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INFORMATION AND THE OPERATION OF MARKETS:
TESTS BASED ON A
GENERAL EQUILIBRIUM MODEL OF
LAND LEASING IN INDIA

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**Information and the Operation of Markets:
Tests Based on a General Equilibrium Model of Land Leasing in India**

This paper develops an estimable general equilibrium model of land leasing to test the extent to which information is commonly held in a village and whether village markets are efficient. The results have ramifications for the estimation of agricultural household models and for our understanding of rural institutions. The model is derived from the primitives of the production technology, the extent of information and the distributions of assets and several household unobservables. Simultaneity and selection issues are dealt with explicitly in a two-stage maximum likelihood estimation procedure using panel data from India.

Keywords: Agricultural household models, information, sharecropping, land markets, general equilibrium.

Recent years have seen an increasing interest in incorporating correct informational assumptions in behavioral economic models. This paper develops an estimable general equilibrium model of land leasing in order to investigate whether information is commonly held among villagers in a rural agricultural setting and whether village markets are complete and efficient. While these questions are simple, the answers have some broad ramifications for the estimation of agricultural household models, for our understanding rural institutions and, in particular, for our understanding of land contracts.

New theoretical models in the development literature have sought to explain the existence of various community-level institutions on the basis of different assumptions about asymmetries of information. One set of theories explains the existence of institutions on the basis of informational asymmetries within communities. Examples include theories of permanent labour contracts; interlinkages between markets, such as joint credit/labour contracts; and sharecropping contracts in the land market². By contrast, another set relies on the superiority of information within, versus outside of, communities. For example, in the literature on formal and informal credit markets and insurance, common group information is used as a basis for credit risk analysis, the mitigation of adverse selection and moral hazard problems, and the enforcement of obligations³.

While the existence of institutions which appear to exploit informational advantages or to overcome informational problems is often used to suggest that information is, or is not, widespread in villages, to avoid circularity one would like independent evidence to support such assumptions. It is, however, difficult to devise econometric tests. Measures of the individual characteristics or actions about which one cares whether there is information are often unavailable or inherently unobservable: skill, reliability, effort, and so on. One of the objectives of this paper is to provide evidence on this point. The results suggest that information, in this case about the relative farming skill of farmers, is widespread in a village environment.

The second issue addressed in the paper, whether village input markets function well, is of central

² See, for example, Eswaran and Kotwal (1985a), Braverman and Gausch (1984), Hoff, Braverman and Stiglitz (1993) and the references cited therein, and the discussion of sharecropping below.

³ On group lending see Besley and Coate, 1991, and Hulme, 1990; on state-contingent lending, Udry, 1994; on informal insurance, Platteau, 1990.

importance to the recent modelling and estimation of agricultural household models. (See Singh, I., *et al.*, 1986 for a discussion of the econometric issues.) These models recognize the fact that households in agrarian settings are both producers and consumers. A crucial issue for the estimation of these models is whether household decisions regarding production can be treated as separable from those concerning consumption. If markets are complete and efficient, then the models are recursive, with production decisions being independent of preferences and asset ownership. It follows that production and consumption equations need not be estimated simultaneously.

There have been few empirical tests of the proposition that rural input markets are well functioning. Benjamin (1992) and Pitt and Rosenzweig (1986) are two examples, both of which focus exclusively on the labour market and both of which test different implications of market imperfections. The first study tests whether labour demand is related to household demographic structure. The second tests whether household illness, which lowers family labour input, also lowers farm profits, or whether the fall in family labour is compensated by hired labour. The results of both studies suggest that separability is an appropriate assumption. This paper provides a related test of separability based on input markets. Here the tested implication of separability is that asset ownership should not influence the land leasing decisions of households. This paper extends earlier tests to the full range of productive input markets, including labour.

A more specific reason for being interested in the answers to the questions considered in this paper is that they contribute to our understanding of land contracts. The role of different contract forms has generated a great deal of theoretical interest in recent years. In the context of land leasing, this interest has both a long history and a particular importance given efforts by many governments to suppress a widespread form of leasing contract: share tenancy (see Bell, 1990; and Osmani, 1991). Given the theoretical arguments (following Marshall, 1890) and empirical evidence (e.g., Bell, 1977; and Shaban, 1987) that sharecropping is an inefficient form of contract, its persistence in large parts of the world remains something of a puzzle.

Assumptions about the extent of information in a village and the imperfection of input markets

underpin two prominent theories of share contracting⁴. The first theory is based on an assumed asymmetry of information between landlords and prospective tenants or wage laborers about the latter's entrepreneurial ability. Share contracts, it is argued, co-exist with other forms of contracts as a way of *screening* workers by skill levels. A separating equilibrium exists with different ability workers making different contract choices, thereby increasing landowner profits (Hallagan, 1978; Allen, 1980). The second theory proposes that share contracts are a response to *imperfect or missing input markets* (Bell and Zusman, 1976; Bliss and Stern, 1982; Eswaran and Kotwal, 1985b). In this situation, land moves to the owner of the non-marketable input(s). In particular, skill has been suggested as one input which motivates leasing because it does not have a market independent of labor and is difficult to monitor. The results allow one to reject the asymmetric information assumption which lies behind screening as a rationale for multiple contracts. Villagers are aware of those who are more skilled and lease in and out in accordance with this information. On the other hand, the finding that several input markets are imperfect lends support to the second explanation for sharecropping.

A number of other papers have considered the functioning of input rental markets as a determinant of leasing behavior - for example, Bell and Sussangkarn (1988), Bliss and Stern (1982), and Skoufias (1991). The methodology used here extends previous work in several directions. Leasing equations are generated from the primitives of the production technology and the distribution of information, assets and several unobservables. The non-linearities in the land cultivated equations are modelled explicitly and both time variant and invariant errors are accommodated.

The estimations and tests presented in the paper are based on both the land leasing behavior and the agricultural output of all farm households in the north Indian village of Palanpur. Agricultural households make decisions about whether and how much land to lease, either in or out, and then they cultivate. The test of whether input markets are imperfect hinges on whether owned inputs reflect the inputs *utilized* in production and thus influence both leasing and output. With complete and efficient rental markets, owned inputs should be poor proxies for input use and have insignificant coefficients when

⁴ There are many other theories and they are not mutually exclusive. One popular idea, initially posited by Cheung (1969) and developed in Stiglitz (1974), is that share contracts allow risk sharing between the landlord and the tenant.

included in a production function. (This is directly analogous to the attenuation bias arising from mismeasurement.)

The test of the extent of information regarding the relative farming skill of households is whether household ability, or 'skill' influences its success in obtaining land in the leasing market. Since sharecropping contracts involve the division of output, if villagers know which households are relatively more skilled then those households should be able to obtain more land under lease, conditional on their other productive assets.

Implementing this test clearly requires a measure of relative household farming skill. By utilizing panel data on both leasing decisions and output it is possible to identify three types of household characteristics which are unobservable (at least to the econometrician). One is skill which is discussed below. In addition, the model also allows for two unobservable household characteristics which vary over time. The first is a stochastic shock affecting only output. The second is known to villagers at the time of contracting and so influences both leasing and output. This is obtained by inverting the leasing equation. While the context is very different, the use of leasing data to identify unobservables in the production function is related to current innovations in productivity estimation, as discussed in Griliches and Mairesse (NBER, 1995). For example, Olley and Pakes (1994) estimate a non-parametric model of investment to back out a (single) production function unobservable.

The panel nature of the data is exploited to obtain a measure of the relative farming skill of households - associated with a time invariant unobservable characteristic which affects both leasing behavior and output. A coefficient, θ , appears on the unobserved skill variable in the equation determining the amount of land that a household can leased in. A null hypothesis of no information corresponds a θ of zero while a null of perfect information corresponds a θ of one.

The fact that there is a well defined null hypothesis corresponding to perfect information is one of the benefits of the structure put on the model. By contrast consider the somewhat analogous methodology found in the labour literature. A measure of the individual unobservable variable 'ability' is estimated from, for example, schooling choices. These measures typically take the form of inverse Mill's ratios, and are given coefficients in wage equations to test for the impact of ability on earnings (for example, Willis, 1986, and Taber, 1995). In the absence of a model of how ability affects earnings if

recognized by employers, it is impossible to specify a null hypothesis which corresponds to perfect information.

