, and where, in conformity with the empirical data, we assume that the output share is equal to one half for all contracts.[3] We assume that plot size is fixed and identical for all landlords and is thus unavailable as a contractual instrument.[4] In order to lighten notation, both the price of the output and the price of the input are normalized to one. Moreover, we will assume in much of what follows that both x and b are scalars.[5] The production technology is assumed to satisfy the usual properties : $F_q > 0, F_x > 0, F_{xx} < 0$. Both parties to the contract are (in order to simplify the exposition) assumed to be risk-neutral. The parameter q represents the productivity of tenants and is assumed to be distributed across the peasant population according to the probability density function $g(q)$ over the interval $[\underline{q}, \overline{q}]$. In this section q will be assumed to be known to both the tenant and the landlord.

[2] In what follows, we shall use the terms "sharecropping contract" and "cost-sharing contract" interchangeably, since, in the Tunisian village that will be the object of the empirical portion of this essay, cost-sharing only appears in the context of sharecropping contracts. Moreover, given that there is almost no heterogeneity in the output share (in almost all cases it is given by a 50-50 split), the only significant source of variations in contractual form in sharecropping contracts in the village is given by their cost-sharing component.

[3] Several explanations have been given in the literature for the relative constancy of output shares. These include (i) fairness, (ii) social norms, and (iii) transaction costs involved in a finer definition of output shares. Theorists have also found imaginative manners of justifying the resort to linear sharing rules (HolmstrÖm and Milgrom, 1987, Hurwicz and Shapiro, 1978)

[4] This assumption is crucial for what follows. In contrast to our model, the choice of plot size is the key to the model proposed by Allen (1985). In the empirical portion of the paper, we present evidence that lends support to our assumption concerning the exogeneity of plot size.

[5] The model generalizes straightforwardly to the case where x is a vector; where appropriate, the implications of higher-dimensionality will be spelled out explicitly.

The key to understanding an empirically observable cost-sharing contract in terms of the standard theory of adverse selection lies in its cost-sharing component. Note that the landlord's objective function may be rewritten as

$$\frac{1}{2}F(q,x)-t\ ,$$

where $t=(1-b)x$, while the tenant's objective function can be expressed as

$$\frac{1}{2}F(q,x)-x+t\ .$$

The expression $t=(1-b)x$ thus represents the transfer from the landlord to the peasant. This expression is readily observable using the survey data at our disposal since we possess information regarding both the level of inputs used at the plot level as well as the share of the cost of each input borne by the tenant.

The first-best optimum

We consider a situation in which relative factor endowments are such that land is relatively scarce and sufficiently well-qualified potential tenants are relatively numerous, resulting in competition among tenants for tenancy contracts. This assumption squares quite nicely with the observed relative factor endowments encountered in the Tunisian village that will be the object of our empirical analysis, as well as with the general perception expressed by the inhabitants of the village that we encountered during fieldwork. The landlord's optimization problem is therefore given by :

$$\max_{\{x,t\}}\frac{1}{2}F(q,x)-t \quad s.t. \quad \frac{1}{2}F(q,x)-x+t\ \geq W\ ,$$

where W is the tenants' (common) level of reservation income.[6] Since the constraint is necessarily binding (the landlord's profits being decreasing in t), we can substitute for t into the objective function, yielding the following unconstrained problem :

$$\max_{\{x\}}F(q,x)-x-W\ .$$

This yields the following characterization of the optimal contract :

(1) $\quad F_x(q,x^*(q))-1=0\ ,$

[6] For simplicity, we assume that q is strictly a measure of the agricultural productivity of tenants and does not lead to differences in reservation levels of tenant income. Later on, we shall briefly discuss empirical evidence that suggests that this assumption is not unreasonable.

(2) $$t^*(q) = W - \frac{1}{2}F(q, x^*(q)) + x^*(q), \quad \forall \quad q \; ;$$

that is, the landlord sets the first-best optimum level of factor inputs and adjusts the transfer function so that the tenant is just indifferent between accepting a cost sharing contract and pursuing her alternative activity.

Consider now the relationship linking the optimal transfer function to the tenant's productivity. Differentiating equation (2) with respect to q , we obtain :

$$\frac{dt^*(q)}{dq} = -\frac{1}{2}\left(F_q(q, x^*(q)) + F_x(q, x^*(q))\frac{dx^*(q)}{dq} \right) + \frac{dx^*(q)}{dq},$$

which implies (using equation (1)) that

(3) $$\frac{dt^*(q)}{dq} = \frac{1}{2}\left(\frac{dx^*(q)}{dq} - F_q(q, x^*(q)) \right).$$

Note, by implicit differentiation of equation (1), that we can immediately show that

$$\frac{dx^*(q)}{dq} = -\frac{F_{xq}(q, x^*(q))}{F_{xx}(q, x^*(q))}.$$

Thus $dx^*(q)/dq$ will be positive as long as $F_{xq} \geq 0$, which corresponds to the usual Spence-Mirlees sorting condition (Spence, 1974, Mirlees, 1971). In what follows, we shall assume that this is indeed the case. This implies that the relationship between the transfer function and q will be ambiguous, at least as long as we do not impose additional constraints on the production technology, since :

(4) $$\frac{dt^*(q)}{dq} = \frac{1}{2}\left(-\frac{F_{xq}(q, x^*(q))}{F_{xx}(q, x^*(q))} - F_q(q, x^*(q)) \right).$$

What sort of assumption leads to a clearly defined sign in equation (4) ? Consider the following three potential restrictions on the production technology :

ASSUMPTION A : $\dfrac{F_{xq}(q, x^*(q))}{F_{xx}(q, x^*(q))} + F_q(q, x^*(q)) > 0$.

ASSUMPTION B : $F(q, x)$ is of the form $F(q, x) = q\,F(x)$.

ASSUMPTION C : $F(q, x)$ is homogeneous of degree $k < 1$ in x ,

that is : $F(hx) = h^k F(x), \quad h > 0$.

These three assumptions allow one to state the following PROPOSITION :

PROPOSITION 1 : In the absence of adverse selection,

(i) under ASSUMPTION A, $dt^*(q)/dq < 0$;

(ii) under ASSUMPTIONS B and C, and for $k \in (0,1/2)$, $dt^*(q)/dq < 0$.

PROOF : (i) immediate; (ii) see APPENDIX.

Since it does not appear implausible to assume that productivity q enters in multiplicative form in the production technology (and this corresponds to the empirical parameterization implemented in section 4) we will also invoke ASSUMPTION B in section 3 when dealing with the same problem under asymmetric information.

The preceding result in terms of the transfer function can easily be transposed into the context of the cost-sharing contracts that one observes in practice by simply noting that

$$t^*(q) = W - \frac{1}{2}F(q, x^*(q)) + x^*(q) = (1 - b^*(q))x^*(q),$$

where $b^*(q)$ is the optimal cost share, which implies that :

$$b^*(q) = \frac{1}{x^*(q)}\left(\frac{1}{2}F(q, x^*(q)) - W\right).$$

Differentiating with respect to q , one obtains :

$$\frac{d\,b^*(q)}{dq} = \frac{\frac{1}{2}\left(F_q(q, x^*(q)) + \frac{dx^*(q)}{dq}\right)x^*(q) - \frac{dx^*(q)}{dq}\left(\frac{1}{2}F(q, x^*(q)) - W\right)}{\left(x^*(q)\right)^2},$$

which can be re-expressed as :

$$\text{(5)} \qquad \frac{d\,b^*(q)}{dq} = \frac{\frac{1}{2}F_q(q, x^*(q))x^*(q) + \frac{dx^*(q)}{dq}\left(\frac{1}{2}\left(x^*(q) - F(q, x^*(q))\right) + W\right)}{\left(x^*(q)\right)^2},$$

or equivalently

$$\text{(6)} \qquad \frac{d\,b^*(q)}{dq} = \frac{\frac{1}{2}F_q(q, x^*(q)) + \frac{dx^*(q)}{dq}\left(\frac{1}{2} - b^*(q)\right)}{x^*(q)}.$$

Again, there is no clear manner of signing this expression without additional restrictions on the technology. Under ASSUMPTIONS B and C, however, we have the following :

PROPOSITION 2 : In the absence of adverse selection, under ASSUMPTIONS B and C (and for $k \in (0,1)$),

(i) when x is a scalar, $d\,b^*(q)/dq > 0$;

(ii) when x is an N-dimensional vector of factor inputs $x = (x_1,\ldots,x_j,\ldots,x_N)$, a necessary condition for the transfer function to be decreasing in q is that

$$\sum_{j=1}^{j=N} x_j^*(q)\frac{d\,b_j^*(q)}{dq} > 0\,,$$

i.e., it cannot be the case that $d\,b_j^*(q)/dq < 0,\ \forall\ j$.

PROOF : see APPENDIX.

Note that PROPOSITION 2 (ii) simply reflects that there are many ways to skin a cat when the cost-sharing component of the contractual instrument is multidimensional, in contrast to when it is constituted by a scalar $b^*(q)$. That is, not all cost shares need to be increasing in q for the transfer function to be decreasing in q, but a sufficiently large proportion of them must necessarily be so.

It is worth pointing out that, at the optimum, a landlord's profit is an increasing function of her tenant's level of productivity, since, by the Envelope Theorem :

$$\frac{d}{dq}\Big(F(q,x^*(q)) - x^*(q) - W\Big) = \frac{\partial}{\partial q}\Big(F(q,x^*(q)) - x^*(q) - W\Big) = F_q(q,x^*(q)) > 0\,.$$

This result implies that there is a lower bound on the type of peasant that will be offered a cost sharing contract. This limit type, which we may denote by q', is defined implicitly by $F(q',x^*(q')) - x^*(q') - W = R$, where R is the (common) individually rational level of profits of landlords.

As a final note to this section, consider the problem of contractual choice. Suppose that, besides offering their plot of land under a sharecropping tenancy, landlords also have the option of offering fixed rental contracts. In this case, their optimization problem, if we adhere to the notation used so far, is given by :

$$\max_{\{x,t\}}\ -t \quad s.t. \quad F(q,x) - x + t \ \geq W\,,$$

where $-t$ represents the rental payment (which is independent of output) from the tenant to the landlord. Since the tenant's individual rationality constraint holds with equality, this last problem can be translated into the unconstrained problem :

$$\max_{\{x\}} F(q,x) - x - W \, .$$

The optimal contract is obviously characterized by the conditions :

$$F_x(q, x^*(q)) - 1 = 0 \, ,$$

$$t^*(q) = W - F(q, x^*(q)) + x^*(q) \, .$$

The first FOC, being identical to equation (1), implies that the level of inputs will be the same under a fixed rental contract as under a cost-sharing contract. Evaluated at the optimum, the landlord's objective function is manifestly given by

$$F(q, x^*(q)) - x^*(q) - W \, ,$$

which is identical to the corresponding expression for the cost sharing contract. It follows that landlords are indifferent between the two contractual forms. Moreover, since tenants are always held to their individually rational level of income, they too are indifferent between selecting a cost sharing or a fixed rental contract, $\forall \;\; q$. We state this obvious result as a PROPOSITION for reference in what follows :

PROPOSITION 3 : In the absence of adverse selection, the probability of choosing a fixed rental contract over a sharecropping contract is independent of q.

This general indifference property corresponds to the classic result due to Cheung (1968, 1969), transposed to the context of adverse selection (Cheung addressed the issue of moral hazard in the presence of a costless supervision technology).

3. ASYMMETRIC INFORMATION

In contrast to the preceding section, we now assume that q is unobservable to the landlord. The timing of the one shot game between tenants and landlords is as follows : (i) the landlord announces a menu of sharecropping contracts represented by the transfer function $t(q)$ and a level of physical input $x(q)$; (ii) the peasant then selects the contractual relationship of her choice, which means formally that she chooses a message $\tilde{q}$ as a function of her true type q.

The Revelation Principle and incentive compatibility

By the Revelation Principle, we know that the landlord can confine her attention to mechanisms that induce the potential tenant to truthfully reveal her type, i.e., the best response that a potential tenant can make to a contractual offer is to report her true type q through her choice of the appropriate contract. Technically, this means that it must be the case that :

$$q = \arg\max_{\{\tilde{q}\}} \frac{1}{2} F(q, x(\tilde{q})) - x(\tilde{q}) + t(\tilde{q}) .$$

The necessary first order condition (FOC) for the existence of an incentive compatible contract is thus given (differentiating the preceding expression with respect to $\tilde{q}$) by:

(7) $$\left(\frac{1}{2} F_x(q, x(\tilde{q})) - 1\right)\frac{dx(\tilde{q})}{dq} + \frac{dt(\tilde{q})}{dq} = 0 .$$

For q to be the optimal response, it must therefore be the case that :

(8) $$\left(\frac{1}{2} F_x(q, x(q)) - 1\right)\frac{dx(q)}{dq} + \frac{dt(q)}{dq} = 0, \quad \forall q .$$

The derivative of equation (7) with respect to $\tilde{q}$ is given by :

$$\left(\frac{1}{2} F_{xx}(q, x(\tilde{q}))\right)\frac{dx(\tilde{q})}{dq} + \left(\frac{1}{2} F_x(q, x(\tilde{q})) - 1\right)\frac{d^2x(\tilde{q})}{dq^2} + \frac{d^2t(\tilde{q})}{dq^2} \le 0 ,$$

which implies that the second order condition (SOC) is given by

(9) $$\left(\frac{1}{2} F_{xx}(q, x(q))\right)\frac{dx(q)}{dq} + \left(\frac{1}{2} F_x(q, x(q)) - 1\right)\frac{d^2x(q)}{dq^2} + \frac{d^2t(q)}{dq^2} \le 0, \quad \forall \quad q .$$

Notice that differentiating equation (8) with respect to q (equation (8) is an identity and its derivative is thus equal to zero) allows us to write :

$$\frac{1}{2}\left(F_{qx}(q, x(q)) + F_{xx}(q, x(q))\right)\frac{dx(q)}{dq}$$
$$+\left(\frac{1}{2} F_x(q, x(q)) - 1\right)\frac{d^2x(q)}{dq^2} + \frac{d^2t(q)}{dq^2} = 0, \quad \forall q .$$

Substituting into the SOC (equation (9)) yields :

$$-\frac{1}{2} F_{qx}(q, x(q))\frac{dx(q)}{dq} \le 0, \quad \forall \quad q .$$

Since, by assumption, $F_{qx}(q, x(q)) \ge 0$ (the Spence-Mirlees sorting condition, see section 2), the SOC boils down to the condition that

(10) $\quad \dfrac{dx(q)}{dq} \geq 0, \quad \forall \quad q$.

By the usual arguments (e.g. Laffont, 1990, chapter 10) these local necessary conditions are sufficient globally.

Note that equation (8) is a first order differential equation that defines the optimal transfer function $t(q)$. Using Leibnitz's Rule, equation (8) can be integrated, yielding :

(11) $$t(q) = -\int_{\underline{q}}^{q} \frac{dx(s)}{ds}\left(\frac{1}{2}F_x(s, x(s)) - 1\right)ds + K \ .$$

Moreover, for it to be accepted by the tenant, the contract must satisfy the following individual rationality constraint :

(12) $$\frac{1}{2}F(q, x(q)) - x(q) + t(q) \geq W \ .$$

Substituting from equation (11) into equation (12), one can rewrite the latter as

(13) $$\frac{1}{2}F(q, x(q)) - x(q) - \int_{\underline{q}}^{q} \frac{dx(s)}{ds}\left(\frac{1}{2}F_x(s, x(s)) - 1\right)ds + K \geq W \ .$$

The appropriate choice of the constant of integration K in equation (13) thus allows one to readily satisfy this individual rationality constraint.

The landlord's problem under asymmetric information

We are now ready to summarize the landlord's constrained optimization problem as follows :

PROBLEM A $\quad \max\limits_{\{x(q),\, t(q)\}} \int_{\underline{q}}^{\bar{q}} \left(\frac{1}{2}F(q, x(q)) - t(q)\right) g(q)\,dq \quad$ s.t.

(8) $$\left(\frac{1}{2}F_x(q, x(q)) - 1\right)\frac{dx(q)}{dq} + \frac{dt(q)}{dq} = 0, \quad \forall \quad q$$

(10) $$\frac{dx(q)}{dq} \geq 0, \quad \forall \quad q$$

(12) $$\frac{1}{2}F(q, x(q)) - x(q) + t(q) \geq W, \quad \forall \quad q$$

where it is worth recalling that the first two constraints (equations (8) and (10)) guarantee truthful revelation of q, while the third constraint (equation (12)) ensures that tenants accept the proffered contracts. We shall now transform the constrained optimization problem given by PROBLEM A into one of optimal control that is amenable to treatment by Pontryagin's Maximum Principle.

