Land Tenure, Investment Incentives, and the Choice of Techniques: Evidence from Nicaragua

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The choice of cultivation techniques is a key determinant of agricultural productivity and has important consequences for income growth and poverty reduction in developing countries. Household data from Nicaragua are used to show that the choice of cultivation technique depends on farmers' tenure status even when techniques are observable and contractible. In particular, tree crops are less likely to be grown on rented than on owner-cultivated plots. Further evidence indicates that the result follows from landlords' inability or unwillingness to commit to long-term tenancy contracts rather than from agency costs due to risk aversion or limited liability.
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The importance of agriculture for the welfare of the poorest can hardly be overstated. The adoption of new cultivation techniques is a key determinant of agricultural productivity, and their promotion is often at the core of development projects. Thus, identification of obstacles to the diffusion of new techniques is crucial to the design of development policies.

This article assesses whether cultivation techniques differ on plots cultivated by their owners from those on plots cultivated by tenants. The analysis looks at the effect of ownership status on the cultivation of trees in combination with annual crops in a sample of Nicaraguan farms. Growing a mix of trees and annual crops is generally more profitable than growing annual crops alone. Trees are both profitable in their own right and enhance nutrient recycling, conserve soil moisture, maintain fertility, and reduce soil erosion.

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The analysis finds that Nicaraguan farmers are more likely to grow trees on plots they own than on plots they rent. The result holds both in a sample of farmers that cultivate an owned and a rented plot and in a cross-section of pure owners and pure tenants.

Following the finding that ownership status does matter, the article seeks to shed some light on the mechanisms that drive the difference between owners and tenants. The separation of ownership and cultivation rights is key because landowners cannot observe the effort exerted by tenants. This affects the choice of cultivation techniques through two channels. First, landowners might not adopt techniques that are complementary to unobservable production effort if they cannot provide the tenants with sufficiently strong effort incentives.[1] Second, landowners might not adopt techniques that require noncontractible investment, for instance in maintenance, if they cannot commit to letting tenants reap the benefits of their investment.

The first channel implies that tenants' wealth determines incentive costs and hence the equilibrium choice of effort and techniques. Indeed, theories of moral hazard in agriculture indicate that landowners might not be able to provide tenants with sufficiently strong effort incentives because of either risk aversion or limited liability, both of which are more important when the tenant is poor (Stiglitz 1974; Braverman and Stiglitz 1986; Mookherjee 1997; Banerjee, Gertler, and Ghatak 2002). Contrary to this prediction, however, tenants' wealth is not a significant determinant of tree cultivation in Nicaragua.

Further analysis reveals that the probability of tenants' farming trees is higher when their tenancy contract is longer. The results indicate that long-term commitment is important. This finding is in line with the observation that since a tenant's effort affects tree productivity in the future, proper incentives can be provided only by offering a long-term contract that makes the tenant's pay conditional on future output.

Long-term contracts, however, are rare in Nicaragua. A cursory look at the history of land policies and current land laws suggests a number of reasons why landlords might be unwilling to commit to long-term contracts. Following the 1979 Sandinista revolution, large landholdings not managed by their owners were expropriated and redistributed to former tenants and landless peasants. Landlords may fear another reform and hence prefer not to make long-term commitments. In addition, current land laws grant strong rights to long-term tenants and make their eviction difficult, effectively increasing the cost of long-term commitments.

The findings in this article are in line with those of Shaban (1987), who shows that the productivity differential between owner-cultivated and sharecropped plots in a sample of Indian farms derives from different levels of both

1. It is important to note that, in contrast to noncontractible effort, contractible techniques can be chosen by the owner of the land regardless of whether the land is rented out or cultivated directly. In other words, the fact that tenants face different incentives has no direct consequence for the choice of techniques if these are subject to contract.

observable and unobservable inputs. In addition, the evidence on the effects of ownership status on tree cultivation is complementary to Besley's (1995) findings for Ghana, where owners-cultivators who hold secure rights to their plots are more likely to grow trees. This article instead compares plots cultivated by tenants with plots cultivated by their owners and also finds that tenure security goes together with tree cultivation. It also finds that on tenant-cultivated plots trees are more likely to be grown by tenants who have long-term contracts.[2]

Section I presents the data and the empirical strategy. Section II illustrates the main results. Section III discusses the predictions of a tenancy theory and offers an interpretation of the results. Section IV briefly touches on policy implications and areas for further research.

I. Data Description and Empirical Strategy

This section describes the data, the main variables, and the empirical approach.

Data Description

Nicaragua is one of the poorest countries in Latin America. In 1998, the year of the survey data used in this study, per capita GNP was $430, about half the population lived below the poverty line. The economy relies heavily on the rural sector. In 1998, agriculture accounted for a third of GDP and almost half the population lived in rural areas. The distribution of landholdings and hence the incidence of tenancy derive from a number of land reforms implemented between 1981 and 1997. In 1981, the Sandinista National Liberation Front (FSLN) expropriated large land holdings and redistributed them to landless peasants, tenants, and farmers cooperatives (Decretos 760 and 782).

The democratic government elected in 1990 privatized and redistributed state-owned land and recognized the property rights acquired by both individual farmers and farmers cooperatives through the FSLN land reform.[3] Land distribution is still very unequal. According to the latest Agricultural Census (2001), the Gini coefficient is 0.71, only slightly improved from 0.79 in 1963.

