Land Tenure, Incentives and the Choice of Production Techniques in Rural Nicaragua.

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Abstract

The adoption of new production technique is a key determinant of agricultural productivity, diversification and growth in developing economies. This paper presents evidence on the effect of land tenure on the choice of techniques that are observable and contractible. The analysis focusses on trees, which, grown in combination with annual crops, have been shown to increase soil productivity in a variety of settings. The results suggest that: (i) tenure status matters, i.e. trees are more likely to be grown on owned rather than rented plots; (ii) the effect of tenure is stronger for wealthier farmers, i.e. poor owners and poor tenants are equally unlikely to farm trees whereas rich owners are more likely than rich tenants to farm trees; and (iii) tenants' wealth is not a significant determinant of tree cultivation.

Altogether the results indicate that the success of land redistribution crucially depends on the identity of the beneficiaries and that the inefficiency of land rentals derives from some form of contractual incompleteness rather than from limited liability.

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Key words: land tenure, incomplete contracts.

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1 Introduction

The adoption of new production techniques is a key determinant of agricultural productivity and also of structural change, as income growth allows farmers to diversify out of agriculture and into sectors with higher growth potential. Identifying the factors that hamper the adoption of new production techniques is therefore essential to devise policies to reduce poverty and promote growth in developing countries.

This paper presents evidence on the link between land tenure and the choice of contractible production techniques. The paper addresses two questions. First, it analyses how the choice of techniques depends on whether the landowner farms his own land or rents it out to a tenant. Second, it aims to assess whether the evidence is consistent with a class of models based of asymmetric information and, within these, whether it is possible to discriminate between complete and incomplete contracts models. The paper provides some evidence on the micro foundations of the effect of land inequality on productivity and growth, as the incidence of tenancy naturally depends on the degree of land inequality. Relatedly, the paper provides evidence on the desirability of land redistribution, a policy measure often attempted in many developing countries (Binswanger et al 1995).

I analyse the effect of land tenure on tree cultivation in a sample of households from rural Nicaragua. Growing trees in combination with annual crops, a technique known as $agroforestry$, is generally more profitable than growing annual crops alone because, besides being profitable on their own right, trees enhance nutrients recycling, conserve soil moisture, maintain fertility and reduce soil erosion.[1] Tenancy is widespread in Nicaragua and the data display sufficient variation in tenure status to identify the effect of land tenure on the choice of technique. Importantly, some of the farmers in the sample cultivate both an owned and a rented plot, which allows to separate the effect of tenure status from individual heterogeneity. Identifying the links between tenure status and agricultural productivity is an issue of great relevance in Nicaragua, where the agricultural sector accounts for a third of gross domestic product and land reform is often at the heart of the policy debate.[2] In general, the land tenure issue is crucial in Central and South America, where the land distribution is highly unequal and the productivity differential in favour of small family farm the largest in the world (Banerjee, 1999). It is then quite surprising that the existing literature on land tenure pays almost no attention to this region.

Economic theory suggests that land distribution and hence land tenure matter

[1] Agroforestry (the combination of annual and perennial crops) has recently been promoted by most agricultural development institutions (see www.fao.org or www.icraf.cgiar.org) and NGOs. Current et al (1996)'s study of 21 agroforestry projects in Central America show that this practice is profitable under a broad range of conditions.

[2] Agriculture's share in GDP is 33%, much higher than in Nicaragua's wealthier neighbors: Costa Rica (10%), El Salvador (10%), Guatemala (23%) and Honduras (18%). (Source: World Bank World Development Indicators, at http://www.worldbank.org/data/countrydata/countrydata.html#DataProfiles).

when information is asymmetric. Importantly, asymmetric information might affect the choice of production techniques even if these are observable and contractible, as is the case for trees, as long as their profitability depends on non contractible inputs.

The fact that agricultural productivity depends on the farmer's non observable effort might affect the choice of production techniques both when the land is farmed by a tenant and when it is farmed by its owner. Tenants face a moral hazard problem vs. the landowner, who, if first best incentives for effort cannot be provided, might resist the adoption of techniques that are complementary to unobservable effort, even when these are more profitable in a first best sense. (Braverman and Stiglitz 1986, Banerjee *et al* 2002). Owner cultivators who need to borrow to finance cultivation face a moral hazard problem vs. the lender, and thus might be unable to afford better, yet more expensive, techniques because of credit constraints The comparison of technique choice under tenancy and under owner-cultivation is, ultimately, an empirical question.

The results in this paper suggest that farmers are more likely to grow trees on the plots they own rather than on the plots they rent. The result holds both in the sample of farmers that cultivate an owned and a rented plot, and in the cross section of pure owners and pure tenants, thus ruling out explanations exclusively based on individual heterogeneity.

A closer look at the theoretical literature suggests that the comparison of technique choice under tenancy and under owner-cultivation depends on the source of contractual inefficiency, on the farmers' wealth and, importantly, on the interaction between the two.

Under tenancy the landowner must provide incentives to the farmers he hires to cultivate his land. Since output is the only signal for the tenant's effort, first best incentives can be provided by offering a contract that makes the tenant the only residual claimant on output. Inefficiency therefore only arises when incentive provision is costly or unfeasible. This might happen because the farmer is risk averse and hence must be compensated to bear production risk (Stiglitz 1974), because the farmer is subject to limited liability which prevents the use of punishment as an incentive device (Banerjee et al 2002, Mookherjee 1997, Shetty 1988) or because contracts are incomplete (Banerjee 1999). The choice of technique under tenancy depends on the wealth of the tenant in the cases of either limited liability or risk aversion, provided that the degree of risk aversion is, as typically assumed, decreasing in wealth. If contracts are incomplete, in contrast, tenant's wealth is irrelevant since incentives cannot be provided to rich and poor tenants alike.

Under owner cultivation, in contrast, the choice of techniques always depends on the farmers' wealth as poor cultivators might be unable to afford tree cultivation because of credit constraints, regardless of whether these derive from limited liability, risk aversion or contractual incompleteness.

Further empirical analysis reveals owner cultivators are more likely to grow trees when they are rich while tenants' wealth is not a significant determinant of tree cultivation. In addition, I find that tenure status matters the most at high levels of wealth and that poor tenants and poor owners are equally unlikely to farm trees. This indicates that credit constraints might be binding for owners and that the inefficiency of land rentals derives from some form of contractual incompleteness rather than from limited liability or, with the usual caveat, from risk aversion.

One possible interpretation of this result relies on the observation that since current effort affects tree productivity in the future, incentives can be provided only by making the tenant's pay conditional on future output, that is by offering a long term contract. In line with this explanation, I find that the probability of tenants farming trees is increasing in the length of the contract but also that most contracts in the sample are only one or two years long. Long term contracts might be rare because courts are unable to enforce them or because they are intrinsically more complex, especially if optimality requires history dependent payments.

Alternatively, landlords might be unwilling, rather than unable, to commit to long term contracts. A cursory look at the history of land policies and current land laws in Nicaragua suggests a number of reasons why landlords might not want to offer long term contracts. Following the Sandinista revolution of 1979, land that was rented out got expropriated and redistributed. Landlords might fear another reform and hence prefer not to commit. In addition, current land laws grant strong rights to long term tenants, mostly by making eviction of stable tenants difficult, and thus reduce flexibility and increase the cost of committing long term for the landlords.

This paper offers two contributions to the existing empirical literature on land inequality and agricultural productivity. First, it analyses the link between tenure status and the choice of production techniques, on which there is little empirical evidence (Feder 1985). Although a large body of evidence suggests that small owner-cultivated farms are more productive than large farms that rely on hired labor and than farms managed by a tenant (Berry and Cline 1979, Binswanger et al 1995), few contributions have looked at the determinants of such differences. Importantly, Shaban (1987) shows that, for a sample of Indian farmers, the productivity differential is not driven by individual heterogeneity: farmers who cultivate both owned and rented plots appear to be more productive on the plots they own, compared to the plots they rent. The difference derives both from different levels of non-observable inputs (e.g. labor) and from differences in irrigation, which, like trees, is a contractible technique.

Second, the paper attempts to test between different models of tenurial inefficiency and provides evidence which can be used to assess whether, in this setting, land tenancy contracts are incomplete. While contractual incompleteness has received great attention in the theoretical literature, attempts at testing its predictions are quite rare.[3] Results in this paper suggest that contractual incompleteness has important consequences for the analysis of the effect of tenure status on technique choice in rural Nicaragua.

[3] See Chiappori and Salanie (2000) for a general review.

The remainder of the paper is organized as follows. Sections 2 discusses theories and their empirical predictions. Section 3 presents the data and the empirical methodology. Section 4 illustrates the main results. Section 5 addresses econometric concerns. Section 6 concludes.

2 Theoretical Background.

2.1 Tenants.

The key ingredient of any analysis of agricultural tenancy is asymmetric information, which can result in the underprovision of non contractible effort and, as a consequence, can affect the choice of contractible production techniques that are complementary to effort.

Agricultural productivity depends on the tenant's discretionary care, which is unobservable by the landlord and whose effects on output are indistinguishable from those of other factors such as the weather. Information asymmetry per se, however, does not generate inefficiency. In fact, the landlord can provide incentives by conditioning the tenant's pay on output that is a signal for effort. In particular, if the landlord offers a "fixed rent" contract, such that the tenant makes a lump-sum payment (rent) and keeps the entire output, the tenant, being the only residual claimant, chooses the first best level of effort.

Departures from first best occur when incentive provision is costly or altogether unfeasible. The literature suggests three reasons for why this might be the case. First, if the tenant is risk adverse fixed rent contracts are suboptimal because under this arrangement the tenant bear the whole production risk (Stiglitz, 1974). In other words, a risk neutral landlord can achieve a higher payoff by insuring the tenant against bad outcomes, that is by making the tenants' pay less sensitive to the realization of output. Insurance, however, reduces the tenant's stake in success and hence leads to underprovision of effort. If risk aversion is, as generally assumed, decreasing in wealth, the theory predicts that poorer tenants are more likely to get risk sharing arrangements and hence to exert less effort.

A second set of theories suggests that, risk considerations aside, tenants' productivity might be lower than first best if tenants are subject to limited liability (Banerjee et al 2002; Mookherjee 1997, Shetty 1988). Fixed rent contracts provide incentives by rewarding tenants in case of success while punishing them in case of failure. Limited liability makes incentive provision costly by imposing an upper bound on the feasible punishment. When the limited liability constraint binds, therefore, the landlord can only provide incentives by increasing the reward for success. Since rewards are costly, the landlord might achieve a higher payoff by providing weaker incentives. Like in the case of risk aversion, the level of effort that maximizes the landlord's payoff is lower than the level of effort that maximizes production. Also, since the limited liability constraint is more likely to bind when the tenant is poor, poorer tenants are more likely to exert less effort. Models of risk aversion or limited liability share the assumption that contracts are complete and, as a consequence, yield the prediction that ownership does not matter *per se*. In both cases efficiency can be restored by a sufficiently large transfer of wealth to the tenant without altering the distribution of property rights (Banerjee 1999, Mookherjee 1997).

The third potential source of inefficiency is contractual incompleteness, which might derive from the courts' inability to enforce tenancy agreements or from their complexity (Banerjee 1999).[4] In the most extereme case, if the tenants' pay cannot be conditioned on output, incentives cannot be provided at all. This is mostly relevant when tenants' pay need to be conditioned on future output, that is in the case of long term agreements, especially when the optimal contract prescribes history dependent payments. Compared to models of risk aversion or limited liability, in this case the inefficiency does not depend on the tenants' wealth. That is, contractual incompleteness makes incentive provision difficult for rich and poor tenants alike.