Write the surplus of the tenant (the difference between her income and her reservation level of income) as

$$S(q) = Y - W = \frac{1}{2} F(q, x(q)) - x(q) + t(q) - W \ .$$

Obviously, in the absence of informational asymmetries, this surplus was zero as each tenant was driven down to her individually rational level of income (see equation (2) in section 2). Consider the derivative of $S(q)$ with respect to q :

$$\frac{dS(q)}{dq} = \dot{S}(q) = \frac{1}{2}\left(F_q(q, x(q)) + F_x(q, x(q)) \frac{dx(q)}{dq} \right) - \frac{dx(q)}{dq} + \frac{dt(q)}{dq} \ .$$

Combining this with equation (8) yields :

(8') $$\dot{S}(q) = \frac{1}{2} F_q(q, x(q)) \geq 0 \ .$$

Since the tenant's surplus is increasing in q, it follows that if the individual rationality constraint (re-expressed as $S(q) \geq 0$) holds for the lowest productivity tenant (of type $\underline{q}$), it will also do so, *a fortiori*, for all others. It follows that we may replace the individual rationality constraint by

(12') $$\frac{1}{2} F(\underline{q}, x(\underline{q})) - x(\underline{q}) + t(\underline{q}) \geq W \ .$$

Now note that the integrand in the landlord's objective function can be re-expressed as

$$\frac{1}{2} F(q, x(q)) - t(q) = F(q, x(q)) - x(q) - S(q) - W \ .$$

In what follows, and in order to render the derivations analytically tractable, we will assume that the probability density function of q can be represented by the uniform density. Moreover, in order to simplify notation, we impose the normalization $\overline{q} - \underline{q} = 1$. It follows that we may rewrite the landlord's optimization problem as :

PROBLEM B $\max_{\{x(q),S(q)\}} \int_{\underline{q}}^{\bar{q}} \left(F(q, x(q)) - x(q) - S(q) - W \right) dq$

$$\text{(8')} \qquad \dot{S}(q) = \frac{1}{2} F_q(q, x(q))$$

$$\text{(10)} \qquad \frac{dx(q)}{dq} \geq 0, \quad \forall \quad q$$

$$\text{(12')} \qquad \frac{1}{2} F(\underline{q}, x(\underline{q})) - x(\underline{q}) + t(\underline{q}) \geq W$$

This is simply an optimal control problem in which the control variable is $x(q)$ and the state variable is $S(q)$. We can therefore write the Hamiltonian as :

$$\text{(14)} \qquad H(q) = F(q, x(q)) - x(q) - S(q) - W + l(q) \frac{1}{2} F_q(q, x(q)),$$

where $l(q)$ is the costate variable, and where, for the time being, we ignore the constraint given by equation (10). A straightforward application of Pontryagin's Maximum Principle yields the usual two necessary and sufficient conditions :

$$\text{(15)} \qquad \dot{l}(q) = -\frac{\partial H(q)}{\partial S} = 1,$$

$$\text{(16)} \qquad 0 = \frac{\partial H(q)}{\partial x} = F_x(q, x(q)) - 1 + l(q) \frac{1}{2} F_{qx}(q, x(q)),$$

plus the transversality condition :

$$\text{(17)} \qquad l(\underline{q}) = 0 .$$

Consider equation (15). Using the transversality condition (equation (17)) allows one to integrate this differential equation, yielding :

$$\text{(18)} \qquad l(q) = q - \underline{q} .$$

Substituting into (16) then yields :

$$\text{(19)} \qquad 0 = \frac{\partial H(q)}{\partial x} = F_x(q, x(q)) - 1 + (q - \underline{q}) \frac{1}{2} F_{qx}(q, x(q)) .$$

Consider the solution to this equation, denoted by $\hat{x}(q)$, which is implicitly defined by the expression:

$$\text{(20)} \qquad F_x(q, \hat{x}(q)) - 1 + (q - \underline{q}) \frac{1}{2} F_{qx}(q, \hat{x}(q)) = 0 .$$

For the special case in which the landlord is dealing with a peasant of productivity $q = \underline{q}$, we get the usual result that $\hat{x}(\underline{q}) = x^*(\underline{q})$: the lowest productivity tenant uses the level of input that corresponds to the first-best optimum ; all other tenants (with $q > \underline{q}$) extract a positive surplus from the contractual relationship ($S(q) > 0$ for $q > \underline{q}$) because of the distortion induced by the non-observability of q.

Now the pertinent question is whether $\hat{x}(q)$ is increasing in q as is required by the constraint that we have so far neglected ($dx(q)/dq \geq 0$, equation (10)). By implicit differentiation of equation (20), it is immediate that $\hat{x}(q)$ will be increasing in q as long as

(21) $$\frac{d\hat{x}(q)}{dq} = -\frac{3F_{qx}(q,\hat{x}(q)) + (q-\underline{q})F_{qqx}(q,\hat{x}(q))}{2F_{xx}(q,\hat{x}(q)) + (q-\underline{q})F_{qxx}(q,\hat{x}(q))} \geq 0.$$

Is this a reasonable assumption in the context of this model ? Suppose that ASSUMPTION B is satisfied (namely, that $F(q,x) = q\,F(x)$). Then we have $F_{qxx}(q,x) = F_{xx}(x) < 0$, $F_{qqx}(q,x) = 0$ and $\hat{x}(q)$ is manifestly increasing in q.

ASSUMPTION B is, of course, stronger than what one really needs to guarantee that the input level is increasing in the tenant's productivity, but it is somewhat more appealing at the heuristic level than the condition that follows directly from equation (21).

Note that, under ASSUMPTION B we can write :

$$F_x(q,x(q)) = q\,F_x(x(q)) \text{ and } F_{qx}(q,x(q)) = F_x(x(q)).$$

It follows that one can rewrite equation (20) as :

$$q\,F_x(\hat{x}(q)) - 1 + (q-\underline{q})\frac{1}{2}F_x(\hat{x}(q)) = 0.$$

After simplification, this yields :

(20') $$\hat{x}(q) = F_x^{-1}\left(\frac{2}{3q-\underline{q}}\right).$$

Since the corresponding value in the first best optimum under ASSUMPTION B is given by

$$x^*(q) = F_x^{-1}(1/q),$$

it follows that $\hat{x}(q) \geq x^*(q)$. Under ASSUMPTION B, the landlord is thus compelled to set a level of input that is higher than the first best optimal level in order to mitigate the adverse selection problem.

What will the relationship between the optimal transfer and q be in this context when $\hat{x}(q)$ is indeed the solution to the landlord's problem, that is, when the condition given by equation (21) is satisfied? The answer is given in the following PROPOSITION :

PROPOSITION 4 : In the presence of adverse selection, and when equation (21) is satisfied (and *a fortiori* under ASSUMPTION B), $d\hat{t}(q)/dq \geq 0$.

PROOF : see APPENDIX.

Thus, the optimal transfer function in the presence of asymmetric information, is an *unambiguously increasing* function of q as long as the condition given in equation (21) is satisfied. This result will be obvious to readers familiar with the mechanism-design literature. In order to derive the corresponding comparative statics for the cost share recall, since $\hat{t}(q) = (1-\hat{b}(q))\hat{x}(q)$, that :

$$(22) \qquad \frac{d\hat{t}(q)}{dq} = (1-\hat{b}(q))\frac{d\hat{x}(q)}{dq} - \hat{x}(q)\frac{d\hat{b}(q)}{dq},$$

where $\hat{b}(q)$ denotes the optimal cost share under asymmetric information. Solving for $d\hat{b}(q)/dq$ yields :

$$(23) \qquad \frac{d\hat{b}(q)}{dq} = \frac{1}{\hat{x}(q)}\left((1-\hat{b}(q))\frac{d\hat{x}(q)}{dq} - \frac{d\hat{t}(q)}{dq}\right).$$

Substituting the expression for $d\hat{t}(q)/dq$ from the proof of PROPOSITION 4 (see APPENDIX) yields :

$$(24) \qquad \frac{d\hat{b}(q)}{dq} = \frac{1}{2}\left(1-2\hat{b}(q)-(q-\underline{q})\frac{1}{2}F_{qx}(q,\hat{x}(q))\right)\frac{d\hat{x}(q)}{dq}\frac{1}{\hat{x}(q)}.$$

The sign of this last expression is ambiguous.

We can make some headway in understanding the source of this ambiguity by considering equation (24) under ASSUMPTIONS B and C. We do so in the following PROPOSITION :

PROPOSITION 5 : In the presence of adverse selection, and under ASSUMPTIONS B and C,

$$\frac{d\hat{b}(q)}{dq} = \frac{3}{(1-k)(3q-\underline{q})}\left[\frac{\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^2}F_x^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds-\left(\frac{1-2k}{2k}\right)F_x^{-1}\left(\frac{1}{\underline{q}}\right)+W}{F_x^{-1}\left(\frac{2}{3q-\underline{q}}\right)}-\left(\frac{2q-\underline{q}}{3q-\underline{q}}\right)\right]$$

PROOF : see APPENDIX.

The interest of this rather cumbersome expression lies in the fact that it highlights that the sign of $d\hat{b}(q)/dq$ depends not only on q but, more importantly, on W, the reservation level of the tenant's utility. For relatively large values of W, it will be more probable that $d\hat{b}(q)/dq > 0$, whereas the opposite will be true for relatively small values of W.[7]

In order to drive home this point, and to provide some intuitive content to what has been so far a rather abstract discussion, consider the following parametric example in which the differential equation that implicitly defines the optimal transfer function $\hat{t}(q)$ (equation (12)) yields a closed-form solution. Let $F(q,x) = q\sqrt{x}$. Then it is immediate that :

$$\hat{x}(q) = \frac{1}{16}\left(3q-\underline{q}\right)^2,\ \frac{d\hat{x}(q)}{dq} = \frac{3}{8}\left(3q-\underline{q}\right),\ F_x(q,\hat{x}(q)) = \frac{2q}{3q-\underline{q}}.$$

It follows that one may write :

$$\frac{d\hat{t}(q)}{dq} = -\left(\frac{1}{2}F_x(q,\hat{x}(q))-1\right)\frac{d\hat{x}(q)}{dq} = \frac{3}{8}\left(2q-\underline{q}\right).$$

Straightforward integration of this expression thus yields :

$$\hat{t}(q) = \frac{3}{8}q^2 - \frac{3}{8}\underline{q}q + K,$$

where K is a constant of integration that must be chosen so as to satisfy the individual rationality constraint. From the individual rationality constraint (equation (12')), we can then immediately deduce that the constant of integration in the preceding expression is given by $K = W$. It follows that the optimal transfer function is given by :

$$\hat{t}(q) = \frac{3}{8}q^2 - \frac{3}{8}\underline{q}q + W.$$

From the definition of the transfer function, it follows that the optimal cost share is given by :

$$\hat{b}(q) = 1 - \frac{\hat{t}(q)}{\hat{x}(q)} = \frac{3q^2 + \underline{q}^2 - 16W}{\left(3q - \underline{q}\right)^2}.$$

Differentiation with respect to q then yields:

$$\frac{d\,\hat{b}(q)}{dq} = \frac{6\left(16W - \underline{q}\,(q + \underline{q})\right)}{\left(3q - \underline{q}\right)^3}.$$

The optimal cost share under asymmetric information can therefore be an increasing or a decreasing function of q, depending upon the value of the tenant's reservation level of income and on her level of unobserved productivity, q, since $d\,\hat{b}(q)/dq < 0$ for $q > 16W/\underline{q} - \underline{q}$, whereas $d\,\hat{b}(q)/dq > 0$ for $q < 16W/\underline{q} - \underline{q}$.

Rental contracts and contractual choice under asymmetric information

Consider now a fixed rental contract. It is easily shown (the proof is relegated to the APPENDIX as it is similar to that for the cost sharing contract) that, under a fixed rental contract, the derivative of the tenant's surplus with respect to q will be given by

$$\dot{S}(q) = F_q(q, \hat{\hat{x}}(q)) \geq 0,$$

while the input level (denoted here by $\hat{\hat{x}}(q)$) under the fixed rental contract will be implicitly determined by

$$F_x(q, \hat{\hat{x}}(q)) - 1 + (q - \underline{q})F_{qx}(q, \hat{\hat{x}}(q)) = 0.$$

(Note that $\hat{\hat{x}}(q)$ will be increasing in q under a condition, given in the APPENDIX, that is similar to equation (21); $\hat{\hat{x}}(q)$ will, of course, be increasing in q under ASSUMPTION B). For a fixed rental contract to be chosen by a peasant of type q over the corresponding cost sharing contract, it must be the case that the surplus she receives from doing so is greater than what she would receive under cost sharing. This corresponds to the condition that

(25) $$\frac{d}{dq}\left(S_{\mathrm{Re}nt}(q) - S_{Share}(q)\right) = \dot{S}_{\mathrm{Re}nt}(q) - \dot{S}_{Share}(q) = F_q(q, \hat{\hat{x}}(q)) - \frac{1}{2}F_q(q, \hat{x}(q)) > 0.$$

The following PROPOSITION establishes that this is indeed the case, at least under ASSUMPTION B. A COROLLARY, relegated to the APPENDIX, establishes conditions under

[7] This ambiguity necessarily carries over to the case in which x is an N-dimensional vector of factor inputs (see PROPOSITION 2 (ii) for the case in the absence of adverse selection).

which the converse of PROPOSITION 6 is true, namely that higher productivity tenants will choose cost-sharing contracts over fixed rental contracts.[8]

PROPOSITION 6 : In the presence of adverse selection, and under ASSUMPTION B, the probability of choosing a fixed rental contract over a sharecropping contract is an increasing function of q .

PROOF : see APPENDIX.

Summary of testable hypotheses

What is the upshot of all this? The empirically relevant differences between the first best optimum and the case of asymmetric information are given by PROPOSITIONS 1 to 6. First, in the absence of adverse selection concerns, contractual choice will be independent of the productivity of the tenant, parameterized by q (PROPOSITION 3), whereas when adverse selection is present, the probability of choosing a cost-sharing over a fixed rental contract will be significantly related to q (PROPOSITION 6). Second, if the problem of adverse selection is not pertinent *per se*, then the transfer from the landlord to the tenant will be a decreasing function of the tenant's level of productivity, (PROPOSITION 1). On the other hand, in the presence of asymmetric information, that is, when there is a departure from the first best optimum caused by the presence of adverse selection, then the transfer from the landlord to the tenant will be an increasing function of the productivity of the tenant (PROPOSITION 4). Third, in the absence of adverse selection, it *cannot* be the case that *all* of the cost-shares borne by the peasant are decreasing functions of q (PROPOSITION 2). In the presence of adverse selection, on the other hand, the relationship can go in either direction (PROPOSITION 5). The following table synthesizes the testable hypotheses that allow one to distinguish between contractual environments where adverse selection is present from those in which it is absent.

[8] Why, intuitively, should this ambiguity persist, when other authors (e.g. Braverman and Guasch, 1984) have been able to persuasively sign contractual choice as a function of a peasant's unobservable level of productivity ? The answer is simple, and lies in their restriction to linear or piecewise linear contracts. Here, on the other hand, through our use of the general form $t(q)$, which is readily interpretable in terms of cost-sharing, we are not restricting our attention to any given class of transfer functions. Note also, as pointed out by Braverman and Stiglitz (1982), that cost-sharing is simply an example of an *interlinked* sharecropping contract.

Testable hypothesis	**No adverse selection**	**Adverse selection**
Choice between fixed rental and sharecropping contracts	(PROPOSITION 3) Will be independent of tenant productivity $\dfrac{d\,\Pr(share-vs-rent)}{dq}=0$	(PROPOSITION 6) Will depend upon tenant productivity $\dfrac{d\,\Pr(share-vs-rent)}{dq}\neq 0$
Transfer from landlord to tenant under a cost-sharing contract	(PROPOSITION 1) Will be a decreasing function of tenant productivity $dt^{*}(q)/dq<0$	(PROPOSITION 4) Will be an increasing function of tenant productivity $dt^{*}(q)/dq>0$
Share of cost of a given factor input j borne by the tenant	(PROPOSITION 2) Cannot be a decreasing function of tenant productivity for all factor inputs i.e., it cannot be the case that $d\,b_j^{*}(q)/dq<0\ \ \forall\ j$	(PROPOSITION 5) Can be either an increasing or a decreasing function of tenant productivity $d\,b_j^{*}(q)/dq \lessgtr 0$

These contrasting implications allow us to test directly for the relevance of adverse selection, since we have data (stemming from cost sharing and fixed rental contracts in Tunisia) regarding (i) contractual choice, (ii) the transfer function from landlords to tenants under cost-sharing, and (iii) the cost share associated with each factor input. It is worthwhile emphasizing that the theoretical propositions summarized above provide a powerful test for the presence or absence of adverse selection, as well as of the validity of the underlying theoretical model *per se*. To whit, if adverse selection characterizes contractual relationships in the village and the theoretical model represents a reasonable approximation to the reality in the field, there are three testable implications that must *simultaneously* be verified. The same is true were adverse selection to be absent.

4. EMPIRICAL IMPLEMENTATION : CONSTRUCTING A MEASURE OF HOUSEHOLD PRODUCTIVITY

The main empirical challenge that is addressed in this section is that of constructing a plausible indicator of each tenant's level of productivity q with which to test the hypotheses formulated in our theoretical treatment of the problem. Our empirical implementation of the theoretical model outlined in sections 2 and 3 is divided into two parts. First, we estimate a plot-level production function for all households in the sample using panel estimation with household-specific fixed effects. We are able to do so because we have plot level data at our disposal, and all households in the sample cultivate two or more plots of land: the two dimensions of the panel are therefore plots, on the one hand, and households, on the other (the resulting panel is unbalanced). Estimation based on the within estimator allows us to obtain a measure of household-specific fixed effects. Second, this measure of total household productivity is purged of observable household characteristics in order to arrive at a measure of household productivity that will be potentially non-observable to landlords.[9] This "purged" variable corresponds to the parameter q that constituted the crux of the theoretical portion of the paper. In part 5, we use these measures of household-specific productivity to explicitly test the three hypotheses formulated in sections 2 and 3. We also consider several ancillary hypotheses that follow from our theoretical model in order to assess the robustness of our measure of household productivity. Finally, in part 6 (which also concludes the paper) we consider the empirical relevance of those determinants of contractual choice that are not part and parcel of our theoretical model, offer some evidence regarding the mechanism through which landlords and tenants would appear to match, and provide additional evidence that confirms the robustness of our basic results to changes in specification.

Parameterizing the model

Let i index plots of land and let h index tenant households ($i = 1,...,I, \quad h = 1,...,H$). A plot is defined as a parcel of land on which a given crop is cultivated during a given season (there are two agricultural seasons in the agroclimatic zone to which the Tunisian village in question belongs). The production technology is described by the function :

$$F(\,l\,(q_h, Z_h), x(X_{ih}, T_i, A_i), h_{ih})\,,$$

where

[9] It is interesting to note that Glaeser (1991) uses a procedure that is similar in spirit to our own to investigate the knowledge available to employers regarding their employees, in the context of the US labor market. His measure of potentially unobservable worker productivity is given by the residual of a regression of the employee's wage on schooling and potential work experience.

