Land Distribution, Incentives and the Choice of Production Techniques in Nicaragua

by

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ABSTRACT

Does the distribution of land rights affect the choice of contractible techniques? I present evidence suggesting that Nicaraguan farmers are more likely to grow effort-intensive crops on owned rather than on rented plots. I consider two theoretical arguments that illustrate why property rights might matter. In the first the farmer is subject to limited liability; in the second the owner cannot commit to output-contingent contracts. In both cases choices might be inefficient regardless of land distribution. The efficiency loss, however, is lower when the farmer owns the land. Further evidence suggests that, in this context, the inefficiency derives from lack of commitment.

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1 Introduction

The allocation of property rights can have a strong impact on productivity when, because of private information, complexity or enforcement problems, market contracts fail to achieve efficiency. Since many agricultural tasks cannot be monitored, contracts in the rural markets of developing economies are particularly sensitive to these issues. The pattern of land ownership, which determines whether plots are cultivated by the owner or rented out, is therefore likely to be an important determinant of agricultural productivity. The empirical evidence on tenancy contracts (Shaban 1987, Laffont and Matoussi 1995, Banerjee Gertler and Ghatak 2001) does indeed suggest that asymmetric information matters in agriculture and can reduce productivity considerably. Given that agriculture is the main source of income for most of the world's poor, identifying the exact mechanisms through which land distribution affects agricultural productivity is essential to devise effective policies to reduce poverty and promote growth.

This paper aims to assess whether and how land distribution affects agricultural productivity through the choice of production techniques. The main purpose is to study how the choice of contractible techniques, such as irrigation and crop mix, depends on whether the landowner cultivates his own land. In principle, since techniques are contractible, the landowner should be able to choose the optimal technique regardless of whom cultivates the land. In practice, however, the profitability of a given technique might depend on other non-contractible inputs and hence, through these, on land distribution.

Empirical analysis of the crop choice of Nicaraguan farmers reveals that the distribution of property rights on land does matter for crop choice. In particular, farmers are more likely to grow tree crops on the plots they own rather than on the plots they rent. What makes the result interesting is that growing tree crops, generally in combination with annual crops, is more profitable but also more effort intensive than growing annual crops alone.

Can asymmetric information provide a consistent explanation for the empirical evidence? Instinctively, it could be argued that, because of moral hazard, farmers choose less effort and hence less effort intensive techniques on rented plots. This argument, however, needs to be qualified. First, since techniques are contractible they can be chosen by the owner of the land regardless of whether he cultivates it directly. In other words, that tenants face different incentives is of no consequence because ultimately it is the owner of the land who decides upon production techniques. Second, since farmers who cultivate their own land often need to borrow to finance cultivation, moral hazard arises regardless of the ownership structure. In other words, when the farmer is hired to cultivate the land he faces a moral hazard problem vis-a-vis the landlord; when the farmer owns the land and borrows to finance cultivation he faces a moral hazard problem vis-a-vis the lender. In fact, an owner-farmer who borrows against future output might want to exert less than the optimal level of production effort if doing so reduces the expected value of repayment.

The paper develops two models in which land distribution determines the choice of non-contractible effort and contractible production techniques. In line with the empirical evidence, both models predict that farmers'ownership leads to a more efficient choice of contractible and non-contractible inputs if these are complements in production. The source of inefficiency, however, differs.

In the first model the farmer is subject to a limited liability constraint and the inefficiency arises because limited liability imposes an upper-bound on the punishment that either the lender or landlord can inflict on the farmer and makes providing effort incentives costly. The distribution of property rights determines the farmer's disagreement payoff *ex-ante*, hence the structure of optimal contract and the implied level of incentives, which in turn determine the choice of effort and production techniques.

