Testing for Separation in Agricultural Household Models and Unobservable Household-Specific Effects

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Abstract

When market structure is complete, factor demands by households will be independent of their characteristics, and households will take their production decisions as if they were profit-maximizing firms. This observation constitutes the basis for one of the most popular empirical tests for complete markets, commonly known as the "separation" hypothesis. In this article, we show that most existing tests for separation using panel data are potentially biased towards rejecting the null-hypothesis of complete markets, because of the failure to adequately control for unobservable household-specific effects. Since the variables on which the test for separation is based cannot be identifed in most panel datasets following the usual covariance transformations, and are likely to be correlated with the household-specific effect, neither the within nor the variance-components procedures are able to solve the problem. We show that the Hausman-Taylor 1981 estimator, in which the impact of covariates that are invariant along one dimension of a panel can be identifed through the use of covariance transformations of other included variables that are orthogonal to the household-specific effects as instruments, provides a simple solution. Our approach is applied to a rich Tunisian dataset in which separation —and thus the null of complete markets— is strongly rejected using the standard approach, but is not rejected once correlated unobservable household-specific effects are controlled for using the Hausman-Taylor instrument set.

Keywords: panel data, household-specific effects, household models, testing for incomplete markets, development microeconomics, Tunisia.

JEL: O120, C230, D130, D520.

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One of the most widely-used empirical tests for the presence of market imperfections in developing countries is provided by the so-called "separation" hypothesis. Numerous papers, including the seminal article by Benjamin (1992), have tested the hypothesis that factor demands on a farm will be independent of household characteristics, when market structure is (almost) complete. The early litterature is well summarized in Singh, Squire, and Strauss (1986), while Udry (1999) covers the more recent literature as well as providing two careful applications to African plot-level data.

Separation implies that the marginal productivity of inputs will be a function solely of plot characteristics and prices, and that households take their production decisions as if they were risk-neutral profit-maximizing firms. In contrast, when factor demands are a function of household characteristics, marginal productivities are not equated across households and production is inefficient.

The purpose of this article is to demonstrate that: (i) in most cases, the standard test for separation using panel data is biased towards rejecting the null-hypothesis of complete markets because of a problem of unobservable household-specific effects; (ii) the usual covariance transformations performed on panel data cannot solve this problem; but (iii) the Hausman and Taylor (1981) estimator can. After developing a simple plot-level household model that provides a coherent framework within which to examine the separation hypothesis, we show, using a rich plot-level Tunisian dataset, that the null-hypothesis of complete markets is rejected using the standard approach, while it is not once correlated household-specific, time-varying effects are controlled for using the Hausman-Taylor estimator.

The intuition behind our approach

In a plot-level version of the test for separation, the equation being estimated on agronomic data is given by:

$$(1) \quad Y_{iht} = X_{iht}\delta + Z_{ht}\gamma + \varepsilon_{iht},$$

where Y_{iht} is labor usage on plot i, cultivated by household h, at time t, X_{iht} is a matrix of plot characteristics, Z_{ht} is a matrix of household characteristics, and ε_{iht} is a disturbance term that satisfies the usual Gauss-Markov assumptions. Separation is then associated with a simple F-test on the exclusion restriction that $\gamma = 0$. In one of the best-known versions of the test for separation (Benjamin 1992), Z_{ht} is household size.

The main problem associated with this procedure is that the disturbance term ε_{iht} can be decomposed into a nested error components structure given by:

$$(2) \quad \varepsilon_{iht} = \mu_t + \lambda_h + \lambda_{ht} + \eta_{iht},$$

where μ_t is a shock common to all plots and households at time t, λ_h is a time-invariant household effect, λ_{ht} is a household-time effect, and η_{iht} is a disturbance term that satisfies the usual assumptions (see Baltagi, Song and Jung 2001). In most plot-level datasets used in the literature, each household cultivates several plots. This is a standard panel data framework, with one dimension being given by plots, the second by households, and the third by time. Although λ_h can be accounted for by a "within" procedure which transforms variables into deviations with respect to their household-specific means (over *all* time periods), there remains λ_{ht}. Since it is probable that λ_{ht} is correlated with Z_{ht}, the least-squares estimate of γ, even after the standard "within" transformation, will be biased with, in the scalar case:

$$\text{(3)} \quad \operatorname{p\,lim} \widehat{\gamma}_w = \gamma + \frac{cov[\lambda_{ht}, \hat{e}_{iht}]}{\sigma_e^2},$$

where σ_e^2 is the variance of the residual $\hat{e}_{iht}$ from the auxiliary "within" regression of household size on X_{iht} (see Hsiao 1986, p. 64, equation (3.9.3)).[1] If $cov[\lambda_{ht}, \hat{e}_{iht}] \neq 0$, as is likely in the context of what is essentially a labor demand equation, then *all standard tests of separation are biased towards rejecting the null-hypothesis of complete markets*, when the "true" value of γ is zero. One may therefore reject the null not because market structure is necessarily incomplete, but simply because of a banal problem of unobservable heterogeneity. Conversely, assume that the population value of γ is positive (say, because, labor markets are imperfect and labor usage is therefore an increasing function of household size), but that $cov[\lambda_{ht}, \hat{e}_{iht}] < 0$. In the case of a factor demand equation, the second hypothesis is likely to be the case (for an empirical example, see Gardebroek and Lansink 2003, who find a negative, though insignificant, correlation between the household-specific effect and family labor availability, in the context of two variable input demand equations). Then standard tests of the separation hypothesis could fail to reject the null, if these two effects cancel out.

The usual econometric response to a problem of unobservable heterogeneity in panel data is to apply one of the standard covariance transformations, such as the "within" procedure. Here, this would involve expressing all variables as deviations with respect to their household-specific means, *at a given t*. While, under the assumption of the exogeneity of the explanatory variables with respect to η_{iht}, this does allow one to recover unbiased estimates of δ, it has the regrettable side-effect of eliminating the variable(s) upon which the test for separation is based since, when one sweeps out λ_{ht}, one also sweeps out Z_{ht}. Since it is highly likely that λ_{ht} is not orthogonal to Z_{ht}, random effects are not an answer, as they too will yield biased estimates of γ.

Moreover, standard instrumental variables (IV) procedures, in which one would simply instrument for Z_{ht}, are not usually implementable. This is because admissible exogenous IVs that would be correlated with Z_{ht} but are orthogonal to λ_{ht} are usually not available or, if they are, should probably already be included in Z_{ht} for theoretical reasons.

The problem, which is similar in spirit to that of consistently estimating the returns to education using panel data when schooling is correlated with the individual effects, can be solved using the Hausman-Taylor (1981, henceforth, HT) IV estimator, which permits one to control for unobservable household-specific, time varying effects that are correlated with Z_{ht}, while allowing one to identify γ. Our work builds on previous applications of the HT estimator to the problem of understanding differences in productivity among farms using two-dimensional (farm (h)-time period (t)) panel datasets. Gardebroek and Lansink (2003) consider the determinants of productivity differentials among specialized pig breeding farms in the Netherlands, and interpret the correlation between time-invariant farm variables and the farm-specific effects in a total factor productivity context. Deininger and Olinto (2000), for their part, use the HT estimator in order to assess the impact on the productivity of Zambian farmers of time-invariant household characteristics such as female-headship, distance to market, the availability of extension services, and farmer education. To the best of our knowledge, however, the HT estimator has not been used in the context of the debate concerning the separation hypothesis, and has not been applied to plot-level data.

A simple household model

In what follows, we consider a simple theoretical model of a household composed of two members, and which cultivates several plots of land. We do this because our use of plot-level Tunisian data in the empirical portion of this article, rather than data aggregated at the farm level, raises several interesting issues that have not been adequately underscored in the context of the literature on the separation hypothesis, with the notable exception of Udry (1996, 1999). We begin by presenting the Pareto-optimal baseline, and show that the separation property holds at the plot level, meaning that the marginal productivities of family and hired labor will be equated across plots cultivated by a given household, as well as between households. In the next section of the article, we will consider five different market imperfections that can lead to distinct patterns of violations of the separation null. For readers unfamiliar with household models as applied to developing country agriculture, a useful primer is provided by Bardhan and Udry (1999).