Another benefit of the structure is that it allows an explicit treatment of simultaneity and selection issues - problems which are intractable in reduced form estimations (see section 4). Both the land cultivated by a household and its agricultural output are functions of the unobservables. This simultaneity is addressed with the joint estimation of land cultivated and output equations. The allocation of land for cultivation is a function of the production technology, the degree to which villagers are informed about each other's farming skill, the distribution of input ownership and the distribution of unobservable characteristics, including skill. Given the amount of land owned by each household, it follows that the tenurial status of each household - whether it is a tenant, landlord or a household which does not participate in the leasing market - is similarly endogenously determined. This 'selection' into types is important as it generates a non-linearity in the function relating land cultivated to assets and unobservables, with the non-linearity arising from changes in the allocation equation across status. Thus the leasing equation cannot be estimated using a reduced form linear approximation as seen in most previous studies.⁵

The following section of the paper provides a brief description of agriculture and other relevant aspects of the evolving Palanpur economy which motivate the structure of the analysis which follows. The second section outlines the model of land allocation and characterizes equilibria in the leasing market. Section 3 sets forth the econometric structure of the model and section 4 describes the two-stage maximum likelihood procedure used in estimation. It also includes a discussion of the problems which arise with what might appear to be simpler approaches to answering the same questions considered here. The final section presents estimation results and offers concluding comments.

⁵ The bias induced by a relationship between an discrete explanatory variable and the disturbance term is often termed a selection effect (for example, in the labour literature when a schooling dummy is related to unmeasured ability). In this case, because the (continuous) functional relationship between the explanatory variable land cultivated and the disturbance term differs by categories - tenant, landlord, non-participant - the econometric issue dealt with here could be thought of as a combination of selection and simultaneity problems.

1. The Palanpur Economy

The analysis presented in this paper is based on data from two household surveys of Palanpur, a village located in the district of Moradabad in western Uttar Pradesh⁶. The survey years were 1974/75 and 1983/84 (henceforth 1974 and 1983). All village households were surveyed and detailed information was collected on family structure, occupation, land ownership and cultivation, production, incomes, assets, and related variables.

Palanpur is surrounded by open fields covering about 2,560 *bighas* (approximately 400 acres). At the beginning of the 1983 survey, the village numbered 960 inhabitants, divided into 143 households. Agriculture is the most significant component of the Palanpur economy. There are two main seasons in the agricultural year, rabi and kharif. The data used here pertain to the production of wheat during the rabi season.

While fixed-rent leasing does occasionally occur in Palanpur (absentee landlord, immediate need for payment), the principal contractual arrangement is sharecropping. Although declining somewhat in importance, in 1983 such contracts still covered 80 percent of all leasing. The standard contract (*batai*) involves the equal sharing of both outputs and cash inputs between landlord and tenant, with labour being entirely provided by the tenant.⁷ In 1974, 21.0 percent of village land was under lease during the rabi season and by 1983 it had increased to 26.4 percent. These figures tend to underplay the importance of leasing in the village as, for example, in 1983, 74 percent of all households were party to a leasing contract. In contrast, sales of land occur infrequently and usually as a consequence of distress.

Within the village, agriculture became more intensive over the period in the use of modern inputs such as fertilizers, motorized irrigation devices (pumping sets) and new seed varieties. New farming

⁶ The 1974/75 study was conducted by Christopher Bliss, Nicholas Stern, and S.S. Tyagi (Jr.) and the results are reported in Bliss and Stern (1982). The 1983/84 survey was directed by the same researchers in collaboration with Jean Drèze; the field work was carried out by Jean Drèze and Naresh Sharma. Survey data is also available for 1957/58 and 1962/63.

⁷ For further details on the terms of sharecropping contracts in Palanpur, see Bliss and Stern (1982) and Sharma and Drèze (1990).

practices (such as double-cropping) and seeds were first introduced before 1974. Although 1983 was a poor year for agriculture in Palanpur (due to drought, hot winds and various pest attacks), by that point agricultural practices had intensified still further. In 1974, for example, Persian wheels, a traditional form of irrigation utilizing bullock power, still made a large contribution to irrigation (there were 22 Persian wheels and 9 diesel pumping sets) whereas in 1983 very few Persian wheels were in active use and there were 22 pumping sets.

Over the period Palanpur also became more closely linked to the wider economy outside the village. The rapid growth of population, from 757 in 1974 to 960 in 1983, heightened pressure on land and increased the incentive for seeking off-farm employment. At the same time there was an improvement in employment opportunities outside the village, mainly in nearby towns. As a result, the number of regular outside jobs among households increased from 37 in 1974 to 54 in 1983. These jobs contributed around one third of total village income in 1983. However, while off-farm jobs are attractive to villagers in Palanpur because of the comparatively high and stable incomes they generate, such jobs are *not* readily available and access appears limited by family and caste connections.

Input Markets

Consideration of the input markets in Palanpur suggests many reasons to expect that they might not operate smoothly.

The most common form of labour contract in Palanpur is casual agricultural wage labour. A striking feature of the labour market is that many households with excess labour will not hire it out on the market because working for another household is regarded as demeaning. Drèze, Lanjouw and Stern (1992) find that households involved in agricultural labour are highly represented among the long-term poor. They suggest that this is a selection rather than a wage effect - only households already in distress chose to undertake such labour. For some of the higher caste households, working for a lower caste household is so distasteful that it is not really an option at all. In 1983, only 25 villagers were regularly available for agricultural labour (Drèze and Mukherjee, 1989). Women, in particular, very rarely engage in wage labour. For them to work alongside male family members in the fields is only slightly more common. As a result, for most households (male) family labour is likely to represent a fixed amount of agricultural labour available to the household. Even where laborers are hired, family size is a relevant constraint on

the total labour available to a household as hired labour is invariably supervised.

Non-labour inputs can, in principle, be purchased or their services rented. The hiring of bullock services is rare. This is discussed in Bliss and Stern (1982) where they point out disadvantages to both sides of a possible transaction in bullock services. Because bullocks are valuable animals, bullock owners work with them as they are reluctant to entrust hirers with care of the animals. The provision of labour services to the hirer in this way may be unattractive to a bullock owner if he is from one of the higher castes, particularly as his work effort may be supervised. From the hirers' point of view, the fact that the owner comes with the bullocks may be a disadvantage if the household already has plenty of labour. Furthermore, there is an issue of timing - the demands for draught power in a village often coincide and a farmer wishing to hire services may find no bullocks available. Although irrigation services (Persian wheels, pumping sets) may also be subject to this last consideration, there is an active rental market.

As an alternative to rental, the purchase and sale of inputs to adjust to the amount of land available for cultivation may not be possible (or desirable) in the short run and may be limited even in the longer run. Because there is considerable turnover (Sharma and Drèze, 1990) tenants do not have even implicit long-term contracts on parcels of land. Purchasing durable inputs to use on land leased for one season is likely to require their sale at the end of the season. In addition, some inputs are inherently lumpy. Bullocks, for instance, not only provide power for a large area relative to the average landholding in Palanpur, but are also invariably used in pairs. Animals and machinery alike are prone to die or break down, introducing a risk element to ownership which may constrain purchases, particularly for poorer households.

The financial resources required to invest in agricultural assets are not trivial, so credit constraints may also limit access to such assets through purchase. The credit market in Palanpur can be broadly divided into four segments: interest free credit from friends and relatives, low interest credit from state institutions (including rural banks and a local Credit Cooperative), commercial credit from urban goldsmiths and pawn-brokers, and high interest credit from village moneylenders (see Drèze, Lanjouw and Sharma, 1993). Nominal interest rates vary widely between these four sources (from zero in the case of friends and relatives to about sixty per cent per year in the case of village moneylenders), but non-price factors limit arbitrage. The riskiness and expense of taking out large loans, and rationing in the supply of credit, constrains the purchase of complementary assets (see Kochar, 1992).

2. The Leasing Model

This section presents a model of land leasing based on the optimizing behavior of households. Farmers are assumed to maximize expected net agricultural income, and in pursuing this goal they may decide to be either landlords (LL), tenants (T), or they may choose not to participate in the land leasing market (0). Note that throughout the paper a landlord is defined as someone *net* leasing out and vice versa for a tenant.⁸ The return from cultivation differs across these choices. In order to determine the optimal decision for each household, this section first derives value functions for each choice of tenurial status, denoted V_{LL} , V_T , and V_0 . These specify the return that a farmer expects to receive from his own cultivation and cropshares on leased land, conditional on his owned assets and unobservable characteristics. The second part of the section discusses the leasing market equilibria, both uniqueness and existence.

The following model is developed in terms of a general production function. Equations for the specific functional form used in estimation are in the following section. Let

$$y_i = f(h_i, k_i; A_i, \Omega_i, \lambda) - p_{ki}'k_i \quad (1)$$

represent the net output when h_i bighas of land are cultivated by household i with a vector of purchased inputs, k_i , and a vector of owned assets, A_i . Ω_i is a vector of error terms, λ a vector of parameters, and p_{ki} a vector of marketed input prices⁹. Maximizing over k_i , let

$$y_i = g(h_i; A_i, \Omega_i, \lambda, p_{ki}) \quad (2)$$

⁸ Farmers may, and do, lease in and lease out land concurrently. They may wish to consolidate their cultivated area if, with the division among family members of land owned, their holdings have become scattered. Alternatively, they may wish to reduce risk of crop loss by spreading out their plots. However, both of these considerations affect the geographical composition of land cultivated while we are interested here in adjustments to the amount of land cultivated.