In the second model the inefficiency arises from the fact that the parties cannot commit to contracts that are contingent on output. In this context the landowner always has an incentive to expropriate the other party's investment, which results in low-powered incentives when the landlord owns the land and in a credit constraint when the farmer owns the land. Since ownership entails residual control rights on the asset, in this case the distribution of property rights determines the farmer's disagreement payoff *ex-post.*

Both theories predict that the outcome is closer to first best when the farmer owns the land and that the ownership structure makes little difference when farmers are poor. However, the two models yield a different prediction regarding the link between farmers' wealth and the choice of techniques. If the inefficiency derives from limited liability, farmers' wealth determines the cost of providing incentives and therefore affects technique choice both when the farmer owns and when the farmer rents the land. If the inefficiency derives from the inability to commit, however, farmers's wealth determines borrowing requirements and therefore affects technique choice when the farmer owns the land while it is of no consequence when the landlord owns the land as he is unable to commit with poor and rich tenants alike.

The analysis of crop choice by a sample of Nicaraguan farmers who either own or rent a plot reveals that wealth is a significant determinant of crop mix only when the farmer owns the plot. The cross sectional evidence thus suggest that, in this context, the inability to commit seems to be the main source of inefficiency.

The remainder of the paper is organised as follows. Section 2 presents the two models and discusses their empirical implications. Section 3 describes the data-set, discusses the econometric models, presents the evidence on crop choice and a test between the two models. Section 4 discusses the related literature. Section 5 concludes.

2 Theory

2.1 Set-Up.

There are two agents, L and F, and a plot of land. It is assumed that only F can farm the land, that L is always wealthier than F, and that both agents are risk neutral. Property rights on land are fully defined and can be assigned either to L or to F.[1] When L owns the land he hires F to cultivate it, as in the standard landlord-tenant set-up. When F owns the land, he cultivates it and borrows from L if necessary.

There are two states of the world, good and bad, and output in each state depends on the chosen production technique. For simplicity assume that there is a continuum of techniques indexed by the parameter t and that both output and production costs are increasing in t. Finally, the probability of the good state depends on $e \in [\underline{e}, \bar{e}]$, which represents the non-contractible effort that F devotes to cultivation.

In particular, production depends on effort, on the state of the world, and on the chosen technique as follows:

(i) Output is $g(t)$ in the good state and $b(t)$ in the bad state and $g(t) > b(t)$, $g' > 0$, $b' > 0$ $\forall t$

(ii) The good state occurs with probability $p(e)$, $p \in (0, 1), p' > 0$, $p'' \leq 0$.

Note that (i) and (ii) imply that effort and technique are complements in production.

Production costs are as follows:

(iii) technique t costs t;

(iv) effort entails disutility $d(e)$ for the farmer, where $d' > 0$ and $d'' \geq 0$.

The choice of t is assumed to be plot-specific. The analysis thus applies to problems such as crop choice, which is the focus of the empirical analysis, but also the choice of irrigation schemes, drainage systems and the level of mechanisation. It does not apply to non verifiable techniques such as maintenance or to investments that are easily transferable, such as the purchase of tractors or tools.

Without loss of generality, assume that L pays for t, that he keeps the entire output and that he transfers c_g and c_b to F in the good and bad state, respectively. Depending on his wealth, when F owns the land he might need to borrow from L to finance t ex-ante.

$F's$ and $L's$ utility are equal to:

$$p(e)\,[c_g] + (1 - p\,(e))\,[c_b] - d(e) \qquad (U_F)$$

$$p(e)\,[g(t) - c_g] + (1 - p\,(e))\,[b(t) - c_b] - t \qquad (U_L)$$

[1] That property rights are fully defined implies that the owner has complete control over the asset (i.e. he can sell it, bequeath it, mortgage it etc.). I do not analyse intermediate cases such as joint ownership of the asset or the assignment of partial rights (for instance right to cultivate but not to sell etc.).

Since e is non contractible, F will choose e to maximise U_F, which yields the incentive compatibility constraint:

$$(c_g - c_b) = q(e) = \frac{d'(e)}{p'(e)} \tag{IC}$$

Assume that when contracts are signed L has all the bargaining power, regardless of the distribution of property rights. This is without loss generality, as argued below, and it is an appropriate assumption in cases when land and credit are scarce and labour is abudant.