While the discussion above focusses on non contractible effort only, these models can be easily extended to derive predictions on the choice of contractible techniques. Indeed if effort provision is below first best, the landowner might resist the adoption of techniques that are complementary to effort, even when these are contractible and more profitable in a first best sense (Braverman and Stiglitz (1986), Banerjee et al (2002)).

2.2 Owner cultivators.

Common wisdom suggests that productivity is higher on plots that are cultivated by the owner as opposed to a tenant. However, while the theories above suggest that asymmetric information might affect the choice of techniques on rented plots they do not necessarily imply that owner cultivators make first best efficient choices. In fact, if the farmer must borrow to finance cultivation, asymmetric information about the level of effort generates a moral hazard problem vis a vis the lender.

If the farmer is subject to limited liability, the debt overhang reduces his stake in the success outcome and therefore leads to underprovision of effort. Mookherjee (1997) compares the choice of effort of tenants and owner cultivators in the case of limited liability. The important difference between the two is that owner cultivators have more bargaining power vis a vis the lender than tenants have vis a vis the landlord. Since in the case of limited liability the inefficiency derives from the fact that the principal does not want to reward effort as this would result in a higher payoff for the agent, an increase in the reservation utility (or bargaining power) of the agent results in higher rewards and hence higher effort. As in the case of tenants, the underprovision of effort might lead to the adoption of techniques that are less sensitive to effort, even when these are not the most profitable in a first best sense.

Clearly also risk aversion can affect the choice of effort when the land is farmed by its owner. A risk averse owner might want to purchase insurance against output

[4]For the theoretical foundations of incomplete contracts in a general setting see Hart and Moore (1999) and Tirole (1999).

failure, which, as in the textbook moral hazard problem, diminishes the incentives to exert effort to avoid failure and, as a consequence biases the choice of the farmer towards techniques that are less sensitive to effort. If the inefficiency derives from risk aversion, however, owners and tenants who are equally risk averse and have equal access to similar insurance mechanisms, choose the same level of effort and, other things equal, adopt similar cultivation techniques.

Finally, contractual incompleteness affects the choice of techniques directly to the extent that it limits the amount of available credit. For instance, if repayment cannot be made conditional on the realization of output, the loan amount will be at most equal to the value of output in case of failure minus the opportunity cost of funds for the lender. Credit constraints might therefore hamper the adoption of profitable, yet more expensive, techniques. If both credit and tenancy contracts are incomplete, the effect of land tenure on technique choice is generally ambiguous as it depends on the relative severity of distortions in the land rental and credit markets.

2.3 Tenants, Owner Cultivators and Trees: Predictions.

The choice of technique analysed in this paper is dichotomous: farmers can either grow trees together with annual crops or annual crops alone. The problem is interesting because most tree crops in Nicaragua are more sensitive to effort, more expensive, and, in a first best sense, more profitable than annual crops.

Theory suggests that whether tenants cultivate trees depends on their wealth and on the source of inefficiency. When contracts are complete and tenants are either risk averse or subject to a limited liability constraint, poor tenants should be less likely to cultivate trees because providing incentives for effort to poor tenants is costly and trees are more sensitive to effort than annual crops. When contracts are incomplete, however, the landowner cannot provide incentives to rich and poor tenants alike, implying that tenants' wealth should not be a significant determinant of tree cultivation.

Whether owners grow trees, in contrast, always depends on their wealth, regardless of the source of inefficiency. This follows from the fact that the choice of techniques under farmer ownership can be inefficient only if the farmer needs to borrow to finance cultivation. Thus, wealthy farmers who do not need to borrow should be more likely to grow trees, regardless of whether contracts are complete or not.

Since asymmetric information affects the choice of techniques both on owned and on rented plots, the comparison between the two depends on the source of inefficiency and on the wealth of the farmers. While precise statements require an exact specification of the production and costs functions, the following considerations hold more generally.

When contracts are complete and the inefficiency derives from limited liability, there is a treshold of wealth above which the limited liability constraint does not bind and technique choice is efficient regardless of tenure status. When the limited liability constraint binds, i.e. when farmers are poor, owner cultivators exert more effort and should therefore be more likely to choose techniques that are complementary to effort.

When contracts are incomplete and tree cultivation is not feasible under tenancy regardless of the wealth of the tenant, the difference between tenants and owner cultivators is larger when farmers are rich. Indeed, incompleteness might result in a credit constraint for the owners when they are poor, while it is of no consequence when they are rich.[5] Theoretical predictions can then be summarized as follows:

A. If contracts are complete and farmers are subject to limited liability:
(a1) the probability of choosing effort intensive techniques is increasing in farmers' wealth regardless of tenure status;
(a2) the effect of tenure status on technique choice is stronger for poor farmers.
B. If contracts are incomplete:
(b1) the probability of choosing effort intensive techniques does not depend on farmers' wealth if a tenant farms the land while it is increasing in farmers' wealth if the owner farms the land and is subject to a credit constraint;
(b2)the effect of tenure status on technique choice is stronger for rich farmers.

3 Context, Data and Empirical Strategy.

3.1 Context

Nicaragua is among the poorest countries in the American continent: in 1998, per capita GNP was $430 and about 50% of the population lived below the poverty line. As of 1998, agriculture accounted for one third of GDP and almost one half of the population lived in rural areas. During the last 50 years Nicaragua has suffered from two natural catastrophes[6] and serious civil strife. After twenty years of *guerrilla*, the Sandinista National Liberal Front (FSLN) led a successful insurrection in 1979 and ruled for 10 years, after which it lost a democratic election against the National Opposition Union.

The chain of political events which began in 1979 has had a profound impact on land distribution, on land markets and on the structure of tenancy agreements. Until 1981, land distribution was extremely concentrated: 20% of the country land, for instance, were owned by the dictator's family alone. In 1981, the FSLN expropriated large extensions of land –either abandoned, undercultivated or rented out– and redistributed it to landless peasants, existing tenants and farmers' co-operatives.[7]

[5] Obviously, if tree cultivation is feasible under tenancy the prediction is reversed: poor owners will be less likely than tenants to grow trees while there will be no difference at higher levels of wealth. The former case is more realistic.

[6] A major earthquake (1972) and a devastating hurricane (1998) had a profound impact on the Nicaraguan economy.

[7] See *Apropriacion por el estado de los bienes abandonados* Decreto No. 760, and *Ley de reforma agraria.* Decreto No. 782

The democratic government elected in 1990 promulgated a number of laws[8] which recognised and legitimised the property rights acquired by farmers through the FSLN land reform. In addition to recognising existing farmers' rights these laws also established indemnification procedures for expropriated owners and privatisation and redistribution of State owned land to small farmers. Finally, the government also took measures to restore the property registry and to strenghten land titling, both by creating new titles for newly redistributed land and by converting existing titles.

Land markets in Nicaragua continue to be highly imperfect for a number of reasons. Under the FSLN regime, land rights could only be bequeathed or used as collateral to obtain credit. Land sales and divisions were forbidden until 1990. Post-1990 rights could be traded although the transfer of rights acquired through the land reforms of 1995 and 1997 was again limited to bequests and collateral for a period of five years after the issue of the title. Furthermore, the lack of a consistent nationwide landownership record, combined with the fact that with the FSLN reform new titles were assigned without revoking the old ones, substantially increase the transaction costs for land sales, as identifying the rightful owner is quite expensive and time consuming.

3.2 Data

I use household data from the 1998 Nicaragua Living Standard Measurement Survey (LSMS) matched with town data from the 1995 Nicaragua Census. The Survey covers the entire country, and the sampling strategy is based on Census data.[9]

The 1998 LSMS contains detailed information on the agricultural activities of 1497 households, 1258 of which can be used in the analysis. Of these, 57% farm their own plots, 36% farm rented plots and 7% farm both an owned and a rented plot. The data also contains information on household demographics, other economic activities and on the value of household's assets –consumer durables, farm assets, business assets, livestock, land and house– which can be aggregated to build a measure of wealth. I use the 1995 Census to collect information at the town level such as size, education level, and proxies for infrastructure.

The analysis focuses on the choice between growing a mix of annual and tree crops versus growing annual crops only. With a few exceptions, the main tree crops grown in Nicaragua –coffee, citrus, bananas and mangoes– are more profitable and also more effort intensive compared to annual crops –maize, beans, cassava.[10] Growing tree crops in combination with annual crops can be more profitable than growing annual crops alone because, besides being more profitable on their own right, tree crops

[8] See *Decreto-Ley de revision de confiscaciones (*Decreto 11-90), *Ley de estabilidad de la propriedad (*Ley No.209) and *Ley sobre propriedad reformada urbana y agraria* (Ley No.278).

[9] Six census segments in the regions of Nuova Segovia and RAAN could not be surveyed because of security problems. See World Bank (2000).

[10] The potential exceptions are mangoes –which seem to require very little effort– and possibly bananas. The results, however, are robust to the exclusion of mangoes and bananas from the group of effort intensive tree crops.

enhance nutrients recycling, conserve soil moisture, maintain fertility and reduce soil erosion. Interestingly, permanent crops cover about 10% of Nicaragua's agricultural land, a much lower share than in its wealthier neighbors.[11] The correlation between share of permanent crops and GDP per-capita in Central America for 1998 was 0.94.

Growing annual crops alone, however, is cheaper and less effort intensive.[12] The relative profitability of one technique over the other then ultimately depends on the level of effort exerted by the farmer.

The survey asks farmers to name the two main crops they grow and then collects information on every crop grown in the last twelve months.[13] It does not, in other words, contain precise information on the area devoted to each crop. However, the distinction between "main" and "other" crops provides evidence on the relative importance of different crops. Enumerators were infact instructed to identify the two crops that occupied most of the farm area and list them as "main crops".[14] To separate farmers who grow a mix of trees and annual crops from those who grow annual crops only I define two variables. The first, *tree_mix* is equal to 1 when the farmer grows at least one tree crop. The second, *tree_main*, is equal to 1 when at least one of the main crops is a tree. These two variables represent, respectively, an upper and a lower bound estimate of the number of farmers that grow tree crops. The first variable overestimates the number of farmers who choose a combination of tree and annual crops since, according to the definition a farmer counts as growing trees even if he grows only one. As reported in Table 1.1, about 58% of the farmers in the sample grow a mix of annual and tree crops. The second variable underestimates the number of farmers who grow tree crops because it only counts those farmers for whom these are one of the two most important crops, while farmers grow on average four different crops. As reported in Table 1.1, the sample average of *tree_main* is just 9%.

The main tree crops in the sample are coffee, banana, mango, and citrus. Since coffee and citrus are more expensive and more effort intensive than annual crops while mangoes and bananas may not be, I have also redefined the dependent variable as *tree_mix2*, equal to 1 when the farmer farms at least one coffee or citrus tree together with annual crops.

Table 1.1 also reports the means and standard deviations of the variables employed in the analysis, both for the whole sample and for the sub-sample of pure owners and tenants. Note that owner-cultivators are on average richer, older and farm larger

[11] The share of permanent crops is 55% in Costa Rica, 30% in El Salvador, 29% in Guatemala and 19% in Honduras. GDP per capita in Nicaragua is $430, compared to $3,700 in Costa Rica, $1900 in El Salvador, $1,675 in Guatemala and $857 in Honduras.