⁹ Without a market, the implicit price of owned assets is assumed to be zero, although it is recognized that bullocks and people need more food when working and there is some level of disutility from labor.

represent the net output when h_i bighas of land are cultivated with optimal levels of any marketed inputs. It is assumed that

[A1] $g(0;.) = 0$; $g(h;.)$ is twice differentiable and strictly concave in h , and that the land cultivated by a household, owned and under lease, can be aggregated in the production function.

The first restrictions on the production function are standard. The last, which implies that inputs are allocated by households across their cultivated land without regard to ownership, is not a general feature of agricultural production. For example, Bell (1977), Hossain (1977) and Shaban (1987) find lower productivity on tenanted land than on owned land in other parts of South Asia. However, this assumption could not be rejected for Palanpur in statistical tests reported elsewhere (Bliss and Stern, 1982).¹⁰

Consider first a household which cultivates an area h . Because output must be shared on leased land, the total agricultural profit the household receives depends on the relation between h and the land owned by the household, LO - that is whether $h > LO$ (tenant), $h = LO$ (non-participant), or $h < LO$ (landlord). Below we define the profit that a household would receive given each choice. However, the optimal choice over tenurial status must be made from those which are actually available to the household. Not participating is, of course, always an option. A sufficient condition for leasing out to be an option is that there be at least one landless villager not otherwise employed. On the other hand, as we shall see, leasing in land may or may not be possible for a given household depending on its characteristics.

Value Functions

For any household, agricultural profits under each type of tenurial status may be defined as follows:

¹⁰ In fact Bliss and Stern find that, controlling for both crop and household, yields on tenanted land are actually higher than on owned land (although with a small sample size the difference is not statistically significant).

Landlord: The expected¹¹ net agricultural profit of a landlord household is

$$\pi_{LL}(h; C, LO, A, \Omega, \lambda, p_k) = g(h; \cdot) + C (LO - h), \quad (3)$$

where C is the expected, per bigha, value of leasing out, a value which is defined implicitly below¹².

Although C is determined endogenously by the demand and supply of land, it is treated parametrically by landlords. That is, landlords are assumed to ignore the negative impact of an additional bigha of leasing on the village equilibrium average product on tenanted land (and hence on their return on land already leased). It would, in any case, be only a second order effect given the amount of land (owned or leased) under cultivation by tenants in Palanpur. C replaces the vectors of assets and unobservables of all other households which would otherwise enter the profit function of household i . It summarizes all of the market information relevant to household i 's optimization problem. Landlords retain an amount of land, h , and lease out $(LO - h)$, choosing h so as to maximize their profits. This implies that they cultivate until the expected net product that they receive from own cultivation of the marginal bigha is equal to the expected return from leasing¹³:

$$g'(h; \cdot) = C. \quad (4)$$

¹¹ For expositional simplicity the expectations operator has been suppressed. Expectations are taken with respect to the relevant agent - which is an important consideration as information may differ across agents. It should be understood that outputs are in expectation at the time of contracting and the stochastic shocks are independent of tenurial status. Household subscripts have also been suppressed.

¹² It is assumed that there is nothing advantageous in specific tenant/landlord pairings. In other words, C is common to all agents. The fact that pairings change over years supports this assumption, although there are more within caste pairings than would be suggested by random sorting.

¹³ Individual random deviations from optimizing behavior are accommodated in the empirical estimation. See the discussion in section 3 under error ϵ .

Transactions costs would put a floor on the minimum transaction size. It is assumed that in Palanpur such costs are low, an assumption which is supported by the fact that parcels as small as one-half of a bigha are leased. For an estimation of leasing costs in other parts of India see Skoufias (1995).

⇒ (using [A1] to ensure invertability)

$$h_{LL} = \min\{ (g')^{-1}(C), LO \}. \quad (5)$$

Let $V_{LL}(C, LO, A, \Omega, \lambda, p_k) = \pi_{LL}(h_{LL}; C, LO, A, \Omega, \lambda, p_k)$ (6)

be the maximized expected return to a household if it decides to be a landlord household. If $g'(LO;.) > C$ then the household does not gain from leasing out any of its land and $V_{LL} = V_0$ (defined below).

Non-Participant: By definition, for non-participants $h = LO$ so their expected return equals their expected net agricultural profit:

$$V_0(C, LO, A, \Omega, \lambda, p_k) = \pi_0(LO; .) = g(LO; .). \quad (7)$$

Tenant: Under the 50/50 sharecropping contract,

$$\pi_T(h; C, LO, A, \Omega, \lambda, p_k) = g(h;.)[1/2 + 1/2(LO/h)]. \quad (8)$$

The 50/50 sharing rule of the *batai* contract is imposed here (see section 1). There are a few dimensions in which bargaining over the distribution of returns may occur, such as the amount of animal manure that a tenant must provide per bigha or the extent of low cost credit for the purchase of inputs to be provided by one of the parties. They are not extensive, however. Multiple interlinkages between parties are not commonly observed in Palanpur and tenant/landlord relationships are typically shortlived which limits the ability to move away from the explicit 50/50 share "price" in response to demand and supply factors. Of course, it is impossible to prove the absence of side payments. The sharing rule assumption is not trivial as it is necessary for identification of the model.

It is assumed here, and shown in section 3 for the production function used in the empirical analysis, that

[A2] $\text{If } d\pi_T/dh \geq 0 \text{ at } h = h^*, \text{ then } d\pi_T/dh \geq 0 \text{ at } h > h^*.$

The reason for making this assumption is that it implies that if a farmer leases in any land at all then he would like to lease in as much land as possible. This allows us to consider only the landlord's decision rule when determining the allocation of land across tenants¹⁴. Given this assumption and [A1], it is easily argued that optimal decisions by landlords imply a distribution of leased land which equates across tenants the expected amount (C) paid per bigha. That is, the expected average product of tenants is equated, and with the 50/50 cropshare,

$$1/2[g(h)/h]_i = C \quad i = 1, \dots, t, \quad (9)$$

where t is the number of tenants. This equation implicitly defines h_T , the maximum amount of land that the household can obtain (for $h_T \geq LO$). Again, by [A2], if the household is a tenant household, h_T will be accepted and thus can be used to define

$$V_T(C, LO, A, \Omega, \lambda, p_k) = \pi_T(h_T; C, LO, A, \Omega, \lambda, p_k). \quad (10)$$

If a household would like to lease in but cannot do so ($h_T < LO$), that is, a household for which

$$1/2[g(LO)/LO] < C, \quad (11)$$

then $V_T = V_0$. It is also possible, since $d\pi_T/dh < 0$ has not been ruled out, that a household may be *able* to lease in, but not *desire* to lease in ($h_T < h^*$). This possibility is addressed in the following section in the context of the more specific model used in estimation.

Figures 1a and 1b show the net leasing position of a single household as a function of the implicit price C , given that tenurial status is chosen optimally. When C is high, the household leases out land and h is determined by the landlord equation $g'(h; \cdot) = C$. When C is low, the household is able to lease

¹⁴ It may not be immediately clear why a household may not be willing to lease in small amounts of land (i.e., why h^* may be greater than LO). The reason is that when a farmer leases in a bigha of land it has a negative impact on the average product on all of his cultivated land because his fixed inputs are diverted to the new land. This 'cost' of leasing is borne entirely by the tenant for the first bigha leased. As the ratio of owned to leased land falls, more of this cost is shared by landlords.

in land and h is determined by the tenant equation $(1/2)[g(h;.)]/h = C$. There may exist a range of C where the household does not participate in the leasing market. It is also possible for the function $h(C)$ to be discontinuous as in figure 1b, a case discussed below.

Equilibria

There are two possible equilibria in the land leasing market and they are characterized by the following conditions:

$$\begin{array}{ll} \text{For } \ell \text{ landlords:} & V_{LLi} \geq V_{Ti}, V_{Oi} \\ & \text{and } g'(h_{LLi}) = C, \quad i = 1, \dots, \ell. \end{array}$$

$$\begin{array}{ll} \text{For } t \text{ tenants:} & V_{Ti} \geq V_{LLi}, V_{Oi} \\ & \text{and } 1/2[g(h_{Ti})/h_{Ti}] = C, \quad i = 1, \dots, t. \end{array}$$

$$\text{For } n \text{ non-participants:} \quad V_{Oi} \geq V_{LLi}, V_{Ti}, \quad i = 1, \dots, n.$$

$$\begin{aligned} \ell + t + n &= \text{the number of cultivating households and,} \\ \sum h_i &= \text{the total amount of agricultural land (feasibility).} \end{aligned}$$

The aggregate net demand for leased land at each implicit price C is simply the horizontal sum of the individual net demands $[\Sigma(h_i - LO_i)]$. Two possible leasing market equilibria exist. The first has $\ell + t = 0$, that is, all households choose not to participate in the leasing market and all are on the vertical segment of their net leasing functions (figure 1a). In this equilibrium, the implicit price C which 'clears' the market may not be unique. Non-uniqueness would be a problem since C is a parameter to be estimated. However, this equilibrium is ruled out if there is one landless household. (Given [A1], $[g(h;.)]/h \rightarrow \infty$ as $h \rightarrow 0$ so landless households are always able and willing to take land under lease.) There are landless households in Palampur and this equilibrium is not empirically relevant.