Assume, moreover, that the reservation utility of the farmer is u_1 if he owns the land and u_2 if he does not, where $u_1 \geq u_2$. The reason why property rights affect the disagreement payoff of the farmer is that if F and L do not reach an agreement and the farmer owns the land he can still cultivate it on the basis of his own financial resources whereas if the farmer does not own land he must seek employment elsewhere. The assumption reflects the fact that the bargaining power of the owner-cultivator vis-a-vis the lender is larger than the bargaining power of the tenant vis-a-vis the landlord. In other words, assuming that the reservation utility of the farmer is higher when he owns the land is equivalent to assume that farmers who own the land have more bargaining power when contracts are signed.

In what follows I will compare the choice of technique under the two alternative ownership modes. I will presents two arguments that justify why the distribution of property rights might affect the choice of effort and technique. Both theories predict that, for given parameters ranges, the choice of t and e is inefficient and that the extent of the inefficiency depend on the distribution of property rights on land. The source of inefficiency, however, differs.

The model in Section 2.3 follows the literature on tenancy contracts, property rights and agricultural productivity (Mookherjee 1997, Banerjee et al 2001) and extends it to analyse technique choice. It assumes that L and F can commit to the terms of the contract and that F is subject to a limited liability constraint. The inefficiency arises from the fact that the limited liability imposes an upper-bound on the punishment that L can inflict on F and makes incentive provision costly. The distribution of property rights determines the farmer's disagreement payoff *ex-ante* hence the level of the participation constraint, hence the structure of optimal contract and the implied level of incentives, which in turn determine e and t.

The model in Section 2.4, on the other hand, assumes that the parties cannot credibly commit to output-contingent contracts. In this case the distribution of property rights determines the farmer's disagreement payoff *ex-post.* Indeed since both the non-contractible effort and the contractible investments are asset specific and ownership entails full control rights on the asset, the owner always has an incentive to expropriate the other party. Thus, when L owns the land he can expropriate $F's$ investment in effort, which is embodied in it. If, on the other hand, F owns the land and borrows from L he would want to expropriate the returns of the contractible investment.

Section 2.2 below analyses the benchmark case of unlimited liability and full commitment and shows that in this case first best can be achieved regardless of the distributions of property rights. The result follows from the fact that, absent other constraints, the moral hazard problem generated by the uncontractability of e can be solved by an appropriate incentive compatible contract.

2.2 Benchmark Solution: Unlimited Liability, Full Commitment.

Since L has all the bargaining power he chooses (e, t, c_b) to maximise his utility subject to $F's$ incentive compatibility and individual rationality constraints. Denote the solution by e^* and t^*, the first order conditions are:

$$p'(e^*)\left[g(t^*) - b(t^*)\right] - d'(e^*) = 0 \qquad (FB_e)$$

$$p(e^*)\left[g'(t^*) - b'(t^*)\right] + b'(t^*) - 1 = 0 \qquad (FB_t)$$

Since total (expected) welfare is equal to:

$$W = p(e)g(t) + (1 - p(e))b(t) - t - d(e)$$

e^* and t^* are the first best levels of e and t, i.e the levels that maximise total welfare.

Intuitively L can induce the first best level of effort by creating a sufficiently large spread between what F receives in the good and bad state and then extract all the surplus with a lump-sum transfer. Since the first best level of effort is chosen, the first best technique will be chosen as well. Notice that the only difference between ownership modes is that F receives a higher share of the surplus if his disagreement payoff is larger when he owns the land. As argued above, that L has all the bargaining power under both ownership structures is irrelevant for the choice of (e, t): if F were to have more bargaining power the choice of (e, t) would be the same although the distribution of surplus would differ.

2.3 A model of limited liability (and full commitment).

Assume now that F is subject to a limited liability constraint such that $c_g + w \geq s$ and $c_b + w \geq s$, where w is $F's$ wealth and s his subsistence consumption. In order to provide incentives for non contractible effort, c_g must be larger than c_b so that only the second constraint would bind, if any. Assume also that contracts are complete and fully enforceable.

The problem is the same as in section 2.2 above, with the addition of the limited liability constraint.