Household data from the 1998 Nicaragua Living Standard Measurement Study survey are used for the analysis. The survey covers the entire country, and

2. To the extent that trees increase agricultural productivity, the evidence in this article speaks to the microfoundations of the well-known aggregate relationship between land inequality and agricultural productivity. A large literature suggests that small owner-cultivated farms are more productive than large farms that rely on hired labor and than farms operated by tenants, yet there is little evidence on the determinants of such differences. The issue is especially relevant in Central and South America, where land distribution is highly unequal and the productivity differential in favor of small family farms is the largest in the world (Binswanger, Deninger, and Feder 1995 Banerjee 1999).

3. See Ley de Proteccion a la Propiedad Agraria. Ley 88 (April 2, 1990) Decreto-Ley de revision de confiscaciones Decreto 11–90 (May 11, 1990), Ley de estabilidad de la propriedad Ley 209 (November 30, 1995), and Ley sobre propriedad reformada urbana y agraria Ley 278 (November 26, 1997).

the sampling strategy is based on population data from the 1995 Census. The survey contains detailed information on the agricultural activities of 1,258 households. Of these, 57 percent farm their own plots, 36 percent farm rented plots, and 7 percent farm both an owned and a rented plot. In addition, 11 percent of owner-cultivators also rent out land. No household in the sample rents in and out at the same time. Finally, most farms in the sample consist of one or two plots.

The unit of analysis is the household. In general, one household member—typically the household head—is solely responsible for agriculture and takes all farming decisions, whereas other household members provide farming labor. Interviews about the farming activities of the household are held with the household member who manages the farm in 97 percent of the cases.

Dependent Variables

This article analyzes the choice between growing a mix of annual and tree crops and growing annual crops only. The combination of annual and tree crops has recently been promoted by most agricultural development institutions and nongovernmental organizations since tree crops enhance nutrient recycling, conserve soil moisture, maintain fertility, and reduce soil erosion. The opportunity cost in terms of other crop yields is low because annual crops can be grown under the trees. Evidence from agroforestry projects in Central America suggests that this practice is profitable under a broad range of conditions (Current, Lutz, and Scherr 1995).[4]

With a few exceptions, the main tree crops grown in Nicaragua—coffee, citrus, bananas, and mangoes—are more profitable, but also more expensive and effort intensive, than the main annual crops (maize, beans, and cassava). The sample average fertilizer expenditure, for instance, is about twice as high for farmers who grow a combination of trees and annual crops (406 cordobas compared with 217 cordobas). The relative profitability of one technique over the other is therefore likely to depend on the level of effort exerted by the farmer.

The survey asks farmers to name the two main crops they grow and collects information on every crop grown in the last 12 months. To separate farmers who grow a mix of trees and annual crops from those who grow annual crops only, two variables are defined. The first, *tree_mix*, is equal to one when the farmer grows at least one tree crop. The second, *tree_main*, is equal to one when at least one of the main crops is a tree. To be clear, *tree_mix* is defined at the farm level; whether the farmer grows trees is known but not on which plot if the farm comprises more than one. In contrast *tree_main* is defined at the plot level.

These two variables represent an upper and a lower bound estimate of the number of farmers who grow trees. The first variable overestimates the number

4. There is a clear positive correlation between national income and tree cultivation in Central America. Trees cover about 10 percent of Nicaragua's agricultural land, compared with 55 percent in Costa Rica, 30 percent in El Salvador, 29 percent in Guatemala, and 19 percent in Honduras. The correlation between share of tree crops and 1998 GDP per capita is 0.94. (Crop data are from FAO, FAOSTAT Land Use; GDP data are from World Bank *World Development Indicators*.)

of farmers who choose a combination of tree and annual crops because, according to the definition, even a farmer who grows only one tree is counted as growing trees. About 58 percent of the farmers in the sample grow a mix of annual and tree crops (table 1), which is in line with the 2001 rural Census figure of 52 percent. The second variable underestimates the number of farmers who grow trees because it counts only farmers for whom trees are one of the two most important crops, whereas farmers grow on average four different crops. The sample average of *tree_main* is just 9 percent.

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, the dependent variable was also redefined as *tree_mix2*, equal to one when the farmer farms at least one coffee or citrus tree together with annual crops. About 42 percent of farmers in the sample grow coffee or citrus according to this definition.

Unconditionally, there is a clear difference between crops grown by tenants and those grown by owner-cultivators. In particular, trees are more likely to be grown on owner-operated plots: 63 percent of owners grow at least one tree, whereas 49 percent of tenants do. The difference is more striking for the *tree_main* variable: 13 percent of owners grow trees as a main crop compared with only 4 percent of tenants. All the differences are statistically significant at conventional levels.

Farmers who cultivate both owned and rented plots are more similar to the owner-cultivators. Trees are one of the two main crops in 12 percent of the plots cultivated by these farmers. The structure of the survey is such that the other two measures of tree cultivation (*tree_mix* and *tree_mix2*) cannot be built in this sample. Indeed, while respondents were asked to report the two main crops grown on each plot separately, information on other crops is pooled at the farm level, and it is therefore impossible to establish whether these are grown on the rented or the owned plot.

TABLE 1. Descriptive Statistics for Dependent Variables

Dependent variable	All farmers	Farmers who cultivate owned plots only	Farmers who cultivate tenanted plots only	Farmers who cultivate both owned and tenanted plots
Tree_mix	0.58	0.63	0.49	
	(0.49)	(0.48)	(0.50)	
Tree_mix2	0.42	0.48	0.34	
	(0.49)	(0.49)	(0.47)	
Tree_main	0.09	0.13	0.04	0.12
	(0.29)	(0.33)	(0.19)	(0.32)

Note: Numbers in parentheses are standard deviations.