We assume that there are two types of family members, men and women, and two types of hired labor, male and female. This corresponds to the situation in the Tunisian village that will be the object of our empirical analysis. Consider a household, indexed by h, constituted by two members indexed by $j = M, F$, that cultivates several plots of land, indexed by $i = 1, ..., I_h$. Individual j consumes a quantity c_k^j of good $k = 1, ..., K$; c^j is therefore the $1 \times K$ vector of private goods consumed by individual j, whereas total household consumption is given by the $1 \times K$ vector $c = c^M + c^F$. Total labor supply of individual j is equal to L^j. Public goods produced within the household are given by Z. Preferences of individual j are given by $U^j = U^j \left(c^M, c^F, Z, L^M, L^F, \Omega\right)$, where Ω is a vector of taste shifters such as household demographics or land ownership. This specification of preferences allows for joint household production, as well as for altruism between household members.

Consider a plot, indexed by i, that is cultivated in crop k. Then output on such a plot is given by $q_i^k = F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)$, where A_i represents the characteristics of plot i, including plot size, soil type and irrigation status, and H_i^j (L_i^j) is hired (family) labor of sex j used on the plot. Using the notation in Udry (1996), where the set of plots cultivated in crop k are denoted by $P^k = \{i|\,\text{crop } k \text{ is grown on plot } i\}$, the total production of crop k by the household is given by:

$$(4) \quad q^k = \sum_{i \in P^k} q_i^k = \sum_{i \in P^k} F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right), k = 1, ..., K,$$

and the $1 \times K$ vector of outputs of all goods is given by $q = \left(q^1, ..., q^k, ..., q^K\right)$. Public good production within the household is given by:

$$(5) \quad Z = Z\left(L_Z^M, L_Z^F\right).$$

The time constraint of household member j is given by:

$$(6) \quad L^j = L_Z^j + \sum_i L_i^j + L_W^j, j = M, F,$$

where L_W^j is household member j's time on the labor market. Finally, letting $p = \left(p^1, ..., p^k, ..., p^K\right)$ denote the $1 \times K$ vector of output prices, the household's budget constraint is given by:

$$(7) \quad pc' \leqslant pq' - w^M \sum_i H_i^M - w^F \sum_i H_i^F + w^M L_W^M + w^F L_W^F + I,$$

where w^j denotes the wage rate paid to hired labor of sex j, and I is non-labor income. From the usual corollary to the First Theorem of Welfare Economics (see e.g. Varian 1978), and for any Pareto weight $\lambda > 0$, the intra-household allocation of resources will be Pareto-optimal as long as it solves the problem:

$$(8) \qquad \max_{\{c,L,H,P^k\}} U^M + \lambda U^F \quad s.t. \;\; (4),(5),(6) \text{ and } (7).$$

It is then straightforward to show that the necessary first-order conditions (FOCs) associated with (8) imply that:

$$(9) \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j} = \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} = \frac{w^j}{p_k},$$

for $k = 1, ..., K, j = M, F, i = 1, ..., I_h$. The conditions given in (9) state that the marginal productivity of family labor of sex j will be equated to the marginal productivity of hired labor of the same sex in the production of a given crop, and that these marginal productivities will be the same across all plots cultivated by a given household, as well as *between* households.

Market imperfections

The literature on household models is replete with examples of market imperfections that lead to violations of the conditions that underly separation. In what follows, we consider the most commonly appealed to market imperfections and examine their consequences on the optimality conditions derived above. These market imperfections include credit constraints, labor market imperfections, imperfect land rental markets or tenure rights, imperfect insurance markets, marketing constraints, or various combinations of these.

Credit constraints

Consider the problem given in (8), to which we append a working capital constraint of the form $w^M \sum_i H_i^M + w^F \sum_i H_i^F - w^M L_W^M - w^F L_W^F - I \leqslant B$, where B is the working capital available to the household. The assumption in models of this type is that factor payments must be made at the beginning of the season, leading to the need for short-term credit. Examples of household models that concentrate on credit constraints (often in combination with imperfect supervision of hired labor) as a source of non-separation include Eswaran and Kotwal (1986), Feder (1985), Feder et al. (1990) and Carter and Wiebe (1990). Let μ denote the Lagrange multiplier associated with the household's budget constraint (equation (7)), and let φ denote the Lagrange multiplier associated with the credit constraint. Then the ensuing FOCs imply that:

$$\text{(10a)} \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} = \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j}$$

$$\text{(10b)} \qquad = \left(\frac{\mu(\Omega, I, B) + \varphi(\Omega, I, B)}{\mu(\Omega, I, B)}\right)\frac{w^j}{p_k},$$

for $k = 1, ..., K, j = M, F, i = 1, ..., I_h$. These conditions imply that the marginal productivities of family and hired labor of sex j are equated across plots cultivated by a given household. In contrast to the separable case, marginal productivities differ *between* households, because of the presence of the Lagrange multiplier φ, which is household-specific, and will be a function of household characteristics (Ω, I, B).

Labor market imperfections

Labor market imperfections constitute one of the most commonly appealed to sources of violations of the separation hypothesis. Representative examples in the literature include Lopez (1984), Benjamin (1992), Jacoby (1993), Skoufias (1994), Lambert and Magnac (1995), Sadoulet, DeJanvry and Benjamin (1998), Sonoda and Maruyama (1999), and Bowlus and Sicular (2003). Consider a constraint on the amount of labor that a household can "export" on the labor market: $L_W^j \leqslant \overline{L}_W^j$. Then, denoting the Lagrange multipliers associated with these constraints by ψ^j, the ensuing FOCs imply that:

$$\text{(11a)} \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j} = \frac{w^j}{p_k},$$

$$\text{(11b)} \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} = \frac{w^j}{p_k} - \frac{\psi^j(\Omega, I, \overline{L}_W^j)}{\mu(\Omega, I, \overline{L}_W^j)p_k},$$

for $k = 1, ..., K, j = M, F, i = 1, ..., I_h$. The first condition implies that the marginal productivity of hired labor will be equated across plots cultivated by the same household, as well as across plots cultivated by different households. The second condition implies that the marginal productivity of family labor will be equated across plots cultivated by a given household, but will not be the equated across households. Moreover, the marginal productivities of family and hired labor will not be equated within households.

Now consider a constraint on the other side of labor market that takes the form of a limit on the amount of labor that the household can hire: $\sum_i H_i^j \leqslant \overline{H}^j$. Then, denoting the Lagrange multiplier associated with these constraints by ψ^j, the FOCs associated with the problem imply that:

$$\text{(12a)} \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j} = \frac{w^j}{p_k} + \frac{\psi^j(\Omega, I, \overline{H}^j)}{\mu(\Omega, I, \overline{H}^j)p_k},$$

$$\text{(12b)} \qquad \frac{\partial F^k\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} = \frac{w^j}{p_k},$$

for $k = 1, ..., K, j = M, F, i = 1, ..., I_h$. These conditions are the mirror image of those given in the case of labor exports. The first condition implies that the marginal productivity of hired labor will be equated across plots cultivated by a given household, but will differ between households. The second condition implies that the marginal productivity of family labor will be equated across plots cultivated by a given household, as well as between households. As with the constraint on the labor export side, the marginal productivities of family and hired labor will not be equated within households.

Marketing constraints

Consider a constraint that takes the form of an upper bound $\overline{Q}^l$ on the amount of crop l that the household can sell. More formally, the constraint in question can be written as $\sum_{i \in P^l} F^l\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right) - \left(c_l^M + c_l^F\right) \leqslant \overline{Q}^l$. Letting ϕ^l denote the Lagrange multiplier associated with the constraint, the FOCs that correspond to the problem then imply that, for those plots on which crop l is grown:

$$\text{(13a)} \qquad \frac{\partial F^l\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} = \frac{\partial F^l\left(L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j}$$

$$\text{(13b)} \qquad = \frac{\mu(\Omega, I, \overline{Q}^l) w^j}{\mu(\Omega, I, \overline{Q}^l) p_k - \phi^l(\Omega, I, \overline{Q}^l)},$$

for $k = 1, ..., K, j = M, F, i = 1, ..., I_h$. These conditions imply that the marginal productivities of family and hired labor are equated across plots cultivated by a given household in crop l, but that these marginal productivities will differ between households. For other crops $k \neq l$ that are not subject to the marketing constraint, the conditions given in the unconstrained case continue to hold.