(Sources: crop data: FAO, FAOSTAT Land Use, GDP data:World Bank World Development Indicators)

[12] The sample average fertiliser expenditure, for instance, is about twice as high (406 vs. 217 cordobas) for farmers who grow a combination of trees and annual crops.

[13] Farmers in the sample grow on average four different crops.

[14] See "Manual de Instrucciones del Encuestador" and "Manual de Critica y Codificacion", available at http://www.worldbank.org/lsms.

plots than tenants. Education, however, does not vary by ownership status and both owner cultivators and tenants seem equally distributed across towns.

At first sight there is a clear difference between crops grown by tenants and owner cultivators, as the latter are significantly more likely to grow a mix of annual and tree crops. The difference is particularly striking for coffee (14% vs. 4%), which is possibly the most effort intensive but also most profitable crop.

3.3 Empirical Strategy.

Let $mix_i \in \{0, 1\}$ be a variable that equals 1 if farmer i grows a combination of trees and annual crops. Farmer i will prefer to grow trees when the expected returns from doing so $R_i(trees)$ are larger than the expected returns from annual crops, that is

$$mix_i = \begin{cases} 1 & if\ R_i(trees) - R_i(annual) > 0 \\ 0 & otherwise \end{cases} \qquad [1]$$

To identify the effect of tenure status on tree cultivation I look at two samples, both from the 1998 LSMS. The first, and largest, is a cross section i.e. the effect of tenure status is identified by the differences between pure owners and pure tenants. The second, smaller, sample contains information on farmers who cultivate both an owned and a rented plot, and hence allows to control for individual heterogeneity. The cross-sectional data, however, is possibly more useful for two reasons. First, one can analyze the impact of a number of variables other than tenancy status, a possibility which is precluded in the smaller sample because of its size. Second, point estimates from the "mixed owner-tenant" sample might be quite different compared to the larger population of pure owners and pure tenants if selection into the "mixed owner-tenant" status is not random.

A. Cross Section.

A.1. Least Squares Estimates.

The general crop choice equation I estimate by OLS is of the form:

$$mix_{iv} = \alpha own_{iv} + \mathbf{x}_{iv}\beta + \mathbf{z}_v\delta + e_{iv} \qquad (2)$$

Where mix_{iv} denotes the choice of farmer i in town v. The variable own_{iv} equals 1 if farmer i owns the plot, and zero otherwise. Farmers' specific variables ($\mathbf{x}_{iv}$) in most specifications include wealth, education, age, gender, social capital (proxied by the number of social groups the farmer belongs to), and the size of the cultivated plot. These are included to control for farmers' characteristics which could affect crop choice and, if omitted, create a spurious relationship between ownership status and the dependent variable. Finally, town specific variables ($\mathbf{z}_v$) include total population (a proxy for town size) and distance to market. The reason these variables affect crop choice is that while most annual crops can be grown for home consumption, most of the yield of tree crops is likely to be sold rather than consumed at home.

Exchange is presumably easier in larger towns and transportation costs are lower in towns which are closer to a market.[15] To control for other geographical and/or policy characteristics, all the regressions include province fixed effects.

The linear probability model has a number of advantages with respect to discrete choice models such as probit or logit. In particular, it is possible to include fixed effects without biasing the coefficients and omitting relevant variables is of less consequence because the coefficients of the included variables are biased only if the two are correlated (Yatchew and Griliches, 1985). In addition, Hausman *et al* (1998) show that measurement error (i.e. misclassification) of the dependent variable can strongly bias the coefficient estimates in discrete models. The drawback of the linear model is that it is less efficient and might yield estimates outside the feasible range, especially when the mean of the dependent variable is close to 0 or 1. The mean of the main dependent variable used in the analysis is, in this case, 0.58 and estimates are then very rarely outside the feasible range. Reassuringly, the probit and OLS estimates of the ownership coefficient are very similar.

A.2. Propensity Score Matching.

To measure the pure effect of tenure status, one should observe technique choices by farmers that have been randomly allocated between tenanted and owned plots. Needless to say, the available data is nowhere close to such ideal. Nonexperimental matching procedures, however, might yield estimates that improve over linear regression estimates in the sense of being closer to those produced by a randomized experiment. Matching estimators are widely used in the program evaluation literature to estimate, as in this case, the effect of a causal variable that can only take two values. The main difference between linear regression and matching estimators is the weighting scheme; matching estimators give more weight on the difference between similar observations. This might lead to different point estimates if the effect of ownership on the probability of growing trees varies with observable characteristics.[16]

Due to the large number of observable farmer characteristics, I use matching estimators based on the propensity score, that is, I estimate the conditional probability of being an owner, conditional on the observables in equation (2) and match observations with a similar propensity score. The literature suggest a number of alternative criteria of similarity, which result in different estimators. Here I use three estimators

[15] As a further control, I have also run all the regressions including a categorical variable that equals 0 if the town is not on a paved road, 1 if it is on a secondary road, 2 if on a main road, 3 if on the highway. This variable was never significant. This and other results not reported for reasons of space are available from the author upon request.

[16] See Angrist and Krueger (2000) and Heckman *et al* (1998) for details. Heckman *et al* (1998) show that when the effect of "treatment" (in this case ownership) is identified by comparing the outcome for the treated group to the outcome of a non-random non-treated group there are three sources of bias. First, there is selection bias deriving from unobservable characteristics that, in this case, determine the choice of being an owner or a tenant. Second, estimates might be biased because the supports of observables do not overlap, in this case, for instance, it is clear that the support of wealth is much wider for owners than for tenants. The third source of bias follows from the fact that the distribution of observable characteristics differs within the two groups. Matching estimators effectively eliminate the last two sources of bias but not the first.

that lie at different points of the trade-off between the quantity and the quality of matches. The stratification method indentifies intervals of the range of the propensity score such that within each interval observations have on average the same propensity score regardless of tenure status and then computes the difference in the probability of tree cultivation between observations that lie in the same interval. The nearest neighbor method, in contrast, maximises the quantity of matches as it compares the outcome for each "owner" unit with the "tenant" unit that is closest in terms of the propensity score. Finally, the kernel method strikes a compromise between the other two, that is it matches every "owner" unit with all "tenant" units but it gives more weight to units that are closer in terms of the propensity score.

B. Farmers Fixed Effect Specification.

Both the linear regression and the matching estimates of the effect of ownership on tree cultivation suffer from selection bias on unobservables. In other words, ownership itself might be driven by some omitted characteristic that also drives crop choice. To address this issue I use the information on the famers who cultivate both owned and rented plot and estimate (2) with farmers' fixed effects to control for individual heterogeneity:

$$mix_{ij} = \alpha own_{ij} + b_i + \gamma y_{ij} + e_{ij} \tag{3}$$

Where now mix_{ij} denotes the choice of farmer i on plot j, b_i is the farmer fixed effect and only plot varying characteristics (i.e. size) can be included in the regression. While this specification addresses any concerns deriving from individual heterogeneity, it cannot be employed as the main specification since, due to the small sample size, the effect of farmers' specific variables on different plots cannot be precisely estimated.

C.Testing Alternative Explanations.

The limited liability and incomplete contracts models discussed in section 2, yield different predictions on the effect of land tenure on tree cultivation as a function of farmers' wealth. In particular, if contracts are complete and the inefficiency derives from limited liability we expect the effect of land tenure on tree cultivation to be stronger for poorer farmers. More precisely, there exist a treshold of wealth after which the limited liability constraint does not bind and technique choice is efficient regardless of tenure status. In other words, rich owners and rich tenants should be equally likely to grow trees while poor owners should be more likely than poor tenants to grow trees. In contrast, if contracts are incomplete we expect the effect of land tenure on tree cultivation to be stronger for richer farmers. Since both theories predict that the effect of tenure status varies discontinuosly with wealth, I allow the effect of tenure status to be different at different points of the wealth distribution, that is I augment equation (2) by including the interaction of tenure status with quartile dummies and estimate:

$$mix_{iv} = \alpha_1 own_{iv} + \sum_{q=2}^{4} \alpha_q own_{iv} * d_q + \mathbf{x}_{iv}\beta + \mathbf{z}_v\delta + e_{iv} \tag{2'}$$

The coefficient α_1 thus measures the marginal effect of tenure status for farmers in the first quartile, while α_q measure the additional effect for farmers in quartile q. The predictions of the limited liability model then imply $\alpha_1 \geq \alpha_2 \geq \alpha_3 \geq \alpha_4$, where one inequality should be strict. For instance, if the threshold of wealth after which the limited liability does not bind lies close to the upper bound of the second quartile, we expect $\alpha_1 = \alpha_2 > \alpha_3 = \alpha_4$. In contrast, the incomplete contract model predicts $\alpha_1 \leq \alpha_2 \leq \alpha_3 \leq \alpha_4$, where, again, one inequality should be strict.

Finally, the theoretical models yield precise predictions on the effect of wealth on tree cultivation according to tenure status. To test these I estimate:

$$mix_{iv} = \alpha * wealth + \mathbf{y}_{iv}\beta + \mathbf{z}_v\delta + e_{iv} \tag{4}$$

on the sample of owners and tenants separately. The vector $\mathbf{y}_{iv}$ includes all the variables described above plus, in some specifications, additional variables that are tenure specific as, for instance, the length of the tenancy agremeent for tenants. According to the limited liability model we expect $\alpha > 0$ for both owners and tenants, since the inefficiency derives from the fact that poor farmers cannot be punished in case of failure. According to the incomplete contracts model, however, $\alpha = 0$ for tenants since it is difficult to provide incentives to rich and poor tenants alike. Depending on whether contractual incompleteness generates a credit constraint one could also observe $\alpha > 0$ for owners, as rich owners do not need to borrow and hence are not affected.

3.4 Econometric Concerns.

The identification of the effect of ownership on tree cultivation raises a number of concerns. First, the survey contains no information on plot characteristics other than size. The estimate of the effect of ownership on crop choice could therefore be biased if (i) tree crops necessitate a specific soil type and (ii) all plots of that specific soil type are cultivated by owners. This could be the case if, for instance, because of moral hazard, in equilibrium all land which is suitable for tree cultivation is owner operated.

I address this issue by exploiting information on the mode of acquisition of the plot, that is by introducing an interaction term between ownership and a dummy variable that equals one when the plot has been obtained via land reform, as opposed to purchase or inheritance. The rationale behind this test is the following. Since the reform redistributed land that was previously rented out then if, as postulated above, the equilibrium was such that only land unsuitable for tree cultivation was rented out, plots obtained by land reform must be unsuitable for tree cultivation. Therefore if ownership were exclusively proxying for soil type there should be no difference between tenants and owners who cultivate a plot obtained via land reform. In other words, the coefficient on ownership and that of the interaction between land reform and ownership should be of the same magnitude and opposite sign.

Alternatively, the issue of omitted soil type can be partially addressed by introducing town dummies in [2], that is by estimating:

$$mix_{iv} = \alpha own_i + \mathbf{x}_i\beta + d_v + e_{iv} \tag{4}$$

The idea behind [4] is that since the sample covers the entire country, soil characteristics are likely to vary across towns at least as much as they do within each town.[17] Thus, if the results are driven by unobservable soil quality, this should be, at least in part, be picked up by the town fixed effects (d_v) and should result in a large change in the ownership coefficient.