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

Looking at the statistics for the individual crops reveals that owners and tenants are equally likely to grow any type of annual crop, but owners are significantly more likely to grow any type of tree. The difference is particularly striking for coffee (14 and 4 percent), which is possibly the most effort intensive but also most profitable crop.

Farmer and Household Characteristics

The empirical analysis identifies the effect of ownership on tree cultivation both from the cross-section of farmers who either own or rent a plot and from the sample of farmers who cultivate both an owned and a rented plot. The survey does not contain information on the plots that are rented out by a subset of the owners.

Table 2 presents the descriptive statistics for a number of farmer and household characteristics. Two patterns emerge for every wealth measure. First, tenants are significantly poorer than owner-cultivators. Second, owners who rent out are significantly richer than owners who do not.

In the presence of moral hazard in both the credit and tenancy markets, household wealth plays an important role for the choice of technique for both owner-cultivators and tenants. Indeed, for owner-cultivators, wealth determines the relevance of credit constraints and hence whether the farmers can afford to grow trees. Credit constraints themselves matter much less for tenants, as the owners of their plots are typically wealthy and can finance tree cultivation if they find it profitable. Nevertheless, models of moral hazard with either risk aversion or limited liability indicate that tenants' wealth determines the cost of providing incentives for noncontractible effort and hence the choice of cultivation techniques when these are complementary to effort.

Farmers who manage household agricultural activities are on average 44 years old and have two years of formal education (see table 2). Most (93 percent) of them are male. To control for scale effects in wealth and the availability of family labor, household size is controlled for throughout. The average household size is about six, regardless of ownership status. Households that cultivate both a tenanted and an owned plot tend to be larger (seven) than households that own or rent only (six). Other measures of household structure, such as the number of adults or the dependency ratio, also do not vary by ownership status and are not reported for reasons of space. The average farm is 25 *manzanas* (about 18 hectares) and owner-cultivated farms are on average significantly larger than tenanted farms. The standard deviation of farm size is quite high in all samples.

Finally, table 2 reports two town-level variables that are employed in the analysis: population, a measure of town size, and the sample average distance to the closest market for agricultural produce. The average town has a population of 40,000 and the average farm is about 2 hours from the market. Both variables are included because most of the yield of tree crops is likely to be sold rather than consumed at home, and exchange is presumably easier in

TABLE 2. Descriptive Statistics for Farmer and Household Characteristics

Farmer characteristics	Farmers who cultivate owned plots only	Farmers who cultivate tenanted plots only	Test 1, p-value	Farmers who cultivate both owned and tenanted plots	Farmers who cultivate owned plots and rent out some land	Farmers who cultivate owned plots and do not rent out some land	Test 2, p-value
Household wealth*10^{-4}	9.30	1.17	0.00	6.23	14.7	8.6	0.043
	(25.14)	(2.98)		(9.03)	(29.5)	(24.5)	
Durables value *10^{-4}	0.130	0.066	0.00	0.071	0.225	0.118	0.056
	(0.469)	(0.165)		(0.129)	(0.590)	(0.452)	
House value*10^{-4}	1.42	0.725	0.00	1.26	2.18	1.32	0.011
	(2.83)	(2.29)		(2.11)	(5.11)	(2.40)	
Number of bedrooms	2.05	1.72	0.00	2.16	2.44	2.01	0.002
	(1.21)	(0.949)		(1.23)	(1.76)	(1.12)	
Farmer's age	47.0	39.0	0.00	44.2	47.1	47.0	0.941
	(15.3)	(14.5)		(15.8)	(15.7)	(15.2)	
Farmer's gender (female = 1)	0.086	0.053	0.03	0.035	0.101	0.084	0.617
	(0.281)	(0.224)		(0.184)	(0.306)	(0.278)	
Farmer's education (years)	2.34	2.09	0.17	1.78	2.91	2.26	0.087
	(3.16)	(2.65)		(2.60)	(3.40)	(3.13)	
Household size	6.37	6.13	0.18	7.09	5.97	6.42	0.202
	(2.94)	(2.86)		(3.58)	(2.72)	(2.97)	
Farm size (*manzanas*)	37.2	6.79	0.00	8.86	44.4	36.40	0.438
	(87.1)	(23.8)		(24.5)	(79.9)	(88.1)	
Town size (population in thousands)	37.1	43.6	0.07	42.5	31.2	37.8	0.299
	(53.1)	(66.2)		(37.2)	(22.3)	(55.7)	

(Continued)

TABLE 2. Continued

Farmer characteristics	Farmers who cultivate owned plots only	Farmers who cultivate tenanted plots only	Test 1, p-value	Farmers who cultivate both owned and tenanted plots	Farmers who cultivate owned plots and rent out some land	Farmers who cultivate owned plots and do not rent out some land	Test 2, p-value
Average distance to market-town	1.90 (1.02)	1.82 (0.98)	.21	1.89 (0.92)	1.95 (0.99)	1.89 (1.03)	0.641
Number of observations	718	454	86	79	639		

Note: Numbers in parentheses are standard deviations.

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

larger towns and transportation costs are lower in towns that are closer to a market. Owner-cultivators, tenants, and landlords are equally distributed across towns.

Empirical Strategy

Let mix_i be a variable that equals one if farmer i grows a combination of trees and annual crops and zero otherwise. Trees will be grown when the expected return, $R_i(trees)$, is larger than the expected return from growing annual crops, that is

$$\begin{array}{ll} mix_i = 1 & \text{if } R_i(trees) - R_i(annual) > 0 \\ mix_i = 0 & \text{otherwise.} \end{array} \tag{1}$$

Two samples from the 1998 survey are used to identify the effect of ownership status on tree cultivation. The first contains information on farmers who cultivate both an owned and a rented plot. The second contains information on farmers who cultivate either an owned or a rented plot.