Insurance market failure

Barrett (1996) and Kevane (1996) consider the effect on the separation hypothesis of imperfect insurance markets in conjunction with imperfect labor or land markets. Here, we focus on insurance market failure alone.

Assume that the production technology on plot i is now given by:

$$\text{(14)} \quad q_i^k = F^k\left(\theta_i, L_i^M, L_i^F, H_i^M, H_i^F, A_i\right),$$

where θ_i is a stochastic shock to production. If we denote the vector of stochastic shocks affecting all of the plots cultivated by household h by $\theta = (\theta_1, \theta_2, ..., \theta_i, ..., \theta_{I_h})$ which is assumed to be distributed according to the joint probability density function (*pdf*) $g(\theta)$ then the household's optimization problem is given by:

$$(15) \quad \max_{\{c,L,H,P^k\}} E_{\theta_h}\left[U^M + \lambda U^F\right] \quad s.t. \;\; (4), (5), (6) \text{ and } (7),$$

where $E_\theta\left[U^M + \lambda U^F\right] = \int \cdots \int \left(U^M + \lambda U^F\right) g(\theta)\, d\theta_1 d\theta_2 ... d\theta_i ... d\theta_{I_h}$. In the absence of an insurance market that would allow the household to equate the marginal utility of its consumption across states of nature (formally, this would imply a full set of state-contingent prices, one for each potential realisation of θ), the associated FOCs which implicitly define optimal labor inputs will then be given by:

$$(16a) \quad E_\theta\left[\left(\frac{\partial U^M}{\partial c_1^M} + \lambda\frac{\partial U^F}{\partial c_1^M}\right)\left(\frac{\partial F^k\left(\theta_i, L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial L_i^j} - \frac{w^j}{p_k}\right)\right] = 0,$$

$$(16b) \quad E_\theta\left[\left(\frac{\partial U^M}{\partial c_1^M} + \lambda\frac{\partial U^F}{\partial c_1^M}\right)\left(\frac{\partial F^k\left(\theta_i, L_i^M, L_i^F, H_i^M, H_i^F, A_i\right)}{\partial H_i^j} - \frac{w^j}{p_k}\right)\right] = 0,$$

for $j = M, F, i = 1, ..., I_h$.[2] The consequence of insurance market failure is that optimal input use on plot i is a function not only of plot i's characteristics but, through the marginal utility of consumption $\frac{\partial U^M}{\partial c_1^M} + \lambda\frac{\partial U^F}{\partial c_1^M}$, of the characteristics $(A_1, ..., A_i, ..., A_{I_h})$ of *all* of the plots cultivated by the household. Of course, since the marginal utility of consumption is a function of household characteristics, optimal input use will also be a function of household characteristics, and marginal productivities will differ between households. In the absence of other constraints, however, the marginal productivities of family and hired labor will be equated, within a given household.

The tenancy market

The existing literature has focused on imperfect land rental markets or tenure rights (Gavian and Fafchamps 1996; Carter and Yao 2002), as well as on the interraction between land and labor market imperfections (Carter and Olinto 2003). To the best of our knowledge, little or no attention has been devoted to the impact of share tenancy *per se* on the separation hypothesis.

Consider now a situation, as is the case in the Tunisian village that will be the focus of the empirical portion of this article, in which there is an active land rental market in which sharecropping and fixed rental contracts arise. Let

$$(17)\quad P^{km} = \{i|\,\text{crop } k \text{ is grown on plot } i \text{ under a contract of type } m\},$$

where $m = OO$ (owner operator), RI (rented in), RO (rented out), SI (sharecropped in), SO (sharecropped out). When a household rents in plot i under a sharecropping contract it retains a fraction α_i of output and pays a fraction β_i of the costs associated with the plot; when it rents in a plot under a fixed rental contract, it is residual claimant and *pays* a fixed rental equal to R_i; when it rents out a plot under a sharecropping contract, it retains a fraction $1 - \alpha_i$ of output and pays a fraction $1-\beta_i$ of costs; finally, when a household rents out a plot under a fixed rental contract, it *receives* a fixed rental payment equal to R_i. The household's budget constraint is therefore given by:

$$
\begin{aligned}
(18)\quad \sum_k p_k \left(c_k^M + c_k^F\right) \leqslant \sum_k \Bigg(& \sum_{i\in P^{kOO}\cup P^{kRI}} \begin{bmatrix} p_k F^k(.) \\ -\left(w^M H_i^M + w^F H_i^F\right) \end{bmatrix} \\
& + \sum_{i\in P^{kSI}} \begin{bmatrix} p_k \alpha_i F^k(.) \\ -\beta_i \left(w^M H_i^M + w^F H_i^F\right) \end{bmatrix} - \sum_{i\in P^{kRI}} R_i \\
& + \sum_{i\in P^{kSO}} \begin{bmatrix} p_k (1-\alpha_i) F^k(.) \\ -(1-\beta_i)\left(w^M H_i^M + w^F H_i^F\right) \end{bmatrix} + \sum_{i\in P^{kRO}} R_i \Bigg) \\
& + w^M L_W^M + w^F L_W^F + I,
\end{aligned}
$$

to which, temporarily redefining A_i so that it represents *only* the surface area of plot i, one must now append a constraint on land ownership: $\sum_{i\in P^O} A_i \leqslant A^O$, where $P^O = P^{OO} \cup P^{RO} \cup P^{SO}$ (the set of plots owned by the household) and where A^O represents household land ownership. Note that the household chooses factor input use on those plots (i) that it cultivates as an owner-operator ($i \in P^{kOO}$) and (ii) that it rents in either under a fixed rental (P^{kRI}) or a sharecropping contract ($i \in P^{kSI}$). It does not choose labor inputs on those plots that it rents out ($i \in P^{kSO} \cup P^{kRO}$).

Consider a household (the landlord, denoted by superscript L) that wishes to rent a plot indexed by s to a tenant (denoted by superscript T). Assume that the landlord's problem is given by a standard principal-agent specification with moral hazard, in which the landlord sets (α_s, β_s) and chooses the crop k to be grown on the plot, whereas the tenant chooses factor inputs. Let $\overline{V}^T$ denote the tenant household's reservation level of welfare. Then the landlord's optimization problem is given by

$$\max_{\left\{c^L, L^L, H^L, P^k, \alpha_s, \beta_s, s \in P^k\right\}} U^{LM} + \lambda^L U^{LF} \quad s.t. \;\; (4), (5), (6), (18) \text{ and } s.t.$$

$$\text{(19a)} \qquad \left(c^T, L^T, H^T\right) = \underset{\left\{c^T, L^T, H^T, P^k_{i \neq s}\right\}}{\arg\max} \; U^{TM} + \lambda^T U^{TF},$$

$$\text{(19b)} \qquad U^{TM} + \lambda^T U^{TF} \geqslant \overline{V}^T.$$

Constraint (19a) is the incentive compatibility constraint which stems from the tenant's input choices (among other things) being unobservable to the landlord, and it is the subset $\left(L_s^{TM}, L_s^{TF}, H_s^{TM}, H_s^{TF}\right)$ on the left-hand-side of (19a) that is of particular concern to us here. Constraint (19b) is the tenant's participation constraint.