The second equilibrium involves leasing ($\ell + t > 0$) and it is straightforward to show that in this equilibrium C is unique. When household net leasing functions are continuous, as depicted in figure 1a, this property translates to the aggregate net leasing function. With at least two households leasing, and hence off the vertical segment of their net leasing curves, the aggregate net leasing function is also

monotonically decreasing in C . As C increases, the amount of land that all households desire to retain for cultivation, assuming that they can find tenants at C , goes to zero ($\Sigma(h_i - LO) \rightarrow -H$ as $C \rightarrow \infty$). As C falls the amount of land that households would be able to obtain under lease, assuming a perfectly elastic supply at C , goes to infinity ($\Sigma(h_i - LO_i) \rightarrow \infty$ as $C \rightarrow 0$). Together with continuity and monotonicity these limits ensure that aggregate net leasing is zero at a single value of $C > 0$.

Finally, as shown in figure 1b, there can be a discontinuity in the household net leasing function which rules out non-participation. This arises *only* with imperfect information and only over a restricted portion of the distribution of the unobservables (a formal discussion is in the appendix under 'scenario two'). If this situation arises then equilibrium may not exist¹⁵. It is assumed that equilibrium exists - and the finding of perfect information is consistent with this assumption.

3. Econometric Specification

This section uses the characteristics of equilibrium from the previous section to derive estimating equations for a specific production function. The production function is assumed to be Cobb-Douglas in labour, land, and marketed inputs. Other inputs, such as draught power and irrigation devices, and the unobservable factors enter production as shift parameters. The inputs are treated differently because land, labour (and seeds) suffice to produce a non-zero quantity of output, whereas land or labour alone do not. Let

$$y_{it} = h_{it}^{\gamma} L_{it}^{\beta} \exp\{X_{it}'\psi + S_i + \eta_{it} + \epsilon_{it}\}, \quad (13)$$

where

$$X_{it}'\psi = \alpha_0 + \alpha_1 V_{it} + \alpha_2 PW_{it} + \alpha_3 PS_{it},$$

represent the conditional production function for household i in year t , conditional on the application of optimal levels of marketed inputs. This corresponds to the function $g(h,k;.)$ in the previous section. In the absence of information about intra-village variation in input prices, an independent effect of marketed

¹⁵ Clearly some allocation of land does happen. Existence refers to whether the rules derived from the model fully describe the resulting allocation.

inputs is not identifiable and is subsumed in α_0 . Differences in marketed input use due to household-level price variation will end up in the error terms S_i or η_{it} (see below).

For the production function specified both assumptions [A1] and [A2] apply:

[A1] The first assumption holds provided $\gamma < 1$ and $L > 0$ for all cultivating households.

[A2] For the production function specified,

$$d\pi_T/dh = [g(h; \cdot)/2h] [\gamma - (1-\gamma)(LO/h)]. \quad (14)$$

Thus $d\pi_T/dh \geq 0$ for all $h \geq (1-\gamma)LO/\gamma$, and [A2] is satisfied. Notice from the first derivative of π_T that whenever $2\gamma > 1$, $h^* = LO$. That is, if this parameter relationship holds, and if a household is willing to lease in at all, it will be willing to lease in any amount of land available to it regardless of how small.

Variables

See Table 1 for descriptive statistics.

Output (y)

Output is gross annual output of rabi season wheat measured in 1,000 1974 rupees (as are all monetary values).

Land cultivated (h)

Measured in units of 10 bighas = 1.56 acres. Some households may have income earning opportunities outside of cultivation leading them to lease out all of their land. This type of leasing behavior is not an adjustment of land to agricultural assets, the phenomenon that the model is designed to capture. Since selection into outside jobs does not appear to be based on characteristics associated with farm productivity, such households are simply dropped from the data (see section 1).

Labor (L)

Labor is a composite indicator including all adult male members of the household between the

ages of 16 and 60 who do not have a job outside of agriculture. It also includes boys of age 10-15 plus adult women with an independent parameter, w , indicating their value as laborers relative to an adult male. Given the social constraints in the village on women working outside of the home one expects this parameter to be substantially less than one.

Bullock power (V)

Bullock power is measured by the total value of livestock owned by the household. Ideally one would like a seasonal flow rather than a stock variable for draught power. Since a bullock's value reflects discounted future flows, V will overstate the seasonal flow of service more for young animals than for old animals and will be a noisy proxy as a result.

Irrigation devices (PW, PS)

PW and PS are 0/1 dummy variables indicating whether or not the household owned a Persian wheel or a diesel pumping set respectively.

Error Structure - $\Omega = \{S, \eta, \epsilon\}$

Error S - 'Skill'

This component of the error vector captures unobservable heterogeneity in the cultivation skill of households - that is, differences in aptitude, experience, and commitment. This component is measured by the within-household covariance in disturbances.

As part of a residual, 'skill' includes any mismeasurement in relevant variables, both included or omitted, which is constant over time. For instance, differential access to borrowed or rented inputs (e.g., a brother's bullock) could creep into this skill measure, although it seems unlikely that a household would be able to maintain a privileged position in this respect over a decade. A more plausible possibility is that 'skilled' dynasties happen to own land of particularly good quality. As land sales in Palanpur are rare, the land owned by a dynasty does remain relatively unchanged over time. However, land quality indicators were found insignificant in research using the 1974 data. This may simply be a result of the rather crude nature of the land quality indicators, but it nevertheless suggests that quality does not affect output markedly. As noted above, because of a lack of data, households are assumed to face the same prices for marketed inputs. If, in fact, some households face lower prices then, all else equal, they will

apply more inputs and appear more productive. Finally, wealth might be thought to influence agricultural productivity indirectly through its effect on the labor/leisure choices of farmers. The measure of labour is numbers of bodies rather than person/hours. To the extent that more wealth lowers the amount of farm labour represented by each person, a wealthier household will appear less productive than a poorer household. Thus 'skill' as measured here incorporates effort.

The 'skill' component of the disturbance vector is known to the household but may or may not be known to other households in the village - a question that we test in the empirical estimation below.

Error η

η is that component of the disturbance vector which is independent across households and time and known to all agents at the time of contracting. It incorporates any time variant mismeasurement in variables, in particular due to the use of proxy variables such as bullock stocks versus flows for draught power and numbers of people versus hours for labour. It also includes any discrepancy between inputs used and inputs owned due to rental.

Error ϵ

ϵ is that component of the disturbance which is independent across time and is not known to anyone at the time of contracting. This unanticipated stochastic shock to production would include, for example, weather and pest attacks, and is likely to be correlated across households in a given year.

Any stochastic element which affects leasing but not output, for example, individual deviations from optimal leasing decisions, simply entails a redefinition of η and ϵ . Allowing for such deviations, say δ , the composite disturbance in the leasing equations would be $S + (\eta + \delta)$, and that in the output equation would be $S + (\eta + \delta) + (\epsilon - \delta)$.

Distribution of Ω :

$$\Omega \sim N(-\text{diag}[\Sigma]/2, \Sigma)$$

where Ω is the stacked vector of error terms for all households and all years. Ω is assumed to be independent of the vector of land owned, LO , and the (now matrix) of owned inputs, A . The mean of Ω , denoted μ , is specified as $(-\text{diag}[\Sigma]/2)$ in order that the mean of $\exp\{\Omega\} = 1$. While it seems

appropriate that, in expectation, the disturbances should not affect output, this is largely for convenience in the following equations. It is not a substantive assumption as differences between the true mean and that specified only affect the estimated value of α_0 , the production function constant.