- Z_h is a K dimensional vector of observable household characteristics that directly affect agricultural productivity (each household characteristic will be denoted by Z_{kh}, $k=1,...,K$) ;
- A_i is an M dimensional vector of observable plot-specific characteristics ;
- X_{ih} is an N dimensional vector of physical inputs on plot i; each individual input will be written X_{jih} where j ($j=1,...,N$) indexes each input ;
- T_i is the surface of the plot of land ;
- q_h is a scalar measure of household productivity that may, potentially, be unobservable to landlords when q_h corresponds to tenants ;
- $l(.,.)$ is an aggregator function which transforms the $K+1$ dimensional vector of observable household characteristics and household productivity into a scalar measure of total household productivity; this function is strictly increasing in q_h;
- $x(.,.,.)$ is an aggregator function that transforms the $N+M+1$ dimensional vector of observable physical inputs, plot characteristics and plot size, into a scalar measure of factor input; this function is increasing in each X_i, as well as in T_i;
- h_{ih} is the household-plot level disturbance term, which represents stochastic shocks to production such as pest infestations and weather.

Let $F(l(q_h,Z_h),x(X_{ih},T_i,A_i),h_{ih}) = l(q_h,Z_h)F(x(X_{ih},T_i,A_i))\exp\{h_{ih}\}$ and $l(q_h,Z_h)$ be of the form

$$l(q_h,Z_h)=\exp\{q_h\}\prod_{k=1}^{k=K} Z_{kh}^{g_k} .$$

Through the appropriate normalization of q_h, this specification corresponds to ASSUMPTION B (multiplicative productivity). Then the production function can be rewritten, after taking logarithms on both sides, as :

$$(26) \qquad \ln Y_{ih} = \ln F(x(X_{ih},T_i,A_i)) + \sum_{k=1}^{k=K} g_k Z_{kh} + \underbrace{q_h + h_{ih}}_{e_{ih}} .$$

Note that our disturbance term $e_{ih} = q_h + h_{ih}$ is composed of two parts : an unobservable (to the econometrician) household effect (q_h), and the household-plot disturbance (h_{ih}). The problem were one to estimate this equation by ordinary least squares is that it is clear (even assuming that h_{ih} is orthogonal to the explanatory variables) that

(27) $\quad E(e_{ih} \mid X_{ih}, Z_h, T_i, A_i) = E(q_h \mid X_{ih}, Z_h, T_i, A_i) \neq 0$.

This is because, *a priori*, we expect q_h to be correlated with X_{ih} since optimizing behavior on the part of the peasant implies that $X_{ih} = X_{ih}(l(q_h, Z_h), T_i, A_i)$ (in the case of adverse selection, this would be the empirical counterpart to equation (20) in section 3 above). This is where the within estimator becomes important:[10] for variables that vary across plots and are correlated with q_h, transforming the former into deviations with respect to their corresponding household means provides legitimate instruments because they will no longer be correlated with the fixed effect. In other words, the projection that is used in the within estimator (transforming variables into differences with respect to their household mean) effectively orthogonalizes the elements of X_{ih} with respect to q_h. Thus, we will be able to obtain an unbiased and consistent estimate of $q_h + \sum_{k=1}^{k=K} g_k Z_{kh}$ as well as of the other parameters of interest in the production technology. Given that the empirical issue that we must address in the context of production function estimation is obtaining a measure of household productivity q_h (that landlords, when q_h applies to tenants, will potentially not be able to observe), we may be reasonably confident that, by using the within estimator, we are able to fulfill this task.

Of course, it is possible that X_{ih} (again because it is chosen according to equation (20) and is not randomly drawn by nature) is correlated with the household-plot disturbance term h_{ih}, which may represent omitted plot characteristics as well as idiosyncratic shocks.[11] In this case, the obvious answer is to apply an instrumental variable estimator based on exogenously determined plot-level instruments. These are, however, not available. Another possible solution, given that the data we will be using corresponds to four seasons (two seasons for each year) would be to include plot-specific fixed effects that would allow one to control for time-invariant unobservable plot characteristics. We are unable to do so since we cannot

[10] See, e.g., Hausman and Taylor (1981, p. 1380), for a particularly clear exposition.
[11] Fafchamps (1993) shows, in the context of West African agriculture, that this problem may indeed be significant.

follow a given plot over time because of the particular manner in which the land rental market operates in the village.[12]

A final argument in favor of using the within estimator in order to obtain a measure of household productivity stems from the origins of the estimator itself. Both Hock (1962) and especially Mundlak (1961) proposed the within estimator as a means of obtaining estimates of production function parameters that would be free of omitted variable bias due to unobservable household-level characteristics.

Specifying the production technology

An important issue that must be addressed in the context of the estimation of equation (26) involves the specification of the functional form for $F(x(X_{ih}, T_i, A_i))$. There are many options available (see, e.g. Nadiri (1982) for a summary) but our choice is conditioned by dint of the fact that (i) there are a substantial number of observations for which certain inputs are zero, and (ii) we believe it to be inappropriate in this particular context to assume a constant elasticity of substitution among all factor inputs. Our choice falls upon the modified nested or two-level CES production function (Sato (1967); see Udry (1996) for a recent application). We divide our factor inputs into two subgroups, in which the aggregator takes the CES form.

Our two subgroups here are land on the one hand, and labor, on the other. Labor is an aggregate of family labor (X_{FAMLAB}) and hired labor ($X_{HIRELAB}$). Land ($LAND$), for its part, is an aggregate of chemical fertilizer and herbicides ($X_{HERB} + X_{FERT}$) and manure (X_{MANURE}) costs and a modified measure of land. This modified measure of land takes into account the area of the plot (T), as well as soil type through four dummy variables ($SOIL_c$, $c = 1,\ldots,4$), an irrigated plot dummy (d_{IR}), and plowing intensity (X_{PLOW}). To be more specific, the functional form that is implemented (where we drop the plot and household subscripts for clarity) is given by :

[12] For example, plot A under owner-operatorship in the season 1 may be divided into plot B under sharecropping and plot C under owner-operatorship in season 2, where plot C also includes portions of what corresponded to a plot D in season 1. The inability to follow plots over time is, unfortunately, a common characteristic of detailed agronomic data such as our own or those produced by ICRISAT in the context of Burkina Faso (see Udry, 1996).

$$(28)\qquad F(.) = \left[a_T \underbrace{LAND}_{\substack{\text{aggregate}\\ \text{land input}}}{}^{r} + (1-a_T)\underbrace{\left(\left[d_F X_{FAMLAB}^{\Pi} + (1-d_F) X_{HIRELAB}^{\Pi} \right]^{\frac{1}{\Pi}} \right)^{r}}_{\text{aggregate labor input}} \right]^{\frac{n}{r}}$$

where the aggregate land input is given by

$$(29)\qquad \begin{aligned} LAND = T&\left(1 + w_{IR} d_{IR} + w_{PLOW} X_{PLOW} + \sum_{c=1}^{c=4} w_c SOIL_c\right) \\ &\times\left(1 + f\left(\frac{w_{CHEM}\left(X_{HERB} + X_{FERT}\right) + w_{MANURE} X_{MANURE}}{1 + w_{IR} d_{IR} + w_{PLOW} X_{PLOW} + \sum_{c=1}^{c=4} w_c SOIL_c}\right)^{\Phi}\right) \end{aligned}$$

Finally, note that once equation (26) has been estimated using the functional forms given by equations (28) and (29), the resulting fixed effect will not correspond to q_h *per se*; rather, it corresponds to $q_h + \sum_{k=1}^{k=K} g_k Z_{kh}$. This is because the within procedure will sweep out q_h as well as the observable household-specific variables Z_h that are constant across all plots worked by a given household. It follows, in order to obtain our measure of q_h, that we will then have to regress the household-specific fixed effect stemming from the production function estimation on the vector of observable household characteristics in order to purge any observable household effects from our measure of potentially unobservable household productivity. The residual from this last equation will yield our estimate of potentially unobservable household productivity q_h, whereas the predicted value of the fixed effect (predicted, that is, by observable household characteristics) yields a scalar measure of productivity-enhancing observable household characteristics.[13] *Of course, if the empirical tests implemented in what follows should reject the presence of adverse selection, the implication would be that* q_h *is in fact observable to landlords.*

The village

The data used in this paper stem from two detailed field surveys carried in the Tunisian village of El Oulja in 1993 and 1995. The reader is referred to Ai, Arcand and Ethier (1998)

[13] Note that it is important from the theoretical standpoint that our measure of household productivity q_h be uncorrelated with observable household characteristics Z_h, and this will be the case by construction.

for a description of the data.[14] That the village does in fact correspond to a compact society in which labor is relatively immobile, as we alluded to in the introduction, is reflected by the fact that an elderly woman who arrived in the village 60 years ago from a neighboring community as a result of marriage is still refered to as “the stranger”. This impression is also confirmed by the average difference between the date of birth of the inhabitants and the date at which they arrived in the village, which is essentially zero. Table I provides summary statistics for those variables that will constitute the basis of our empirical work. The relative fluidity of the land rental market is reflected in the Lorenz curves presented in Figure 1 : the Lorenz curve associated with the distribution of land ownership is Lorenz-dominated by the Lorenz curve associated with the distribution of the total amount of land farmed by a given household, reflecting the significant role played by the land rental market in reducing differences in the marginal product of land across different households.

Results : estimating the production technology
and constructing our measures of household productivity

The results of estimating equation (26) by nonlinear least-squares with household-specific fixed effects are presented in Table II. As expected in the case of developing country agriculture long run returns to scale are approximately constant, as indicated by the estimate of n. There is little substitution between the aggregate land input and the aggregate labor input, as indicated by the low value of r. The estimated upper-level production function is thus quite near a constant returns to scale Cobb-Douglas production function whose arguments are aggregate labor and aggregate land input. There is relatively little substitutability between family and hired labor as indicated by the small (and marginally significant) value of Π. This is unsurprising in light of the clear division of tasks between hired and family labor that we observed in the village during field work. A kernel estimation of the distribution of the resulting household-specific fixed effects is presented in Figure 2.

Table III presents the results from purging the fixed effects of the impact of observable household characteristics. It is worth pointing out that the total amount of owned land cultivated by the household has a negative effect on the household-specific fixed effect, while total hectares cultivated does not appear to have any significant impact. As would be

[14] Earlier studies of this village include Matoussi and Nugent (1989) and Laffont and Matoussi (1996). These studies are based on surveys carried out in 1985 and 1986, and survey design was not compatible with our own.

expected, the labor endowment of the household has a statistically significant positive impact on the household-specific fixed effect.

A puzzle emerges with respect to the average level of schooling of household members, which has a significantly negative impact on the household-specific fixed effect. This result has been obtained by a number of researchers working on African agriculture.[15] The consensus that appears to be emerging is that the most likely explanation for the negative impact of human capital on various measures of the productivity of agricultural households is that household members who are particularly productive (and observably so), are drawn away from agricultural activity *per se* (the literature summarized in FAO (1998) also points in the same direction). This would appear, moreover, to be particularly true for female household members whose contribution to agricultural output within the framework of team production may not be adequately recognized within a male-dominated society. Furthermore, since non-agricultural activities may provide a level of remuneration that is more comensurate with the level of qualifications attained by relatively well-qualified female household members, it is perhaps not surprizing that they are increasingly drawn away from agricultural production for purely individually rational motives. Diversification of sources of household income into non-agricultural activities that require a higher level of human capital than agricultural production may also explain why such behavior is rational even in the context of unitary models of household behavior. Regardless of the operational motive, non-agricultural activities provide a substantial portion of total household income for a number of households in the village, and access to these activities is relatively easy. We would therefore conjecture that the aforementioned hypotheses provide a plausible explanation for the observed puzzle.

Turning now to the endowment in human capital of the household head, one might expect experience, proxied by age, and schooling to significantly affect the household-specific fixed effect : they do not.[16] Livestock ownership, for its part, has no significant impact on agricultural productivity, which is unsurprising given the relatively limited importance of animal draft power in the village (this is in sharp contrast to other environments, such as

[15] So much so that it was one of the principal topics discussed at a recent symposium held in Ouagadougou (see AUPEL-UREF, 1999). A typical example stems from the estimation of frontier production functions. See Audibert, Mathonnat, Nzeyimana, and Henry (1999). Numerous references on the topic of rural non-farm income are summarized in FAO (1998).

[16] A well-known argument put forward by Jamison and Lau (see their reply to criticisms of their work in Jamison and Lau, 1987, and the references cited therein) holds that the human capital of peasants is particularly important

village India). Agricultural machinery ownership, on the other hand, is an important determinant of household productivity. Figure 3 presents a kernel estimate of the distribution of our measure of potentially unobservable household productivity, given by the residual of the equation presented in Table III. The first part of Table VII presents summary statistics regarding the estimated household-specific fixed effect, our scalar measure of observable household characteristics, and our measure of household-specific productivity.

5. TESTING FOR THE PRESENCE OF ADVERSE SELECTION

It should be clear from the summary at the end of the theoretical portion of this paper that the first hypothesis that we aim to test is whether contractual choice is independent of the tenant's potentially unobservable level of productivity. *A priori*, this could be done by estimating a simple probit regression in which the dependent variable takes on the value of one when the plot is cultivated by a sharecropper, and zero when the plot is rented out under a fixed rental contract. Before proceding with this test for the presence of adverse selection based on contractual choice, it is important to note however, that the subsample of plots cultivated under tenancy contracts (113 plots) is not chosen randomly, since we also have a large number of observations corresponding to owner-operators (306 plots) in the sample used to estimate the production technology. Failure to control for this potential source of sample-selection bias in the contractual choice equation might lead to incorrect inference regarding the impact of tenant household productivity on the choice between sharecropping and fixed rental contracts. Given that the equation (contractual choice) that is potentially subject to sample-selection bias corresponds to a problem of discrete choice, the appropriate empirical procedure is to estimate the renting out and contractual choice equations simultaneously using full information maximum likelihood (FIML), in order to exploit any correlation that may exist between the disturbance terms of the two equations while concomitantly controling for sample selection problems. This corresponds to the censored bivariate probit model implemented, for example, by Boyes, Hoffman and Low (1989).[17]

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in environments in which technological change is occuring. This was not the case in the village in question during the two years under consideration.

[17] A simple Heckman-Lee procedure is not, unfortunately, appropriate when the equation subject to sample-selection bias corresponds to a problem of discrete choice; moreover there is a gain in the efficiency stemming from simultaneous estimation.

The decision to rent out

The basic specification is thus given by (i) a renting out equation and (ii) a contractual choice equation. In the renting out equation, the dependent variable is equal to one when the plot is rented out under a sharecropping or fixed rental contract and equal to zero when it is cultivated by an owner-operator (later on, we will also use a renting out equation in order to assess the validity of our measure of household productivity as it applies to *landlords*). The baseline results from estimating the renting out and contractual choice equations by censored bivariate probit are presented in the first column of Table IV (for the renting out equation) and the first column of Table V (for the contractual choice equation). We begin by discussing the results corresponding to the renting out equation, where the explanatory variables are constituted by plot characteristics (four soil dummies, an irrigated plot dummy and plot area in hectares), a year dummy, two crop dummies (wheat and other grains, and garden vegetables), and two characteristics of the landlord: the peasant landlord dummy is equal to one when the landlord associated with the plot is herself a peasant, while the resident landlord dummy is equal to one when the landlord in question resides in the village.

First, it is interesting to note that plot size has an important positive impact on the probability of renting out. This may correspond to omitted plot characteristics being correlated with plot size (smaller plots tends to be associated with a higher level of output per hectare and may therefore be assigned on a priority basis to owner-operatorship), but it may also stem from resource constraints faced by landlords who are unable to effectively cultivate particularly large plots themselves. Moreover, as we will argue below, plot size does not appear to be a choice variable controlled by landlords, who are thus unable to perfectly adjust the size of their holdings to its optimal level through the land rental market. Second, the peasant landlord and resident landlord dummies both have a significantly negative impact on the probability of renting out. This is to be expected : non-peasant landlords have manifestly self-selected out of agricultural production, while non-resident landlords, though some do cultivate plots as owner-operators, face substantial transaction costs in working their own land.

Contractual choice

The specification of the contractual choice regression is given by :

(30) $\Pr[SHARE_i = 1] = fQ_i + hq_h^T + x_{ih}$,

where q_h^T is the previously constructed measure of household productivity, as it applies to tenants (hence the "T" superscript, in order to distinguish it from household productivity as it applies to the landlord, which we will denote by q_h^L), and $SHARE_i$ takes on the value of one when the plot is rented out under a sharecropping contract and zero when it is cultivated under a fixed rental contract. The matrix of explanatory variables Q_i includes a dummy variable that indicates whether the two parties to the contract were involved in a similar contractual relationship during the previous agricultural season in order to control for the potential impact of repeated interaction (more on this below); Q_i also includes two characteristics of the landlord that may affect contractual choice. First, we include the resident landlord dummy. *A priori*, one might expect non resident landlords to have a preference for fixed rental contracts (since sharecropping contracts involve substantial managerial input on the part of landlords, see Eswaran and Kotwal, 1985, for the standard arguments based on double-sided moral hazard). Second, we include the peasant landlord dummy : landlords who are themselves farmers may be better able than others to mitigate informational concerns stemming from knowledge of the agricultural technology. Finally, agricultural year and plot area controls are included.

Our null hypothesis that there are no adverse selection problems in the village is given by: $H_0 : h = 0$, while the alternative hypothesis is that adverse selection concerns are significant and is given by $H_A : h \neq 0$. The results for the contractual choice equation which, it should be recalled, is estimated simultaneously with the renting out probit, are presented in the first column of Table V. Note that the estimated correlation between the disturbance terms in the renting out and contractual choice equations (given by r) is not significantly different from zero, indicating that sample selection bias in the contractual choice equation should not be of particular concern.