The key point from the standpoint of the separation hypothesis is that the solution in $\left(\alpha_s, \beta_s, s \in P^k\right)$ to the landlord's optimization problem will be a function of tenant household characteristics (Ω^T, I^T, A^{OT}), and this will be the case even if the tenant's production decisions are *a priori* separable, because of the presence of the participation constraint. Since $\overline{V}^T$ will be a function of (Ω^T, I^T, A^{OT}), it follows that $\left(\alpha_s, \beta_s, s \in P^k\right)$ will be so as well. Moreover, if one replaces the simple principal-agent model sketched above by a Nash bargaining approach in which the terms of the tenancy contract depend on both parties' threat points, then the optimal contract will also be a function of the landlord's characteristics (Ω^L, I^L, A^{OL}).[3] The upshot is that the input choices taken by the operator household on a plot under a tenancy contract will be a function of the *effective* input prices, since the FOCs for the operator household that stem from the incentive compatibility constraint (19a) are given by:

$$\text{(20a)} \qquad \frac{\partial F^k\left(L_s^M, L_s^F, H_s^M, H_s^F, A_s\right)}{\partial H_s^j} = \frac{\partial F^k\left(L_s^M, L_s^F, H_s^M, H_s^F, A_s\right)}{\partial L_s^j}$$

$$\text{(20b)} \qquad = \frac{\beta_s(\Omega^T, I^T, A^{OT}, \Omega^L, I^L, A^{OL})}{\alpha_s(\Omega^T, I^T, A^{OT}, \Omega^L, I^L, A^{OL})} \frac{w^j}{p_k}.$$

While the input prices in (20b) are parametrically taken by the operator household, they are, by construction, functions of the household characteristics of both parties to the contract. As a result, marginal productivities will not be equated between households. Moreover, if a tenant household interacts with several landlords, the effective input prices will differ among plots: as such, marginal productivities will not necessarily be equated among the plots cultivated by a given tenant household.

Empirical implementation

The effects on the separation null of the market imperfections considered above imply that a number of household characteristics (Z_{ht} in equation (1)) are prime candidates for tests based on exclusion restrictions. Table 1 summarizes several empirical studies that have tested the separation hypothesis using exclusion restrictions based on household demographics (upper part of the table), as well as a number of related studies that, while not based on the framework set out in equation (1), test the separation hypothesis by directly estimating the marginal product of labor (lower part of table). The household demographics in question correspond to Ω in the theoretical model presented earlier, and the violation of the separation null in this case is often, though not exclusively, ascribed to imperfect labor markets.

Table 2 summarizes studies that are based on a broader set of exclusion restrictions, including various measures of wealth, land ownership, non-farm income and the area cultivated on other plots. Wealth and land ownership, while they may affect preferences (and hence enter Ω), may also be associated with easier access to credit, and may therefore correspond to an increase in B. An increase in land ownership (A^O in the theoretical discussion of tenancy), insofar as it is associated with an active land rental market, may also be associated with a relaxation of any credit constraints that may exist (to see this, it suffices to extract the appropriate working capital constraint from (18) and the land ownership constraint). Non-farm income, on the other hand, clearly corresponds to I. Finally, the area cultivated on other plots (which sometimes also appears as the total area cultivated by the household) is linked to the longstanding debate on the relationship between farm size and farm productivity. While the presence of a binding working capital constraint usually implies a significant (negative) effect of the area of other plots on plot labor demand, imperfect insurance markets can also lead to a similar result, if one (reasonably) collapses the vector $(A_1, ..., A_i, ..., A_{I_h})$ of the characteristics of all of the plots cultivated by the household (as in the section on insurance market failure) into the surface area of other plots (given that the surface of plot i is already included as an explanatory variable in any plot-level estimation).

Identification strategy

Before considering the use of the HT estimator in the context of tests of the separation hypothesis, which lies at the heart of this article, it is essential to address the empirical issues that flow from our theoretical treatment of tenancy. First, observe that it is essential to control explicitly for the effects of tenancy when estimating labor demand equations, since failure to do so (given that the terms of tenancy contracts are themselves functions of operator household characteristics —see equation (20b)), could result in a spurious rejection of the separation null. A second, related issue, is that crop choice, on plots under tenancy, is likely to be endogenous. Within the framework given by equations (1) and (2), this implies that a subset of X_{iht}, which we denote by X_{2iht}, will be correlated with $\lambda_{ht} + \eta_{iht}$.

Equation (20b) however, furnishes one with an appropriate identification strategy. Though operator household characteristics are indeed correlated with the terms of tenancy contracts and with crop choice, they appear as Z_{ht} in the structural form, and are therefore not admissible IVs. *Landlord* household characteristics, *expressed as deviations with respect to operator household time-specific means* (which we denote by

W_{iht}) are, on the other hand, admissible IVs, since they are by construction orthogonal to λ_{ht} (and thus orthogonal to Z_{ht} as well). Moreover, it is very likely that W_{iht} is orthogonal with respect to η_{iht}. Finally, W_{iht} will be correlated with the terms of the tenancy contracts (and with crop choice on plots under tenancy) as long as a sufficient number of tenants interact with more than one landlord.[4] This last condition (that the proposed IVs must be sufficiently "strong": $E[W'_{iht}X_{2iht}] \neq 0$) is essentially an empirical issue, and we demonstrate below that this appears to be the case in our data.

Crop choice, which is also correlated with $\lambda_{ht}+\eta_{iht}$, warrants additional attention, but this time because of a problem of degrees of freedom. As will be shown below, our Tunisian data provide a particularly rich characterization of tenancy, in that one can control for 8 effective inputs prices (cost-to-output share ratios β/α). But this wealth comes at a cost in that there are also 9 crops grown in the village. Despite possessing a plethora of landlord household characteristics with which to instrument the cost-to-output share ratios, these are not sufficient to instrument crop choice directly as well. The solution we adopt here is inspired by Thomas and Strauss (1997) who, while estimating a Mincerian wage equation while needing to control for a worker's sectoral choice, collapse the latter into a *scalar* hazard rate stemming from a first-stage multinomial logit procedure. Here, this means performing a multinomial logit estimation on crop choice, using landlord characteristics as explanatory variables (alongside other exogenous plot characteristics in order to avoid running a "forbidden regression"), and inserting the predicted hazard rate as an explanatory variable in X_{iht}, in place of the 8 crop choice dummies. Careful attention must then be paid to the estimated variance-covariance matrix at the second stage, given the generated nature of the regressor.

Identification of the operator household characteristics Z_{ht} while simultaneously controlling for household-time specific effects λ_{ht}, which constitutes the crux of our approach to testing the separation null, is achieved through the IVs provided by the HT procedure, to which we now turn.

Adapting the Hausman-Taylor instrument set

Consider the specification given in equation (1), where we divide X_{iht} into two parts: $X_{iht} = [X_{1iht}; X_{2iht}]$. Recall that X_{2iht} denotes those elements of X_{iht} that stem from tenancy (the cost shares and the predicted crop choice hazard rate) and that are correlated with $\lambda_{ht} + \eta_{iht}$. The problem of consistently estimating their impact on Y_{iht} was addressed above, using "conventional" excluded IVs. Setting X_{2iht} aside, let X_{1iht} be those remaining elements of X_{iht} that are uncorrelated with $\lambda_{ht} + \eta_{iht}$. The matrix of time-varying household characteristics Z_{ht} is assumed to be correlated with λ_{ht}, while being orthogonal to η_{iht}.[5]

The set of IVs proposed by HT (1981), adapted to the three-dimensional panel structure and to our slightly more complicated context in which $E[X'_{2iht}\eta_{iht}] \neq 0$ (in the original HT specification they assume that $E[X'_{2iht}\eta_{iht}] = 0$), is therefore $[Q_{vt}X_{1iht}; P_{vt}X_{1iht}]$, where P_{vt} and Q_{vt} are the idempotent matrices that perform the "between" and "within" transformations at time t, respectively. Under the assumption that X_{1iht} is uncorrelated with $\lambda_{ht} + \eta_{iht}$, $Q_{vt}X_{1iht}$ and $P_{vt}X_{1iht}$ are legitimate IVs since $E[(Q_{vt}X_{1iht})'(\lambda_{ht} + \eta_{iht})] = E[(P_{vt}X_{1iht})'(\lambda_{ht} + \eta_{iht})] = 0$. The basic intuition behind the HT estimator is that only the λ_{ht} component of the error term is correlated with Z_{ht}, which allows one to use $P_{vt}X_{1iht}$ as IVs for Z_{ht}. The HT estimator therefore allows one to control for unobservable correlated household-specific time-varying effects λ_{ht}, while allowing one to identify the parameters of interest (γ) in the context of testing for separation. A necessary condition for identification is that the number of elements of X_{1iht} be greater than the number of elements of Z_{ht} (HT 1981, PROPOSITION 3.2, p. 1385). These results have been extended by Amemya and MaCurdy (1986) and Breusch, Mizon, and Schmidt (1989) who suggest a broader set of IVs that should improve efficiency. Their approach, however, is only possible on balanced data, which is not the case in the dataset used in this article or, for that matter, in most plot-level agronomic datasets. Moreover, Baltagi and Khanti-Akom (1990) and Cornwell and Rupert (1988) have shown that the gains in efficiency obtained by using these extended HT instrument sets are very limited.