Farmer Fixed-Effect Specification

First, the effect of ownership status on tree cultivation is analyzed by comparing owned and rented plots cultivated by the same farmer. Throughout, a linear probability model is used to estimate the choice in equation (1). The crop-choice equation estimated is of the form:

$$mix_{ij} = \alpha + \beta own_{ij} + \gamma size_j + b_i + e_{ij} \tag{2}$$

where mix_{ij} denotes the choice of farmer i on plot j, own_{ij} equals one when farmer i owns plot j, $size_j$ is the area of plot j, and b_i is the farmer fixed effect.

Using a linear probability model instead of a discrete choice model entails both advantages and disadvantages. The main reason to use it in this context is that including farmer fixed effects does not bias the coefficients when the model is linear. In addition, measurement error (misclassification) of the dependent variable can strongly bias the coefficient estimates in discrete models, while it is of much less consequence when the model is linear (see, for example, Hausman, Abrevaya, and Scott-Morton 1998). In addition, omitted variables are less troublesome in a linear model than in a probit because the coefficients of the included variables are biased only if the two are correlated (see Yatchew and Griliches 1985).

The main advantage of fixed-effect estimates is that the effect of ownership on tree cultivation does not suffer from selection bias on individual unobservables. However, fixed-effect estimation, by definition, does not allow comparing the effect of ownership status with the effect of other farmer characteristics on the choice of production techniques. To this purpose, the remainder of the analysis focuses on the cross-sectional evidence from the sample of pure owners and pure tenants.

Cross-Section Specification: Least Squares Estimates

The general crop choice equation estimated by least squares is:

$$mix_{iv} = \alpha + \beta own_{iv} + \mathbf{x}_{iv}\gamma + z_v\delta + \eta_p + e_{iv} \tag{3}$$

where mix_{iv} denotes the choice of farmer i in town v. The variable own_{iv} equals one if farmer i owns the land and zero otherwise. The $\mathbf{x}_{iv}$ term is a vector of household and farmer characteristics, which include household wealth and size and farmer's age, gender, and educational achievement. Town characteristics, z_v, include town population and the sample average distance to market. To control for other geographic and policy characteristics, all regressions include province fixed effects (η_p).

Cross-Section Specification: Matching Estimates

Nonexperimental matching procedures might yield estimates that improve over linear regression estimates in the sense of being closer to those produced by a randomized experiment. The main difference between linear regression and matching estimators is the weighting scheme; matching estimators give more weight to 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. To allow for this, the following section reports estimates for the average treatment effect of ownership on tree cultivation, using nearest neighbor matching over farmer and town characteristics.

II. The Effect of Ownership Status on Tree Cultivation

Following Abadie and Imbens (2004), the bias-adjusted estimator is used to purge the estimates of the bias due to matching over several covariates. The inverse of the sample variance–covariance matrix of the covariates is used to specify the weight given to each variable in defining nearest neighbor matches.

Main Results

Fixed-Effects Estimates. The estimates of crop-choice equation (2) are presented in table 3. The effect of ownership is identified from the comparison of owned and rented plots cultivated by the same farmer. The dependent variable is *tree_main*, which equals one when one of the two main crops is a tree. The structure of the survey does not permit building the other two measures (*tree_mix* and *tree_mix2*) in this sample.

The results show that ownership status matters: farmers are more likely to grow trees on the fields they own than on the fields they rent. The coefficient

TABLE 3. Land Ownership and Trees: Linear Probability Model Fixed-Effect and Cross-Section Estimates

	Fixed effects	Cross-section					
	Tree_main	*Tree_mix*		*Tree_mix2*		*Tree_main*	
Variable	(1)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Farmer owns plot	0.182***	0.144***	0.120***	0.135***	0.108***	0.090***	0.073***
	(0.045)	(0.03)	(0.032)	(0.029)	(0.031)	(0.015)	(0.016)
Household wealth*10^{-6}			0.127*		0.129**		0.198***
			(0.065)		(0.056)		(0.046)
Farmer's age			0.002**		0.004***		0.001**
			(0.001)		(0.001)		(0.001)
Farmer's gender			0.013		−0.005		0.039
			(0.054)		(0.057)		(0.038)
Farmer's education (years)			0.009*		0.005		0.009**
			(0.005)		(0.005)		(0.004)
Household size			0.011**		0.007		−0.007***
			(0.005)		(0.005)		(0.002)
Farm size*10^{-3}			−0.562***		−0.381**		−0.235*
			(0.207)		(0.188)		(0.131)
Plot size*10^{-3}	−668						
	(1.25)						
Town size*10^{-6}			0.354		0.336		0.180
			(0.228)		(0.236)		(0.186)
Average distance to market town			−0.063***		−0.046***		−0.029***
			(0.016)		(0.016)		(0.010)
Percent increase in probability when moving from tenancy to ownership		29	24	39	30	248	157
Province fixed effect	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations (farmers)	86	1172	1172	1172	1172	1172	1172
R^2	0.08	0.02	0.10	0.02	0.10	0.02	0.15

*Significant at the 10 percent level; **Significant at the 5 percent level; ***Significant at the 1 percent level.

Note: Numbers in parentheses are standard errors based on White's robust "sandwich" estimator for the asymptotic covariance matrix. The percentage change is calculated as the percentage change in the predicted probability of cultivating trees evaluated at the sample mean of all dependent variables when the ownership dummy goes from zero (tenant) to one (owner).

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

on the ownership variable is significant at more than the 1 percent level, which is quite surprising given the small sample size. The marginal effect of tenure is 0.18, which is large considering that the sample mean of *tree_main* is 0.12.