The most important result is that the null hypothesis of no adverse selection, corresponding to a statistically insignificant coefficient associated with our measure of tenant productivity (q_h^T), is strongly supported by the data : the coefficient is equal to –0.097 with an associated z-statistic of -1.13. This result firmly rejects the theoretical result derived in PROPOSITION 6 and supports the indifference result given by PROPOSITION 3. In terms of contractual choice (i.e., choosing between sharecropping and fixed rental contracts), it would appear that adverse selection plays no important role in this village.

Discussion

While the preceding result in terms of contractual choice suggests that asymmetric information in the form of adverse selection does not exist in the village, it would appear to be worthwhile to investigate whether our measures of household productivity are in fact credible empirical representations of their theoretical counterparts. In other words : can we be reasonably confident, based on additional empirical evidence driven by our theoretical construct, that our measures do in fact correspond to household productivity ? In what follows, we present just such a test by considering the relationship linking the decision to rent out (versus choosing to cultivate the plot oneself) and our measure of household productivity as it applies to *landlords*.

In the case of the first-best optimum, the profit of the landlord if she rents out her land (be it under a sharecropping or a fixed rental contract, given the indifference result derived at the end of part 2) is given by :

$$F(l(q^T,Z^T),x^*(l(q^T,Z^T)))-x^*(l(q^T,Z^T))-W\ ,$$

where, transposing the empirical notation of part 4 into the theoretical model, $l(q^T,Z^T)$ is the household-specific fixed effect of the tenant (recovered from estimation of the production function). If the landlord chooses to cultivate the plot as an owner-operator, the corresponding expression is given by :

$$F(l(q^L,Z^L),x^*(l(q^L,Z^L)))-x^*(l(q^L,Z^L))-R,$$

where $l(q^L,Z^L)$ is the household-specific fixed effect of the landlord (again stemming from estimation of the production function) and we recall that R is the landlord's reservation level of welfare (see the brief discussion following PROPOSITION 2). By the Envelope Theorem, it is immediate that :

$$\begin{aligned}
&\frac{d}{d\,l(q^L,Z^L)}\left[\begin{array}{l}\left(F(l(q^L,Z^L),x^*(l(q^L,Z^L)))-x^*(l(q^L,Z^L))-R\right)\\ -\left(F(l(q^T,Z^T),x^*(l(q^T,Z^T)))-x^*(l(q^T,Z^T))-W\right)\end{array}\right]\\
&\quad=\frac{\partial}{\partial\,l(q^L,Z^L)}\left(F(l(q^L,Z^L),x^*(l(q^L,Z^L)))-x^*(l(q^L,Z^L))-R\right)\\
&\quad=F_l\,(l(q^L,Z^L),x^*(l(q^L,Z^L)))>0.
\end{aligned}$$

It follows that the probability of the landlord choosing to lease out her land is a decreasing function of her household-specific fixed effect :

$$(31) \qquad \frac{\partial \text{ Pr[plot rented out]}}{\partial l(q^L, Z^L)} < 0 \,;$$

ceteris paribus, more productive landlords are more likely to cultive their own land as owner-operators. Note, since there is no reason *a priori* to suppose that landlords do not know their own productivity q^L, that the derivative in question is respect to the landlord's household-specific fixed effect $l(q^L, Z^L)$, and not with respect to q^L. There is, of course, a problem associated with this estimation stemming from the presence of a substantial number of landlords who did not cultivate any land themselves, and for whom no value of $l(q^L, Z^L)$ therefore existed.[18] We therefore proceeded in two manners. First, we estimated the renting out equation on the subsample of observations which corresponded to peasant landlords. Second, we carried out the estimation by setting $l(q^L, Z^L) = 0$ for those landlords for whom $l(q^L, Z^L)$ did not exist since their household-specific fixed effect in agricultural activity must presumably have been extremely low for them to have chosen not to cultivate any land. The results do not differ qualitatively and we therefore present those results corresponding to the second option in the last two columns of Table IV. In column 2 of Table IV we include the peasant landlord and resident landlord dummies alongside $l(q^L, Z^L)$, whereas in column 3 $l(q^L, Z^L)$ appears alone : in both cases, the probability of renting out is a decreasing function of $l(q^L, Z^L)$ and the associated coefficient is highly significant, as is predicted by our theoretical model. This simple test therefore provides additional confirmation that the fixed effects extracted from production function estimation do in fact constitute credible representations of household productivity. Moreover, this test is squarely geared towards rejecting the validity of our empirical measure of aggregate household productivity since it is based upon information (the fixed effects) recovered from an estimation procedure that is based upon the household *cultivating* a given set of plots, which is then applied to plots that the household in question does not cultivate (the plots rented out).

A further test of our theoretical model is provided by a particularly strong implication of our simple theoretical construct when combined with our finding, based at least on contractual

[18] For a number of plots the landlord is the Tunisian army, while for several others, despite our efforts during fieldwork, we were unable to satisfactorily identify the landlord.

choice, that landlords do in fact observe q_h^T. Recall from PROPOSITION 3 that the landlord will be indifferent, in the absence of adverse selection, between renting out under a sharecropping or a fixed rental contract. Since q_h^T would appear to be observable to landlords, the distinction between q_h^T and $l(0,Z^T)$ is moot. Therefore, if our theoretical model is correct and there is no adverse selection, it must be the case that contractual choice is independent not only of q_h^T, but of $l(q^T,Z^T)$ as well. In column 2 of Table V we therefore replace q_h^T by $l(q^T,Z^T)$, whereas in column 3 we include q_h^T and $l(0,Z^T)$ (our scalar measure of household productivity based upon observable household characteristics) simultaneously. In column 2, the coefficient associated with $l(q^T,Z^T)$ is statistically indistinguishable from zero, while the same is true of the coefficients associated with q_h^T and $l(0,Z^T)$ in column 3. Thus, a particularly strong implication of our model when there is no adverse selection is not rejected by the data.

The transfer function

The second hypothesis, related to the presence of adverse selection, that we aim to test is whether the transfer function from the landlord to the tenant on plots under cost-sharing contracts is effectively an increasing or a decreasing function of the tenant's productivity q_h^T. Our test for the relevance of adverse selection is therefore implemented by the following regression :

(32) $t_{ih} = fW_i + mq_h^T + z_{ih}$,

where z_{ih} is the corresponding disturbance term and W_i is a matrix of explanatory variables constituted by the appropriate inverse Mills ratio (in order to control for potential sample-selection bias) stemming from our previous probit estimation of the determinants of contractual choice (column 1 of Table V), and plot size in order to account for possible scale effects.

Our null hypothesis that there is no adverse selection problem in the village is represented by: $H_0 = m < 0$, while the alternative hypothesis is that adverse selection concerns are significant and is given by $H_A = m > 0$. Results for the estimation of equation (32) are presented in the first column of the upper portion of Table VI. Here again, the data strongly support the null hypothesis of no asymmetric information. The coefficient associated with our measure of unobserved tenant productivity is equal to –5.546, with an associated p-value of 0.02 (t-statistic of –2.37). The theoretical hypothesis corresponding to PROPOSITION 1 (the transfer function is decreasing in q in the absence of asymmetric information) is not therefore rejected by the data, whereas the hypothesis corresponding to PROPOSITION 4 is.

It is interesting to note that this finding supports our initial assumption that factor endowments are such that relatively numerous, sufficiently well-qualified, tenants compete for relatively scarce tenancy contracts. If we consider the alternative hypothesis that landlords compete for relatively scarce tenants, it is intuitively obvious (and easy to prove analytically) that the transfer function must continue to be an increasing function of q_h^T for landlords to be able implement an incentive compatible selection mechanism in the presence of adverse selection. For the case in which q_h^T is known to landlords, on the other hand, landlords will be driven down to their individually rational level of welfare, and (in contrast to what obtains when tenants are relatively abundant) the transfer function will also be *increasing* in q_h^T. Our empirical results with respect to the transfer function, which we found to be decreasing in q_h^T, therefore support both the hypothesis that q_h^T is known to landlords and our initial hypothesis that tenants are relatively abundant and land is relatively scarce.[19]

Cost shares

It should be obvious from the logical standpoint that if, as we have found, $dt_{ih} / dq_h^T < 0$, then it must be the case that PROPOSITION 2 (ii) holds, namely that it cannot be the case that all cost shares are decreasing in q_h^T. It may be asking too much of the data to hope that b_{ji} will be an increasing function of q_h^T for a substantial number of factor inputs (indexed by j), substantial enough to ensure, that is, that we do in fact have $dt_{ih} / dq_h^T < 0$. Nevertheless, the second part

[19] Another strong assumption made at the outset in the theoretical model was that the individually rational level of welfare of tenants was independent of their household productivity q. In order to test this hypothesis, we regressed non-agricultural income, which may provide a measure of outside opportunities available to tenants, on observable household characteristics and q. We found non-agricultural income to be independent of q, as we had postulated. Moreover, in conformity with our arguments revolving around the puzzling (negative) coefficient associated with human capital in the procedure by which we purged the household-specific fixed effects of observable household characteristics, the *maximum* level of schooling attained by a household member was a statistically significant determinant of non-agricultural income.

of Table VI presents the results obtained from estimating the following cost-share equation for each of the ten factors inputs under consideration :

$$b_{jih} = JY_i + s_j q_{hi}^T + k_{jih}, \quad j = 1,...,10 .$$

Our null hypothesis for the presence of adverse selection is that a substantial number of s_j's are negative, whereas in the absence of adverse selection (that is, if landlords do in fact observe q_h^T), a substantial number of s_j's must be positive. Since b_{ji} is bounded by zero below and by one above, it would appear to be essential to estimate this equation using a tobit procedure. Alternatively, since b_{ji} takes on a limited number of discrete values (0, 0.50, 0.66, 0.70, 0.75, 1) it would appear equally reasonable to estimate the equation by ordered probit. We did both. Remarkably, none of the ten different estimated s_j's was negative and significantly different from zero, either in the tobit or in the ordered probit specifications. Since the ordered probit which, in our opinion, is that most faithful to the structure of the data, classified observations into two broad categories (b_{ji} = 0 versus b_{ji} = 1), we present the simpler probit estimates corresponding to the dependent variable being equal to one when b_{ji} = 1 (the peasant bears the entirety of the costs associated with the input in question) and b_{ji}=0 otherwise.[20] As is clear from the results presented in the lower portion of Table VI, all cost shares are non-decreasing in q_h^T, and it is only for the case of the plowing and irrigation shares that s_j is non-significantly different from zero.

In order to convince ourselves that these results were robust to changes in specification, we also estimated the preceding relationship by a probit procedure with *input-specific* random effects, in which the dependent variable was identical to the simple probits presented above, but where each input-specific block was stacked so as to produce a 393-dimensional vector.[21] That is, we estimated

$$b_{ih} = JY_i + \sum_{j=1}^{j=N} s_j q_{hi}^T + \sum_{j=1}^{j=N} i_j + k_{ih},$$

where i_j is the input-specific random effect. The results are presented in the second part of Table VI, below the corresponding cost share equation (we only present the input-specific slope coefficients), and confirm the findings based upon the individual cost share equations.

[20] The tobit and ordered probit results are available from the authors upon request.

The result also holds when the coefficients associated with the different cost shares are restricted to being equal, as is shown by the results presented in the second column of the upper portion of Table VI.

These results provide strong support for our previous finding based upon the transfer function: on the basis of the relationship between each cost share and q_h^T, contractual relations in the village do not appear to be characterized by adverse selection. On the contrary, all of the evidence that we have presented strongly supports the contention that q_h^T is observable to landlords.

6. Concluding Remarks

Given that all of the empirical results presented in this paper suggest that there is no adverse selection and that our theoretical model provides a reasonable description of contractual relations in the village, it would appear to be interesting to investigate the functioning of the land rental market more closely. We also offer some evidence that plot size is not a choice variable available to landlords, an assumption that constituted a key aspect of our theoretical model. It would also appear to be worthwhile, since adverse selection does not appear to provide an explanation for contractual choice in the village, to briefly consider what does. We do so by providing some limited evidence based upon the dynamics of contractual relationships. These last results also indicate that our basic findings are not driven by problems stemming from simultaneity bias.

The land rental market and the choice sets of landlords

The question we seek to answer is the following : what assumption regarding the choice sets of landlords, in terms of the potential tenants that they may rent out their land to, is most consistent with our data ? For plots that are effectively cultivated under sharecropping or fixed rental contracts, it is obvious that we have the information pertaining to the productivity of the tenant. For plots under owner-operatorship, on the other hand, we must impose some form of theoretical structure in order to obtain a measure of the productivity of the potential

[21] We estimated using a probit procedure with random effects because, as pointed out by Hsiao (1986, pp. 158-163), fixed effects procedures do not produce consistent estimates of the slope parameters that are of interest, hence the resort to random effects.

tenant who was in fact rejected by the landlord. The strategy here is exploratory : construct different measures of the productivity of the potential tenant that the landlord rejected in favor of owner-operatorship, and see which assumption gives the most reasonable result in a renting out probit.

In the case of the first-best optimum, which is consistent with our previous empirical findings, the most obvious solution is to assume that information flows perfectly in the village and that a landlord who cultivates a plot herself therefore rejected the *most* productive available tenant. Given the relative factor endowments of land and labor, it is unlikely that there is excess demand for tenants. And our assumption that tenants are driven down to their individually rational level of welfare squares with observed factor endowments, with the aforementioned hypothesis and, more importantly (as noted above) with our finding that the transfer function is indeed decreasing in q_h^T.

Let Λ denote the set of all potential tenants, indexed by their total productivity, available to the landlord, from which we exclude the landlord herself if she rented in land, that is $l(q^L, Z^L) \notin \Lambda$. Then the previous hypothesis, which we may refer to as "perfect matching" implies that the rejected tenant was a tenant whose total productivity $l(q^T, Z^T)$, was defined by

$$l(q^T, Z^T) = \left\{ l(q^T, Z^T) \in \Lambda \,\middle|\, l(q^T, Z^T) \geq l(\tilde{q}^T, \tilde{Z}^T),\ \forall\ l(\tilde{q}^T, \tilde{Z}^T) \in \Lambda \right\}.$$

An alternative hypothesis corresponds to a land rental market in which, despite the absence of adverse selection concerns, contractual arrangements are based on kinship or long run relationships among tightly-knit subgroups of households. One particular subgroup of households that would appear to be relevant for a given landlord is given by the set of tenant households with which, if she does indeed rent out some land, she engages in contractual relationships. We will refer to this hypothesis as that of "limited matching". Let $\Lambda^L \subset \Lambda$ denote the set of tenants to which the landlord in question rents out land. We may then define the rejected potential tenant as

$$l(q^{TL}, Z^{TL}) = \left\{ l(q^{TL}, Z^{TL}) \in \Lambda^L \,\middle|\, l(q^{TL}, Z^{TL}) \geq l(\tilde{q}^{TL}, \tilde{Z}^{TL}),\ \forall\ l(\tilde{q}^{TL}, \tilde{Z}^{TL}) \in \Lambda^L \right\}.$$

Other market structures are also possible. Suppose that, despite the absence of adverse selection, landlords and tenants are matched randomly. That is, once a pair constituted by a given landlord and a given tenant has been formed, the outcome is given by the first-best optimum ; but the formation of the pair in question obtains in a random fashion. Then a landlord who chooses to cultivate a given plot herself did so because the expectation of the productivity of the tenant with which she would have been matched was sufficiently low that it was in her interest to cultivate the plot under owner-operatorship. Under ASSUMPTION B (multiplicative productivity), and assuming that the potential tenant in question belongs to Λ, the expected productivity of the tenant with which the landlord would have been matched is given by :

$$E_{l(q^T,Z^T)\in\Lambda}[l(q^T,Z^T)] = m_{l^T} .$$

A similar expression, $E_{l(q^{TL},Z^{TL})\in\Lambda^L}[l(q^{TL},Z^{TL})] = m_{l^{TL}}$, corresponds to the assumption that the potential tenant belongs to Λ^L. It should be obvious from the preceding discussion that

(33) $$\frac{¶\ \Pr[\text{plot rented out}]}{¶ z} > 0,\ z = l(q^T,Z^T),\ l(q^{TL},Z^{TL}), m_{l^T}, m_{l^{TL}} ,$$

if the market structure that one is assuming in each case constitutes a reasonable approximation to what actually obtains in the village. On average, each landlord faces a total of 1.18 tenants, with a non-negligible number landlords facing two or more tenants. The potential for a significant difference between perfect matching and random matching therefore exists in the data.

The second part of Table VII provides summary statistics on those variables generated under the four matching procedures described above. All summary statistics are provided for the full sample of plots, for those plots under owner-operators, and for plots that are rented out. Table VIII provides results corresponding to the comparative statics regarding the decision to rent out given by equation (33).

Any reasonable matching procedure must necessarily be associated with a *positive* coefficient on the generated value of potential tenant productivity, and this is the criterion we adopt in order to identify those matching procedures that are manifestly inconsistent with the data. Since both perfect matching and perfect random matching produce negative coefficients associated with tenant productivity, it follows that the set of potential tenants available to a given landlord cannot, by any stretch of the imagination, be held to be constituted by all tenants potentially available in the village. The implication is that the matching procedures that the data, coupled with our hypotheses, do not reject outright are given by limited perfect matching and limited random matching, with a likelihood ratio test coming down squarely in favor of limited perfect matching.[22] Thus, for a given contractual relationship, there is no departure from the first-best optimum in the sense that landlords observe the productivity of the tenant they are faced with. On the other hand, our evidence suggests that, despite the absence of informational asymmetries, the land rental market exhibits a substantial degree of friction in that landlords effectively limit themselves to a relatively small set of *potential* tenants at any given time. It is therefore possible that the total agricultural output of the village could be greater if the choice sets used by landlords were more broadly based, in the sense that landlords may, by restricting themselves to a limited set of tenants, be foregoing potentially more productive matches.