The first order conditions are:

$$p'[g(t) - b(t)] - d' - (1-\lambda)pq' = 0 \tag{1}$$

$$p(e)[g' - b'] + b' - 1 = 0 \tag{2}$$

$$\lambda + \theta = 1 \tag{3}$$

Where λ and θ are the Lagrange multipliers for the individual rationality and the limited liability constraint, respectively. The Appendix shows that due to the limited liability constraint, first best can be achieved if and only if farmer's wealth is high enough (i.e. $w + u_i > p(e^*)q(e^*) - d(e^*) + s$). If not the limited liability constraint binds and both e and t are lower than first best as shown by the following:

Result 1. *Regardless of the distribution of property rights the choice of effort and production technique depends on the farmer's wealth. If the farmer is poor the limited liability constraint binds and both choices will be inefficient under either ownership mode.*

Intuitively if the limited liability constraint binds, L cannot simultaneously provide full incentives and extract the whole surplus. In other words, since the lender/landlord must guarantee a minimum level of consumption in the bad state, the only way of providing incentives is to offer a premium in the good state. It follows that, since the payment in the bad state is higher for poor farmers[2], providing incentives to poor farmers is costly, thus, in equilibrium, less will be provided, leading to $e < e^*$. As a consequence, L will choose $t < t^*$.

The next result shows that if F is subject to limited liability the distribution of property rights matter for the choice of (e, t).

Result 2. *If the farmer is poor so that the limited liability constraint binds, the choice of both effort and techniques is weakly more efficient under $F's$ ownership than under $L's$ ownership.*

Result 2 derives from the fact that $F's$ reservation utility is weakly higher when he owns the land than when he does not. Notice that when both the limited liability and the individual rationality constraint bind, effort is chosen to satisfy the individual rationality constraint. Since the equilibrium level of effort is increasing in u, the level of effort chosen under $F's$ ownership is weakly higher than the level of effort chosen under $L's$ ownership. Intuitively, the inefficiency

[2]If the limited liability constraint binds $c_b = s - w$.

arises because, due to the lower bound on c_b, L cannot simultaneously provide full incentives and extract the whole surplus. In order to extract the entire surplus, that is to push F to his reservation utility, L must reduce c_g. By doing so, however, he reduces effort incentives. The higher is $F's$ reservation utility, the lower the inefficiency, since the equilibrium level of c_g, and hence effort incentives, is increasing in u.

Thus, if u is higher for a farmer who owns the land than for a farmer who does not, the equilibrium level of e will be higher when the farmer owns the land. As argued above, u might be higher for a farmer who owns the land because he can cultivate it using his own financial resources if he does not reach an agreement with the lender. It then follows that if the farmer is very poor, so that cultivation financed by own resources yields utility less or equal to u, then the choice of (e, t) is the same under both ownership modes.

Summing up, the effect of the distribution of property rights on investment depends on farmers' wealth as follows:

Result 3. *The distribution of property rights matters for the choice of production techniques when farmers' wealth is neither too high nor too low. For intermediate levels of farmer's wealth, the choice will be closer to first best when the farmer owns the land.*

Intuitively, when farmers's wealth is high the limited liability constraint does not bind and first best can be achieved regardless of the distribution of property rights. When farmers' wealth is lower and the limited liability constraint binds the distribution of property rights matters because farmers who own the land have a higher reservation utility, as explained above. The reservation utility of a farmer who owns the land, however, depends on the expected profits under self cultivation, which in turn are lower the lower his wealth. It follows that when farmers' own financial resources are very low there is no difference between the reservation utility of a farmer who owns the land and of a farmer who does not, so that, again, the distribution of property rights does not matter. Figure 1 graphs the equilibrium level of t chosen under the two alternative ownership modes as a function of the farmer's wealth.

As noted by Mookherjee (1997) in this context land sales from landlords to tenant cannot be Pareto improving. Indeed, since L has all the bargaining power he could offer a contract which mimicks the credit contract under farmer's ownership if it were best for him to do so. Intuitively, since because of limited liability the landlord cannot extract the extra surplus that would arise if the farmer were to own the land, he is better off by not selling.

This also explains why in equilibrium the reservation utility of owner-farmers is higher than the reservation utility of tenants: tenants would clearly prefer to own, as this guarantees higher utility, but landlords are not willing to sell.