The variance of the components of the disturbance vector are assumed equal across households and they are denoted σ_s^2 , σ_η^2 and σ_ϵ^2 . Off diagonal elements of Σ include a within dynasty covariance (due to S) and a within time covariance (due to ϵ). All other off diagonal elements are zero. The first covariance is dealt with directly in the estimation by modelling S as a dynasty random effect. The second is not incorporated directly. It is, however, potentially important as it entails a divergence between the expected value of $\exp\{\epsilon\}$ ($= 1$), which effects the estimate of α_0 via equations relating to the amount of land leased, and the sample mean of $\exp\{\epsilon\}$ ($\neq 1$), which effects the estimate of α_0 via the output equation. This inconsistency could introduce biases into estimates of the other parameters. To avoid this problem, survey information is used to provide an estimate of the average ratio between output realized at the end of the harvest and that predicted at the beginning of the season. For 1974 this ratio is estimated as 1.15 and for 1983, a year of poor harvests, as 0.65 (see Table 1). This ratio is used to adjust realized output (down in 1974, up in 1983) so that the sample mean of $\exp\{\epsilon\}$ equals one as assumed.

Land allocation equations

Given the production function above and the equilibrium conditions in section 2, we can specify the amount of land that a household would cultivate under each tenurial status, conditional on LO, A, the parameter vector λ and different values of the unobservables, (S, η):

Landlord:
$$h_{LL} = \min\{ [\gamma L^\beta \exp\{X'\psi + S + \eta\} / C]^{1/(1-\gamma)}, LO \}. \quad (15)$$

Again equations are in expectation with respect to the relevant agent and i,j,t subscripts have been suppressed.

Tenant:
$$h_T = \max\{ [L^\beta \exp\{X'\psi + \theta S + \eta\} / 2C]^{1/(1-\gamma)}, LO \}. \quad (16)$$

The parameter θ captures the possibility that landlords do not have perfect information about the skill

level of households and therefore may not take skill into account in allocating land to tenants.

Non-participant: Of course, by definition, $h_0 = LO$.

These equations for land cultivated may be used in the value functions defined in the previous section to obtain:

$$V_0 = [LO^\gamma L^\beta \exp\{X'\psi + S + \eta\}], \quad (17)$$

$$V_{LL} = C [LO + (1-\gamma)/\gamma] [\gamma L^\beta \exp\{X'\psi + S + \eta\} / C]^{1/(1-\gamma)}, \quad (18)$$

$$V_T = C \exp\{(1-\theta)S\} [LO + (L^\beta \exp\{X'\psi + \theta S + \eta\} / 2C)^{1/(1-\gamma)}]. \quad (19)$$

V_0 is simply the expected net return to cultivating land owned. V_{LL} is the return that the household would expect from leasing out all of its land, $C*LO$, (where C is equal to its marginal product in equilibrium), plus the difference between its marginal product and the average product it expects to obtain on the land it retains. V_T is the amount of land cultivated by the tenant plus LO , the term in $[\]$, times one half of the average product on that land *expected by landlords* (C in equilibrium) adjusted by the difference between the landlords' expectations and the tenant's expectations. If $S = 0$ or if landlords are perfectly informed ($\theta = 1$) then their expectations coincide and this term falls out.

4. The Estimation Procedure

The model is estimated using maximum likelihood. The contribution to the likelihood function for a given dynasty is the joint probability of observing its actual combination of land cultivated and output levels in each year, conditioning on its land owned and assets. For any observed leasing choice there are some combinations of the unobservables (η , S) which are inconsistent with that choice. This is discussed at length in the appendix where it is also shown that the likelihood does not have an explicit form unless $2\gamma > 1$. Assuming that this parameter restriction holds, the contribution to the likelihood function of a given household is:

$$\frac{1}{\sigma_\epsilon \sigma_\eta \sigma_S} \int_S \left[\prod_{L, T} \phi(\epsilon) \phi(\eta) \cdot \prod_0 \left[\int_{\eta'}^{\eta^*} \phi(\epsilon) \phi(\eta) d\eta \right] \right] \phi(S) dS \quad (20)$$

where $\phi()$ is the standard normal density function and the subscripts LL, T, 0 beneath the product operators indicate contributions to the likelihood in years when a household has the tenorial status landlord, tenant or non-participant, respectively. The integrand η' represents the maximum value of η for a household to lease out, defined by setting $h_{LL} = LO$:

$$\eta' = \ln [LO^{(1-\gamma)} C / \gamma L^\beta \exp\{X'\psi + S\}]. \quad (21)$$

Similarly, η^* represents the minimum value of η necessary for a household to lease in land, defined by setting $h_T = LO$:

$$\eta^* = \ln [2LO^{(1-\gamma)} C / L^\beta \exp\{X'\psi + \theta S\}]. \quad (22)$$

The probabilities are¹⁶:

$$\begin{aligned} \text{Landlords:} \quad \phi(\epsilon) &= \phi[\{\ln(y) - \ln(h) - \ln(C/\gamma) - \mu_\epsilon\} / \sigma_\epsilon] \\ \phi(\eta) &= 0 \quad \text{for } S < 0, \theta < 1 \text{ and } \eta > \eta^*; \text{ or } S > 0, \theta > 1 \text{ and } \eta > \eta^*, \\ &= \phi[\{(1-\gamma)\ln(h) - \beta\ln(L) - X'\psi - S + \ln(C/\gamma) - \mu_\eta\} / \sigma_\eta] \quad \text{else.} \end{aligned}$$

¹⁶ η^* is the value of η where there is a discontinuity in the land cultivated equation in cases where a discontinuity occurs as depicted in figure 1b. See the appendix for details.

$$\begin{aligned} \eta^* &= (1-\gamma) \left[\ln\{ LO [\exp\{(1-\theta)S\} - 1] \} \right. \\ &\quad \left. - \ln\{ [(1-\gamma)/\gamma][\gamma L^\beta \exp\{X'\psi + S\}/C]^{1/(1-\gamma)} - [\exp\{(1-\theta)S\}][L^\beta \exp\{X'\psi + \theta S\}/2C]^{1/(1-\gamma)} \} \right] \end{aligned}$$

$$\begin{aligned}
\text{Tenants:} \quad \phi(\epsilon) &= \phi[\{\ln(y) - \ln(h) - (1-\theta)S - \ln(2C) - \mu_\epsilon\} / \sigma_\epsilon] \\
\phi(\eta) &= 0 \quad \text{for } S < 0, \theta < 1 \text{ and } \eta < \eta^x; \text{ or } S > 0, \theta > 1 \text{ and } \eta < \eta^x, \\
&= \phi[\{(1-\gamma)\ln(h) - \beta\ln(L) - X'\psi - \theta S + \ln(2C) - \mu_\eta\} / \sigma_\eta] \quad \text{else.}
\end{aligned}$$

$$\begin{aligned}
\text{Non-Participants:} \quad \phi(\epsilon) &= \phi[\{\ln(y) - [\gamma\ln(h) + \beta\ln(L) + X'\psi + S + \eta] - \mu_\epsilon\} / \sigma_\epsilon] \\
\phi(\eta) &= \phi[\{\eta - \mu_\eta\} / \sigma_\eta].
\end{aligned}$$

$$\text{For all households:} \quad \phi(S) = \phi[\{S - \mu_S\} / \sigma_S].$$

For *any* observed leasing behavior there are some levels of S which are inconsistent with that behavior. In the case of non-participation this is dealt with by explicitly bounding S so as to remain in a region with a strictly positive probability of non-participation. The bound is $S_b = [\ln(1/2\gamma)] / (1-\theta)$. If $\theta < 1$ S_b is a minimum and if $\theta > 1$ it is a maximum. As $\theta \rightarrow 1$, $S_b \rightarrow +/\infty$. If a household is active in the leasing market in all surveyed years, S is integrated over the range $(-\infty, \infty)$ with inconsistent events given probability zero via $\phi(\eta)$. Details are in the appendix.

The parameters of the model were estimated using data on 76 households which cultivated in both years as well as a smaller set of data on households which cultivated in a single year (19 in 1974 and 10 in 1983). The households surveyed in a single year do not, of course, contribute to the estimation of the parameters related to skill, σ_S and θ , directly but they are included to improve the efficiency of the other estimates.

A problem arises if one attempts to estimate the model as specified above directly. The problem lies in the probability $\phi(\eta)$ for tenants. The numerator of the equation for η contains the term $[\ln(2C) - \alpha_0]$ (recall that α_0 is part of $X'\psi$). Only the parameter C , and not α_0 , appears in the probability $\phi(\epsilon)$. By setting α_0 equal to the $\ln(2C)$ which maximizes the probability $\phi(\epsilon)$ and setting all other coefficients to zero, one can ensure that η is exactly zero, and thus $\phi(\eta)$ positive, regardless of the value of σ_η . At

this point the likelihood $\rightarrow \infty$ as $\sigma_\eta \rightarrow 0$ so the global maximum-likelihood estimator is inconsistent. (An analogous situation arises in the switching regression model. See Quandt and Ramsey, 1978.)