The second main concern derives from the inclusion of the wealth variable. While this is essential for most theories and must be included since it is likely to be correlated with tenure status, it does raise a number of issues. Wealth is defined as the total value of household assets, that is it includes information on farm assets and livestock which are likely to be determined simultanously with the decision to plant trees. This would happen, for instance, if trees require more expensive tools or if tree cultivation and animal husbandry are substitutes. Moreover, trees could affect land value, which is itself part of wealth. Other components of wealth such as the value of consumer durables and of the house, however, are not directly related to the decision of planting trees and can be used as instruments for total wealth. Since IV estimates of the coefficient of interest are very similar to those obtained by OLS, OLS is used throughout while IV estimates are presented at the end as a robustness check.

A related issue is that of pure reverse causality, that is cultivating trees make farmers richer. In this case the OLS estimate of the ownership effect in equation 2 is inconsistent. However it can be shown that it tends to be smaller than the "true" value. That is, estimating:

$$mix_{iv} = \alpha own_{iv} + \beta wealth_{iv} + e_{iv} \tag{2}$$

while ignoring that:

$$wealth_{iv} = \lambda mix_{iv} + \eta_{iv}$$

where $\lambda > 0$; implies that:

$$plim(\hat{\alpha}) = \alpha \left(\frac{\sigma_\eta^2 + \lambda\sigma_{\eta e}}{\sigma_\eta^2 + 2\lambda\sigma_{\eta e} + \lambda^2\sigma_e^2} \right) \tag{5}$$

and the term in parenthesis is smaller than one whenever $\lambda\sigma_e^2 \geq -\sigma_{\eta e}$, which is always the case if $\sigma_{\eta e} \geq 0$ (see Appendix for details). In this context one can reasonably assume that $\sigma_{\eta e} > 0$ since omitted variables such as farmers' ability affect wealth and tree cultivation in the same direction, e.g. more able farmers are more likely to cultivate trees and also to be able to accumulate wealth.

[17] Town dummies explain 68% of the variation of the (unit) value of land in the sample.

4 Results

The Effect of Tenure Status.

The first column of table 2 reports the OLS cross-section estimates of equation (2). The results suggest that trees are more likely to be grown on owner-cultivated plots. Evaluating at the sample mean of all independent variables, a transfer of ownership to the farmer increases the probability of growing trees by 26%. Results also indicate that trees are more likely to be grown by richer farmers, by farmers who belong to some social association/group and by farmers who live in large towns and/or towns that are close to the market, which presumably derives from the fact that tree yields are mostly sold rather than consumed at home.[18] Finally, trees are more likely to be cultivated on smaller plots. The province fixed effects (not reported) are jointly significant.

The second and third column report OLS results for alternative definition of the dependent variable. When the tree dummy equals one only for the most effort sensitive crops, that is citrus and coffee, results are qualitatively unchanged but a transfer of ownership to the farmer increases the probability of growing trees by 33%, which suggests, as is reasonable, that the effect of tenure status is stronger for crops that are more prone to moral hazard problems. The difference, however, is not statistically significant.

Column (3) shows that results are also qualitatively unchanged when the dependent variable is $tree\_main$, i.e. when farmers are classified as growing trees when trees are one of the two main crops. The effect of tenure status is however considerably larger in this case as a transfer of ownership to the farmer increases the probability of growing trees by almost two hundred percent. As argued above, this variable strongly understates the number of farmers who grow tree crops and therefore provide an upper bound on the effect of tenure status. Column 4 presents the empirical estimates of equation (3), i.e. it includes farmer's fixed effects. The dependent variable is $tree\_main$, since neither $tree\_mix1$ or $tree\_mix2$ are available.[19] The results show that, even controlling for every source of individual heterogeneity, tenure status matters: a given farmer is more likely to grow trees on the fields he owns than on the fields he rents. The coefficient on the ownership variable is significant at more than the 1% level, which is quite surprising given the small sample size. The marginal effect of tenure is significantly higher than in the larger sample. One possible explanation is that the endogeneity of wealth biases the cross section estimate of the ownership effect downwards as indicated in equation (5). Given sample size, however, it is not possible to credibly establish whether this is due to an

[18]Other individual specific variables such as wife's education, household's demographic composition, whether the farmer belonged to a producers' group and whether the farmer had reported to be credit constrained were not significant.

[19]The survey asked respondents to report the two main crops grown on each plot separately. Information on other crops is pooled at the farmers' level and is therefore impossible to establish whether these are grown on the rented or on the owned plot.

intrinsic difference between farmers who cultivate both types of plot and farmers who cultivate one alone.

Table 3 presents the matching estimates based on the propensity score.[20] To assure that the balancing property is satisfied I use wealth quartile dummies instead of the continuous definition of the wealth variable.[21] Column (1) shows that the OLS point estimates are lower than the one obtained with the continuous variable, although the difference is not statistically significant at conventional levels. Columns (2) to (4) report the matching estimates for each of the three alternative definitions of the dependent variable. The matching estimates are between 2 and 3 times larger than OLS estimates for two out of the three dependent variables and the effect of tenure status is precisely estimated in all cases. The difference between OLS and matching estimates indicate that the effect of tenure status varies with observable characteristics, an issue which is examined in more detail in the following section. For ease of exposition, and without loss of generality, the analysis that follows will employ the more general definition of *tree_mix*.[22]

Tenure Status and Farmers' Wealth: Testing Alternative Explanations.

Column (1), Table 4 presents estimates of equation $2'$, i.e. I allow the effect of tenure status to be different at different points of the wealth distribution. Results show that tenure status does not have a significant impact on crop choice when farmers are very poor, i.e. when they belong to the first quartile. In contrast the effect is significantly different from zero at the 10% level in the second quartile and at more than 5% in the third and fourth.[23] In addition, the coefficient of the ownership dummy in the lower quartile is significantly different from the coefficient in higher quartiles. Also, the coefficient increases as farmers get richer but not significantly so.[24] A transfer of ownership from tenants to owners within the same wealth class would result in an increase in the probability of cultivating trees of 47% in the fourth quartile, 36% in the third and 27% in the second, thus indicating that pooling farmers

[20] These are computed using the STATA codes by A.Ichino and S.Becker available at http://www.iue.it/Personal/Ichino/Welcome.html#pscore

[21] The balancing hypothesis is satisfied when observations with the same propensity score have the same distribution of observable characteristics, independently of tenure status. Due to the low number of observations the hypothesis is not satisfied when the continuous wealth variable is used.

[22] Results for *tree_mix*2 and *tree_main* are generally similar and available from the author on request.

[23] The result does not seem to be due to lack of variation: thirteen percent of farmers in the first quartile are owners. The percentage increases to 55 in the second, 83 in the third and 92 in the fourth. Note that tenure status is significantly different from zero in the fourth quartile even if tenants are only 5% of the sample.

[24] When the effect of tenure status is allowed to vary monotonically with wealth, i.e. by introducing a simple interaction between wealth and the ownership dummy, it changes in the right direction (the interaction term is positive) but not significantly so. The result is clearly driven by the fact that tenure status does not matter for very poor farmers only while its effect is the same for farmers on or above the second quartile. That is, the relationship is increasing but not monotone.

of different classes bias the marginal effect of tenure status downwards.[25]

While this provides some evidence against the limited liability model, the result might derive from the fact that the limited liability constraint binds up to, and including, the fourth quartile. To examine the matter further, table 5 estimates whether the impact of wealth on crop choice differs according to whether the plot is cultivated by the owner or by a tenant. Columns (2) and (3) estimate equation [4] for tenants and owner-cultivators separately. The results suggest that wealth only matters when the farmer owns the land: the wealth coefficient is significant in column (2) but not in column (3). This too points to the fact that, in this context, the inefficiency seems to derive from the inability to commit rather than from limited liability. Indeed, according to the latter, wealth should affect technique choice under tenancy as well as under owner cultivation.

There are a number of reasons why the inability to commit to output contingent contracts might be the relevant source of inefficiency in this particular context. First, since trees are long lived and since effort affects their long term profitability, the result might derive from the fact that long-term commitments are typically more difficult to adhere to. Second, even if long-term agreements were credible, landlords might be unwilling to commit to a long term contract because this might eventually grant land rights to the tenant. This issue is of great relevance in Nicaragua where in 1981 rented land was redistributed from large landowners to tenants and sharecroppers[26] and where the present Consititution and Reform Laws favour small owner-cultivators and makes it difficult to evict long-term tenants.[27] In fact, most tenancy contracts in the sample are short-term.[28]

Not surprisingly, trees are more likely to be grown on rented plots when the contract is long-term (column (5)). Interestingly, it is the length of the contract, rather than the duration of the relationship that matters. That is, tenants who have been farming the same plot for long are not more likely to grow trees unless the contract is long-term as well. I also find that the form of the tenancy agreement (i.e. rent vs. sharecropping) does not enter significantly. This might be because the choice of form depends on the characteristics of the tenant that are already included in the regression or because the length of the agreement is the only binding constraint (results not reported for reasons of space). Column (5) also shows that tenants who have received technical assistance are more likely to farm trees, possibly a reflection of the fact that tenants who have acquired special skills are more "irreplaceable", which, in turn, makes long-term commitments more credible. Still, it might be argued that technical assistance is endogenous because tree crops are more difficult to cultivate, implying that farmers who grow them need more technical assistance. If this were

[25]Similar results can be obtained by estimating equation (2) on four separate subsamples–i.e. one per quartile.

[26]See *Decreto No.*782 19/7/81, Artt.2 and 9.

[27]See e.g. Constitution Politica,Titulo VI, Cap. II.

[28]About 60% of contracts are one year long, 20% are two years long and only 6% last longer than 5 years.

the case, however, technical assistance should be positively correlated with trees regardless of the ownership mode, but assistance is not significant when the farmer owns the land (column (4)).[29]

Finally, one might expect the lack of commitment that drives the results of the incomplete contract model to be less serious if the tenant and his landlord belong to the same family because repeated interactions might help sustain the cooperative outcome. This view is not supported by the empirical evidence: as shown in column (5), the relationship between tenants and landlords does not affect crop choice.

That wealth affects crop choice for owner-cultivators suggests that credit constraints matter. From the questionnaire we learn that only 20% of farmers are currently in debt (see Table 5). Most of the others (about 80%) wanted to borrow but could not, either because they would be rejected, because loans are too expensive or because there are no lenders in the community. Only 20% of non-borrowing farmers do not borrow because they do not need or do not want to.

Although this evidence indicates that credit constraints might play a role it is not possible to exclude that the result is driven by unobservable farmer characteristics that drive both wealth and the decision to grow trees. For instance, entreprenuership might have a positive impact on both variables. While identifying the effect of owners' wealth on tree cultivation is interesting, it goes beyond the scope of this paper.

Note that owner-cultivators are more likely to grow trees the longer they have held the plot (column (4)). The results might be driven by tenure security: the longer a farmer holds a plot, the less likely he is to lose it because of title disputes. This is quite a serious issue in Nicaragua, where, because of the sequence of land reforms enacted by different governments there can be up to three title-holders for the same plot.[30] Not surprisingly, holding a title of any kind has no significant effect on crop choice. Moreover, only 10% of the farmers who do not have a title, report to be afraid of losing their land. This suggests that $de\ facto$ tenure security is more relevant than formal titling. Still it must be noted that the new titling programme has only started very recently[31] so that no definite conclusion can be drawn at this stage.