The usual manner of addressing the unbalanced nature of panel data in the context of the HT estimator is described by Gardner (1998), which Gardebroek and Lansink (2003) have extended to the context of system estimation. Here, we deal with the unbalanced nature of the panel and estimate the variance-covariance matrix in a slightly more flexible manner, for three reasons. First, given that one of the explanatory variables —the predicted crop choice hazard rate— is a generated regressor, we bootstrap all standard errors (using 500 replications). Second, while θ-differencing, as set out in the original HT procedure (and subsequently adapted by Gardner 1998), is the most efficient estimator when the error structure does indeed correspond to a random effects specification, it is highly likely in plot-level data that the disturbance term η_{iht} is correlated across plots operated by a given household. This implies a less stringent structure for the variance-covariance matrix, and involves clustering of η_{iht} at the household-time (ht) level. By allowing for arbitrary intra-cluster correlation and heteroskedasticity at the household-time level, we thus relax the assumption that the correlation within each cluster is constant and has a nested form. Finally, given that the key explanatory variables (Z_{ht}) are at a higher level of aggregation than the dependent variable, the usual arguments of Moulton (1986, 1990) suggest that failure to control for intra-household clustering will result in downward bias in the estimated standard errors.

In summary, our identification strategy is provided by a combination of conventional "excluded" IVs and those furnished by the HT procedure. The correlation of X_{2iht} with $\lambda_{ht} + \eta_{iht}$ is purged through the conventional IVs W_{iht}, whereas that between Z_{ht} and λ_{ht} is eliminated using the HT IVs $P_{vt}X_{1iht}$, with $Q_{vt}X_{1iht}$, the remaining component of X_{1iht}, identifying X_{1iht}. Notice also that identification of the parameters associated with the separation null (γ) is achieved entirely through the HT IVs (and not through W_{iht}), since $E[W'_{iht}Z_{ht}] = 0$ by construction.[6]

The three-dimensional nature of our dataset allows us an additional degree of freedom in terms of the definition of HT-type IVs. Above, we considered orthogonality conditions of a component of X_{iht} ($P_{vt}X_{1iht}$) with respect to $\lambda_{ht}+\eta_{iht}$. But the three-dimensional nature of the data also allows us to construct IVs based on orthogonality conditions with respect to variables that have been purged of their time-invariant household-specific component which is correlated with λ_h. An advantage of this procedure is that, in empirical applications, the orthogonality of $P_{vt}X_{1iht}$ with respect to λ_h could be suspect. Purging $P_{vt}X_{1iht}$ of its component that is correlated with the time-invariant household effect, λ_h, should render it more palatable as a potential instrument set. In that case, the set of HT-type IVs is given by $[Q_{vt}X_{1iht}; \widetilde{X}_{1iht}]$, where $\widetilde{X}_{1iht} = Q_v(P_{vt}X_{1iht})$ denotes the matrix of HT IVs that has been purged of its component which is correlated with λ_h.

The village and the exclusion restrictions

The data used in this article were collected in the village of El Oulja, Tunisia, which has been extensively described in Matoussi and Nugent (1989) and Laffont and Matoussi (1995). The village lies in the Medjerda river valley in northwestern Tunisia, in the governorate of Beja. The agricultural zone in question is one of the most fertile in Tunisia, with more than three quarters of plots having access to irrigation. A substantial portion of the crops grown in the village are destined for the produce markets of Tunis, which is, however, 100 km away, with road conditions being sometimes difficult during the winter rains (i.e. marketing constraints may be binding for some of the bulkier crops). Descriptive statistics corresponding to the variables used in the empirical work are presented in tables 3 and 4. As in the theoretical model, our data allow us to distinguish between four types of labor inputs $\left(L_i^M, L_i^F, H_i^M, H_i^F\right)$ on each plot: family and hired labor, which is then further divided into its male and female components. Average labor input per hectare (expressed in person days over the year) is equal to 79 for male family labor (L_i^M), 32 for female family labor (L_i^F), 39 for male hired labor (H_i^M) and 42 for female hired labor (H_i^F). The average total labor input per hectare is equal to 194 person days.

Plot characteristics include four soil types (clay, red, sandy and "barren" soil, with the mixed soil type being the excluded category), irrigation status, and plot size.[7] These six variables constitute our X_{1iht} matrix, with the exception of plot size, which we assume to be correlated with λ_{ht}, as it may be set by landlords on plots under tenancy (to put things explicitly, we use Q_{vt}(plot size) as an IV, and do *not* use P_{vt}(plot size)). However, it is *a priori* unlikely that plot size is correlated with λ_{ht}, in that this variable is largely determined by the rigid crop rotation cycle in the village, and landlords have very little latitude in adjusting plot size on an *ad hoc* basis. The same argument holds for the soil type of each plot.

The land rental market is active in the village, and this is reflected in our data: approximately one quarter (124) of the 477 plots in our sample are farmed under either sharecropping (45 plots) or fixed rental contracts (79 plots), with both contractual forms involving cost-sharing, although this is relatively infrequent under fixed rental. Though there is no variation in input prices ($\frac{w^j}{p_k}$) because the data correspond to a single village, heterogeneity in cost-shares induces variation in the *effective* price faced by the households cultivating the plots of land. On sharecropped plots, slightly more than one half of the cost-shares (β) are equal to 50%, one third 100%, one sixth 0%, with the remainder being equal to 75, 70 or 66%. Similarly, though the output shares (α) tend to cluster around the focal point of 50%, α is equal to 75, 70 or 66% on 13% of sharecropped plots. Descriptive statistics concerning the cost- and output-sharing components of the tenancy contracts (where we group plots under sharecropping and fixed rental together) are reported in table 4. The 8 cost-to-output share ratios, plus the predicted crop choice hazard rate constitute the matrix X_{2iht}.

On average, operator households cultivate 3.1 plots per year. When they rent in plots under tenancy contracts, 54% of operator households interact with two or more landlords. This ensures that there is enough within-operator household variation in the elements of W_{iht} for them to be able to act as IVs for the cost-to-output share ratios and the predicted crop choice hazard rate. The twelve landlord characteristics included in W_{iht} are non-agricultural income, landownership, residency status (in the village or not), occupational status (peasant or not), years of schooling, net wealth, household size, prime-age females in household, value of livestock, value of agricultural machinery, age, and pension income.

We consider four variables for our test of the separation null, based on our theoretical plot-level model of the household, as well as on the most common empirical specifications summarized in tables 1 and 2. Descriptive statistics corresponding to the variables in question are presented in the lower portion of table 3. The first three variables correspond to Z_{ht}. The first exclusion restriction is based on household demographics (an element of Ω), and involves the operator household's stock of prime-age labor. This variable is likely to be correlated with λ_{ht} in the presence, for example, of unobservable health shocks to adult household members. The second exclusion restriction takes the form of household land ownership (A^O in the theoretical discussion of tenancy), which is a major component of household wealth (part of Ω), and may also affect credit availability (B). This last interpretation renders the correlation of land ownership with λ_{ht} highly probable, in that many credit transactions in the village take place informally (and go unreported), and involve female household members.[8] The third exclusion restriction involves short-term liquidity (I), represented by household non-farm, transfer and pension income. Here, unobservable income or consumption shocks to the household render it likely that I and λ_{ht} are correlated.