Is plot size chosen by landlords ?

Recall from Table V, that contractual choice is independent of plot size. This suggests that some sort of sorting mechanism based on plot size, in the spirit of Allen (1985), does not appear to be at work. At this point, it would seem to be worthwhile answering the following question : if plot size is not an instrument used, as Allen (1985) would have it, as a sorting mechanism, what role does it play ? Or is plot size exogenously determined by plot rotation and other purely technological concerns ? The question is potentially important since a key assumption made at the outset in our theoretical model was that plot size was fixed.

The simplest mechanism that could explain plot size, and thus render it a choice variable controlled by landlords, would be to assume that landlords adjust plot size so as to equate the marginal productivity of land across plots that they cultivate as owner operators with that on plots rented out under tenancy contracts. It would seem plausible, if evidence were to indicate that landlords do not even carry out this simple arbitrage, to assume that plot size is indeed fixed.

[22] In the first three columns of Table IX, we assess the importance of landlord and plot characteristics as determinants of observed tenant productivity. Here, the focus is more descriptive and we seek to answer questions of the following type : do more productive landlords tend to match with more productive tenants ? Are particularly productive tenants assigned plots with a given set of characteristics ? It is particularly interesting to note that the repeated interaction dummy does not have any statistically significant impact in any of the estimated relationships. This confirms that adverse selection issues *per se*, even if they were present, are not resolved through repeated interaction since one would expect, in that case, tenant productivity to be an increasing function of the repeated interaction dummy.

Consider a landlord, who owns $\bar{L}$ hectares of land, and who must allocate that land between a plot which she rents out (L) and a plot which she cultivates herself ($\bar{L}-L$). Then her very simple optimization problem, which constitutes a slightly more realistic alternative to that presented in part 2, is given by :

$$\max_{\{x,y,L,t\}} \left(\frac{1}{2}q^T F(x,L)-t\right)+\left(q^L F(y,\bar{L}-L)-y\right)$$
$$s.t.\ \frac{1}{2}q^T F(x,L)-x+t \geq W.$$

In the absence of adverse selection, since the individual rationality constraint is binding, this simply boils down to

$$\max_{\{x,y,L\}} \left(q^T F(x,L)-x-W\right)+\left(q^L F(y,\bar{L}-L)-y\right).$$

The associated necessary first order conditions are given by

$$q^T F_x(x^*,L^*)-1=0$$
$$q^L F_y(y^*,\bar{L}-L^*)-1=0$$
$$q^T F_L(x^*,L^*)-q^L F_L(y^*,\bar{L}-L^*)=0$$

Now assume the following :

ASSUMPTION E : $F_{LL}-(F_{xL})^2/F_{xx}<0$.

ASSUMPTION E guarantees that the second order condition holds strictly and that our FOCs are also sufficient. We then have the following result :

PROPOSITION 7 : In the absence of adverse selection, and under ASSUMPTION E,

$$dL^*/d\bar{L}>0,\ dL^*/dq^T>0,\ dL^*/dq^L<0.$$

PROOF : see APPENDIX.

PROPOSITION 7 potentially provides an extremely simple explanation for the role played by plot size in the contractual relationship : landlords might choose plot size so as to equate the marginal productivity of land across plots of land that they own. Notice that this would not imply that the marginal product of land is equated across all plots, only that it is so on plots controled by a given landlord. Empirical results corresponding to a test of this hypothesis are presented in the last column of Table IX. Contrary to PROPOSITION 7, the size of plots that are rented out is *decreasing* in $l(0,Z^T)$ and *independent* of $l(q^L,Z^L)$. Thus, landlords manisfestly do not adjust the size of plots that they rent out so as equate the marginal productivity of land across plots that they own. It would therefore seem plausible to assume that plot size is indeed not a choice variable available to landlords.

Contract renewal

An interesting feature of the empirical results regarding contractual choice presented in Table V was that the only variable which appeared to significantly influence the choice between a fixed rental and sharecropping contract was whether the contract in question constituted a renewal. In what follows, we briefly consider (i) the determinants of contract renewal and, in particular, its link to tenant productivity, (ii) differences in the determinants of contractual choice between contracts that are renewals and those that are not, and (iii) the joint determination of contractual choice and contract renewal within the context of a transaction costs framework.

The admittedly limited information regarding the dynamics of the tenancy relationship linking a landlord with a tenant that we have is furnished by our knowledge of whether a given tenancy contract represents the renewal of the same contract from the previous year. In order to investigate how the renewal (or, equally interesting, the non-renewal) process operates, we began by estimating a probit equation in which the dependent variable takes on the value of one if the contract is a renewal, and zero otherwise. The results are presented in the first column of Table X. We allowed the probability of renewal to be a function of our scalar measure of tenant household characteristics $l(0, Z^T)$ (the portion of the fixed effect predicted by observable household characteristics), the resident and peasant landlord dummies, our measure of tenant household productivity q_h^T, plot size, and the usual soil and year dummies. In order to control for potential sample selection problems, this equation was estimated by FIML jointly with the renting out equation using the censored bivariate probit procedure. Somewhat unexpectedly, the probability of a contract being a renewal of the previous year's arrangement is *decreasing* in the productivity of the tenant or, in other words, short-term contracts appear to be associated with higher productivity tenants. Furthermore, this same probability is increasing in plot size: there appears, therefore, to be some tradeoff involved, *regarding contract renewal*, in which increased plot size compensates for low tenant productivity, and *vice-versa* (recall however that contractual choice *per se* is independent of plot size, see Table V, and that plot size does not appear to be a choice variable under the control of landlords). What is puzzling is that, contrary to what one might expect, landlords do not appear to use the threat of non-renewal of contracts as a means of obtaining higher quality tenants.[23] There may, and this is likely in the context of a compact village society, some egalitarian principle at work.[24]

The "dumb-cousin" conjecture

An informed conjecture, given that we have found no evidence for the presence of adverse selection in the village, is that those contracts that are renewed are between family members, the tenant component of which would be unable to find gainful employment if a landlord who is a relation (and a benevolent one at that) did not "automatically" provide a plot of land. The assumption of benevolence may be relaxed somewhat when one recalls that social obligations in Tunisian society place a heavy responsibility on better-off family members to look after their less fortunate cousins (and all the inhabitants of the village are, essentially, cousins). Moreover, if the landlord involved did not provide the plot of land, it might well be the case that she would be obliged to look after the household in question through income transfers that might be greater than the opportunity cost of renting out the land in question to a low-productivity family member.

Contractual choice and tenant productivity once more

In order to be sure that contractual choice was indeed independent of tenant household productivity and that our previous results (presented in Table V) were not simply driven by a

[23] This finding is coherent with a result, presented in Table IX, and discussed in note 22, which shows that tenant productivity is independent of the repeated interaction dummy.

[24] It is important to be cautious in the interpretation of the coefficient associated with q_h^T in the preceding estimation since the equation in question manifestly suffers from omitted variable bias. If the contractual relationship represents a renewal, then it is the productivity of the incumbent tenant which is observed, and we do not know the productivity of the potential tenant who was rejected in favor of the incumbent. However, we do know that the productivity of the incumbent who was retained was higher than the productivity of the alternative tenant who was rejected. On the other hand, when the contract is not a renewal, we do not observe the productivity of the incumbent tenant who was dropped, but we do observe the productivity of the tenant that replaced her. Moreover, we know, since it was not a renewal, that the productivity of this last tenant must be larger than that of the previous incumbent. It follows that the coefficient associated with the productivity of the tenant observed, in what is essentially the second period of a two period-decision problem, actually represents the combination of two effects that go in opposite directions. Another way of seeing this is as follows : the decision to renew is an increasing function of the *difference* between the productivity of the first-period incumbent and that of the alternative tenant who is available. For contracts that are renewals, this difference is *increasing* in the productivity of the observed tenant (the incumbent who stayed on); while for contracts that do

problem of aggregation, we considered the determinants of contractual choice independently on the two subsamples constituted by those tenancy contracts that represented renewals and those that did not. The results are presented in columns 2 and 3 of Table X. In the case of tenancy contracts that do *not* represents renewals of existing contracts, an increase in $l(0, Z^T)$ significantly decreases the probability that the contract in question will be a sharecropping contract, the *only* example that we have encountered so far of contractual choice being a function of either of the components that make up the tenant's household-specific fixed effect. The coefficient associated with q_h^T, on the other hand, was statistically indistinguishable from zero, which confirms all of our earlier findings regarding the independence of contractual choice with respect to tenant productivity. For contracts that do represent a renewal, on the other hand, contractual choice is independent of both components of the tenant-specific fixed effect.

The nutrient-depletion hypothesis

Why might low productivity tenants be associated with contract that are renewed and high productivity tenants be associated with a sequence of spot contracts, apart from explanations based on egalitarian principles such as the "dumb cousin conjecture ? In other words, can one construct an explanation that is consistent with individually rational behavior on the part of landlords ? One possibility is driven by the observation that the intensity with which one works the soil will tend to reduce its productivity in the following period. Since high productivity tenants will use inputs more intensively, it follows that their second period output will, *ceteris paribus*, be lower, unless their higher level of productivity is sufficient to compensate for nutrient depletion. If this is not the case, then it may be in the interest of landlords to rent out their plot under a contract that is renewed for a second period to low productivity tenants, while renting using spot contracts to tenants of relatively high productivity. An algebraic illustration of the nutrient depletion hypothesis is given in the APPENDIX.

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not constitute renewals, this difference is *decreasing* in the productivity of the observed tenant (the alternative tenant who replaced the unobserved incumbent).

Contractual choice, contract renewal and
the (written) nature of contracts

Given that tenant productivity does not appear to be a significant determinant of contractual choice, what is ? First, note that our finding that contractual choice is independent of the landlord's place of residence and of her being a peasant herself (Table V) suggests that transaction costs involving landlord characteristics do not constitute a satisfactory explanation for contractual choice in the village, since both variables should, *a priori*, be associated with higher transaction costs for landlords. On the other hand, we do possess one direct measure of transaction costs that are likely to be greater for plots under cost-sharing contracts (because of the large number of cost share parameters that must be explicitly specified, as well as the decisionmaking powers of the two parties to the contract that must also be explicitly spelled out) : this is given by a dummy variable which indicates whether the contract in question was written or oral.

A final source of concern regarding the empirical results on contractual choice presented in Table V in light of the results regarding contract *renewal* presented above is that contractual choice and contract renewal may be jointly determined, implying that contract renewal is in fact an endogenous variable in the contractual choice equation. The coefficient associated with tenant productivity might therefore be inconsistent, and our basic result regarding the independence of contractual choice and q_h^T might be entirely be driven by simultaneity bias.

In order to assess whether this was indeed the case, and whether the (written) nature of contracts was significantly related to contractual choice and contract renewal, we estimated a system of three probit equations by full information maximum likelihood. The three equations were given by a contractual choice equation, a contract renewal equation and (in order to incoporate the transaction costs concerns raised above) an equation in which the dependent variable was equal to one when the contract was written and zero when it was oral. Several aspects of the results, which are presented in Table XI, are worth highlighting.[25] First, cost-sharing contracts are much less likely to be written than are fixed rental contracts (see column 1), which squares nicely with the transaction cost argument sketched above. Second, when a contract represents a renewal, it is much less likely that it will be written

[25] We inserted a more detailed set of crop dummies in the contractual choice equation presented in column 3 of the Table, first, in order to provide our system with several degrees of overidentification and, second, to see whether a finer level of disaggregation at the crop level might affect the results : it does not.

(again, see column 1); again, this is quite plausible, as one of the advantages of renewing a contract is presumably given by the savings obtained by not having to stipulate all of the contract terms in writing anew. Third, when contractual choice is included in the contract renewal equation and is allowed to be an endogenous variable (column 2), it is not statistically significant at the usual levels of confidence; however, as with the simple contract renewal equation presented in column 1 of Table X, low productivity tenants are more likely to be renewed. Our previous finding that low productivity tenants are more likely to be renewed is thus robust to the joint determination of contractual choice and contract renewal. Fourth, when contract renewal is allowed to be endogenous in the contractual choice equation (column 3), it is not longer statistically significant at usual levels of confidence. On the other hand, and this confirms our earlier findings in a single equation framework, contractual choice continues to be independent of tenant productivity, even when we allow contractual choice, contract renewal and the nature of the contract to be jointly determined. This provides further evidence that adverse selection is not present in this village.

The upshot

In accordance with a widely-held belief of many development economists, the empirical results presented in this paper strongly support the absence of adverse selection, in terms of the predicted relationship between contractual choice and tenant productivity, in terms of the relationship linking the optimal transfer function from landlords to tenants to the productivity of tenants, and in terms of the corresponding relationship for the share of the cost of each factor input borne by the tenant. While theorists may be disappointed by these results that imply that the problem focused on by mechanism design does not appear to be important empirically, at least in this village, the result in and of itself is, we would hasten to add, interesting. In particular, it provides the first rigorous empirical evidence that we are aware of that, within a compact village society, adverse selection is indeed not present. Previous empirical work on the same village (Ai, Arcand and Ethier, 1998) has shown that, while statistically significant, moral hazard concerns are not a quantitatively important determinant of resource allocation. If both moral hazard (hidden actions) and adverse selection (hidden types) do not lie at the root of contractual choice, and therefore at least in part at the heart of departures from the first-best optimum, what does ? Or were Schultz (1964) and Cheung (1968, 1969) right ?

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APPENDIX

PROOF OF PROPOSITION 1 (ii): $dt^*(q)/dq < 0$ under ASSUMPTIONS B and C.

When $F(x)$ is homogeneous of degree k, we know that $xF_x(x) = kF(x)$ and $xF_{xx}(x) = (k-1)F_x(x)$. It follows that one can rewrite equation (4) as

$$\frac{dt^*(q)}{dq} = -\frac{1}{2}\left(\frac{F_x(x^*(q))}{q\,F_{xx}(x^*(q))} + F(x^*(q))\right) = -\frac{x^*(q)}{2}\left(\frac{1}{q\,(1-k)} + \frac{F_x(x^*(q))}{k}\right).$$

But, from the FOC for the first best optimum under ASSUMPTION A ($q^{-1} = F_x(x^*)$), this reduces to

$$\frac{dt^*(q)}{dq} = \frac{x^*(q)}{2q\,k}\left(\frac{2k-1}{1-k}\right),$$

which will be negative as long as $k \in (0,1/2)$.
[Q.E.D.]

PROOF OF PROPOSITION 2 :

PROOF OF PROPOSITION 2 (i) : $d b^*(q)/dq > 0$ under ASSUMPTIONS B and C.

Using the same two properties of homogeneous functions as in the previous proof, and applying the FOC for a first best optimum under ASSUMPTION B allows one to rewrite equation (5) as :

$$\frac{d b^*(q)}{dq} = \frac{\frac{1}{2}F(x^*(q))x^*(q) + \frac{dx^*(q)}{dq}\left(\frac{1}{2}\left(x^*(q) - q F(x^*(q))\right) + W\right)}{\left(x^*(q)\right)^2} = \frac{W}{q(1-k)x^*(q)} > 0 .$$

[Q.E.D.]

PROOF OF PROPOSITION 2 (ii) : when x is an N-dimensional vector of factor inputs, it cannot be the case that $d b_j^*(q)/dq < 0, \ \forall \ j$.

We know from PROPOSITION 1 that

$$\frac{dt^*(q)}{dq} = (1 - b^*(q))\frac{dx^*(q)}{dq} - x^*(q)\frac{d b^*(q)}{dq} < 0$$

for the case where x is a scalar. When x is an N-dimensional vector of factor inputs, the corresponding expression is given by :

$$\frac{dt^*(q)}{dq} = \sum\nolimits_{j=1}^{j=N}(1 - b_j^*(q))\frac{dx_j^*(q)}{dq} - \sum\nolimits_{j=1}^{j=N} x_j^*(q)\frac{d b_j^*(q)}{dq} < 0 .$$

Since it would appear to be reasonable to suppose that

$$\sum\nolimits_{j=1}^{j=N}(1 - b_j^*(q))\frac{dx_j^*(q)}{dq} > 0 ,$$

it follows that a necessary condition for the transfer function to be decreasing in q is that

$$\sum\nolimits_{j=1}^{j=N} x_j^*(q)\frac{d b_j^*(q)}{dq} > 0 .$$

Of course, this condition is not sufficient. On the other hand, if $d b_j^*(q)/dq < 0 \ \forall \ j$, then it would impossible for the transfer function to be decreasing in q.
[Q.E.D.]

PROOF OF PROPOSITION 4 : $d\hat{t}(q)/dq \geq 0$ under ASSUMPTION B (Note that ASSUMPTION B is used in the proof solely to guarantee that $d\hat{x}(q)/dq$ is positive.)

We know that the comparative statics of the optimal transfer $\hat{t}(q)$ with respect to q are given by the incentive constraint (equation (8)) when it is evaluated at the solution to the landlord's problem :

$$\frac{d\hat{t}(q)}{dq} = -\left(\frac{1}{2}F_x(q,\hat{x}(q)) - 1\right)\frac{d\hat{x}(q)}{dq} .$$

By the definition of $\hat{x}(q)$ (equation (20)), we know that

$$F_x(q,\hat{x}(q)) = 1 - (q - \underline{q})\frac{1}{2}F_{qx}(q,\hat{x}(q)) .$$

It follows that:

$$\frac{d\hat{t}(q)}{dq}=\frac{1}{2}\left((q-\underline{q})\frac{1}{2}F_{qx}(q,\hat{x}(q))+1\right)\frac{d\hat{x}(q)}{dq}\geq 0\,.$$

[Q.E.D.]