Finally, although tenure status is always a significant determinant of tree cultivation and although its impact is often large, it clearly does not tell the whole story. In most specifications, tenure status and other control variables explain about ten percent of the cross-sectional variation indicating that, not surprisingly, other factors play an important role. Aside from soil quality which is discussed in section 5 below, the literature suggests a host of explanations that are complementary to the one analysed here (Feder 1985). In particular, existing evidence shows that technology

[29]Technical assistance could be proxying for tenant entreprenuership, i.e. only the most "active" tenants seek assistance, which would still fit the story of the tenant being less replaceable. The argument could go the other way though, i.e. only bad tenants need assistance.

[30]That is, there are pre-reform, old-reform and new-reform titles.

[31]Law 209 (1995) established that existing titles could be converted to permanent titles while Law 278 (1997) streamlined the process.

diffusion is social in character, that is, farmers learn from each other (Bandiera and Rasul 2002, Conley and Udry 2002, Foster and Rosenzweig 1995). In addition, the security of property rights has been shown to have a profound impact on long lived investments (Besley 1995, Jacoby *et* al. 2002). The latter issue seems particularly relevant in this context given the long series of land titling programmes that have resulted in more than one person having rights to the same plot. It is important to notice that, however, this affects any landowner regardless of whether he cultivates or rents out his plots and that, therefore, it is not likely to bias the results in any particular direction.

5 Econometric Concerns and Robustness Checks.

The analysis raises a number of econometric concerns. First, the result that owners are more likely than tenants to grow trees might be due to the fact that all land that is suitable for tree cultivation is owner-operated while all land that is unsuitable for tree cultivation is rented out. Table 6 addresses the issue of omitted soil type. To facilitate comparisons, column (1) reports the OLS estimate of equation 2. In Column (2) I add town fixed effects to proxy for inter-town variation in soil type. The basic results are robust to this alternative specification. In particular the coefficient of ownership is not significantly different from the one in column (1) where town effects were omitted. This is reassuring: to the extent that soil quality differs in different towns, it does not appear to vary systematically with tenure status.[32] Although town fixed effects effectively control for differences in soil quality across towns, they clearly cannot account for variation in soil quality within each town. To address this issue, columns (3) and (4) introduce the interaction term between ownership and an indicator of plot acquisition via land reform. The rationale behind this test is the following. Since land reform redistributed plots that were previously rented out, these should be unsuitable for tree cultivation if, as it could be argued, only land of this type is rented out in equilibrium. It then follows that if the ownership variable exclusively captures the effect of omitted soil quality, owners whose plots were previously rented out should be as likely as tenants to grow trees. To keep the comparison clean, it is important to distinguish between plots that were assigned to individual farmers and plots that were assigned to a farmer's group or collective, since the latter organizational form results in a different incentive structure. The results indicate that owners who got their plot individually assigned by land reform do not make different choices compared to owners who bought or inherited their plot. Interestingly, the type of land reform matters: owners who got their plots assigned by collective land reform are as likely as tenants to grow trees. The result might be due to the fact that collective farms face a free rider problem although there is

[32]Town dummies explain 68% of the variation in unit land value in the sample. If unit land value can be interpreted as a proxy for soil quality, the result indicates soil quality varies more across towns than within.

not enough information available to analyse this matter any further. In column (4) I repeat the analysis with town fixed effects: the results are unchanged.

While differences in soil quality do not seem to drive the result that owners are more likely to grow trees, endogenous matching of farmers and soil types could bias the coefficient of wealth towards zero.[33] The argument runs as follows: assume that poorer farmers are more risk adverse and therefore have a strong preference for land of higher quality if this is also less risky. If, at the same time, land of higher quality is better suited for trees one would observe no relationship between tree cultivation and wealth because poor farmers who farm the right type of land cannot afford tree cultivation while richer farmers who can afford tree cultivation do not farm land that is suitable for trees. Since the data contain no measure of soil suitability for trees this argument cannot be investigated directly. Three considerations, however, cast doubt on the practical relevance of this type of matching. First, the agronomic evidence (see Table A1) shows that although individual crops might have specific soil requirements, as a group the annual and tree crops in the sample do not have drastically different soil requirements. In other words, it is generally possible to find at least one tree that can grow in any given soil type.[34] Relatedly, the agronomic evidence also suggest that agroforestry is profitable in a wide range of conditions.[35] Second, I find that wealth is a significant determinant of tree cultivation for owners but not for tenants, suggesting that, if it takes place at all, matching has a substantially different impact according to tenure status, which is difficult to justify. Finally, the fact that tenants farm trees when they are on a long term contract provides support to the idea that contractual incompleteness matters and, relatedly, implies that tenant's wealth is not a significant determinant of tree cultivation because, due to contractual incompleteness, it is difficult to provide long term incentives to rich and poor tenants alike.

The result that wealth is not a significant determinant of tree cultivation under tenancy could be due to a number of reasons that might invalidate the contractual incompleteness explanation suggested above. One possibility is that wealth does not exhibit sufficient variation in the tenants' sample compared to the owners' sample, which makes the coefficient estimates less precise and hence makes it harder to reject the null. Table 1.1. indicates that owners' wealth is on average higher and also has a higher variance. Standard measures of dispersion, however, take similar values in the two samples. For instance, the coefficient of variation is 2.4 for tenants and 2.7 for owners.[36] Measurement error might lead to attenuation bias but this can explain the results only if measurement error is much larger for tenants, which is implausible. A further concern is that the relationship between tree cultivation and wealth is non

[33]For a detailed analysis of endogenous matching and tenancy see Ackeberg and Botticini (2002).

[34]The only exception is that all trees require Ph. levels below 8.5 while some of the annual crops can grow up to 9. Such high values, however, are quite rare.

[35]See for instance Current *et al* (1995)

[36]If land value is excluded from the measure of wealth, the coefficient of variation for owners is actually smaller (2.0 vs 2.4).

linear and that imposing linearity biases the coefficient towards zero. Finally the result might be due to outliers or to the fact that the positive relationship between wealth and tree cultivation for owners only applies to a range of values of wealth where there are no tenants. Table 7 presents further estimates of equation (2) that address some of these concerns. Columns (1) and (2) use wealth quartiles dummies instead of the continuous wealth variable. This should ameliorate the measurement error problem because it is relatively difficult to misclassify farmers using such a coarse definition and also rule out that results are driven by outliers. Moreover, quartile dummies are not sensitive to the lack of variation problem to the extent that the distribution of farmers across quartiles presents similar variation in the owners' and tenants' samples separately.[37] The results are similar to those obtained with the continuous variable: wealth is significant in the owner sample but not in the tenant sample. Moreover estimates of the quartile coefficients are equally precise in both samples.

Colums (3) and (4) present estimates on trimmed samples obtained by cancelling the observations with the 2.5% lowest and the 2.5% highest values of the wealth variable. The results are unchanged. Columns (5) and (6) relax the assumption of linearity by adding the wealth variable squared. Neither wealth term is significant in the tenants' sample, indicating that previous results were not driven by the assumption of linearity. As a further check, I have estimated the relationship between tree cultivation and wealth non parametrically for both owners and tenants, controlling for other independent variables.[38] Figure 1 presents the non parametric estimates with 5% bootstrapped confidence bands. Panel 1A shows that for the sample of tenants, the assumption of linearity is not driving the result. The effect of wealth on the probability of tree cultivation is not significantly different from zero even when no restrictions are imposed on the functional form. The non parametric estimates for owners (Panel 1B) show that the relationship is positive and, again, linearity cannot be rejected. The estimates also show that the results do not depend on the fact that all tenants are poor, i.e. that no tenant is wealthy enough for the positive effect of wealth to kick in. Panel 1C presents non-parametric estimates for a restricted sample of owners (accounting for forty percent of the total owners sample) whose wealth is in the same range as tenants. The relationship is still clearly positive even at the very lowest wealth values.

Table 8 addresses the issue of wealth endogeneity. As argued above there might be a problem of simultaneity since some components of wealth are likely to be determined simultanously with the decision to plant trees. For instance, the definition of wealth

[37]The distribution is as follows: 56.5% of tenants belong to the first quartile, 29% to the second, 11% to the third and 3.5% for the fourth. In contrast, 5% of owners belong to the first quartile, 25% to the second, 33% to the third and 37% to the fourth.

[38]That is, I estimate $m_{iv} = \beta wealth + \mathbf{x}_{iv}\gamma + \mathbf{z}_v\delta + e_{iv}$ by OLS, compute $\hat{y} = \hat{m} - \hat{\beta} wealth$ and then estimate $E(\hat{y}|wealth)$ non parametrically.

Alternatively I have estimated I have estimated γ and δ from the regression in first differences and then estimated $E(y- \mathbf{x}_{iv}\hat{\gamma} + \mathbf{z}_v\hat{\delta}|wealth)$ non parametrically.

includes the value of farm animals, which is likely to bias the results if trees and animal husbandry are substitutes. Similarly, the value of farm tools might depend on crop choice if trees and annual crops require different tools. To address the issue of simultaneity, I instrument total wealth with the components that are not determined simultaneously with the decision of planting trees, that is the value of consumer durables and of the farmer's house. Table 8.1 reports the IV estimates, which indicate that simultaneity did not bias the ownership coefficient nor was it responsible for the result that wealth does not affect tree cultivation in the tenant sample. The IV estimates of the coefficient of wealth are larger than the OLS estimates, suggesting that, possibly, simultaneity was biasing the results downwards, which is consistent with the interpretation of animal husbandry and tree cultivation being substitutes.

This IV procedure, however, fails to address the problem of reverse causality from tree cultivation to wealth. Put simply, farmers who grow trees might be richer because trees are more profitable. Richer farmers can afford more consumer durables and a better house, thus invalidating the use of these as instruments to address reverse causality.

However reverse causality from trees to wealth cannot be held responsible for the main results of the paper. As argued above, the cross section estimates of the ownership coefficient are, if anything, reduced by this type of reverse causality. Moreover, reverse causality cannot be driving the results in the tenants' sample since wealth is not significantly different from zero in that case.The only result which is possibly determined by reverse causality is that wealth is a significant determinant of tree cultivation in the owner sample. One possible reason is that trees make owners richer because they are able to capture the entire surplus while tenants are not (i.e. the surplus is captured by the landlord).

To address this issue one then needs instruments that determine wealth *regardless of tenure status.* To this purpose I use data from the 1995 Census to construct town aggregates that affect both owners' and tenants' wealth in a similar way. A further identifying assumption is that the instruments are not variables of choice for the farmer, that is that farmers do not sort themselves across towns according to town characteristics. Reassuringly, Census data indicate that 95% of the resident population of was born in the towns under study.

The instruments are two measures of education (the literacy rate and the percentage of primary school graduates), one measure of infrastructure (the percentage of houses in the town with direct water supply), and the sample median value of wealth in the town. It is important to notice that although the instruments might have a direct effect on tree cultivation, they do so for both owners and tenants, implying that this cannot explain the differential impact of wealth in the two samples.[39]

The first stage regressions (columns 1,3 and 5, table 8.2) reveal that the instru-

[39]There are 119 towns in the sample. In the IV estimation I do not include the 7 towns in which there are no owners and the 12 towns in which there are no tenants. Very similar results obtain if these are included or if, at the other extreme, only towns where the owner share is between 40 and 60% are included.

ments affect owners' and tenant's wealth in a similar way. Median wealth and town infrastructure have a positive effect on the individual wealth of both owners and tenants. The share of primary school graduates has the right sign but is significantly different from zero in the tenants sample only. Surprisingly, the literacy rate has a negative impact on individual wealth but it is only significant in the tenants' sample. The joint test of significance of the instruments rejects the null in all samples.