Our fourth exclusion restriction, which belongs either in X_{1iht} or in X_{2iht} depending upon the orthogonality assumptions one is willing to make, is given by the area of *other* plots farmed by the household (to use the notation of the subsection on tenancy, this corresponds to $\sum\limits_{r \neq i, r \in P^{all}} A_r$, where $P^{all} = P^{OO} \cup P^{RI} \cup P^{SI}$, for plot i). While a significant negative coefficient associated with this variable is sometimes linked, as mentioned earlier, with the debate surrounding the inverse farm size/productivity relationship, at least three other interpretations are possible.

First, as noted by Udry (1999), a significant negative coefficient can provide indication of a binding working capital constraint, as it implies that inputs are diluted on a given plot as the area farmed on other plots increases. Second, however, and as indicated in our theoretical model, a statistically significant coefficient associated with this variable (once household specific time-varying effects are controlled for) implies that the marginal productivity of the labor input in question is not equated across plots cultivated by a given household, since the variable in question is, by construction, *plot-specific*. In terms of our theoretical model, this would provide evidence in favor of missing insurance markets, though the fact that tenants usually interact with more than one landlord could also yield the result, as shown in the subsection on tenancy. Finally, if one is willing to relax the assumption (on which our theoretical interpretations are based, see the basic optimization problem posed in (8)) of a Pareto-optimal intra-household model, such a finding would also be consistent with an inefficient intra-household allocation of resources. Compelling empirical evidence against the assumption of intra-household Pareto-optimality, in a *Burkinabè* context, has been provided by Udry (1996).

Results

Our empirical results are presented in tables 5 and 6. Many households did not engage in crop production in the second survey year (1995) because of adverse climatic shocks; this explains why the number of household-years (ht) is much smaller than *twice* the number of households (h). A year dummy is included in all specifications (coefficient not presented). In the interests of brevity, we report joint significance tests for the four soil type dummies, the eight cost-to-output share ratios and, for the pooling estimator results (table 5), the eight crop choice dummies.

Results corresponding to the standard test for separation, which does not take the endogeneity of contractual choice and crop choice into account, and which does not control for household-time specific effects, are presented in table 5. This corresponds to a pooling estimator, in which we do, however, allow for clustering at the household-time level in order to render our results comparable with the IV results presented later. As should be obvious from the uppermost part of the table, which groups together the parameter estimates corresponding to our four exclusion restrictions, the data reveal an unambiguous rejection of the separation null, for each type of labor. The only exclusion restriction that is never rejected corresponds to our measure of short-term liquity.

Thiree aspects of these results are worth noting. First, the stock of prime-age labor is positive and statistically significant in the male family labor equation, and insignificant in the three others. Second, land ownership is negative and statistically significant in the male family and hired labor equations. Third, the area on other plots increases the demand for male and female hired labor, while it decreases the demand for female family labor. The first result suggests that there are constraints on hiring in male labor, while the negative coefficient associated with the area of other plots in the female family labor equation could indicate a binding working capital constraint. The negative coefficient associated with land ownership in the male family labor equation suggests, if land ownership is an indication of wealth, substitution effects in favor of additional leisure. On the other hand, the negative coefficient associated with land ownership in the male hired labor equation, and the positive coefficients associated with the area of other plots in the two hired labor equations are puzzling, though the sign of the last two coefficients is compatible with a model in the spirit of Feder (1985) which combines a credit constraint with costs to supervising hired labor. These last two positive coefficients are of course suggestive of a positive relationship between land *holdings* and hired labor demand.

As noted in the introduction, as well as in our discussion of our exclusion restrictions, it is likely that the variables corresponding to our exclusion restrictions are correlated with λ_{ht}, rendering the results presented in table 5 suspect. This is confirmed by the appropriate Hausman tests, which compare a household-time fixed effects specification with the corresponding household-time random effects specification: for all four types of labor, the Hausman test rejects, with an extremely low $p-$value in all cases, as reported in the lowermost line of table 5. The bias identified in equation (3) is therefore manifestly present in conventional tests of the null-hypothesis of complete markets using this panel dataset, given that one strongly rejects the null of the absence of correlation between our exclusion restrictions and λ_{ht}. Of course, household-time (λ_{ht}) *fixed* effects would not allow one to test for separation at all in that they would also sweep out the impact of three of our four exclusion restrictions (those based on Z_{ht}).

In table 6, we present results corresponding to our approach to testing for separation, based on endogenizing tenancy contracts and crop choice using "external" instruments, and dealing with the correlation between Z_{ht} and λ_{ht} using our modification of the HT instrument set.[9] The results are striking. In contrast to what was found in table 5, the null of complete markets is *not* rejected for any of the labor demand equations, in that none of the exclusions restrictions are individually rejected, at the usual levels of confidence. This is confirmed by the joint tests of the significance of the variables associated with our exclusion restrictions, which do not reject the null of separation, at the usual levels of confidence.

The lower part of table 5 reports a number of diagnostic tests of the validity of our IVs. We begin by presenting the Hansen test of the overidentifying restrictions. For all four labor demand equations, the Hansen test does not lead one to reject the orthogonality of our proposed instrument set with respect to the disturbance term, with $p-$values that are all greater than 0.07. However, the Hansen test is potentially inconclusive insofar as it is based on the strong maintained assumption that at least as many IVs as the number of endogenous variables are, indeed, exogenous. As the Hausman-Taylor procedure is very sensitive to the choice of the variables included in X_{1iht} and X_{2iht}, we compute (for each labor demand equation) three "difference Hansen" test statistics which enable us to assess the validity of subsets of IVs (Hayashi 2000). First, we test whether Q_{vt}(log surface of plot) is a valid IV (as assumed in the specification presented in table 6) and do not reject. Second, we do the same for Q_{vt}(area on other plots); again, we do not reject. Third, we test the specification presented in table 6 against the weaker identification strategy (suggested in the subsection on our adaptation of the HT instrument set) in which the matrix of HT IVs is given by $[Q_{vt}X_{1iht}; \widetilde{X}_{1iht}] = [Q_{vt}X_{1iht}; Q_v(P_{vt}X_{1iht})]$. Once again, we do not reject the validity of the specification presented in table 6.[10]

Despite the results of these tests, which do not reject the validity of our identification strategy, there remains the issue of the second condition which must be satisfied by any set of admissible IVs, namely the "strength" of their correlation with the jointly endogenous variables. This point is extremely important in the context of any IV estimation procedure, given the current preoccupation with the "weak instruments" problem (see the excellent surveys by Stock, Wright, and Yogo 2002 and Hahn and Hausman 2003, and a recent very short primer on the ensuing biases by

Hahn and Hausman 2002b).

Our diagnostic tool for assessing this aspect of the validity of our identification strategy is the Hahn and Hausman (2002a) m_3 test, based on the bias-adjusted 2SLS (B2SLS) estimator proposed by Donald and Newey (2001) (see Hausman, Stock, and Yogo 2005 for the appropriate Montecarlo evidence). The m_3 statistic is a joint test of instrument validity (the orthogonality of the IVs with respect to the disturbance term) and instrument strength (the correlation of the IVs with the jointly endogenous explanatory variables). Moreover, it is preferable to traditional diagnostic tools for assessing instrument relevance (such as partial $F-$statistics from the first-stage reduced forms) which have been shown in recent work, such as Cruz and Moreira (2005), to be extremely poor indicators of instrument weakness. Results of the Hahn-Hausman tests, for each labor demand equation, are presented in the last line of table 6, and none reject. Taken together with the non-rejection of the tests of the overidentifying restrictions and the difference-Hansen tests, this suggests that the identification strategy developed in this paper is reasonable and that our results are not driven by a weak instruments problem.

Finally, note that the Hahn-Hausman tests (not reported) of a specification in which P_{vt}(log surface of plot) is added to the instrument set soundly reject for all four labor demands, while the corresponding Hansen tests of the overidentifying restrictions do not. While the second finding suggests that plot size is exogenously determined, and is not chosen by landlords, the outcomes of the Hahn-Hausman tests lead us to remain agnostic concerning the validity of this IV, and warrant basing one's conclusion concerning the separation null on the less restrictive specification presented in table 6.