Similar results are obtained in a random-effects model, and the Hausman test fails to reject the null hypothesis of systematic difference in the coefficients, with a *p*-value of 0.7764. While the power of the test is low because of the small sample size, the result is nevertheless reassuring for the cross-sectional estimates that follow.

LEAST SQUARE ESTIMATES. For all three definitions of the tree variable, the findings indicate that owners are more likely than renters to grow trees (see table 3). The effect is significant at the 1 percent level in all cases. The unconditional effect of ownership on tree cultivation is very close in magnitude to the conditional estimate, suggesting that although owners and tenants differ on a number of observable characteristics, most notably wealth and age, these do not drive the difference in crop choice.

In all cases, ownership status has the largest effect on the probability of growing trees. For instance, for the *tree_mix* variable, the estimates in column 2b of table 3 indicate that the probability of growing trees is 0.12, or 24 percent higher on owner-operated farms. This is equivalent to an increase in educational achievement of 12 years (or four standard deviations), namely the difference between no schooling and completion of basic secondary education. The effect of ownership is also equivalent to an increase of wealth of five standard deviations, or 1 million cordobas ($100,000) and to a decrease in the travel time to the market of 2 hours. The effect of ownership on *tree_mix* (all trees) and *tree_mix*2 (citrus and coffee) is very similar, while it is much bigger for *tree_main*.

Education, wealth, age, and household size are also significant determinants of tree cultivation. Trees are more likely to be grown by better-educated, richer, and older farmers. The effect of household size depends on how the dependent variable is defined. It is positive for *tree_mix*, zero for *tree_mix*2, and negative for *tree_main*. Including other measures of household structure, such as number of adult males or number of children, does not yield additional insights.

The results also show that trees are more likely to be grown on smaller farms, which rules out the hypothesis that there are increasing returns to scale to tree cultivation and that the observed difference between owners and tenants is due to the fact that owners farm larger plots.

Finally, trees are more likely to be grown by farmers in larger towns and in towns that are closer to agricultural markets. The province fixed effects are jointly significant.

The percentage increase in probability that is imputable to the ownership variable is generally large, particularly so for *tree_main* (see table 3, last

TABLE 4. Land Ownership and Trees: Nearest Neighbor Matching Estimates

	(1) *Tree_mix*	(2) *Tree_mix2*	(3) *Tree_main*
Farmer owns plot	0.191*	0.159*	0.082*
	(0.036)	(0.035)	(0.017)
Number of observations	1172	1172	1172

*Significant at the 1 percent level.

Note: Numbers in parentheses are standard errors based on Abadie and Imbens (2004). Heteroskedasticity robust estimator of the variance uses one match within treated and control units. Observations are matched on the same farmer and town characteristics used in table 3

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

column), indicating that tenants are less likely to grow trees and very unlikely to grow them as a main crop.

MATCHING ESTIMATES. Table 4 reports the nearest neighbor estimates of the average treatment effect, using the same set of farmer and town characteristics as in table 3 and a single match for each of the three definitions of the dependent variable. The results show that the effect of ownership is, if anything, larger when identified from the comparison of the most similar observation. The nearest neighbor estimates of the average effect of ownership on *tree_main* is comparable to the ordinary least squares (OLS) estimate, whereas the nearest neighbor estimates of the average effect of ownership on *tree_mix* and *tree_mix2* is one and a half times the OLS estimate. The results indicate that the effect of ownership status on tree cultivation varies with observable characteristics. Further analysis reveals that the effect is increasing in wealth (discussed subsequently).

Finally, the results do not differ with different definitions of the dependent variable. For ease of exposition, and without loss of generality, the analysis that follows employs the more general definition of *tree_mix*.

Econometric Concerns

The analysis raises two main econometric concerns, one due to the unavailability of soil quality measures and the other due to the potential endogeneity of wealth.

First, the fact that soil quality is in the error term biases the estimates if soil quality is correlated with the ownership variable. In particular, if tree crops necessitate a specific soil type and all plots of that specific soil type are cultivated by owners, the ownership variable would also capture the effect of the omitted soil type.

Three strategies are applied to address the issue of omitted soil quality. First, land rental value is used as a proxy for soil type. Second, the effect of

TABLE 5. Soil Type Controls: Linear Probability Model (dependent variable, *tree_mix*)

Variable	(1) Baseline specification	(2) Land value	(3) Town fixed effects	(4) Segment fixed effects	(5) Land reform
Farmer owns plot	0.120***	0.102***	0.092***	0.068*	0.134***
	(0.032)	(0.033)	(0.033)	(0.037)	(0.033)
Land rental value		0.117**			
		(0.005)			
Individual land reform					−0.048
					(0.076)
Collective land reform					−0.105
					(0.066)
Household wealth $*10^{-6}$	0.127*	0.135*	0.102	0.186	0.119*
	(0.065)	(0.073)	(0.076)	(0.149)	(0.063)
Farmer's age	0.002**	0.002**	0.002*	0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Farmer's gender	0.013	0.038	0.011	–0.068	0.010
	(0.054)	(0.058)	(0.057)	(0.068)	(0.054)
Farmer's education	0.009*	0.006	0.009*	0.002	0.009*
	(0.005)	(0.005)	(0.005)	(0.007)	(0.005)
Household size	0.011**	0.010**	0.009*	0.005	0.011**
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)
Farm size$*10^{-3}$	−0.562***	–0.478**	−0.374	−0.651**	−0.555***
	(0.207)	(0.217)	(0.228)	(0.292)	(0.204)
Town size$*10^{-6}$	0.354	0.305			0.379
	(0.228)	(0.232)			(0.234)
Average distance to market-town	−0.063***	−0.063***			−0.065***
	(0.016)	(0.017)			(0.016)
Province fixed effects	Yes	Yes	No	No	Yes
Town fixed effects	No	No	Yes	No	No
Segment fixed effects	No	No	No	Yes	No
Number of observations	1172	1100	1172	915	1172
R^2	0.10	0.10	0.22	0.31	0.10

*Significant at the 10 percent level; **Significant at the 5 percent level; ***Significant at the 1 percent level.