Note that if the farmer is subject to a limited liability constraint the distribution of bargaining power does affect the choice of (e, t). In particular, since the inefficiency arises from $L's$ attempt to extract the entire surplus, any redistribution of bargaining power in favour of F will bring (e, t) closer to first best. If we assume that L and F Nash bargain over the surplus and that the distribution of bargaining power does not depend on the distribution of property rights the results presented above still hold except when F's bargaining weight is one. In this, extreme, case the reservation utility of the farmer does not affect the solution and, as a consequence, the distribution of property rights does not matter.

Relatedly, it can be shown that the model yields similar result if one assumes that L and F Nash bargain over the surplus and that, instead of increasing $F's$ reservation utility, landownership confers more bargaining power to the farmer.

2.4 A model of imperfect commitment (and unlimited liability).

When output can be easily disguised or the judicial system is weak or future contingencies are too costly to specify, personal commitments are not credible and contracts conditional on output are hard to enforce. Although one period output-contingent contracts are quite common in agriculture –sharecropping being the most popular example– committing to contracts contingent on future output is much more harduous. The fact that payments cannot be conditioned on future output is particularly relevant for investments whose return accrue for a number of periods in the future. This is clearly the case for trees that bear fruits for many years or for the choice of any other durable technique for which the impact of effort is long-lasting. To keep matters simple, in what follows the choice of technique is still analysed within a one period model; the inability to commit, however, should be interpreted as affecting future, rather than current, output.

When output contingent contracts are not enforceable, the landowner has an incentive to expropriate the returns of the other party's investment once the investment has been made. Assume, as above, that there are only two possible level of output–good and bad– and that output contingent contracts are not feasible. By definition the owner of the land holds the residual control rights on land and its produce.

Consider first, the case in which F owns the plot. If F can afford the first best level of investment t^*, he does not need to borrow and the outcome is, trivially, first best at (e^*, t^*).

If, however, $F's$ wealth is lower, he might want to borrow to employ a more expensive technique and repay the loan once output has been realised. The lender then takes into account that the farmer cannot commit to repay different amounts in different states and he therefore maximises his utility from the loan subject to repayment being the same in both states of the world. From this it follows that the repayment minus the cash advance F can offer must be less than the output in the bad state.

In the appendix it is shown that, when output contingent repayments are ruled out, the problem reduces to:

$$\max_{R,t} R - t$$

$$[p(e)[g(t) - b(t)] + b(t) - R - d(e) - S(w)] \geq 0$$

$$p'(e)[g(t) - b(t)] - d'(e) = 0$$

$$b(t) + w - R \geq 0$$

Where R is the repayment (principal plus interest), the first constraint is $F's$ individual rationality constraint, the second is the incentive compatibility constraint and the third is a credit constraint. The credit constraint states that repayment cannot be larger than the output in the bad state plus farmers' wealth. Notice that this constraint puts an upper bound on the amount L can recover and is therefore very different from the limited liability constraint in section 2.3 above. There L could not provide strong enough incentives to exert effort as he could not punish enough in the bad state. Here incentive provision is not an issue: since F gets the full marginal benefit of his effort, he will always choose the first best e –which of course depends on t.[3]

The solution –discussed in the Appendix– shows that the equilibrium (e, t) depend on the wealth of the farmer as follows:

Result 4. *When the farmer owns the land first best can be achieved only if the farmer is rich enough. In other words, there exist $\bar{w}(< t^*)$ such that for all $w > \bar{w}$, the lender finances up to t^*, the first best level. For all $w < \bar{w}$, both the choices of effort and technique are inefficient and the inefficiency is decreasing in wealth.*

Proof: see Appendix

Intuitively, when the farmer is rich enough, he needs only needs to borrow a small amount to finance t. In this case the output in the bad state is enough for the lender to recover the principal plus interest. When the farmer is poor, however, the lender does not want to finance t up to first best, because the output in the bad state would not allow him to recover the amount invested. The inefficiency derives from the fact that F cannot commit to repay more in the good state.