The second stage regressions (columns 2,4, and 6 table 8.2) show that the point estimate of the ownership coefficient is the same as the OLS estimate and that wealth matters for owners but not for tenants. The IV coefficient in the owners' sample is larger than the previous OLS estimate, which might indicate the presence of measurement error in the wealth variable. To test for overidentifying restrictions I have regressed the residuals of the second stage on the instruments and the other exogenous variables and then tested the hypothesis that the instruments' coefficients are jointly equal to zero. A rejection of the null should cast doubts on the validity of the instruments. The test passes comfortably (p-values are .90, .62 and .66) which is reassuring given that this type of tests is known to have low power.

Finally, Table 9 reports probit estimates and shows that all previous results are robust to the estimation method. The estimate of the marginal effect of ownership is identical to the OLS estimate, tenure status affects tree cultivation for richer farmers only and wealth is a significant determinant of tree cultivation for owner cultivators but not for tenants.

6 Conclusions.

The analysis of technique choice for a sample of Nicaraguan farmers indicates that owner cultivators are more likely than tenants to grow trees together with annual crops rather than annual crops alone. Importantly, the result holds for a sample of farmers that cultivate both owned and rented plots, implying that the effect derives from tenure status rather than from unobservable farmer characteristics. The estimates imply that a transfer of ownership to the farmer would increase the probability of growing trees by at least twenty-six percent.

Further analysis reveals that the wealth of the tenant is not a significant determinant of tree cultivation, thus indicating that, in this context, the inefficiency does not derive from the difficulty of providing incentives to poor tenants as suggested, for example, by theories of limited liability or risk sharing. Rather, the inefficiency seems to be linked to the fact that long term agreements, which are necessary to provide incentives for tree cultivation, are quite rare in this setting. Such form of contractual incompleteness can be ascribed to the difficulty of enforcing long term agreements but also to the landlords' reluctance of conceding the rights that current laws grant to long term tenants. The paper thus provides evidence on the practical importance of contractual incompleteness.

Altogether, the results have important implications for land policy, a core issue in most developing countries. First, encouraging the use of long term contracts can potentially attenuate the bias against tree cultivation on rented plots. Relatedly, policies that are meant to protect farmers' rights can backfire as landlords take measures to protect their interests. This is not big news for Latin America, which has a long history of landlords acting to undo reforms meant to increase farmers wealth and agricultural productivity (Binswanger *et al* 1995, deJanvry and Saudolet, 1989)

Second, the paper offers some insights on the desirability of redistributive land reform. In particular, the results show that the success of such policy relies crucially on the identity of the beneficiaries. In this sample, poor owners are as unlikely as poor tenants to grow trees while the effect of tenure status is strong for wealthier farmers. Whether this is a pure wealth effect, that could therefore be undone by a transfer of resources to the poorest farmers, or whether wealth proxies for unobservable farmers characteristics cannot be identified from the data used in this paper. The issue is of fundamental importance to evaluate the impact of land redistribution and is left as an open question for future research.

References

[1] Ackeberg, D. and Botticini, M. (2002) "Endogenous Matching and The Empirical Determinants of Contract Form," *Journal of Political Economy*

[2] Angrist, J.D. and Krueger A.B.(2000) "Empirical Strategies in Labor Economics" in O. Ashenfelter and D. Card (eds), Handbook of Labor Economics, North Holland, chapter, 23, vol 3a.

[3] Asamblea Nacional de la Republica de Nicaragua, Ley No. 209, *La Gaceta* No. 227, 01-12-1995.

[4] Asamblea Nacional de la Republica de Nicaragua, Ley No. 278, *La Gaceta* No. 239, 16-12-1996.

[5] Asamblea Nacional de la Republica de Nicaragua, Decreto No. 11-90, *La Gaceta* No. 98, 23-05-1990.

[6] Baland,J.M. and Robinson,J. (2001) "Land and Power" (mimeo, University of California at Berkeley).

[7] Bandiera,O. and Rasul, I. (2002) "Social Networks and the Adoption of New Technology in Northern Mozambique" (CEPR Discussion Paper 3341).

[8] Banerjee,A.V. (1999) "Land Reforms: Prospects and Strategies Massachusetts Institute of Technology", Department of Economics Working Paper: 99/24.

[9] Banerjee,A.V.,Gertler,P.J. and Ghatak,M. (2001) "Empowerment and Efficiency: Tenancy Reform in West Bengal", *Journal of Political Economy*, **110(2)**, *239-280.*

[10] BARDHAN,P. AND UDRY,C. (1999) *Development Microeconomics* (New York: Oxford University Press).

[11] BERRY, R.A., AND CLINE, W.R. (1979) Agrarian structure and productivity in developing countries. Geneva: International Labor Organization.

[12] BESLEY,T. (1995). "Property Rights and Investment Incentives: Theory and Evidence from Ghana", *Journal of Political Economy*, **103(5)**, *903-937.*

[13] BINSWANGER, H., DEININGER, K., AND FEDER, G. (1995). "Power, Distortions, Revolt and Reform inAgricultural Land Relations," in: Behrman, J. and Srinivasan, T.N. (Eds.), Handbook ofDevelopment Economics,III (Ch. 42): 2659-2772, Elsevier Science

[14] BRAVERMAN,A.AND STIGLITZ,J.E.(1986) "Landlords, Tenants and Technological Innovations", *Journal of Development Economics*, **23**, *313-332.*

[15] CONLEY,T. AND UDRY. C. (2000) Learning About a New Technology: Pineapple in Ghana, Working Paper-Yale University.

[16] CURRENT,D.,LUTZ,E. AND SCHERR,S. (1995) "Costs, benefits, and farmer adoption of agroforestry: Project experience in Central America and the Caribbean" (Environment Paper, no. 14. Washington, D.C.: World Bank).

[17] DE JANVRY, A., AND SADOULET, E. (1989) 'A study in resistance to institutional change: the lost game of Latin American land reform',World Development,17:1397-1407

[18] FEDER,G.,RICHARD,E.J.AND ZILBERMAN,D. (1985) "Adoption of Agricultural Innovations in Developing Countries: A Survey", *Economic Development and Cultural Change*, **33(2)**, *255-98.*

[19] FOSTER.A AND M.ROSENZWEIG (1995) "Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture", *Journal of Political Economy* 103(6): 1176-1209.

[20] HART, O. AND MOORE, J. (1999) "Foundations of Incomplete Contracts" *Review of Economic Studies, 66:115-138.*

[21] HAUSMAN, J. ABREVAYA, J. AND SCOTT-MORTON F.M. (1998) "Misclassification of the Dependent Variable in a Discrete-Response Setting" *Journal of Econometrics* 87(2): 239-69

[22] HECKMAN, J., ICHIMURA, H. AND TODD, P. (1998) "Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Program", *Review of Economic Studies*, 64: 605-654.

[23] JACOBY, H.G., LI G. AND ROZELLE S. (2002) "Hazards of Expropriation: Tenure Insecurity and Investment in Rural China" forthcoming *American Economic Review*

[24] JUNTA DE GOBIERNO DE RECONSTRUCCION NACIONAL, Decreto No. 782, Published in La Gaceta No. 188, 21-08-1982.

[25] MOOKHERJEE,D. (1997). "Informational Rents and Property Rights in Land,"' in J. Roemer, ed., Property Rights, Incentives and Welfare, New York: MacMillan Press.

[26] SHABAN,R.A. (1987). "Testing Between Competing Models of Sharecropping", *Journal of Political Economy*, **95(5)**, *893-920.*

[27] SHETTY,S. (1988). "Limited Liability, Wealth Differences and the Tenancy Ladder in Agrarian Economies," *Journal of Development Economics*, **9(1)**, *1-22.*

[28] STIGLITZ,J.E. (1974). "Incentives and Risk Sharing in Sharecropping," *Review of Economic Studies*, **41(2)**, *219-55.*

[29] TIROLE, J. (1999) "Incomplete Contracts: Where Do We Stand?" *Econometrica*, 67: 741-81.

[30] WORLD BANK- POVERTY AND HUMAN RESOURCES DRG (2000) "Basic Information Document, Nicaragua LSMS 1998", http://www.worldbank.org/lsms/country/ni98/docs/ni98bif.pdf

[31] YATCHEW, A. AND GRILICHES, Z. (1985) "Specification Error in Probit Models" *Review of Economics and Statistics*; 67(1): 134-39

APPENDIX: Derivation of Equation (5)

The OLS estimator of α from $mix_{iv} = \alpha own_{iv} + \beta wealth_{iv} + e_{iv}$ is given by:

$$\hat{\alpha} = \frac{cov(o_{iv}, m_{iv})var(w_{iv}) - cov(w_{iv}, m_{iv})cov(o_{iv}, w_{iv})}{var(o_{iv})var(w_{iv}) - (cov(o_{iv}, w_{iv}))^2} \tag{A1}$$

Where, for ease of exposition $o = own$, $m = mix$ and $w = wealth$.
The reduced form of the model, taking into account that $wealth_{iv} = \lambda mix_{iv} + \eta_{iv}$ is

$$\begin{aligned} m_{iv} &= \tfrac{1}{1-\beta\lambda}\left(\alpha o_{iv} + \beta\eta_{iv} + e_{iv}\right) \\ w_{iv} &= \tfrac{1}{1-\beta\lambda}\left(\alpha\lambda o_{iv} + \eta_{iv} + \lambda e_{iv}\right) \end{aligned} \tag{A2}$$

From A2 we get:

$$\begin{aligned} cov(o_{iv}, m_{iv}) &= \tfrac{\alpha}{1-\beta\lambda}\sigma_o^2 \\ var(w_{iv}) &= \left(\tfrac{1}{1-\beta\lambda}\right)^2 \left(\alpha^2\lambda^2\sigma_o^2 + \sigma_\eta^2 + \lambda^2\sigma_e^2 + 2\lambda\sigma_{\eta e}\right) \\ cov(w_{iv}, m_{iv}) &= \left(\tfrac{1}{1-\beta\lambda}\right)^2 \left(\alpha^2\lambda\sigma_o^2 + \beta\sigma_\eta^2 + \lambda\sigma_e^2 + (1+\beta\lambda)\sigma_{\eta e}\right) \\ cov(o_{iv}, w_{iv}) &= \left(\tfrac{1}{1-\beta\lambda}\right)\alpha\lambda\sigma_o^2 \end{aligned}$$

which implies that:

$$plim(\hat{\alpha}) = \alpha\left(\frac{\sigma_\eta^2 + \lambda\sigma_{\eta e}}{\sigma_\eta^2 + 2\lambda\sigma_{\eta e} + \lambda^2\sigma_e^2}\right)$$

Table 1.1 Variables Means and Standard Deviations

	whole sample	owners	tenants	*mean equality test-Pvalue*	owner-cum-tenant
tree_mix	.58	.63	.49	*.00*	
	(.49)	(.48)	(.50)		
tree_mix2	.42	.48	.34	*.00*	
	(.49)	(.49)	(.47)		
tree_main	.09	.13	.04	*.00*	.12
	(.29)	(.33)	(.19)		(.32)
farmer owns plot	.61				
	(.49)				
total wealth *10^{-4}	59.9	90.7	11.7	*.00*	62.3
	(196.1)	(245.1)	(29.8)		(90.3)
social capital	.49	.52	.46	*.16*	.59
	(.78)	(.78)	(.76)		(.72)
famer's age	46.1	48.6	42.1	*.00*	47.4
	(15.8)	(15.6)	(15.4)		(15.7)
gender (1 is male, 2 female)	1.1	1.1	1.1	*.28*	1.05
	(.31)	(.32)	(.29)		(.23)
education dummy	.46	.46	.47	*.75*	.37
	(.49)	(.49)	(.49)		(.48)
plot size (manzanas)	24.8	36.3	6.86	*.00*	
	(67.6)	(82.5)	(23.3)		
province population*10-4	39.7	37.1	43.6	*.25*	42.5
	(58.6)	(53.2)	(66.1)		(37.2)
average distance to market (hrs)	1.87	1.89	1.82	*.07*	1.88
	(1.01)	(1.02)	(.98)		(.92)

Variables Definition
tree_mix: dummy variable,=1 if the farmer grows a mix of trees (coffee, citrus, mangoes or bananas) and annual crops; **tree_mix2:** dummy variable,=1 if the farmer grows a mix of trees (coffee or citrus only) and annual crops **tree_main**: dummy variable,=1 if trees are a main crop;
total wealth: value of (plot+house+durables+business assets+livestock + farm assets), in thousands of *cordobas.* All values are reported by the respondent. To measure plot value, respondents were asked: how much would it cost to buy one *manzana* of land that has the same characteristics as yours and is located in the same neighborood? **education:** dummy variable, =1 if the farmer has had some formal education; **social capital:** number of groups the household belongs to; **plot size:** 1 manzana=0.69 hectares; **distance to market:** distance from farm to market-- town average.