However, there is a consistent local maximum likelihood estimator in the interior of the parameter space which can be found in this case by estimating the parameters in two stages. In the first stage the likelihood of observing the sample output levels is maximized with respect to a subset of the parameter vector, $\lambda_1 = \{\gamma, \sigma_s, \sigma_e, \theta, C\}$. In the second stage, the full likelihood function is maximized with respect to the remaining parameters, $\lambda_2 = \{\beta, w, \alpha_0, \alpha_1, \alpha_2, \alpha_3, \sigma_\eta\}$, conditional on the parameter estimates obtained in the first stage, $\hat{\lambda}_1$. (For a proof of the equivalence of the limit distributions found by maximizing the likelihood in one and two stages see Amemiya, 1985, 4.2.5.)

The model was estimated using a combination of hill climbing and quasi-Newton search algorithms with numerical forward difference gradients. Integrals with respect to η and S were estimated by numerical quadrature with an eight node approximation¹⁷. Using the two-stage procedure described above, the search algorithm converged to the same location from a wide range of starting values. No bounds were imposed on the parameters. Starting values were chosen with $2\gamma < 1$ and this was never breached during estimation.

Alternative Estimation Approaches

Given the rather complex nature of this modelling and estimation approach it might be asked whether there are simpler, but still reasonable, alternative approaches. One possible alternative would be to estimate a household fixed effects model using those observations with output data for both years to get a measure of S for each household. Then using data on tenants alone one could estimate an equation for land cultivated, with θ the coefficient on the household fixed effect. However, multiple problems arise. First, and most obviously, it is explicit in this approach (as in all those discussed here) that land cultivated is related to both other observed inputs and to components of the disturbance term in the output equation. Thus coefficient estimates would be biased and inconsistent. In fact, looking at

¹⁷ No appreciable changes in the location of convergence were found with finer degrees of approximation.

the probability component $\phi(\epsilon)$ for landlords one can see that land cultivated completely encapsulates S and estimated fixed effects would be zero. In the absence of suitable instruments for land cultivated this problem is insurmountable. Further, land cultivated equations vary across tenurial status and any subsetting of the data in this dimension generates sample selection biases as tenurial status is, itself, a function of unobservable household characteristics. This could be dealt by modelling the selection process but then one is approaching the spirit of the model used here. Finally, a fixed effects approach entails a large drop in the degrees of freedom.

A second approach, treating skill as a random effect, could be implemented by estimating an output equation using data for tenants only and decomposing the variance of the residuals. That part due to a within household component would be an estimate of σ_s^T , the variance of skill levels *among tenant households*. (This differs from σ_s because tenurial status is not independent of S .) Then one could estimate a land cultivated equation and perform a similar decomposition to obtain an estimate of $\theta^2 \sigma_s^T$ (see the probability $\phi(\eta)$ for tenants above). An estimate of θ follows from a comparison of these two. All of the problems noted above arise with this approach including a loss of efficiency which is here due to utilizing only data on tenant households.

5. Results and Concluding Comments

Before turning to the estimation results, two points of interpretation should be noted. First, any mismeasurement in owned assets biases coefficient estimates towards zero and could lead to a failure to reject separability. This is most likely to be an issue with respect to bullocks which are measured in terms of stock value rather than service flow. Second, if ownership of an asset is endogenous, and in particular related to a household's skill level, the coefficient on that asset will be have a positive bias. This could lead to a rejection of separability, that is, ownership might be found to be correlated with output, but the interpretation would be incorrect. Again, this concern is most relevant to bullocks. In the absence of other variables to use as instruments this problem is unavoidable, however the discussion in section one would suggest that the adjustment of durable assets via purchase/sales is unlikely to be a major concern.

The estimation results are presented in Table 2. The first two columns contain estimated

parameter values and standard errors for a general version of the model allowing for differences across the years in most of the production function coefficients, as well as the variances of the unobservables. In the third and fourth columns are estimates for a restricted version of the model which constrains the production function to be the same across periods, sets $\sigma_{\eta t} = \sigma_{\eta}$, and $w = \alpha_2 = \alpha_3 = 0$. The restricted version can be rejected at $\alpha > .01$ ($\chi^2(8) = 19.15$).

The standard errors of the parameter estimates, $\sigma(\hat{\lambda})$, are estimated with a design matrix bootstrap procedure. The data were randomly resampled, the model re-estimated using each new sample, with standard errors then calculated from the resulting set of estimated parameter vectors. The parameter estimates presented in Table 2 are the mean of the resample estimates.

Turning first to the coefficients on observed inputs, we find that both the family labour supply and bullock ownership have a significant impact on household production. This result supports the contention that imperfections in input markets motivate land leasing and help to explain the pattern of leasing across households. It also has the important implication that farm household production and consumption decisions are not separable and must be modelled and estimated taking into account their simultaneity.

If one makes the rather extreme assumption that input markets are completely imperfect, so that owned inputs equal utilized inputs (no mismeasurement), then these estimates can be interpreted as production function coefficients. While the coefficient on labour, β , was constant over the period, that on land, γ , increased. As a result, returns to scale appear to have increased over the period with $\hat{\beta}_t + \hat{\gamma}_t = .74$ in 1974 and $\hat{\beta} + \hat{\alpha} = .92$ in 1983. Statistically, however, constant returns to scale cannot be rejected in either period. (The t-statistic for $\gamma + \beta = 1$ is .753 for 1974 and .175 for 1983.)

The importance of bullock ownership appears to have declined over time, although not significantly. One explanation for this would be that the rental market improved over the period thus making *ownership* a less important determinant of the level of household cultivation. On the other hand, if the bullock rental market has not improved in efficiency then changes in $\hat{\alpha}_1$ would reflect changes in the production function parameter. The decline in $\hat{\alpha}_1$ is likely to reflect a change in the technology of production, with diesel engines providing an alternative source of power.

The parameter measuring the contribution to household production of women and boys relative to men, w , has a point estimate of .107. This is as predicted given the restrictions on female labour outside of the home in Palanpur.

The coefficients on the dummy variables for both forms of irrigation are insignificant. Ownership of a Persian wheel or pumping set does not appear to be an important contributor to household production indicating, again as expected, that the rental markets for irrigation devices are less imperfect than are those for labour and bullock power.

All of the components of the disturbance vector are significant and precisely estimated. There was a substantially higher variance in the unanticipated production shock, ϵ , in 1983 as compared to 1974. As noted in section one, overall the harvest in 1983 was poor. The result here suggests that the events leading to this low harvest had an idiosyncratic impact on cultivators. This could be for two reasons. Some causes of a low yield, such as pest attacks, may be localized in effect. In addition, farmers may vary in their ability to deal effectively with a common problem, such as drought.

The relatively small estimated variance in η would tend to support the claim that input markets are imperfect. The disturbance component η captures discrepancies between owned and utilized inputs which would be large if rental markets are active. While a small variance for this component could be due to households actively renting inputs if they were doing so to the same extent, a more plausible interpretation is that owned assets are a good measure of utilized inputs for most households.

Variation across households in farming ability, measured by $\hat{\sigma}_s$, is an important component of the unexplained variation across households in levels of productivity. That is, controlling for input ownership and allowing for (time variant) factors which are both observable, η , and unobservable, ϵ , to villagers, there remains a substantial degree of variation in the productivity of different cultivating households. A household with a skill level which is one standard deviation higher than the mean is 23 percent more productive than a household with the mean level of skill.

The estimated values of θ , 1.01 and 1.07, indicate that information as to which households are more or less productive is information which is widely known in the village. One can easily reject the null hypothesis that $\theta = 0$ (no information). One cannot reject the null hypothesis that $\theta = 1$ (perfect

information) in the unrestricted version of the model. In the restricted version, one can reject perfect information, but this not because villagers are uninformed but rather that they tend to overestimate skill differences slightly.

The finding that information about the farming skill of villagers is well-known lends support to theories which explain community-level institutions on the basis of common group information. At the same time, it casts doubt on the empirical relevance of those theories which are premised on the assumption that villagers are uninformed about important (unobservable) characteristics of their fellows. Explaining institutions such as sharecropping or interlinkages by reference to their virtues in ameliorating adverse selection problems or to promoting screening through self-selection, does not seem credible in this context.