Consider now the case in which L owns the land. In this case it is L who cannot commit to pay different amounts in different states. This affects $F's$ effort incentives: since he gets the same payment in the good and bad state, he has no incentive to put in effort and will choose the lowest possible level $\underline{e}$. Anticipating this, L will choose the optimal t given $\underline{e}$. The problem thus reduces to:

[3] It can be argued that since there is no limited liability L could use non monetary punishments to induce truth telling, nevertheless such contracts would still be renegotiated since a non-monetary punishment provides no direct utility to the lender.

$$\max_{c_b,t} L = (b(t) - c_b) - t$$

$$c_b - d(\underline{e}) - u \geq 0$$

The solution, reported in the appendix, yields:

Result 5. *When L owns the land the choices of both effort and techniques are inefficient. Moreover, the inefficiency does not depend on the farmer's wealth.*

Intuitively, since the landlord cannot credibly provide incentives for effort he will choose $t<t*$ given that t and e are complements. In contrast to the results of Section 2.3 the equilibrium (e, t) do not depend on $F's$ wealth. The reason is that there the inefficiency stem from the fact that, due to limited liability, the landlord could not provide full incentives to poor tenants. Here, however, the inefficiency derives from the fact that the landlord cannot credibly commit to an incentive compatible contract, regardless of tenant's wealth.

Comparing the results obtained when F owns the land to those obtained when L owns the land, yields:

Result 6. *The distribution of property rights matters for the choice of effort and technique when farmers' wealth is not too low. In this case, both the choice of effort and technique are closer to first best when the farmer owns the land.*

Intuitively,the choice of technique does not depend on F's wealth when L owns the land, since L cannot provide effort incentives to rich and poor farmers alike. In contrast, when F owns the land, investment does depend on wealth. The richer is F, the less he will need to borrow from L, the lower is the inefficiency from lack of commitment. Compared to the limited liability model above, here there is a fundamental asymmetry. That contingent contracts are not feasible always generates a loss of efficiency if L owns the land, but only when F is poor if F owns the land.

The model analysed in this section is an extreme case of the hold-up problem. In a more general model, with a longer time horizon, the parties would renegotiate the contract once investments have been made. In the context of an incomplete contract model, however, results would be similar to the those above, at least as long as the change in the relative bargaining power of the parties ex-post does not depend on farmers' wealth.

Finally, note that, in this context, land sales are Pareto improving as long as the inability to commit to output contingent contracts does not seriously hinder the ability of the landlord to extract the extra surplus deriving from farmer's ownership. [4]

[4] Aside from the effects of limited liability and imperfect commitment, land sales would not be Pareto improving if land had value over and above its productive use. It has been argued that, for instance, land confers political power in countries where it is scarce so that the increase in productivity which would arise if the tenant

3 Empirical Analysis: Tree Crops in Rural Nicaragua.

3.1 Context, Data and Econometric Model.

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[5] 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. The existing pattern of land distribution derives from a number of land reforms enacted between 1981 and 1997. 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.[6] The democratic government elected in 1990 promulgated a number of laws[7] which recognised and legitimised the property rights acquired by farmers through the FSLN land reform. In addition to recognising existing farmers' rights the aforementioned law 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 real property registry and to favour land titling, both by creating new titles for newly redistributed land and by converting existing titles.

Land markets in Nicaragua are 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. After then 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

were to purchase the land is not enough to compensate large landowners for the loss of political power (see Baland and Robinson 2001 for a formal model). This is especially true for poor tenants, whose productivity as owner cultivators would be lower as shown above. Relatedly, land also provides a good hedge against inflation so that again, landlords are better off by not selling if tenants cannot adequately compensate for the value of land as a store of wealth. Finally, because of registry fees, notary fees and land sale taxes, selling land often entails large transaction costs which might be higher than the potential productivity gain.

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

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

[7] 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).

the transaction costs for land sales, as identifying the rightful owner is quite expensive and time consuming.

Data I use household data from the 1998 Nicaragua Living Standard Measurement Survey complemented with village data from the 1995 Nicaragua Census.

The 1998 survey contains detailed information on the agricultural activities of 1497 households. Of these, 56% farm their own plots, 38% farm rented plots and 6% farm both own and rented plots. 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 and house value– which can be aggregated to build a measure of wealth.