Note: Numbers in parentheses are standard errors based on White's robust "sandwich" estimator for the asymptotic covariance matrix. In columns 3 and 4, the town level variables are absorbed by the fixed effects. The number of observations is lower in column 2 because of missing values in the rental value variable, and in column 4 because segments with no variation in ownership status are dropped.

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

ownership is identified from within small geographic areas where the variation in soil type is likely to be small. Third, information on the mode of acquisition of the plot is exploited.

To the extent that the suitability of soil for trees is reflected in the rental value of the land, this can be used to proxy for soil type. The survey asks both owner-cultivators and tenants to report how much their land could be rented for per year. This amount is used to build a measure of rental value for one unit (*manzana*) of land.

Table 5 includes the land value variable in the crop-choice equation. Note that this variable is likely to be endogenous because trees might increase the value of the land. Thus, the coefficient of land value cannot be interpreted as the causal effect of land value on tree cultivation.

That notwithstanding, if the ownership variable were exclusively proxying for land type, its coefficient should drop once land value is controlled for. Instead, the estimated effect of ownership does not change from the base specification when the land-value variable is added (see table 5, column 2). Land value has a positive and significant effect, but it does affect the estimates of the other coefficients. Results are similar in the fixed-effect specification. Land rental value has a positive effect on tree cultivation, and the estimated coefficient of tenure status is unchanged.[5]

The second test identifies the effect of ownership status by comparing owners and tenants within small geographic areas that have more homogeneous soil types because of their size. The survey data permit identification of two such areas: townships and census segments.

Town population varies between 3,000 and 900,000 for the capital, Managua. The median size is 20,000, or about 4,000 households. Town dummy variables explain 67 percent of the variation in unit land value in the sample. Census segments identify very small geographic areas of 50–60 households. They are thus much smaller than a rural village and unlikely to exhibit meaningful soil variation. Not surprisingly, census segment dummy variables explain 80 percent of the variation in unit land value.

If the previous results for ownership status were driven entirely by unobservable soil quality, this should, at least in part, be picked up by the town and segment-fixed effects, resulting in a large drop in the ownership coefficient.

Results for the crop-choice equation with town and segment dummy variables show that the tenure effect is robust to the inclusion of town and segment controls (see table 5, columns 3 and 4). Point estimates are somewhat smaller (0.07 and 0.09) but not significantly different from the baseline estimate (0.12). Note that ownership status and farm size are the only two significant determinants of tree cultivation in the segment fixed-effect regression.

The final test augments the estimated equation with an interaction term between ownership and a dummy variable that equals one when the land was obtained through land reform rather than purchase or inheritance. The reform redistributed only land that had previously been rented out, implying that if all tenanted land is unsuitable for tree cultivation, all farms obtained through land

5. The average rental value is higher for owner-operated than for tenanted land, but the difference is due entirely to the top 3 percent of the rental value distribution. Results are unchanged if these observations are dropped from the sample.

reform must be unsuitable for tree cultivation. Therefore, if ownership were proxying for soil type, owners who have obtained their farms through land reform should be less likely to grow trees than owners who purchased or inherited their farms.[6]

The results indicate that owners who got their farm through land reform do not make different choices than owners who bought or inherited their farm, implying that not all rented land is unsuitable for trees (see table 5, column 5).

Second, farmers' wealth might be endogenous to crop choice if cultivating trees makes farmers richer. In this case the OLS estimate of the ownership effect in equation (3) is inconsistent. The root cause of the problem is that many of the characteristics that make the farmer choose to grow trees are not observable, and some of these also affect the farmer's ability to accumulate wealth. To the extent that omitted variables affect wealth and tree cultivation in the same direction, such that, for instance, more able farmers are more likely to cultivate trees and more able to accumulate wealth, the OLS estimate of the ownership effect is biased downwards.[7] The data do not contain information on exogenous variations in wealth that can be exploited to address this issue.

III. Why Are Tenants Less Likely to Farm Trees?

This section examines theoretical and empirical evidence on why tenants may be less likely to farm trees.

Theoretical Background

The key difference between owners and tenants is that ownership and cultivation rights are separated for tenants. This might explain the observed difference in crop choice if information is asymmetric, in that the owner of the plot cannot observe the effort exerted by the tenant. Moral hazard theories suggest that asymmetric information might affect the choice of cultivation techniques through two channels.

First, landowners might not adopt techniques that are complementary to unobservable production effort if they cannot provide tenants with sufficiently strong effort incentives because of risk aversion or limited liability.

If the tenant is risk averse, providing strong incentives through a fixed-rent contract is suboptimal because the tenant bears the entire production risk (Stiglitz 1974). A risk-neutral landlord can achieve a higher payoff by insuring the tenant against bad outcomes, by making the tenant's pay less sensitive to

6. To keep the comparison clean, it is important to distinguish between farms that were assigned to individual farmers and farms that were assigned to a farmers group or cooperative, whose organizational form results in a different incentive structure. Ley 88 (April 2, 1990), Ley 209 (November 30, 1995), and Ley 278 (November 26, 1997) recognize the property rights acquired by individual farmers and farmers cooperatives with the Sandinistas Land Reform (Decreto 782 and Ley 14, July 19, 1981). See Article 1 Ley 88 and Article 3 Ley 209 and Ley 278.