Table 1

Descriptive Statistics

Variables	1974/75	1983/84
Real Value of Gross Agricultural Output (1,000 1974 Rs)		
- mean	5.66	3.68
- st. dev.	4.29	4.52
Land Cultivated (10 bighas)		
- mean	2.63	2.86
- st. dev	1.58	2.29
Adult Males		
- mean	1.54	1.71
- st. dev	0.76	1.40
Real Value of Draught Animals (1,000 1974 Rs)		
- mean	0.81	0.77
- st. dev	0.64	0.74
Pumpset Dummy		
- mean	0.07	0.27
- st. dev	0.26	0.45
Persian Wheel Dummy		
- mean	0.22	0.23
- st. dev	0.42	0.42
Number of cultivating households in data for given year	95	86
Wheat yields, actual kg. per bigha	114	97
Wheat yields, normal ¹ kg. per bigha	100	150-160
Price Index ²	100	140

Notes:

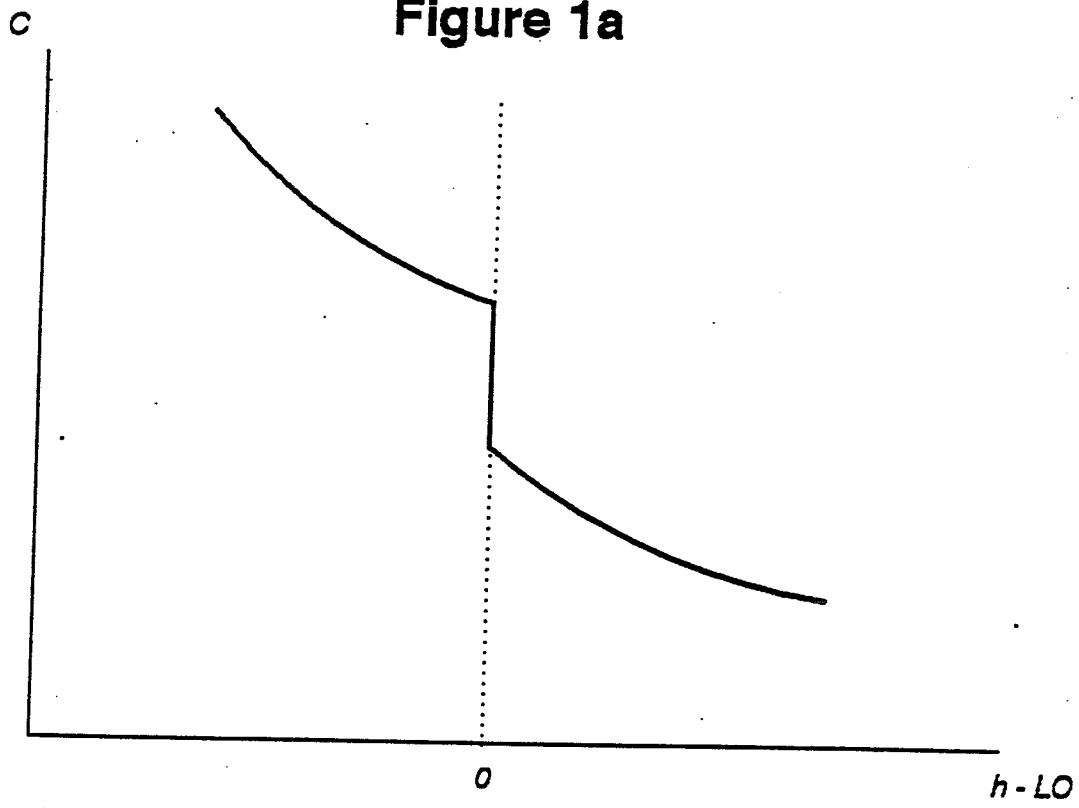
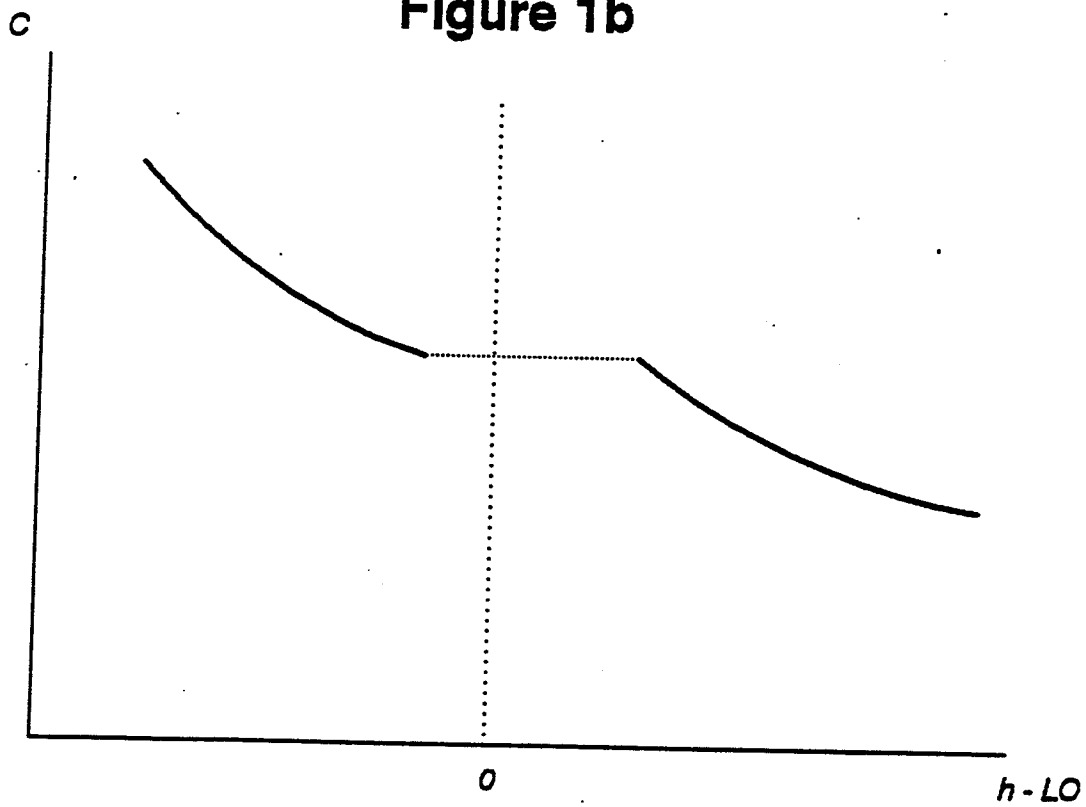
1. "Normal" yields correspond to farmers' expressed expected yields in advance of the year's harvest.
2. The consumer price index for agricultural labourers (CPIAL) from the Bulletin of Food Statistics.

Table 2
Maximum Likelihood Parameter Estimates

Parameters	Estimate ¹	Standard Error ²	Estimate	Standard Error
<i>Observed Inputs:</i>				
γ (land)	0.795**	0.097	0.622**	0.033
γ_7	0.573**	0.037	-	-
β (labour)	0.130**	0.055	0.070**	0.020
β_7	0.125**	0.087	-	-
w (women/boys)	0.107	0.126	-	-
α_0 (constant)	-0.687**	0.099	-0.575	0.059
α_{07}	-0.600**	0.085	-	-
α_1 (bullocks)	0.087**	0.046	0.154**	0.037
α_{17}	0.166**	0.051	-	-
α_2 (persian wheel)	0.050	0.044	-	-
α_3 (pump set)	0.012	0.074	-	-
<i>Errors</i>				
σ_s (skill)	0.208**	0.008	0.206**	0.001
σ_η (observed)	0.170**	0.073	0.163**	0.025
$\sigma_{\eta 7}$	0.155**	0.064	-	-
σ_ϵ (unobserved)	0.551**	0.063	0.536**	0.068
$\sigma_{\epsilon 7}$	0.281**	0.027	-	-
<i>Other:</i>				
θ (information)	1.011**	0.066	1.070**	0.020
C (equilibrium value)	0.294**	0.028	0.263**	0.021
C7	0.254**	0.009	0.261**	0.009
Log-Likelihood I	-128.22		-137.50	
Log-Likelihood II	-107.85		-117.42	

Notes:

1-2. Design matrix bootstrapped standard error estimates based on random resamples from the sample data (35 replications). Parameter estimates are means of the estimates derived from the resamples. ** indicates significance at $\alpha = 0.01$.

Figure 1a**Figure 1b**

Appendix

In order to specify the likelihood function it is necessary to consider the implications of various combinations of the two unobservables (η , S) which influence tenurial status - some combinations are inconsistent with some leasing choices. There are three possible scenarios. These are shown in figure 2, which shows levels of the value functions V_{LL} , V_T , and V_0 for different levels of the unobservable η , holding constant C , LO , A and S . (The figure also highlights the problem of selection bias which arises if tenurial status is not treated as endogenous.)

Let η' represent the maximum value of η at which a household just leases out if it decides to be a landlord household, i.e. η' is defined by setting $h_{LL} = LO$:

$$\eta' = \ln [LO^{(1-\gamma)}C / \gamma L^\beta \exp\{X'\psi + S\}].$$

Let η'' represent the minimum value of η necessary for a household to be *able* to lease in land, defined by setting $h_T = LO$:

$$\eta'' = \ln [2LO^{(1-\gamma)}C / L^\beta \exp\{X'\psi + \theta S\}].$$

Scenario one

$$\eta' < \eta'', \text{ and } \partial V_T / \partial \eta > \partial V_0 / \partial \eta \text{ evaluated at } \eta''.$$

A necessary and sufficient condition for the second part to hold for all households is that $2\gamma > 1$. $\partial h_T / \partial \eta > 0$ and this parameter restriction ensures that $d\pi/dh_T$ is strictly positive (see the derivative under the confirmation of [A2]).