<u>**PROOF OF PROPOSITION 5**</u>. Ambiguity of the sign of $d\hat{b}(q)/dq$ even under ASSUMPTIONS B and C. From the definition of the transfer function, we know that

$$\hat{b}(q)=1-\frac{\hat{t}(q)}{\hat{x}(q)}\,.$$

It follows that

$$\frac{d\hat{b}(q)}{dq}=\left(\frac{d\hat{x}(q)}{dq}\frac{1}{\hat{x}(q)}\right)\left(\frac{\hat{t}(q)}{\hat{x}(q)}\right)-\frac{d\hat{t}(q)}{dq}\frac{1}{\hat{x}(q)}\,.$$

Note that we can write equation (13), the individual rationality constraint (that must be satisfied by the lowest productivity tenant, $q=\underline{q}$) as :

$$\frac{1}{2}F(\underline{q},\hat{x}(\underline{q}))-\hat{x}(\underline{q})-\int_{\underline{q}}^{\underline{q}}\frac{dx(s)}{ds}\left(\frac{1}{2}F_x(s,x(s))-1\right)ds+K=\frac{1}{2}F(\underline{q},\hat{x}(\underline{q}))-\hat{x}(\underline{q})+K=W\,.$$

It follows, under ASSUMPTION B, that the appropriate constant of integration is defined by :

$$K=W-\frac{1}{2}\underline{q}F(\hat{x}(\underline{q}))+\hat{x}(\underline{q})\,.$$

Now recall, also under ASSUMPTION B, that we have $\hat{x}(\underline{q})=F_x^{-1}(1/\underline{q})$; using the same two properties of homogeneous functions as in the proof of PROPOSITION 1 (ii), allows one to rewrite this last expression as :

$$K=W-F_x^{-1}(1/\underline{q})\left(\frac{1-2k}{2k}\right).$$

From equation (11), we know that

$$t(q)=-\int_{\underline{q}}^{q}\frac{dx(s)}{ds}\left(\frac{1}{2}F_x(s,x(s))-1\right)ds+K\,.$$

Since, under ASSUMPTIONS B and C, we have

$$F_x(s,\hat{x}(s))=\frac{2s}{3s-\underline{q}}\,,$$

the transfer function can be rewritten as :

$$t(q)=\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^2}F_x^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds+K\,.$$

From the expression for K derived above, this can be rewritten as :

$$t(q)=\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^2}F_x^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds-\left(\frac{1-2k}{2k}\right)F_x^{-1}\left(\frac{1}{\underline{q}}\right)+W\,.$$

Now consider $d\hat{x}(q)/dq$. Under ASSUMPTIONS B and C (again using the two properties of homogeneous functions), we can rewrite this as

$$\frac{d\hat{x}(q)}{dq}=\frac{3\hat{x}(q)}{(1-k)(3q-\underline{q})}\,.$$

Finally, consider $d\hat{t}(q)/dq$. Using the same two properties of homogeneous functions, this can be rewritten (see the proof of PROPOSITION 4 for the point of departure of the derivation) as

$$\frac{d\hat{t}(q)}{dq}=\frac{1}{2}\left((q-\underline{q})\frac{1}{2}F_{qx}(q,\hat{x}(q))+1\right)\frac{d\hat{x}(q)}{dq}=\frac{3(2q-\underline{q})\hat{x}(q)}{(1-k)(3q-\underline{q})^{2}}\,.$$

In summary, we have

$$\frac{\hat{t}(q)}{\hat{x}(q)}=\frac{\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^{2}}F_{x}^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds-\left(\frac{1-2k}{2k}\right)F_{x}^{-1}\left(\frac{1}{\underline{q}}\right)+W}{F_{x}^{-1}\left(\frac{2}{3q-\underline{q}}\right)}\,;$$

$$\frac{d\hat{x}(q)}{dq}\frac{1}{\hat{x}(q)}=\frac{3}{(1-k)(3q-\underline{q})}\,;$$

and

$$\frac{d\hat{t}(q)}{dq}\frac{1}{\hat{x}(q)}=\frac{3(2q-\underline{q})}{(1-k)(3q-\underline{q})^{2}}\,.$$

Substituting into the expression for $d\hat{b}(q)/dq$ yields :

$$\frac{d\hat{b}(q)}{dq}=\underbrace{\left(\frac{3}{(1-k)(3q-\underline{q})}\right)}_{\frac{d\hat{x}(q)}{dq}\frac{1}{\hat{x}(q)}}\underbrace{\left(\frac{\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^{2}}F_{x}^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds-\left(\frac{1-2k}{2k}\right)F_{x}^{-1}\left(\frac{1}{\underline{q}}\right)+W}{F_{x}^{-1}\left(\frac{2}{3q-\underline{q}}\right)}\right)}_{\frac{\hat{t}(q)}{\hat{x}(q)}}-\underbrace{\frac{3(2q-\underline{q})}{(1-k)(3q-\underline{q})^{2}}}_{\frac{d\hat{t}(q)}{dq}\frac{1}{\hat{x}(q)}}$$

which simplifies to

$$\frac{d\hat{b}(q)}{dq}=\frac{3}{(1-k)(3q-\underline{q})}\left[\frac{\frac{3}{1-k}\int_{\underline{q}}^{q}\frac{2s-\underline{q}}{(3s-\underline{q})^{2}}F_{x}^{-1}\left(\frac{2}{3s-\underline{q}}\right)ds-\left(\frac{1-2k}{2k}\right)F_{x}^{-1}\left(\frac{1}{\underline{q}}\right)+W}{F_{x}^{-1}\left(\frac{2}{3q-\underline{q}}\right)}-\left(\frac{2q-\underline{q}}{3q-\underline{q}}\right)\right]$$

[Q.E.D.]

DERIVATION OF THE OPTIMAL RENTAL CONTRACT UNDER ASYMMETRIC INFORMATION

By the Revelation Principle, we must have

$$q=\arg\max_{\{\tilde{q}\}}F(q,x(\tilde{q}))-x(\tilde{q})+t(\tilde{q})\,.$$

Incentive compatibility is thus given by

$$\left(F_{x}(q,x(q))-1\right)\frac{dx(q)}{dq}+\frac{dt(q)}{dq}=0,\quad\forall q\,.$$

As with the case of the cost sharing contract this condition becomes globally sufficient for $dx(q)/dq\geq 0,\ \forall\ q$. We can then express the landlord's optimization problem as :

$$\max_{\{x(q),t(q)\}}-\int_{\underline{q}}^{\bar{q}}t(q)g(q)dq$$

$$s.t.\quad\left(F_{x}(q,x(q))-1\right)\frac{dx(q)}{dq}+\frac{dt(q)}{dq}=0,\quad\forall\ q$$

$$\frac{dx(q)}{dq}\geq 0,\quad\forall\ q$$

$$F(q,x(q))-x(q)+t(q)\geq W,\quad\forall\ q$$

which, defining the tenant's surplus as $S(q) = Y - W = F(q, x(q)) - x(q) + t(q) - W$, can be rewritten as the following optimal control problem :

$$\max_{\{x(q),S(q)\}} \int_{\underline{q}}^{\bar{q}} \left(F(q, x(q)) - x(q) - S(q) - W \right) dq$$

$$s.t. \quad \dot{S}(q) = F_q(q, x(q))$$

$$\frac{dx(q)}{dq} \geq 0, \quad \forall \;\; q$$

$$F(\underline{q}, x(\underline{q})) - x(\underline{q}) + t(\underline{q}) \geq W$$

By applying Pontryagin's Maximum Principle, one can show that the level of input under the optimal rental contract, which we will denote by $\hat{\hat{x}}(q)$ is characterized by

$$F_x(q, \hat{\hat{x}}(q)) - 1 + (q - \underline{q}) F_{qx}(q, \hat{\hat{x}}(q)) = 0 ,$$

and that $d\hat{\hat{x}}(q)/dq \geq 0$ as long as the following condition is satisfied

$$\frac{d\hat{\hat{x}}(q)}{dq} = -\frac{2F_{qx}(q, \hat{\hat{x}}(q)) + (q - \underline{q}) F_{qqx}(q, \hat{\hat{x}}(q))}{F_{xx}(q, \hat{\hat{x}}(q)) + (q - \underline{q}) F_{qxx}(q, \hat{\hat{x}}(q))} \geq 0 .$$

(This condition is slightly different from the one for the cost sharing contract). One can then show that the derivative with respect to q of the optimal transfer function under the rental contract is given by :

$$\frac{d\hat{\hat{t}}(q)}{dq} = (q - \underline{q}) F_{qx}(q, \hat{\hat{x}}(q)) \frac{d\hat{\hat{x}}(q)}{dq} \geq 0 .$$

PROOF OF PROPOSITION 6 : Under ASSUMPTION B, the probability of choosing a fixed rental contract over a sharecropping contract is an increasing function of q .
By a first order Taylor expansion around $\hat{x}(q)$, one can write:

$$\frac{d}{dq}\left(S_{Rent}(q) - S_{Share}(q) \right) = F_q(q, \hat{x}(q)) + F_{qx}(q, \hat{x}(q))(\hat{\hat{x}}(q) - \hat{x}(q)) - \frac{1}{2} F_q(q, \hat{x}(q)) ,$$

which yields

$$\text{(A1)} \quad \frac{d}{dq}\left(S_{Rent}(q) - S_{Share}(q) \right) = \frac{1}{2} F_q(q, \hat{x}(q)) + F_{qx}(q, \hat{x}(q))(\hat{\hat{x}}(q) - \hat{x}(q)) .$$

It is obvious that this expression depends critically on the difference $\hat{\hat{x}}(q) - \hat{x}(q)$ which, by the FOCs that implicitly determine the level of inputs under the two contracts, may not be signed unambiguously. If $\hat{\hat{x}}(q) - \hat{x}(q) > 0$, then a higher productivity tenant is more likely to choose a fixed rental contract. If the opposite is true, and if $F_{qx}(q, \hat{\hat{x}}(q))(\hat{\hat{x}}(q) - \hat{x}(q))$ is of sufficient magnitude to outweigh the unambiguously positive expression $F_q(q, \hat{\hat{x}}(q))$, then higher productivity tenants will find it in their interest to choose a sharecropping contract. Can more be said if we impose the stronger condition given by ASSUMPTION B? In the case of the fixed rental contract, we have, under ASSUMPTION B :

$$q F_x(\hat{\hat{x}}(q)) + (q - \underline{q}) F_x(\hat{\hat{x}}(q)) = 1 .$$

This yields

$$\hat{\hat{x}}(q) = F_x^{-1}\left(\frac{1}{2q - \underline{q}} \right).$$

Since it is always the case $\forall \;\; q$ that

$$\frac{1}{2q-\underline{q}} \leq \frac{2}{3q-\underline{q}},$$

it follows that (recall equation (20'), which states that $\hat{x}(q) = F_x^{-1}(2/(3q-\underline{q}))$)

$$\hat{\hat{x}}(q) \geq \hat{x}(q);$$

the landlord specifies a higher level of input under a fixed rental contract than under the corresponding cost sharing contract, for a given value of q. Substituting this expression into equation (A1) implies that the higher the level of q, the higher the probability of choosing a fixed rental contract.
[Q.E.D.]

ASSUMPTION D : $F_q(q,\hat{\hat{x}}(q)) - \dfrac{(q-\underline{q})(F_{qx}(q,\hat{\hat{x}}(q)))^2}{2F_{xx}(q,\hat{\hat{x}}(q)) + (q-\underline{q})F_{qxx}(q,\hat{\hat{x}}(q))} < 0$.

COROLLARY TO PROPOSITION 6 : Under ASSUMPTION D, the probability of choosing a fixed rental contract over a sharecropping contract is a decreasing function of q.

<u>**PROOF OF COROLLARY TO PROPOSITION 6**</u>.

Performing two first-order Taylor expansions around $\hat{\hat{x}}(q)$ in equation (20) (which implicitly defines the $\hat{x}(q)$), and combining this with the implicit definition of $\hat{\hat{x}}(q)$ from the derivation of the optimal rental contract under asymmetric information, it is possible to write the difference between $\hat{x}(q)$ and $\hat{\hat{x}}(q)$ as :

$$\hat{x}(q) - \hat{\hat{x}}(q) = \frac{(q-\underline{q})F_{qx}(q,\hat{\hat{x}}(q))}{2F_{xx}(q,\hat{\hat{x}}(q)) + (q-\underline{q})F_{qxx}(q,\hat{\hat{x}}(q))}.$$

Substituting this into the equation for the difference between the surplus under fixed rental and the surplus under cost sharing (re-expressed as a Taylor expansion around $\hat{\hat{x}}(q)$) yields :

$$\dot{S}_{\mathrm{Re}nt}(q) - \dot{S}_{Share}(q) = \frac{1}{2}\left(F_q(q,\hat{\hat{x}}(q)) - \frac{(q-\underline{q})(F_{qx}(q,\hat{\hat{x}}(q)))^2}{2F_{xx}(q,\hat{\hat{x}}(q)) + (q-\underline{q})F_{qxx}(q,\hat{\hat{x}}(q))} \right),$$

which will be negative when ASSUMPTION D is satisfied.
[Q.E.D.]

<u>**PROOF OF PROPOSITION 7**</u>.

The proof follows by straightforward implicit differentiation of the three FOCs. Carrying out the differentiations, one obtains:

$$\frac{dL^*}{d\bar{L}} = \frac{q^L F_{LL}(y^*,\bar{L}-L^*)}{q^T\left(-\dfrac{\left(F_{xL}(x^*,L^*)\right)^2}{F_{xx}(x^*,L^*)} + F_{LL}(x^*,L^*) \right) + q^L\left(-\dfrac{\left(F_{xL}(y^*,\bar{L}-L^*)\right)^2}{F_{xx}(y^*,\bar{L}-L^*)} + F_{LL}(y^*,\bar{L}-L^*) \right)} > 0.$$

$$\frac{dL^*}{dq^T}=-\frac{F_L(x^*,L^*)-q^T\dfrac{\left(F_{xL}(x^*,L^*)\right)^2}{F_{xx}(x^*,L^*)}}{q^T\left(-\dfrac{\left(F_{xL}(x^*,L^*)\right)^2}{F_{xx}(x^*,L^*)}+F_{LL}(x^*,L^*)\right)+q^L\left(-\dfrac{\left(F_{xL}(y^*,\bar{L}-L^*)\right)^2}{F_{xx}(y^*,\bar{L}-L^*)}+F_{LL}(y^*,\bar{L}-L^*)\right)}>0\,.$$

$$\frac{dL^*}{dq^L}=-\frac{-F_L(y^*,\bar{L}-L^*)+q^L\dfrac{\left(F_{xL}(y^*,\bar{L}-L^*)\right)^2}{F_{xx}(y^*,\bar{L}-L^*)}}{q^T\left(-\dfrac{\left(F_{xL}(x^*,L^*)\right)^2}{F_{xx}(x^*,L^*)}+F_{LL}(x^*,L^*)\right)+q^L\left(-\dfrac{\left(F_{xL}(y^*,\bar{L}-L^*)\right)^2}{F_{xx}(y^*,\bar{L}-L^*)}+F_{LL}(y^*,\bar{L}-L^*)\right)}<0\,.$$

[Q.E.D.]

AN ALGEBRAIC ILLUSTRATION OF THE NUTRIENT DEPLETION HYPOTHESIS.