Table 1.2. Main Crops

% of farmers growing:	*entire sample*	*owners*	*tenants*	*proportion equality test-Pvalue*
corn	78	79	77	.26
beans	60	61	59	.35
cassava	17	19	15	.15
millet	13	12	15	.18
citrus	37	40	32	.00
banana	18	20	14	.01
coffee	10	14	4	.00
mango	24	27	21	.02

Table 2. Land Tenure and Trees:Cross Section and Fixed Effect Estimates

	(1)	(2)	(3)	(4)
	cross-section dependent variable is tree_mix	cross-section dependent variable is tree_mix2	cross-section dependent variable is tree_main	fixed effects dependent variable is tree_main
farmer owns plot	.13**	.12**	.08**	.18**
	(.038)	(.033)	(.026)	(.045)
farmer's wealth*10^{-6}	.15**	.13**	.22**	
	(.075)	(.057)	(.052)	
social capital	.06**	.058**	.01	
	(.018)	(.021)	(.01)	
age	.001	.002**	.00	
	(.001)	(.001)	(.000)	
gender	-.05	-.02	-.00	
	(.037)	(.039)	(.024)	
education	.02	.009	.04**	
	(.030)	(.028)	(.018)	
plot size*10^{-2}	-.05*	-.03	-.02*	-0.06
	(.029)	(.021)	(.012)	(.012)
town size	.41**	.39**	.23*	
	(.162)	(.14)	(.14)	
distance to market	-.06**	-.04**	-.03*	
	(.021)	(.019)	(.018)	
province fixed effects	yes	yes	yes	no
hh fixed effects	no	no	no	yes
percent change in probability due to ownership transfer to the	26	33	191	
Nobs=no. of farmers	1172	1172	1173	86
R-squared	.10	.10	.13	.08

Dependent Variables are **tree_mix**=1 if the farmer grows a mix of annual and tree crops, =0 otherwise (column 1)**;** **tree_mix2**=1 if the farmer grows a mix of annual and tree crops AND at least one tree crop is either coffee or citrus, =0 otherwise (column 2) **tree_main**=1 if one of the two main crops is a tree (column 3 and 4). **Robust Standard Errors**, controlling for clustering at the town level, are in parenthesis. ** (*) indicates the coefficient is significantly different from zero at the 5% (10%) level. The **percent change** is calculated as the percent change in the predicted probability of cultivating trees evaluated at the sample mean of all dependent variables when the ownership dummy goes from 0 (tenant) to 1 (owner).

Table 3. Land Tenure and Trees: Matching Estimates

estimation method:	*OLS*	Kernel	Nearest Neighbor	Stratification
tree_mix	*.083**	.173**	.189**	.221**
	(.044)	(.075)	(.077)	(.064)
tree_mix2	*.079**	.229**	.238**	.257**
	(.042)	(.037)	(.045)	(.039)
tree_main	*.071***	.076**	.052**	.077**
	(.022)	(.036)	(.030)	(.036)

Bootstrapped Standard Errors in parenthesis (except for OLS, where robust standard errors allowing for town clustering are used). ** (*) indicates the coefficient is significantly different from zero at the 5% (10%) level. **Matching variables** for the propensity score are wealth quartile dummies, farmer's age, gender and education, plot size, village size, distance to market and province dummies. Same variables are used as controls in the OLS regression. Propensity score is estimated by logit. Matching restricted to the common support.

Table 4. Land Tenure, Trees and Wealth: Testing Alternative Explanations

	(1) all farmers	(2) owners only	(3) tenants only	(4) owners only	(5) tenants only
farmer owns plot	-.04				
	(.082)				
farmer owns plot*q2	.13*				
	(.08)				
farmer owns plot*q3	.18**				
	(.08)				
farmer owns plot*q4	.23**				
	(.09)				
farmer's wealth*10^{-6}	.11*	.13*	-.45	.11*	.93
	(.06)	(.073)	(.745)	(.066)	(1.11)
social capital	.06**	.05**	.07	.05*	(.03)
	(.019)	(.027)	(.027)	(.029)	(.034)
age	.00	.000	.001	-.00	.00
	(.00)	(.001)	(.001)	(.001)	(.002)
gender	-.04	-.06	-.00	-.05	-.02
	(.03)	(.049)	(.077)	(.052)	(.080)
education	.01	.05	-.02	.06*	-.05
	(.03)	(.036)	(.048)	(.038)	(.052)
plot size*10^{-2}	-.06**	.04	-.10	-.05*	-.14*
	(.03)	(.029)	(.075)	(.031)	(.080)
town size	.38**	.53**	.17	.66**	.38
	(.16)	(.202)	(.232)	(.215)	(.237)
distance to market	-.05**	-.04	-.09**	-.04	-.09**
	(.02)	(.023)	(.032)	(.024)	(.036)
family land					-.02
					(.058)
state/commune land					-.05
					(.082)
farmer received technical assistance				.03	.24**
				(.050)	(.086)
contract length: 2 years					.24**
					(.064)
contract length: 3 years					.25**
					(.101)
contract length:>3 years					.34**
					(.103)
tenure length (years farming the same plot)				.005**	-.00
				(.002)	(.004)
farmer has title				.01	
				(.047)	
province fixed effects		yes	yes	yes	yes
Nobs	1172	715	457	679	392
R-squared	.11	.11	.09	.12	.19

Dependent Variable is tree-mix. **Robust Standard Errors,** controlling for clustering at the village level, are in parenthesis. ** (*) indicates the coefficient is significantly different from zero at the 5% (10%) level. The **omitted category** for contract length is 1 year, for land ownership is "private land".

Table 5. Owner Farmers in the Credit Market.

did you ask for a loan or advance purchase?	yes: 19% no:81%	*why didn't you ask for a loan?*	no need	22.4
			wanted to, but too expensive	33.8
			wanted to, but I knew I would not get it	24.9
			no supply of loans in the community	18.8

Too expensive includes the following: (I) interest rate too high; (ii) too costly; (iii) afraid of losing collateral.
Would not get it includes: (I) has no collateral, (ii) has a large debt overhang, (iii) income stream is too variable.

Table 6. Land Tenure and Trees: Controls for Soil Type.

	(1)	(2)	(3)	(4)
farmer owns plot	.13**	.10**	.14**	.11**
	(.038)	(.033)	(.388)	(.034)
farmer's wealth*10^{-6}	.15**	.13*	.14**	.13*
	(.075)	(.081)	(.072)	(.077)
social capital	.06**	.05**	.06**	.05**
	(.018)	(.019)	(.018)	(.019)
age	.001	.001	.001	.001
	(.001)	(.001)	(.001)	(.001)
gender	-.05	-.04	-.05	-.04
	(.037)	(.045)	(.038)	(.045)
education	.02	-.002	.02	-.002
	(.030)	(.030)	(.030)	(.030)
plot size*10^{-2}	-.05*	-.02	-.05*	-.02
	(.029)	(.024)	(.029)	(.024)
town size	.41**	.16	.43**	.19
	(.162)	(.29)	(.163)	(.29)
distance to market	-.06**	-.10**	-.06**	-.10**
	(.021)	(.040)	(.021)	(.040)
plot acquired through individual land reform			-.05	-.03
			(.089)	(.080)
plot acquired through collective land reform			-.13*	-.15**
			(.076)	(.069)
province fixed effects	yes	no	yes	no
town fixed effects	no	yes	no	yes
Nobs	1172	1172	1172	1172
R-squared	.10	.22	.10	.23

Dependent Variable: cropmix. **Robust Standard Errors**, controlling for clustering at the town level in col. 1 and 3, are in parenthesis. ** (*) indicates the coefficient is significantly different from zero at the 5% (10%) level.

Table 7. Land Tenure, Trees and Wealth: Robustness Checks

	(1) owners only	(2) tenants only	(3) owners only	(4) tenants only	(5) owners only	(6) tenants only
farmer's wealth*10^{-6}			.51**	2.14	1.55**	-.24
			(.253)	(2.01)	(.588)	(4.18)
farmer's wealth*10^{-6}, squared					-3.02*	57.2
					(1.58)	(97.63)
2nd wealth quartile	0.13	.03				
	(.08)	(.05)				
3rd wealth quartile	.17**	.04				
	(.09)	(.07)				
4th wealth quartile	.24**	-.07				
	(.10)	(.12)				
social capital	.05*	.07**	.05**	.09**	.05**	.09**
	(.027)	(.026)	(.028)	(.026)	(.028)	(.026)
age	.00	.00	.001	.001	.001	.001
	(.00)	(.00)	(.001)	(.001)	(.001)	(.001)
gender	-.04	-.01	-.09*	-.03	-.08*	-.03
	(.05)	(.07)	(.053)	(.083)	(.053)	(.083)
education	.04	-.02	.05	-.03	.04	-.03
	(.03)	(.05)	(.036)	(.048)	(.036)	(.048)
plot size*10^{-2}	-.04*	-.01	-.07**	-.05	-.07**	-.05
	(.028)	(.01)	(.035)	(.091)	(.035)	(.091)
town size	.53**	.16	.63**	.07	.55**	.07
	(.19)	(.23)	(.198)	(.232)	(.198)	(.229)
distance to market	-.03	-.09**	-.03	-.10**	-.03	-.10**
	(.023)	(.032)	(.023)	(.032)	(.023)	(.031)
province fixed effects	yes	yes	yes	yes	yes	yes
Nobs	715	457	683	438	683	438
R-squared	.12	.10	.11	.10	.12	.10

Dependent Variable: *tree _mix* . **Robust Standard Errors,** controlling for clustering at the village level, are in parenthesis. ** (*) indicates the coefficient is significantly different from zero at the 5% (10%) level. Sample is reduced by cutting the lowest and the highest 2.5%.