In this scenario, households with $\eta < \eta'$ choose to become landlords. Those with $\eta > \eta''$ are both able and willing to become tenants and those in between cultivate their own land and do not participate in the leasing market.

Scenario two

$$\eta' > \eta^*, \text{ and } \partial V_T / \partial \eta > \partial V_0 / \partial \eta \text{ evaluated at } \eta^*.$$

Again a necessary and sufficient condition for the second part is $2\gamma > 1$. The level of η at which the value of leasing out equals the value of leasing in, i.e. where $V_T = V_{LL}$, is denoted by η^* . Setting V_T equal to V_{LL} , one finds that

$$\eta^* = (1-\gamma) \left[\ln \{ LO [\exp\{(1-\theta)S\} - 1] \} \right. \\ \left. - \ln \{ [(1-\gamma)/\gamma][\gamma L^{\theta} \exp\{X'\psi + S\}/C]^{1/(1-\gamma)} - [\exp\{(1-\theta)S\}][L^{\theta} \exp\{X'\psi + \theta S\}/2C]^{1/(1-\gamma)} \} \right].$$

For a household falling under this scenario, if $\eta < \eta^*$ it prefers to lease out and if $\eta > \eta^*$ it prefers to lease in. (Note that in either case the minimum amount of leasing is bounded away from zero.) Households falling under this scenario never choose to be non-participants.

It can readily be shown from the equations for η' and η^* that the first inequality can occur only in two situations, both involving imperfect information. First, if $\theta < 1$ it can occur only for households with $S < 0$. The intuition is that the situation of a household wanting to lease out ($\eta < \eta^*$) while being able to lease in ($\eta > \eta'$) can only arise if the household is not very skilled (hence the desire to lease out) but landlords are not aware of this negative quality (hence the ability to lease in). The second case is if $\theta > 1$ and $S > 0$. Here it is possible to find a household wanting to lease out because of a low η but simultaneously being able to lease in because landlords overestimate the household's skill level and hence are willing to lease to them.

Scenario three

$$\eta' < \eta^*, \text{ and } \partial V_T / \partial \eta \leq \partial V_0 / \partial \eta \text{ evaluated at } \eta^*.$$

In this scenario we have the phenomenon that at the levels of η at which other agents are willing to lease to a household, i.e. η greater than η^* , the household prefers not to enter the leasing market. It is only at higher levels, indicated by η^+ , that the household is also willing to lease in. The level of η at which the curves cross, η^+ , is defined implicitly by $V_T = V_0$ but it does not have an analytical solution.

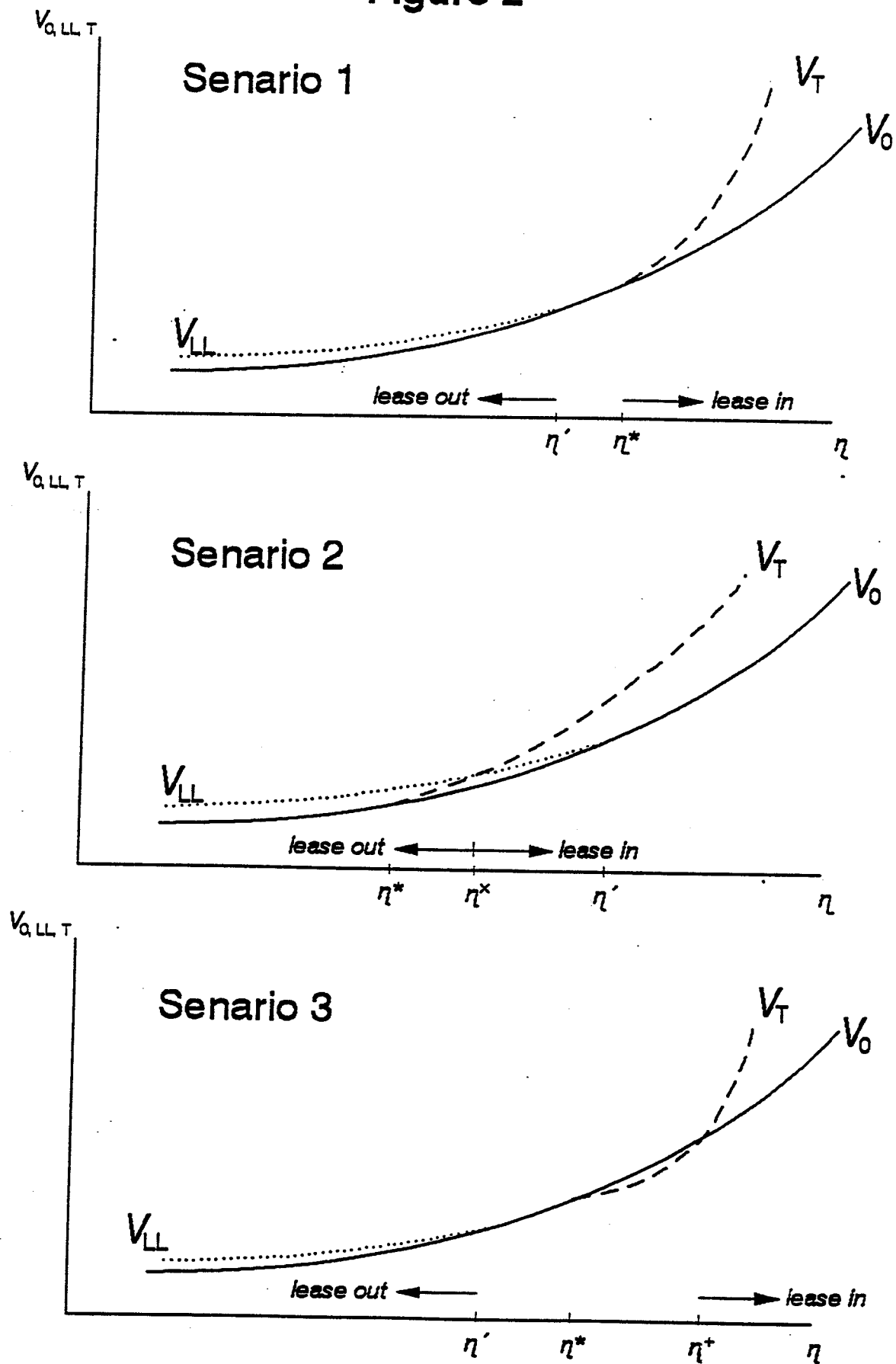
In this scenario, households with $\eta < \eta'$ lease out. Those with $\eta > \eta^+$ lease in. Those between

do not participate, either because they are not able to ($\eta' < \eta < \eta''$) or because they are able but prefer not to ($\eta'' < \eta < \eta'$).

As indicated under scenarios one and two, [$2\gamma < 1$], for *any* observed leasing behavior there are some levels of S which are inconsistent with that behavior. In the case of non-participation this is dealt with in the estimations by explicitly bounding S to remain in scenario one where there is a strictly positive probability of non-participation. In the case where leasing occurs, inconsistent events are given probability zero. (See the discussion under scenario two and the definition of $\phi(\eta)$ in the text).

Similar issues arise if $2\gamma > 1$ but they are more difficult to handle because η^+ does not have an analytic expression. One can show that η^+ exists and is unique. Uniqueness: Noting, as above, that $\partial h_T / \partial \eta > 0$, and the fact that once the amount of land available on lease to a household is attractive to it (that is, greater than h^*), then increasing amounts of land are even more so, it is clear that there can be at most a single crossing of the V_T and V_0 curves. Existence: V_T equals a tenant's total output times his share, $[1/2 + 1/2(LO/h_T)]$. $\partial h_T / \partial \eta > 0$ so the share of total product received by a tenant approaches a floor of $1/2$ as η increases. Since $\partial y / \partial \eta > 0$ and $\partial^2 y / \partial \eta \partial h > 0$, the ratio of the output of a household if it chooses to lease in relative to its output if it cultivates only its owned land increases in η without bound. Thus there exists some level of η for which $V_T > V_0$. (As $LO \rightarrow 0$, $\eta^* \rightarrow -\infty$ and $V_T > V_0$ everywhere.) Because a crossing point exists and is unique, given the equations for V_0 and V_T it could be estimated with a fixed point algorithm. However, to do so - for every function evaluation - would increase estimation time dramatically and add an additional layer of approximation. As a practical matter, starting values were chosen with $2\gamma < 1$ and this was never breached during estimation.

Figure 2



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