Concluding remarks

This article has shown that the rejection of the null-hypothesis of complete markets in household models, based on the widely-used test of the exclusion restrictions implied by separation, can be due to the bias stemming from uncontrolled-for unobservable household-specific heterogeneity, as well as from more conventional endogeneity concerns, such as those linked to tenancy markets. We have developed an alternative approach to this problem, based in part on the instruments suggested by the HT procedure, which we believe furnishes a better answer to this important question.

Our results bring the methodology of testing for separation using panel data into sharper focus. This is because, using our approach, we do not reject the null hypothesis of complete markets, *conditional* on λ_{ht}. If one estimates a labor demand function on US individual *firm* data, as in Griliches and Hausman (1986), one finds correlated individual firms effects, as we have found here for household time-period effects. Thus, by analogy, profit-maximizing behavior by firms is not incompatible with correlated firm-specific effects. However, in our dataset, since labor demand is a function λ_{ht}, it is not independent of household characteristics *per se*, although they are *unobservable* characteristics. If separation is taken in its strictest sense to mean that factor demands should be independent of household characteristics, *unconditional* on λ_{ht}, then we do in fact reject the null-hypothesis of complete markets. The key point here revolves around what *type* of household characteristics fall under the λ_h and λ_{ht} headings. If they are made up of household characteristics that only affect labor demand through their impact on the production technology, and the null of separation is not rejected, then the concept of conditional separation has meaningful operational content. If this condition is not satisfied, and the examples of correlated household-time specific shocks that we have given in this article suggest that this may sometimes be the case, testing for separation in agricultural household models may be partially devoid of meaning.

Despite this *caveat*, a final point concerns the use to which tests of the separation hypothesis are put. As noted by several authors, including Udry (1999), the *pattern* of violations of the separation null often allows one to infer which markets are imperfect. Indeed, the purpose of constructing simple theoretical models of the household in the presence of imperfect markets —such as the one sketched in this article— is often to provide one with comparative statics results which allow one to do just that. Since this article has shown that failing to control for correlated household-time specific effects can significantly bias empirical tests of the separation hypothesis, we believe that our approach to the problem can provide more robust evidence concerning which market imperfections affect the agricultural sector of developing countries.

Notes

[1]There is a corresponding matrix expression when Z_{ht} involves several household characteristics.

[2]In deriving these conditions, we have carried out the substitutions in such a manner that the expressions depend upon the marginal utility of consumption of good 1. There are, of course, K other normalizations that are possible, given the optimality conditions that link the marginal utilities of consumption of the $K-1$ other goods.

[3]This would also be true if one retained the one-sided principal-agent framework (in which all of the bargaining power is on the landlord's side) and the landlord's decisionmaking problem were non-separable.

[4]A simple thought-experiment should suffice to convince one of the validity of this statement. Consider a pure tenant household that interacts with only one landlord. Then landlord characteristics, expressed as deviations with respect to the operator household time-specific means, would all be equal to zero and would offer no identification whatsoever. While the presence of tenant/owner operator households who interact with only one landlord also ensures identification using our proposed instruments, this is slightly misleading since the identification stems solely from differences in characteristics between the landlord and the tenant household. The "true" source of identification in our empirical procedure therefore stems from tenants (who may also cultivate plots as owner-operators) who interact with several landlords; such tenants account for more than half of the plots under tenancy in our data.

[5]This means that all of the elements of Z_{ht} correspond, in the standard HT notation, to Z_{2ht}, and that there are no Z_{1ht} variables.

[6]As we shall see below, one exception to this statement will be constituted by the area cultivated by the household on other plots, which is plot-specific by construction.

Its impact can therefore be identified either (i) through the HT instrument set, (ii) through the excluded instruments (W_{iht}, or through a combination of both), or (iii) by allowing it to be exogenous (and therefore, classifying it as a component of X_{1iht}).

[7]Irrigation status is *not* the value of the irrigation input, rather, it is a dummy variable that indicates whether a plot can be irrigated or not; given that irrigation status depends upon a plot being geographically situated close to an irrigation canal, it is likely that this plot characteristic can be assumed to be exogenously determined.

[8]This also explains, given the traditional North African context, why male household heads are often reluctant to report them.

[9]It is worth noting that the multinomial logit procedure that underlies our endogenization of crop choice performs quite well. The associated pseudo-R^2 is equal to 0.331, while the joint test of the null of zero slope coefficients has a $p-$value below 0.001.

[10]Obviously, testing this subset of overidentifying restrictions is only valid under the maintained hypothesis that $\widetilde{X}_{1iht}$ is uncorrelated with the household-time effects. These are the weakest identifying assumptions that allow one to implement the HT estimator in the present context.

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Table 1: Tests of the Separation Hypothesis Based on Exclusion Restrictions on Household Demographic Characteristics, and Tests of the Separation Hypothesis Based on Estimating the Marginal Product of Labor

Tests of the Separation Hypothesis Based on Exclusion Restrictions on Household Demographic Characteristics				
Authors	Dataset	Exclusion restrictions	Estimated equation(s)	Separation null
Pitt and Rosenzweig 1986	Indonesia, 1978	Family morbidity (no. of sick days)	Farm profits	Not rejected
Deolalikar 1988	India, 1976-78	Hh. size and weight-for-height	Farm outputs	Rejected
Benjamin 1992	Java, 1980	Hh. size and composition	Hh. labor demand	Not rejected
Bowlus and Sicular 2003	China, 1990-1993	Hh. size and composition	Hh. labor demand	Rejected
Grimard 2000	Côte d'Ivoire, 1986	Hh. composition	Farm labor demand	Rejected
Tests of the Separation Hypothesis Based on Estimating the Marginal Product of Labor				
Authors	Dataset	Estimated marg. prod	Marg. prod function of	Separation null
Carter and Wiebe 1990	Kenya, 1989	Labor and fertilizer	Land	Rejected
Jacoby 1993	Peru, 1985/86	Labor	Wage and constant	Rejected
Skoufias 1994	India, 1975-79	Labor	Wage and constant	Rejected

Table 2: Tests of the Separation Hypothesis Based on Exclusion Restrictions on Household Demographic and Other Characteristics.

Authors	Dataset	Exclusion restrictions	Estimated equation(s)	Separation null
Feder et al. 1990	China, 1987	Liquid assets, hh. size, size of hh. labor force	Output supply	Rejected
Benjamin 1994	Java, 1980	Area harvested (previous year)	Farm output, labor demand	Rejected
Barrett 1996	Madagascar, 1990	Land holding, hh. size and income	Marketable surplus	Rejected
Kevane 1996	Sudan, 1990	Wealth, land and labor endowments	Yield per hectare	Rejected
Gavian and Fafchamps 1996	Niger, 1990-91	Hh. manpower, proxies for hh. wealth	Qty. manure on field	Rejected
Sadoulet, DeJanvry and Benjamin 1998	Mexico, 1994	Hh. endowment of unskilled and skilled labor, hh. migration assets, assets affecting utility	Labor intensity	Rejected
Udry 1999	Burkina Faso, 1981-85, Kenya, 1985-87	Hh. size, non-farm wealth, total area on other plots	Plot output, plot labor demand	Rejected
Carter and Yao 2002	China, 1988, 1993	Land-labor endowment ratio	Labor demand	Rejected
Carter and Olinto 2003	Paraguay, 1991, 1994	Land property rights	Cap. invest. demand	Rejected
Vakis et al. 2004	Peru, 1997	Hh labor endowment and cons. chars., hours worked off-farm	Hh.'s on-farm work	Rejected

Table 3: Summary Statistics: Labor Inputs and Output, Plot Characteristics, Cropping Choice, Operator Household Characteristics (477 Plots (i),107 Households (h), 155 Household Time-Periods (ht))