The key assumption is that second period output is decreasing in first period input intensity because of soil depletion. We express this by posing: $F^2_{x_1}(q,x_2,x_1)<0$, where $F^2(q,x_2,x_1)$ is second period output. In order to simplify the exposition, we shall ignore the question of discounting. In the case of a two-period contract, that is, a contract that is renewed, the landlord's optimization problem is given by

$$\max_{\{x_1,x_2,t_1,t_2\}}\frac{1}{2}F^1(q,x_1)-t_1+\left(\frac{1}{2}F^2(q,x_2,x_1)-t_2\right)$$

$$s.t.\quad \frac{1}{2}F^1(q,x_1)-x_1+t_1+\left(\frac{1}{2}F^2(q,x_2,x_1)-x_2+t_2\right)\geq 2W$$

Since the individual rationality constraint is binding, we can write

$$\frac{1}{2}F^1(q,x_1)-x_1+\left(\frac{1}{2}F^2(q,x_2,x_1)-x_2\right)-2W=-t_1-t_2\,.$$

This implies that the landlord's optimization problem, in unconstrained form, can be expressed as :

$$\max_{\{x_1,x_2\}}F^1(q,x_1)-x_1+\left(F^2(q,x_2,x_1)-x_2\right)-2W$$

The necessary conditions that implicitly define the optimal level of inputs are given by

$$F^1_{x_1}(q,x_1^{**})+F^2_{x_1}(q,x_2^{**},x_1^{**})-1=0;$$

$$F^2_{x_2}(q,x_2^{**},x_1^{**})-1=0.$$

Evaluated at the optimum, the landlord's objective function is given by

$$\Pi^{RENEW}=F^1(q,x_1^{**}(q))-x_1^{**}(q)+\left(F^2(q,x_2^{**}(q),x_1^{**}(q))-x_2^{**}(q)\right)-2W$$

where the superscript RENEW denotes a contract that is renewed for the second period. Consider now a sequence of two single-period or "spot" contracts with tenant's of the same productivity q. The landlord's optimization problem is now given by two separate optimization problems :

$$\max_{\{x_1,t_1\}}\frac{1}{2}F^1(q,x_1)-t_1\quad s.t.\ \frac{1}{2}F^1(q,x_1)-x_1+t_1\ \geq W\ ,$$

$$\max_{\{x_2,t_2\}}\frac{1}{2}F^2(q,x_2,x_1)-t_2\quad s.t.\ \frac{1}{2}F^2(q,x_2,x_1)-x_2+t_2\ \geq W\ .$$

Since the individual rationality constraint of the tenant is binding in both cases, we can, as usual, transform these problems into the unconstrained variety ; the necessary conditions for an optimum are therefore given by :

$$F^1_{x_1}(q, x_1^*) - 1 = 0;$$

$$F^2_{x_2}(q, x_2^*, x_1^*) - 1 = 0.$$

Evaluated at the optimum, the landlord's profit's are therefore given by

$$\Pi^{SPOT} = F(q, x_1^*(q)) - x_1^*(q) + \left(F(q, x_2^*(q), x_1^*(q)) - x_2^*(q)\right) - 2W$$

where the superscript SPOT indicates that this corresponds to a sequence of two spot contracts. Let us now consider the difference between the landlord's profits under the two contractual forms, as a function of the tenant's level of productivity :

$$\frac{d\left(\Pi^{RENEW} - \Pi^{SPOT}\right)}{dq} = F^1_q(q, x_1^{**}(q)) + F^2_q(q, x_2^{**}(q), x_1^{**}(q)) - F^1_q(q, x_1^*(q)) - F^2_q(q, x_2^*(q), x_1^*(q)).$$

Now consider ASSUMPTION B. This allows us to rewrite the previous expression as

$$\frac{d\left(\Pi^{RENEW} - \Pi^{SPOT}\right)}{dq} = F^1(x_1^{**}(q)) - F^1(x_1^*(q)) + \left(F^2(x_2^{**}(q), x_1^{**}(q)) - F^2(x_2^*(q), x_1^*(q))\right).$$

Notice that it is immediate that $x_1^*(q) > x_1^{**}(q)$ since, under the sequence of spot contracts, the nutrient depletion externality is not taken into account. It follows that $F^1(x_1^{**}(q)) - F^1(x_1^*(q)) < 0$ so the difference between renewed and spot contracts is decreasing in q when it comes to profit stemming from the first period. On the other hand, when nutrient depletion is taken into account, second period output will necessarily be higher in the context of renewed contracts, for a given level of tenant productivity : $x_2^{**}(q) > x_2^*(q)$. Now consider the differential with respect to q of the difference between second period profits under the two contractual forms. By a first-order Taylor expansion around $(x_2^*(q), x_1^*(q))$, we can write :

$$F^2(x_2^{**}(q), x_1^{**}(q)) = F^2(x_2^*(q), x_1^*(q)) + F^2_{x_2}(x_2^*(q), x_1^*(q))\left(x_2^{**}(q) - x_2^*(q)\right) + F^2_{x_1}(x_2^*(q), x_1^*(q))\left(x_1^{**}(q) - x_1^*(q)\right)$$

This implies that :

$$F^2(x_2^{**}(q), x_1^{**}(q)) - F^2(x_2^*(q), x_1^*(q)) = \underbrace{\underbrace{F^2_{x_2}(x_2^*(q), x_1^*(q))}_{=1}\underbrace{\left(x_2^{**}(q) - x_2^*(q)\right)}_{>0} + \underbrace{\underbrace{F^2_{x_1}(x_2^*(q), x_1^*(q))}_{<0}\underbrace{\left(x_1^{**}(q) - x_1^*(q)\right)}_{<0}}_{>0}}_{>0}$$

so that the difference between second period profits under the two contractual forms is increasing in q. It follows that $d(\Pi^{RENEW} - \Pi^{SPOT})/dq$ is composed of two parts, one negative and one positive

$$\frac{d\left(\Pi^{RENEW} - \Pi^{SPOT}\right)}{dq} = \underbrace{F^1(x_1^{**}(q)) - F^1(x_1^*(q))}_{<0} + \underbrace{\left(F^2(x_2^{**}(q), x_1^{**}(q)) - F^2(x_2^*(q), x_1^*(q))\right)}_{>0}.$$

If the first (negative) effect dominates the second (positive) effect, then the probability of contract renewal will be decreasing in tenant productivity.

Figure 1
Lorenz curves of the distribution of land ownership and the distribution of farm size

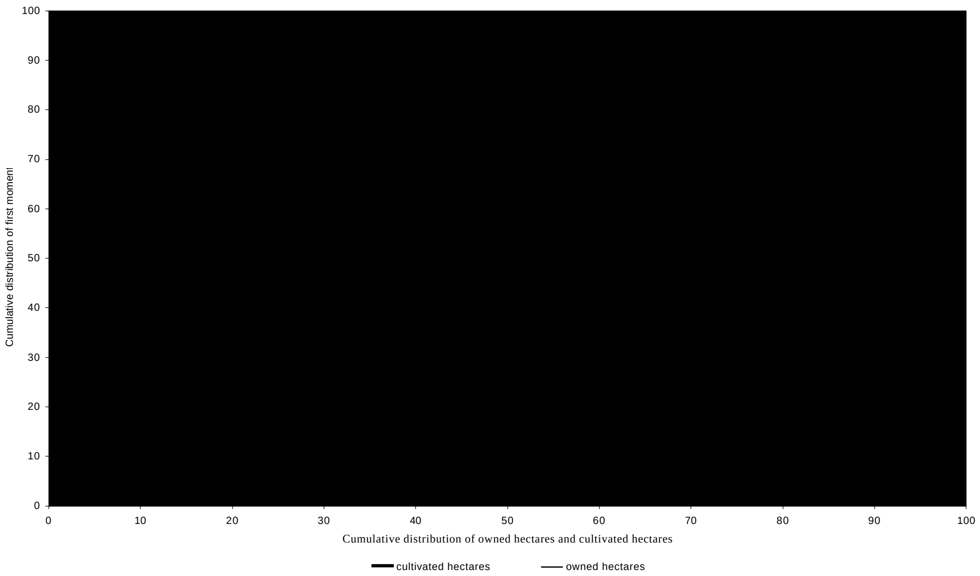


Table I
Summary statistics

Variables	Description of the variable	Mean	Std. Dev.	Min	Max	% censored observations
Output	in dinars	6407.93	13268.86	0	110000	0.00
Factor inputs						
Male family labor	in person-days	90.93	114.20	0	864	3.10
Female family labor	in person-days	22.10	65.82	0	660	68.33
Male hired labor	in person-days	164.29	461.60	0	4180	26.19
Female hired labor	in person-days	104.63	248.78	0	2310	62.38
Cost of irrigation	in dinars	526.68	1183.06	0	14400	14.05
Cost of plowing	in dinars	284.39	526.40	0	3780	4.29
Cost of seeds	in dinars	413.53	1116.40	0	18060	6.67
Cost of fertilizer	in dinars	536.99	1555.88	0	20120	5.48
Cost of manure	in dinars	111.27	561.41	0	10000	65.48
Cost of herbicide	in dinars	238.24	661.98	0	9200	27.62
Cost of transportation	in dinars	241.85	630.57	0	5400	19.29
Cost of pre-harvesting	in dinars	123.67	607.45	0	8500	73.33

Plot characteristics	Description of the variable	Mean	Std. Dev.	Min	Max
Plot area	in hectares	3.87	7.41	0.13	70
Irrigated plot	equals 1 when plot is irrigated, 0 otherwise	0.88	0.30	0	1
Type 1 soil	equals 1 when soil is clay, 0 otherwise	0.19	0.39	0	1
Type 2 soil	equals 1 when soil is red earth, 0 otherwise	0.17	0.38	0	1
Type 3 soil	equals 1 when soil is sandy, 0 otherwise	0.47	0.50	0	1
Type 4 soil	equals 1 when soil is barren , 0 otherwise	0.07	0.25	0	1
Year dummy	equals 1 for 1993, 0 otherwise	0.58	0.49	0	1

Peasant household characteristics	Description of the variable	Mean	Median	Std. Dev.	Min	Max
Age of household head	in years	52.48	51.5	15.14	48	57
Schooling of household head	in years	3.56	1.5	4.47	0	20
Household size	number of persons	7.11	6	4.54	2	27
Household endowment of prime-age males	proportion of household members	0.30	0.29	0.19	0	1
Household endowment of prime-age females	proportion of household members	0.28	0.25	0.17	0	0.71
Average schooling of household members	in years	3.99	4	2.70	0	16.25
Livestock ownership	in dinars	4657	1170	11438	0	102450
Agricultural machinery ownership	in dinars	9500	1750	16346	0	110600

Share of cost borne by the tenant (%), by factor input	**100**	**75**	**70**	**66**	**50**	**0**	Number of observations
Family labor	26	3	-	1	8	1	39
Hired labor	22	-	-	-	13	4	39
Irrigation	5	-	1	1	29	5	41
Plowing	8	-	-	1	10	19	38
Seeds	6	-	-	1	33	1	41
Fertilizer	5	-	1	-	32	2	40
Manure	5	-	-	-	28	2	35
Herbicide	5	-	1	-	34	2	42
Transportation	9	-	-	-	27	6	42
Pre-harvesting	9	-	-	-	23	4	36
Number of observations	100	3	3	4	237	46	393

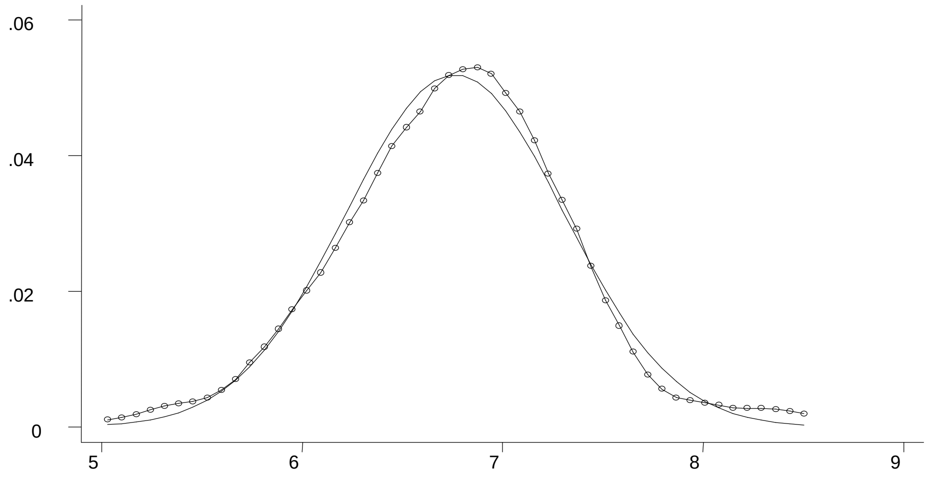
Note : summary statistics at the plot level based on full sample constituted by 420 plots ; household-level statistics correspond to full sample of 160 households ; wage rate in village is of 6 dinars per day for male labor and 5 dinars per day for female labor ; for the case of family labor, cost-sharing is carried out by the landlord sending her own family labor onto the tenant's plot ; for all other factor inputs, it is the cost of the factor input *per se* that is shared.

Table II
Nonlinear least-squares estimates
of the production function with household-specific fixed effects

Uppermost Production function parameters	Parameter values	t-statistics
Returns to scale (n)	1.106	1.31
Substitution (r)	-0.237	-1.22
Distribution (a_T)	0.889	13.49
Aggregate land input		
Modified land input		
Share (f)	0.218	0.54
Elasticity (Φ)	0.254	0.90
Plowing share (w_{PLOW})	-0.0001	-2.05
Irrigated plot dummy (w_{IR})	0.213	1.54
Soil types :		
type 1 (w_1)	-0.411	-1.86
type 2 (w_2)	-0.459	-2.68
type 3 (w_3)	-0.617	-4.50
type 4 (w_4)	-0.453	-2.14
Chemical fertilizer and herbicide share (w_{CHEM})	0.002	0.00
Manure (w_{MANURE})	0.216	0.18
Aggregate labor input		
Substitution (Π)	-0.589	-1.52
Distribution (d_F)	0.559	2.76
Number of observations	420	

Note : t-statistic on returns to scale parameter corresponds to a one-sided test of the null hypothesis that $v \leq 1$. All other t-statistics correspond to two-sided tests. Soil types are clay (type 1), red earth (type 2), sandy (type 3) and "cucurbite" (type 4, which corresponds to lumpy soil); type 4 soil is also sometimes refered to by villagers as being "barren" soil ; excluded soil type is constituted by mixes of the preceding four soil types.

Figure 2
Kernel estimation of the distribution of household-specific fixed effects ($l(q, Z)$)



Kernel estimate of the distribution of household-specific fixed effects

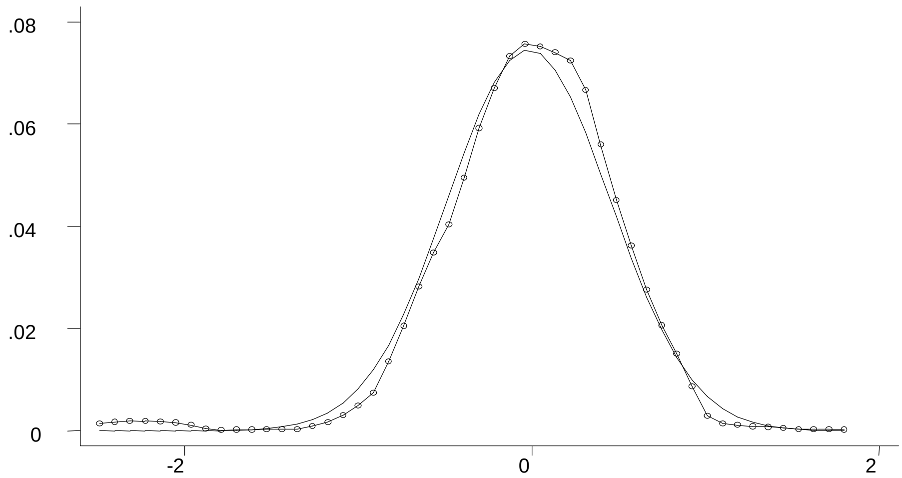
Note : dotted line corresponds to a kernel estimate of the density of the household-specific fixed effects ; smooth line corresponds to a normal density with same mean and variance as the sample.

Table III
Purging the fixed effects of observable household characteristics
(t-statistics in parentheses)

Explanatory variables	Dependent variable : fixed effect from production function estimation
Constant	6.532
	(0.19)
Age of household head	-0.001
	(0.21)
Household endowment of male labor	0.532
	(3.49)
Household endowment of female labor	0.363
	(2.34)
Schooling of household head	-0.009
	(-1.25)
Average schooling of household members	-0.031
	(-2.74)
Total owned hectares cultivated by household	-0.102
	(-3.89)
Total hectares cultivated by household	-0.027
	(-0.95)
Livestock ownership (in dinars)	-0.002
	(-0.26)
Agricultural machinery ownership (in dinars)	0.039
	(5.59)
R-squared	0.17
Number of observations	413

Note : method of estimation is OLS; no problems of heteroskedasticity were detected by the usual tests; 7 observations dropped with respect to production function estimates because of missing variables for certain household characteristics

Figure 3
Kernel estimation of the distribution of household productivity (*q*)



Kernel estimate of the density of household productivity

Note : dotted line corresponds to a kernel estimate of the density of household productivity ; smooth line corresponds to a normal density with same mean and variance as the sample.

Table IV
Correcting for sample selection bias : the determinants of the decision to rent out

Probit estimation : dependent variable = 1 when plot is rented out,
dependent variable = 0 otherwise

	1	2	3
Landlord characteristics			
Resident landlord	-2.899	-3.010	
	(-4.94)	(-5.65)	
Peasant landlord	-2.483	-1.409	
	(-11.02)	(-4.34)	
Household-specific fixed effect of landlord		-0.595	-0.665
$l(q^L, Z^L)$		(-7.85)	(-10.75)
Joint signif. test on landlord characteristics : p-value	0.00	0.00	0.00
Plot characteristics			
Plot area (in hectares)	0.507	0.402	0.322
	(5.67)	(3.12)	(2.93)
Irrigated plot dummy	0.504	1.195	0.711
	(1.31)	(2.45)	(1.84)
Soil dummies : Type 1	-0.357	-1.128	-1.293
	(-0.99)	(-2.09)	(-2.90)
Type 2	0.507	0.145	-0.011
	(1.47)	(0.33)	(-0.03)
Type 3	-0.163	-1.111	-1.134
	(-0.50)	(-3.11)	(-3.28)
Type 4	-0.234	-0.741	-0.632
	(-0.52)	(-1.31)	(-1.30)
Joint significance test on soil dummies : p-value	0.12	0.03	0.00
Year dummy	0.554	0.924	0.877
	(2.38)	(3.05)	(3.63)
Crop dummies : Wheat and other grains	-0.263	-0.486	-0.827
	(-0.79)	(-0.94)	(-1.74)
Garden vegetables	0.687	0.816	0.370
	(2.79)	(2.28)	(1.12)
Joint signif. test on plot characteristics : p-value	0.01	0.01	0.02
Intercept	2.238	4.618	2.078
	(2.78)	(5.47)	(3.33)
% correct predictions	91	97	91
Pseudo R-squared	0.62	0.71	0.57
Log likelihood	-91.88	-46.29	-67.39
Number of observations	419	363	363

Note : z-statistics in parentheses; excluded crop dummy corresponds to all other crops; there are 363 observations in columns 2 and 3 (in contrast to column 1) because of landlords that we were unable to identify satisfactorily; there are 419 observations in column one, despite landlords that cannot be identified satisfactorily, because the residence status of the landlord and the information of whether or not the landlord is a peasant was collected from the tenant who cultivated the plot.