7. The formal proof is available from the author on request.

output. Insurance, however, reduces the tenant's stake in success and leads to the underprovision of effort. Or tenants' productivity might be lower than first best if they are subject to limited liability (Shetty 1988; Mookherjee 1997; Banerjee, Gertler, and Ghatak 2002). Limited liability makes incentive provision costly by imposing an upper bound on the feasible punishment. When the limited liability constraint binds, the landlord can provide incentives only by increasing the reward for success. Since rewards are costly, the landlord might achieve a higher payoff by providing weaker incentives.

Thus if effort provision is below first best, because of either risk aversion or limited liability, the landowner might resist 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, Gertler, and Ghatak 2002).

Second, landowners might not adopt techniques that require noncontractible investment if they cannot provide incentives for the tenant to undertake such investment. For instance, trees require maintenance, but the effects of maintenance investments on productivity go beyond the period in which the investments are undertaken. Tenants will choose the optimal level of maintenance if they can reap the benefits of increased future productivity. Incentives to invest in maintenance can thus be provided by offering tenants a contract long enough to benefit from higher future productivity.

Landlords might be unable to commit not to expropriate the tenant's investment if, for instance, courts are ineffective at enforcing contracts or judges can be bribed. In this case, long-term contracts are ineffective because tenants anticipate that once their investments are sunk, they will be held up (Masters and McMillan 2003).

Even if landlords can credibly commit to a long-term contract, doing so might be costly since they give up the possibility of adjusting the terms of the contract to changes in the environment. They give up the option of cultivating the land themselves for the duration of the contract, and the contract reduces the resale value of the land if a buyer is bound to honor an existing tenancy agreement.

Empirical Evidence

This section examines whether trees are not cultivated on rented plots because effort incentives are low-powered (due to risk aversion or limited liability) or because tenants fear their maintenance investment will be expropriated. Although not mutually exclusive, the two hypotheses have distinct predictions on the effect of wealth and contract duration.

Since poorer tenants are more likely to be risk averse (Binswanger 1980) and because the limited-liability constraint is more likely to be binding for poor tenants, models of risk aversion or limited liability share the prediction that tenants' wealth determines the cost of providing incentives and hence effort and the choice of production techniques. In particular, poor tenants should be less likely to cultivate trees. In contrast, if the mechanism driving the result is that trees require maintenance effort, tree cultivation and contract duration should be correlated. In particular, tenants with short-term contracts should be less likely to cultivate trees.

PREDICTION 1: TENANTS' WEALTH AND TREE CULTIVATION. To establish whether poorer tenants are less likely to cultivate trees, in line with the predictions of moral hazard models with risk aversion or limited liability, the effect of wealth is permitted to differ for owners and tenants in equation (3). The effect of wealth is positive and significant for owner-cultivators and negative and not significant for tenants (table 6, column 1).[8]

That wealth affects crop choice for owner-cultivators is consistent with the notion that moral hazard generates credit constraints, but the result might also reflect unobservable farmer characteristics that drive both wealth and the decision to grow trees, such as entrepreneurship.[9] Identifying the precise mechanism through which owners' wealth affects tree cultivation is beyond the scope of this article, however.

That wealth is not a significant determinant of crop choice in rented plots, in contrast, goes against the predictions of moral hazard models with risk aversion or limited liability, suggesting that low-powered effort incentives are not the binding constraint in this setting.

A possible concern is that the coefficient of wealth is biased toward zero because of endogenous matching of tenants and soil types.[10] The argument runs as follows. Assume that poorer tenants 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, no relationship would be observed between tree cultivation and wealth because poor tenants who farm the right type of land cannot afford tree cultivation while richer tenants who can afford tree cultivation do not farm land that is suitable for trees. However, the findings indicate that wealth is a significant determinant of tree cultivation for owner-cultivators, suggesting that if matching takes place at all it has a substantially different impact according to ownership status, which is implausible.

As noted, owner-cultivators have a higher average wealth with a higher variance than tenants (see table 1). Another possible concern is that wealth does

8. There are not enough farmers who cultivate both an owned and a rented plot to estimate the interaction between wealth and ownership status with farmers' fixed effects.

9. Results from the questionnaire show that only 20 percent of owner-cultivators are currently in debt. About 20 percent of nonborrowing farmers do not borrow because they do not need or do not want to. The rest state that they wanted to borrow but could not, because they thought they would be rejected, because loans are too expensive, or because there are no lenders in the community. Results from the Rural Census (2001) exhibit a similar pattern: only 24 percent of the 200,000 farmers interviewed asked for credit in 2001. Of those who asked, more than a third (37 percent) were turned down.

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

TABLE 6. Empirical Predictions of Moral Hazard Models: Linear Probability Model (dependent variable, *tree_mix*)

Variable	(1) All	(2) Tenants
Farmer owns plot	0.111***	
	(0.033)	
Owner*household wealth *1^{-6}	0.131**	
	(0.068)	
Tenant*household wealth *10^{-6}	−0.541	1.01
	(0.584)	(0.967)
Farmer's age	0.002**	0.003
	(0.001)	(0.002)
Farmer's gender	0.024	0.186*
	(0.054)	(0.107)
Farmer's education (years)	0.009*	0.004
	(0.005)	(0.010)
Household size	0.011**	0.011
	(0.005)	(0.008)
Farm size*10^{-3}	−0.005***	−0.002*
	(0.002)	(0.001)
Town size	0.351	0.203
	(0.223)	(0.332)
Average distance to market-town	−0.064***	−0.080***
	(0.016)	(0.029)
Number of years farming the same plot		−0.005
		(0.004)
Contract length: two years		0.223***
		(0.067)
Contract length: three years		0.268***
		(0.079)
Contract length: more than three years		0.351***
		(0.087)
Contract type: sharecropping		0.097
		(0.118)
Province fixed effects	Yes	Yes
Number of observations	1172	397
R^2	0.4744	0.1870

*Significant at the 10 percent level; **Significant at the 5 percent level; ***Significant at the 1 percent level.