Table 8. IV Estimation-Part I

	(1) first stage/all farmers	(2) second stage/all famers	(3) first stage/owners	(4) second stage/owners	(5) first stage/tenants	(6) second stage/tenants
farmer owns plot	*.02***	.12**				
	(.009)	(.037)				
farmer's wealth*10^{-6}		.27*		.32*		.045
		(.169)		(.174)		(1.04)
house value	*1.46***		*1.95***		*1.96***	
	(.181)		*(.268)*		*(.547)*	
durables value	*16.64***		*17.31***		*1.02***	
	(1.24)		*(1.61)*		*(.039)*	
province fixed effects	yes	yes		yes		yes
Nobs	1172	1172	715	715	457	457
R-squared	.43	-	.45	-	.75	-

Table 8. IV Estimation-Part II

	(1) first stage/all farmers	(2) second stage/all famers	(3) first stage/owners	(4) second stage/owners	(5) first stage/tenants	(6) second stage/tenants
farmer owns plot		.12**				
		(.052)				
farmer's wealth*10^{-6}		.433		1.21*		-10.95
		(.941)		(.74)		(7.77)
median wealth in town	.67**		.88**		.14**	
	(.26)		(.41)		(.07)	
literacy rate	-.09		-.13		-.13**	
	(.19)		(.31)		(.06)	
%of primary school graduates	.15		.35		.18**	
	(.27)		(.43)		(.08)	
%houses with direct water supply	.16*		.29*		.05**	
	(.09)		(.16)		(.02)	
province fixed effects	yes	yes	yes	yes	yes	yes
Test 1 (p-value)	.03		.03		.05	
Test 2 (p-value)		.90		.62		.66
Nobs	1112	1112	664	664	448	448
R-squared	.24	-	.25	-	.17	-

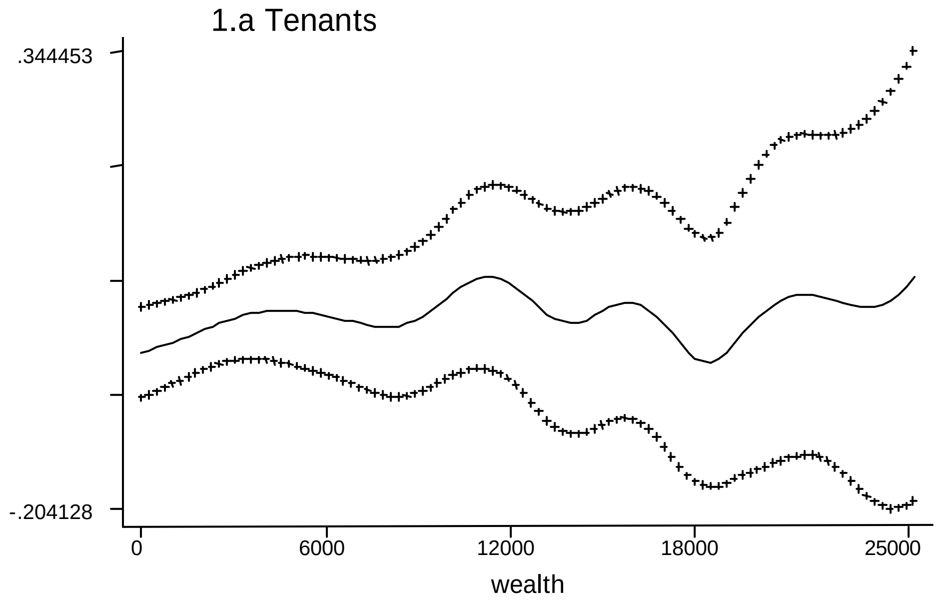
Robust Standard Errors, controlling for clustering at the village level, are in parenthesis. **** (*)** indicates the coefficient is significantly different from zero at the 5% (10%) level. **RHS variables** in all regressions include farmer's age, gender and education, plot size, village size, distance to market. The null hypothesis for **Test 1** is that all coefficients on instruments are equal to zero. **Test 2** is an overidentification test. The null is that the instruments are exogenous and the model is correctly specified.

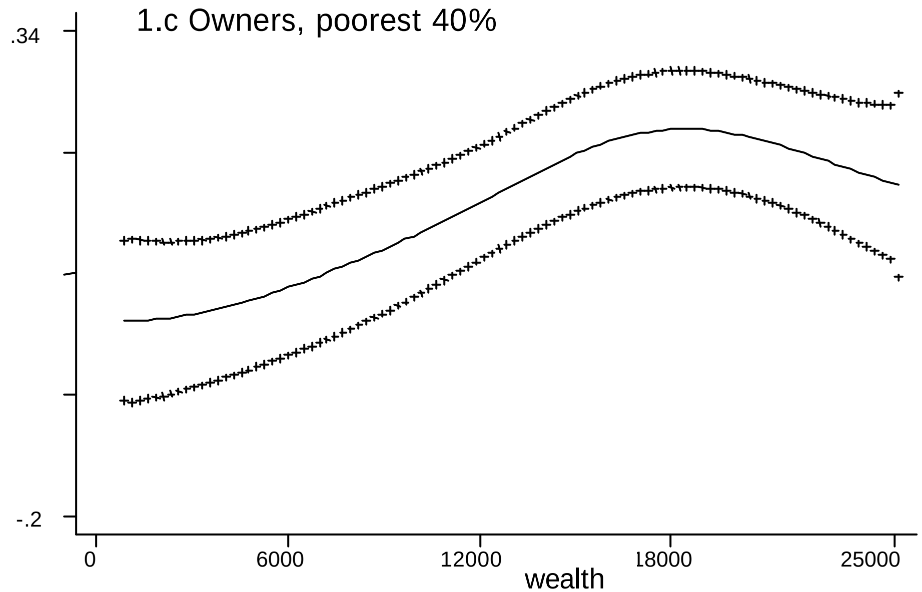
Table 9. Probit Estimates: Marginal Effects.

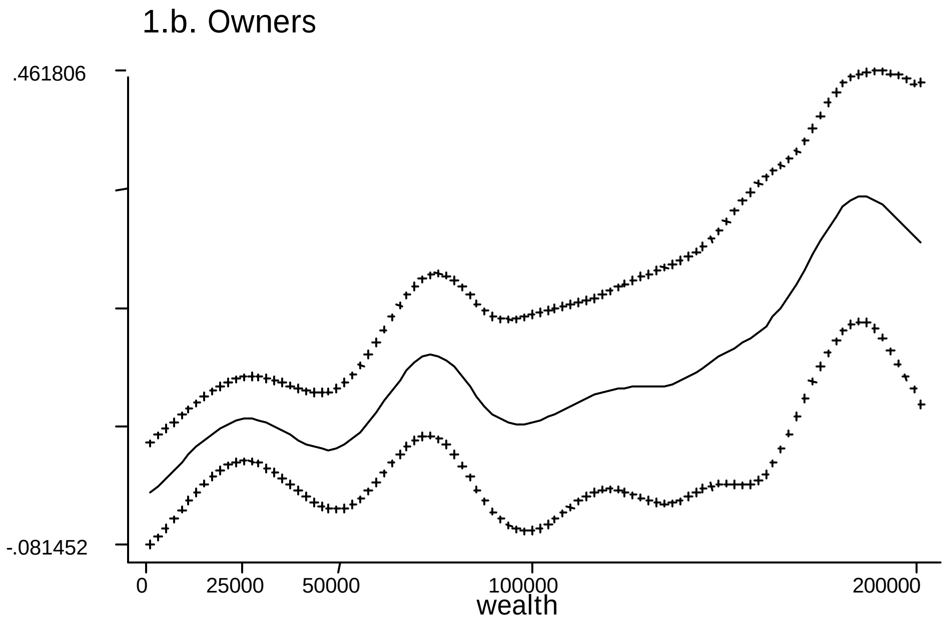
	(1) all farmers	(2) all farmers	(3) owners	(4) tenants
farmer owns plot	.13**	-.05		
	(.040)	(.09)		
farmer's wealth*10^{-6}	.39**	.29	.37*	-.58
	(.195)	(.185)	(.208)	(.877)
farmer owns plot*q2		.14*		
		(.08)		
farmer owns plot*q3		.18**		
		(.08)		
farmer owns plot*q4		.23**		
		(.09)		
social capital	.06**	.06**	.06*	.08**
	(.021)	(.02)	(.030)	(.030)
age	.001	.00	.000	.002
	(.001)	(.00)	(.001)	(.002)
gender	-.05	-.05	-.06	-.012
	(.040)	(.04)	(.051)	(.082)
education	.02	.01	.05	-.02
	(.032)	(.03)	(.038)	(.051)
plot size*10^{-2}	-.09*	-.09**	.076*	-.10
	(.046)	(.047)	(.046)	(.086)
town size	.46**	.44**	.82**	.17
	(.197)	(.20)	(.465)	(.240)
distance to market	-.06**	-.05**	-.04	-.11**
	(.021)	(.023)	(.023)	(.035)
province fixed effects	yes	yes	yes	yes
Nobs	1172	1172	715	457
model p-value	.000	.000	.000	.001

Robust Standard Errors, controlling for clustering at the village level, are in parenthesis. **** (*)** indicates the coefficient is significantly different from zero at the 5% (10%) level.

Figure 1: Non Parametric Estimates.







Note: Gaussian Kernel with 100 grid points. Bandwidth is 1500 in 1.a [standard deviation of *wealth* is 5,711, IQR is 6,800], 11000 in 1.b [standard deviation is 45,850 , IQR is 51,460] and 3500 in 1.c. [standard deviation is 7,674 , IQR is 12,595] Figures 1.a. and 1.b. exclude the top 10% of the sample. Dotted lines are bootstrapped 5% confidence bands (1000 replications).

TABLE A1 SOIL AND CLIMATE REQUIREMENTS

	Temperature	Light	Day Length	Texture	Depth	Drainage	Ph.	Fertility
banana	12-42	1-4	N	M/W/O	D/M	W	4-8.4	H/M
beans	7-32	1-3	S/N	M/W/O	M/S	W	4-9	M/L
cassava	10-35	1-3	S/N	L/M/W/O	M	W/E	4-9	M/L
citrus	13-42	1-2	S/N	L/M/W	D/M	W/E	4-8	M/L
coffee arabica	10-34	1-4	S/N	L/M/O	D/M	W	4.3-8.4	H/M
coffee robusta	12-36	1-4	S/N	M/H/W	M/S	W/I	4-8	H/M/L
maize	10-47	1-2	S/N	M/W/O	M/S	W/E	4.5-8.5	H/M/L
mango	8-48	1-3	S/N	L/M/W	D/M	W/E	4.3-8.5	M/L
millet	15-34	1-2	S/N	M/W	M/S	W/E	5.2-8.2	M/L
plantain	16-38	1-4	N	L/M/W	D/M	W	4.5-7.5	H/M
rice	16-38	1-3	S	W	M/S	W/I	3.5-9	M/L

Source: FAO, Ecocrop 1, Land and Water Digital Media Series.

Notes:1. Temperature in Celsius; 2.Light ranges from 1=very bright to 5=heavy shade; 3. Day Length: N=12hrs, S<12hrs; 4. Texture: W=wide range of soil texture, L=light, M=medium, H=heavy, O=high organic content; 5.Depth: D>150cm, S<50cm, 50cm<M<150cm;6.Drainage: W=well, E=excessive, I=incomplete; 7.Fertility: H=high, M=medium, L=low.