Table V
Contractual choice and tenant productivity
Method of estimation : censored bivariate probit
(z-statistics in parentheses)

Explanatory variables	Dependent variable : = 1 when cost sharing, = 0 when fixed rental $SHARE_i$ (1)	Dependent variable : = 1 when cost sharing, = 0 when fixed rental $SHARE_i$ (2)	Dependent variable : = 1 when cost sharing, = 0 when fixed rental $SHARE_i$ (3)
Intercept	-0.552	0.533	2.033
	(0.50)	(0.21)	(0.38)
Contract is a renewal	-0.743	-0.755	-0.758
	(-2.21)	(-2.23)	(-2.21)
Plot area (in hectares)	0.086	0.076	0.068
	(0.62)	(0.52)	(0.45)
Resident landlord dummy	-0.084	-0.058	-0.034
	(-0.21)	(-0.14)	(-0.80)
Peasant landlord dummy	-0.852	-0.811	-0.782
	(-1.71)	(-1.56)	(-1.44)
Year dummy	0.160	0.158	0.154
	(0.52)	(0.51)	(0.49)
Crop dummies : Wheat and other grains	0.489	0.476	0.478
	(0.87)	(0.84)	(0.83)
Garden vegetables	0.384	0.373	0.378
	(0.93)	(0.89)	(0.89)
Tenant characteristics			
Household-specific fixed effect of tenant : $l(q^T, Z^T)$		-0.158	
		(-0.43)	
Observable tenant characteristics : $l(0, Z^T)$			-0.381
			(-0.48)
Tenant productivity : q^T	-0.097		-0.094
	(-1.13)		(-0.22)
Joint test on observable tenant characteristics and tenant productivity : p-value	n.a.	n.a.	0.52
Estimated value of r : correlation between selection equation and contractual choice equation disturbances (t-statistics in parentheses)	0.603	0.571	0.541
	(1.53)	(1.40)	(1.28)
Log likelihood	-158.62	-158.53	-158.46
% correct predictions	73	73	73
Number of observations	113	113	113

Note: the selection equation (the decision to rent out) and the contractual choice equation are estimated simultaneously by full information maximum likelihood (FIML) using the censored bivariate probit procedure in order to control for potential sample selection bias in the contractual choice equation. We report those contractual choice equations corresponding to the selection equation specification given in column 1 of Table IV. The estimated selection equations were all similar to that presented in column 1 of Table IV, for all contractual choice equation specifications presented in Table V.

Table VI
The transfer function, cost shares, and tenant productivity

	Dependent variable : transfer from landlord to tenant $t(q)$	Dependent variable : $b(q)$ = 1 when tenant bears all costs of the input = 0 otherwise (input shares are stacked over all contracts *and* all inputs)
	(1)	(2)
Method of estimation	Heckman-Lee procedure	Probit with input-specific random effects
Intercept	9.74 (0.49)	-0.111 (-0.35)
Plot area (in hectares)	-0.209 (-0.02)	
Year dummy		-1.317 (-6.90)
Inverse Mills ratio from cost sharing –vs- fixed rental	0.187 (0.00)	
Tenant productivity (q^T)	-5.546 (-2.37)	2.414 (7.66)
R-squared	0.19	n.a.
Number of observations	27	393

Note : estimation in column 1 is by OLS corrected for sample selection bias by using the inverse Mills ratio stemming from the contractual choice probit presented in column 1 of Table V; figures in parentheses in column 1 are t-statistics; estimation in column 2 is constructed by stacking all of the cost shares (transformed into binary form) for each contract and for each factor input, meaning that the number of observations is given by the number of plots under share tenancy multiplied by the number of factor inputs; we estimate by probit with input-specific *random* effects; estimated value of r (the correlation of the residuals for all observations for a given individual) is equal to 0.31 with an associated c^2 of 59.12 (p-value = 0.00) the absence of random effects in the probit is therefore rejected in favor of the chosen specification. Coefficient associated with tenant productivity is restricted to being the same for all factor inputs.

Input-specific equations	Share of family labor	Share of hired labor cost	Share of irrigation cost	Share of plowing cost	Share of seeds cost	Share of fertilizer cost	Share of manure cost	Share of herbicide cost	Share of transport cost	Share of pre harvesting cost
Dependent variable : = 1 when tenant bears all costs of the input = 0 otherwise	probit	probit	probit	probit	probit	probit	probit	probit	probit	probit
Intercept	0.890 (1.87)	0.358 (0.92)	-1.241 (4.33)	-0.274 (-0.86)	-0.250 (-0.58)	-0.534 (1.17)	3.626 (1.57)	-0.669 (-1.53)	0.226 (0.54)	0.115 (0.19)
Year dummy	-0.356 (-0.67)	-0.130 (-0.27)		-1.069 (-1.98)	-2.529 (-4.30)	-1.879 (3.51)	-10.19 (-1.96)	-1.770 (-3.49)	-2.719 (-3.76)	-1.698 (-2.54)
Tenant productivity (q^T)	2.864 (3.11)	2.766 (3.33)	1.253 (1.42)	0.872 (1.07)	3.784 (2.73)	2.764 (2.65)	11.61 (2.10)	2.840 (2.47)	2.997 (2.83)	4.860 (3.92)
Pseudo R-squared	0.25	0.24	0.07	0.15	0.50	0.40	0.79	0.38	0.49	0.46
% correct predictions	78	76	87	83	90	95	94	92	88	85
Number of observations	39	39	41	38	41	40	35	42	42	36
Dependent variable = 1 when tenant bears all costs of the input, = 0 otherwise (input shares are stacked over all contracts *and* all inputs); coefficients associated with tenant productivity are allowed to be input-specific; method of estimation is probit with input-specific random effects ; number of observations = 393 ; estimated value of r = 0.46 , c^2 of 59.77 (p-value = 0.00).										
Tenant productivity (q^T)	2.416 (2.14)	3.151 (2.43)	1.255 (2.48)	0.927 (1.30)	1.917 (3.26)	1.603 (2.79)	1.832 (3.14)	1.641 (2.85)	1.587 (2.77)	3.963 (4.03)

Note : for all probit estimations, z-statistics are in parentheses; probit equation for share of irrigation costs did not converge when year dummy is included; we therefore report results for the case in which the year dummy is excluded. Number of observations in the individual cost-share probits differ because of missing values; number of observations in the transfer function is smaller than in any of the cost-share probits because we dropped any observation for which a cost share was missing.

Table VII
Household productivity measures

	All plots		Plots under tenancy contracts		Plots under owner operators	
Observed values	mean	std. dev.	mean	std. dev.	mean	std. Dev.
$l(q, Z)$ of household cultivating plot	6.69	0.49	6.78	0.44	6.66	0.50
$l(0, Z)$ of household cultivating plot	6.69	0.20	6.76	0.21	6.67	0.20
q of household cultivating plot	-0.00	0.44	0.02	0.37	-0.01	0.20
$l(q^L, Z^L)$	6.04	1.98	2.74	3.28	6.66	0.50
$l(q^T, Z^T)$	n.a.	n.a.	6.78	0.44	n.a.	n.a.
$l(0, Z^T)$	n.a.	n.a.	6.76	0.21	n.a.	n.a.
q^T	n.a.	n.a.	0.02	0.37	n.a.	n.a.
Generated values:	mean	std. dev.	$\mathrm{H}_0 : m_{obs} = m_{ge}$ p-value		mean	std. Dev.
Perfect matching : $l(q^T, Z^T)$	7.19	0.36	0.00		7.35	0.13
Limited perfect matching : $l(q^T, Z^T)$	6.71	0.49	0.00		6.63	0.45
Perfect random matching : m_{l^T}	6.80	0.23	0.23		6.81	0.04
Limited random matching : m_{l^T}	6.69	0.43	0.54		6.63	0.45

Note : total number of plots = 419; plots under tenancy contracts = 113; for limited matching subsample, the total number of plots = 118 with 57 plots under tenancy contracts; we are able to accurately identify the landlord on a total of 363 plots; perfect matching measure based on the cutoff value of potential tenant productivity at the uppermost decile; limited perfect matching measure based on maximum potential value of tenant productivity for the tenants with whom the landlord interacts; limited random matching measure based on the average productivity of tenants with whom the landlord interacts; productivity measures are expressed in thousands of Tunisian dinars; the hypothesis tested in the middle column of the second part of the Table is that the generated potential tenant productivity equals observed tenant productivity, on those plots actually under tenancy contracts ; $l(q^L, Z^L)$ on plots under tenancy contracts calculated by posing $l(q^L, Z^L) = 0$ for non-peasant landlords (those landlords who do not cultivate any land themselves).

Table VIII

The structure of the market for land : the determinants of the decision to rent out

Probit estimation : Dependent variable = 1 when plot is rented out, zero otherwise (z-statistic in parentheses)

	1	2	3	4
Landlord characteristics				
Resident landlord	-3.427	-3.589		
	(-3.24)	(-5.27)		
Peasant landlord	-2.060	-1.263		
	(-6.45)	(-3.93)		
$l(q^L, Z^L)$		-0.651	-1.553	-1.064
		(-5.99)	(-5.96)	(-4.97)
Joint signif. test on landlord characteristics : p-value	0.00	0.00	n.a.	n.a.
Tenant characteristics				
Perfect matching: $l(q^T, Z^T)$	-4.508			
	(-4.41)			
Limited perfect matching: $l(q^{TL}, Z^{TL})$			3.571	
			(3.69)	
Perfect random matching : m_{l^T}		-1.793		
		(-1.65)		
Limited random matching: $m_{l^{TL}}$				2.442
				(3.02)
Plot characteristics				
Plot area (in hectares)	0.560	0.384	1.722	1.348
	(5.00)	(2.89)	(3.84)	(3.80)
Irrigated plot dummy	0.617	1.371	4.067	2.672
	(1.36)	(2.52)	(4.19)	(2.87)
Soil dummies : Type 1	0.136	-1.200	-2.527	-1.786
	(0.30)	(-2.25)	(-3.47)	(-2.69)
Type 2	0.926	0.036	-1.438	-0.677
	(1.88)	(0.10)	(-1.98)	(-1.03)
Type 3	0.286	-1.120	-4.936	-3.722
	(0.79)	(-3.44)	(-4.66)	(-4.56)
Type 4	-0.751	-0.997	-3.338	-2.459
	(-1.26)	(-2.32)	(-2.87)	(-2.65)
Joint significance test on soil dummies : p-value	0.01	0.00	0.00	0.00
Year dummy	0.511	1.033	2.979	2.448
	(1.54)	(4.01)	(3.82)	(3.67)
Crop dummies : Wheat and other grains	-1.060	-0.445	-2.645	-1.528
	(-2.32)	(-0.86)	(-1.99)	(-1.41)
Garden vegetables	0.322	0.862	0.832	1.047
	(0.96)	(2.92)	(0.96)	(1.31)
Joint signif. test on plot characteristics : p-value	0.00	0.02	0.02	0.02
Intercept	34.93	17.38	-17.88	-12.95
	(4.53)	(2.13)	(-2.87)	(-2.35)
% correct predictions	96	97	92	92
Pseudo R-squared	0.80	0.72	0.79	0.73
Log likelihood	-49.48	-43.78	-17.16	-21.70
Number of observations	419	363	118	118

Note: in the case of the limited matching equations (columns 3 and 4), there are 61 plots under owner-operators, 24 plots under sharecropping, and 33 plots under fixed rental contracts; estimation of perfect matching (column 1) did not converge when the landlord-specific fixed effect was included because of colinearity with the tenant-specific fixed effect; we therefore report results for the specification in which the landlord-specific fixed effect is excluded; in columns 3 and 4, all landlords are residents of the village and peasants themselves.

Table IX
Covariates of tenant productivity
(t-statistics in parentheses)

	1 Dependent variable: $l(q^T, Z^T)$	2 Dependent variable: $l(0, Z^T)$	3 Dependent variable: q^T	4 Dependent variable: Area of plotunder tenancy contract
Method of estimation	Heckman-Lee Procedure	Heckman-Lee Procedure	Heckman-Lee Procedure	OLS
Intercept	7.215 (25.90)	6.764 (50.50)	0.484 (1.85)	16.538 (3.58)
Inverse Mills ratio from renting out probit estimation (column 1 of Table IV)	-0.226 (-2.37)	-0.135 (-2.88)	-0.094 (-1.13)	
Landlord characteristics				
Peasant landlord	0.738 (4.12)	0.196 (2.39)	0.533 (3.16)	
Total hectares owned by landlord $\overline{L}$				0.321 (3.51)
Household-specific fixed effect of landlord : $l(q^L, Z^L)$	-0.045 (-2.04)	0.010 (1.01)	-0.054 (-2.49)	0.043 (0.89)
Plot characteristics				
Plot area (in hectares)	-0.073 (-1.35)	-0.062 (-2.35)	-0.015 (-0.31)	
Irrigated plot dummy	-0.055 (-0.32)	0.061 (0.74)	-0.120 (-0.76)	-1.137 (-2.96)
Soil dummies : Type 1	-0.149 (-0.56)	-0.230 (-1.86)	0.063 (0.25)	-0.388 (-0.69)
Type 2	-0.510 (-1.83)	-0.138 (-1.05)	-0.380 (-1.45)	0.104 (0.20)
Type 3	-0.392 (-1.49)	-0.204 (-1.67)	-0.208 (-0.82)	-0.746 (-1.59)
Type 4	-0.917 (-3.07)	-0.446 (-3.20)	-0.491 (-1.71)	-0.553 (-1.11)
Year dummy	0.231 (1.52)	0.137 (1.93)	0.093 (0.65)	
Crop dummies : Wheat and other grains	-0.314 (-1.58)	0.060 (0.64)	-0.383 (-2.08)	
Garden vegetables	-0.133 (-0.95)	0.023 (0.34)	-0.156 (-1.20)	
Contract is a renewal	0.079 (0.72)	0.075 (1.57)	0.002 (0.02)	
Observable tenant characteristics : $l(0, Z^T)$				-2.288 (-3.32)
Tenant productivity : q^T				-0.469 (-1.32)
R-squared	0.38	0.48	0.17	0.56
Number of observations	57	57	57	55

Table X
Contract renewal, contractual choice and tenant productivity
(z-statistics in parentheses)

	All tenancy contracts	Tenancy contract is *not* a renewal	Tenancy contract is a renewal
	1 Dependent variable: = 1 when contract is a renewal = 0 otherwise	2 Dependent variable: = 1 when sharecropping contract = 0 otherwise	3 Dependent variable: = 1 when sharecropping contract = 0 otherwise
Method of estimation	Censored Bivariate Probit	Probit	Probit
Intercept	2.972	18.327	-11.061
	(0.46)	(2.43)	(0.00)
Peasant landlord dummy	-1.102	-1.423	-0.109
	(-2.01)	(-1.87)	(-0.09)
Plot area (in hectares)	0.396	0.284	0.147
	(2.40)	(1.17)	(0.54)
Irrigated plot dummy	0.097	-0.782	-0.573
	(0.19)	(-0.72)	(-0.88)
Soil dummies : Type 1	0.352		
	(0.55)		
Type 2	-0.690		
	(-1.08)		
Type 3	-0.202		
	(-0.38)		
Type 4	-2.428		
	(-1.75)		
Year dummy	0.802	0.429	-0.075
	(2.02)	(0.79)	(-0.16)
Crop dummies: Wheat and other grains		-1.389	7.190
		(-1.26)	(0.00)
Garden vegetables		0.502	6.915
		(1.02)	(0.00)
Tenant characteristics			
$l(0, Z^T)$	-0.526	-2.565	0.911
	(-0.56)	(-2.40)	(0.77)
q^T	-0.802	-0.301	-0.830
	(-1.99)	(-0.60)	(-0.95)
Predicted probability of contract being a renewal		0.085	-2.223
		(0.08)	(-1.29)
Predicted probability of plot being rented out		-0.834	-1.314
		(-0.99)	(-0.96)
Estimated value of r : correlation between selection equation (renting out) and contract renewal equation disturbances (t-statistic in parentheses)	0.436 (1.13)		
Log likelihood	-155.41	-31.37	-25.31
% correct predictions	63	72	78
Number of observations	113	57	56

Note: as with the results reported in Tables IV and V, the selection equation (the decision to rent out) and the contract renewal equation (presented in column 1 above) are estimated simultaneously by full information maximum likelihood (FIML) using the censored bivariate probit procedure in order to control for potential sample selection bias in the contract renewal equation. The selection equation (renting out) specification corresponds to that given in column 1 of Table IV. In columns 2 and 3, we correct for two potential sources of sample selection bias : (i) the plot being rented out, and (ii) the contract being a renewal; we therefore introduced the predicted probability of the plot being rented out (obtained from the censored bivariate probit results corresponding to the selection equation appearing in column 1 of Table IV), and the predicted probability of the contract being a renewal, obtained from the results presented in column 1 above.

Table XI
Contractual choice, contract renewal, and the nature of the contract
Method of estimation : Full information maximum likelihood (FIML)

Explanatory variables	Dependent variable: = 1 when contract is written; = 0 otherwise	Dependent variable: = 1 when contract is a renewal; = 0 otherwise	Dependent variable: = 1 when it is a share contract; = 0 otherwise
Intercept	0.283	1.422	0.783
	(0.65)	(1.91)	(0.74)
Resident landlord			0.559
			(1.34)
Peasant landlord		-0.702	
		(-1.60)	
Plot area (in hectares)	0.452		0.183
	(3.15)		(1.08)
Irrigated plot dummy		-0.766	
		(-1.55)	
Soil dummies: Type 1		0.266	
		(0.40)	
Type 2		-0.572	
		(-0.90)	
Type 3		-0.268	
		(-0.46)	
Type 4		-1.671	
		(-1.51)	
Year dummy			-0.026
			(-0.07)
Crop dummies:			
Wheat			-1.022
			(-1.14)
Other grains			-0.860
			(-0.81)
Potatoes			-0.865
			(-0.96)
Onions			-1.207
			(-1.29)
Tomatoes			-2.054
			(-1.92)
Garden vegetables			-0.864
			(-0.97)
Melon			-2.006
			(-1.98)
Tenant productivity : q^T		-0.831	0.111
		(-2.25)	(0.20)
Endogenous variables			
Sharecropping contract	-0.797	-0.609	
	(-2.08)	(-0.87)	
Contract is renewal	-2.191		-0.972
	(-3.87)		(-1.27)
Log likelihood = -176.07			
Number of observations = 113			

Note: system of three probit equations estimated by FIML; omission of written nature of contract in the renewal and share equations was necessary in order to achieve convergence.