Note: Numbers in parentheses are standard errors based on White's robust "sandwich" estimator for the asymptotic covariance matrix. The residual category for contract length is one year. Contract type = one if the landlord gets a share of the produce (sharecropping) and zero otherwise (fixed rent).

Source: Author's analysis based on data from the 1998 Nicaragua Living Standards Measurement Study survey.

not exhibit sufficient variation in the tenant sample compared with the owner sample, which makes the coefficient estimates less precise and so makes it harder to reject the null. Standard measures of dispersion, however, take similar values in the two samples; the coefficient of variation is 2.4 for tenants and 2.7 for owners.

To investigate whether the wealth coefficient is biased toward zero because the relationship between wealth and tree cultivation is assumed to be linear, the relationship is estimated nonparametrically for both owners and tenants. The nonparametric estimates, not reported for reasons of space, show that for the sample of tenants the effect of wealth on the probability of tree cultivation is not significantly different from zero. In contrast, the relationship between tree cultivation and wealth is positive for owner-cultivators, and linearity cannot be rejected.

PREDICTION 2: CONTRACT DURATION AND TREE CULTIVATION. To assess the importance of noncontractible investment, for instance in tree maintenance, the effect of contract duration on the probability of tenants cultivating trees is estimated. While the relevant variable for investment incentives is the expectation of being able to appropriate future returns—and hence the future duration of the contract—this might be correlated with the duration of previous contracts and hence capture plot-specific skills that the farmer might have accumulated in the past. To address this issue, the specification also controls for the number of years the farmer has been cultivating the same plot. Finally, the specification also controls for the type of tenancy contract, whether sharecropping or fixed rent.

The results indicate that the duration of the tenancy agreement is strongly correlated with tree cultivation: tenants who are employed on contracts longer than one year are more likely to grow trees (see table 6, column 2). The estimated effect of contract duration is large, with the coefficients implying that moving from a one-year contract to a more than three-year contract increases the probability of cultivating trees by 80 percent.

It is the length of the contract not the duration of the relationship that matters. Tenants who have been farming the same plot longer than other tenants are not more likely to grow trees if they are employed on short-term contracts. Finally, the type of tenancy contract (sharecropping or fixed rent) is not correlated with tree cultivation. This suggests that in line with the previous findings on wealth, the duration of the agreement is the only binding constraint. Since both contract duration and crop type might be chosen simultaneously by the landlord, the coefficient of contract length should be interpreted as a correlation with tree cultivation rather than as a causal effect.

What is surprising is that long-term contracts are so rare: 60 percent of contracts are one year long, 20 percent are two years long, and only 6 percent last longer than five years. It may be that most landlords cannot credibly commit to a long-term contract, perhaps because courts are unable to enforce them or because the contracts are too complex, possibly requiring history-dependent payments.

Alternatively, landlords might simply be unwilling to commit to long-term contracts. Although quantitative evidence is unavailable, it could be that Nicaraguan landlords are unwilling to commit to long-term contracts for fear of granting too many rights to tenants. In 1981, rented land was redistributed from large landowners to tenants and landless peasants, and the Constitution (Titulo VI, Cap. II) and reform laws favor small owner-cultivators and make the eviction of long-term tenants difficult.

IV. Conclusions

This analysis of cultivation techniques by Nicaraguan farmers indicates that owner-cultivators are more likely than tenants to grow trees, an effect that seems to derive from ownership status rather than from unobservable farmer characteristics. The effect is due not to risk aversion or limited liability but to the fact that long-term agreements, necessary to provide incentives for noncontractible maintenance investment in tree cultivation, are rare.

The results suggest scope for further investigation of the effect of ownership status on other types of contractible techniques and fixed investments. While immobile investments such as irrigation and farm equipment in this setting are rare, the few that exist are on owner-cultivated plots.[11]

The results have important implications for land policy, a core issue in most developing countries. First, encouraging the use of long-term contracts might lessen the bias against tree cultivation and other long-term investments on rented farms. Operation Barga tenancy reform, implemented in West Bengal in the late 1970s, provides a somewhat extreme example. The reform gave all registered tenants the right to cultivate their plots indefinitely, provided they gave 25 percent of their annual output to the landlord. Operation Barga had a large positive impact on agricultural productivity (Banerjee, Gertler, and Ghatak 2002).

Second, the success of a redistributive land policy depends 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 ownership status is strong for wealthier farmers. Whether this is a pure wealth effect whose impact could therefore be undone by a transfer of resources to the poorest farmers, or whether wealth proxies for unobservable farmer characteristics cannot be identified from the data used in this study. The issue is of fundamental importance for

11. With the same specification as in table 3, analysis shows some evidence that owner-cultivators are more likely to have immobile equipment such as irrigation systems, silos, and barns, while ownership does not affect mobile capital such as water pumps, trucks, and horse carts. Since immobile investments are rare in this setting, the nature of the data precludes further analysis along these lines.

evaluating the impact of land redistribution and is left as an open question for future research.

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