	Mean	Standard deviation	
		total	"within" operator household
Labor inputs in person days per hectare (Y_{iht})			
Female family labor	32	87	51
Female hired labor	42	107	87
Male family labor	79	126	89
Male hired labor	39	84	66
Output (Tunisian dinars)	6,294	13,635	10,379
Plot characteristics (X_{1iht})			
Soil type 1 (clay)	0.190	0.393	0.232
Soil type 2 (red earth)	0.201	0.401	0.244
Soil type 3 (sandy)	0.446	0.497	0.291
Soil type 4 (barren)	0.058	0.235	0.183
Irrigated plot status dummy	0.882	0.322	0.253
Surface of plot (hectares)	5.615	13.535	8.989
Crop choice (X_{2iht})			
Wheat	0.201	0.401	0.327
Other grains	0.071	0.257	0.208
Potato	0.096	0.295	0.273
Onions	0.071	0.257	0.236
Garden vegetables	0.228	0.420	0.354
Tomato	0.113	0.317	0.291
Beetroot	0.025	0.156	0.137
Melon	0.073	0.261	0.218
Fodder	0.119	0.324	0.286
Exclusion restrictions			
Operator household characteristics (Z_{ht}):			
Prime-age adults	5.08	3.10	0.61
Land ownership	22.59	61.15	12.12
Short-term liquidity	744.09	1701.41	1151.08
Area on other plots	20.57	36.62	12.07

Table 4: Summary Statistics: Share of Output Accruing to, and Share of Costs Borne by the Household Operating the Plot, Excluded IVs (477 Plots (i),107 Households (h), 155 Household Time-Periods (ht))

	All plots			Plots under tenancy		
	Mean	Std. dev.		Mean	Std. dev.	
		total	within oper. hh.		total	within oper. hh.
Share of output accruing to operator: % (α)						
Output	95.53	14.02	9.68	83.72	22.94	13.68
Share of costs borne by the operator: % (β)						
Chemical fertilizer	96.05	14.20	9.36	85.64	24.24	13.73
Manure	96.43	13.66	9.23	87.02	23.68	13.50
Irrigation	95.56	16.21	10.74	83.86	27.79	17.50
Plowing	94.75	20.88	13.40	80.90	36.46	20.78
Family labor	98.82	7.92	6.82	95.73	14.71	10.51
Hired labor	97.69	12.33	9.58	91.60	22.49	15.19
Seeds	96.05	13.84	8.89	85.61	23.46	12.40
Transportation	95.91	15.84	9.37	85.11	27.52	14.20
Excluded IVs: landlord household characteristics (W_{iht})						
Non ag. income (dinars)	670.11	1,914	1,351	663.54	2,382	307
Pension income (dinars)	60.77	409.93	127.59	75.38	430.73	221.82
Value of livestock (dinars)	5,247	11,396	6,082	1,339	9,348	8,014
Value of ag. machine. (dinars)	12,059	21,141	11,536	6,598	22,894	12,055
Net wealth (dinars)	22,432	38,020	18,373	17,855	36,899	28,600
Land ownership (hectares)	30.01	78.41	32.84	34.52	96.65	51.05
Schooling of head (years)	4.48	4.97	2.26	5.23	4.82	2.48
Age of head (years)	51.94	13.33	6.27	51.03	11.07	6.54
Size of household	7.17	4.38	2.26	5.32	1.66	0.93
Number of prime-age females	2.04	1.61	0.73	1.19	1.08	0.55
Resident landlord dummy (%)	87.42	33.19	20.30	64.12	48.14	23.91
Peasant landlord dummy (%)	73.16	44.35	29.37	30.53	46.23	26.74

Table 5: Labor Demand Equations: Pooling Estimator, t-statistics in parentheses (477 Plots (i),107 Households (h), 155 Household Time-Periods (ht))

Dependent variable (log per hectare)	Family labor		Hired labor	
	Male L_i^M	Female L_i^F	Male H_i^M	Female H_i^F
	(1)	(2)	(3)	(4)
Exclusion restrictions				
Operator household characteristics:				
Prime-age adults	0.765 (4.04)	0.430 (1.74)	−0.255 (−0.80)	−0.199 (−0.92)
Land ownership	−0.370 (−4.76)	−0.102 (−0.99)	−0.506 (−3.58)	−0.204 (−1.60)
Short-term liquidity	−0.007 (−0.27)	−0.034 (−1.14)	0.017 (0.47)	0.073 (2.80)
Area on other plots	0.011 (0.17)	−0.323 (−3.25)	0.568 (4.66)	0.274 (3.13)
Plot characteristics				
Log surface of plot	−0.956 (−12.35)	−1.057 (−10.97)	−0.501 (−3.61)	−0.558 (−4.41)
Plot irrigation status	0.275 (1.78)	−0.361 (−1.78)	0.483 (1.41)	0.351 (1.30)
Joint signif. of crop dummies : χ^2_8 [p−value]	136.56 [0.00]	5.28 [0.00]	69.71 [0.00]	363.39 [0.00]
Joint signif. of soil types : χ^2_4 [p−value]	10.60 [0.03]	5.24 [0.26]	12.23 [0.01]	7.62 [0.10]
Joint signif. of cost shares : χ^2_8 [p−value]	1.60 [0.99]	6.55 [0.58]	0.84 [0.99]	1.99 [0.98]
Joint signif. of exclusion restrictions: χ^2_4 [p−value]	36.32 [0.00]	23.63 [0.00]	22.80 [0.00]	12.00 [0.01]
Hausman test, λ_{ht}-RE *versus* λ_{ht}-FE: χ^2_{23} [p−value]	33.28 [0.07]	50.97 [0.00]	45.57 [0.00]	66.56 [0.00]
R^2	0.743	0.716	0.407	0.639

Table 6: Labor Demand Equations: Instrumental Variables Estimates, t-statistics in parentheses (477 Plots (i),107 Households (h), 155 Household Time-Periods (ht))

Dependent variable (log per hectare)	Family labor		Hired labor	
	Male L_i^M	Female L_i^F	Male H_i^M	Female H_i^F
	(1)	(2)	(3)	(4)
Exclusion restrictions				
Operator household characteristics (Z_{ht}):				
Prime-age adults	2.791 (0.88)	−0.811 (−0.31)	−1.059 (−0.33)	0.976 (0.16)
Land ownership	−1.348 (−1.54)	−0.323 (−0.47)	−0.891 (−1.03)	−1.039 (−0.58)
Short-term liquidity	0.404 (0.84)	−0.060 (−0.15)	−0.034 (−0.06)	0.368 (0.46)
Area on other plots (X_{1iht})	0.700 (1.15)	−0.113 (−0.25)	0.712 (1.14)	0.855 (0.80)
Plot characteristics				
Log surface of plot (X_{1iht})	−0.896 (−4.71)	−1.036 (−6.51)	−0.736 (−3.12)	−0.735 (−2.15)
Plot irrigation status (X_{1iht})	1.026 (1.27)	−0.196 (−0.41)	1.742 (2.10)	2.525 (2.12)
Predicted crop choice hazard rate (X_{2iht})	1.886 (1.01)	−2.536 (−1.78)	4.116 (1.95)	4.216 (1.25)
Joint signif. of soil types (X_{1iht}): χ^2_4 [$p-$value]	7.27 [0.20]	2.90 [0.71]	11.31 [0.04]	8.64 [0.12]
Joint signif. of cost shares (X_{2iht}): χ^2_8 [$p-$value]	1.01 [0.99]	0.70 [0.99]	2.71 [0.95]	0.86 [0.99]
Joint signif. of exclusion restrictions: χ^2_4 [$p-$value]	6.38 [0.17]	1.16 [0.88]	1.63 [0.80]	1.05 [0.90]
Instrumental variables diagnostics				
Test of overidentifying restrictions: p-value	0.882	0.249	0.869	0.441
Difference Hansen tests: p-values				
Q_{vt}(log surface of plot) valid IV	0.797	0.215	0.695	0.891
Q_{vt}(area on other plots) valid IV	0.941	0.150	0.748	0.823
$P_{vt}X_{1iht}$ valid IV *versus* $Q_vP_{vt}X_{1iht}$ valid IV	0.927	0.368	0.818	0.669
Hahn-Hausman m_3 test statistic: p-value	0.679	0.937	0.970	0.919