I use the 1995 Census to collect information at the village level such as size, distance to market, average education level, religious fractionalisation 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.[8] 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 enhance nutrients recycling, conserve soil moisture, maintain fertility and reduce soil erosion.[9] Growing annual crops alone, however, is cheaper and less effort intensive.[10] The relative profitability of one technique over the other then ultimately depends on the level of effort exerted by the farmer.

In terms of the theoretical models, growing annual crops alone corresponds to a lower t. Note that t is complementary to effort since, due to the higher variance of tree production, the spread between the good and bad state is higher when tree crops are grown in combination with annual crops.[11]

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.[12] It does not, however, contain precise information on the area devoted to each crop. To separate farmers who grow a mix of trees

[8] 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.

[9] Agroforestry (the combination of annual and perennial crops) has recently been promoted by most agrcultural 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.

[10] 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.

[11] It can be argued that, on top of determining output in the good and bad state, crop characteristics also affect the relative probability, with tree crops being more likely to fail at any effort level. In terms of the models above this implies $p(e,t)$ with $p_t < 0$. It can be shown that the results carry through as long as p_e is sufficiently large or p_t sufficiently small. If this is not the case, t can be employed to reduce the moral hazard problem as an increase in t makes expected output less sensitive to e.

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

and annual crops from those who grow annual crops only I define two variables. The first, *crop mix* is equal to 1 when the farmer grows at least one tree crop. The second, *mainmix*, is equal to 1 when at least one of the main crops is a tree.[13] 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 bananas even if he has only one tree. As reported in Table 1.1, about 56% 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 (farmers grow on average four different crops). As reported in Table 1.1, the sample average of *mainmix* is just 8%.

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 plots than tenants. Also, owner-cultivators have, on average, been farming the current plot for a longer time. Education, however, does not vary by ownership status and both owner cultivators and tenants seem equally distributed across villages.

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 (13% vs. 3%).

Econometric Model and Main Concerns.

Contrary to the theoretical model, here the choice of technique is discrete. Let $mix_i \in \{0, 1\}$ be a variable that equals 1 if farmer i grows trees or 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

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

In what follows I employ a linear probability model to estimate the discrete choice model in (1). 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 household 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. The drawback of the linear model is that it 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

[13] The main tree crops 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 *coffee&citrus,* which is equal to 1 when the farmer farms at least one coffee or citrus tree together with annual crops.

used in the analysis is, in this case, 0.56 and estimates are then very rarely outside the feasible range. [14] The general crop choice equation I estimate is of the form:

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

Where mix_{iv} denotes the choice of farmer i in village 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 groups the farmer belongs to), value of livestock 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, village specific variables ($\mathbf{z}_v$) include total population (a proxy for village size) and distance to market. The reason is that tree crops are mostly commercialised rather than consumed at home. Exchange is presumably easier in larger villages and transportation costs are lower in villages which are closer to a market place.[15] To control for other geographical and/or policy characteristics, all the regressions are run with province fixed effects.

The identification of the effect of ownership on crop choice presents two main econometric problems. First, ownership itself might be endogenous, i.e. driven by some omitted characteristics 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, that is I estimate:

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

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.

Second, 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 soil type are cultivated by owners. The available evidence, however, suggest that neither (i) nor (ii) are relevant in this context. 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.[16] Second, the evidence on cropping pattern

[14] Moreover, the model yields similar results when estimated by probit or logit.

[15] As a further control, I have also run all the regressions including a categorical variable that equals 0 if the village 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] 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.

indirectly suggest that there is no systematic difference in terms of soil quality between own and rented plots. For instance, cassava, a crop that is typically grown on very low quality soil, is actually more likely to be grown by owner-cultivators, whereas millet, another "poor" crop is equally likely to be cultivated by owners and tenants, on average. To check robustness, however, I have also estimated (1) using village fixed effects. That is:

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

The idea behind (4) is that since soil characteristics are more likely to vary across villages than within each village, if the results are driven by unobservable soil quality, this should be, at least in part, be picked up by the village fixed effects (d_v). A large change in α therefore indicates that soil characteristics or other village specific variables are important omitted variables. Finally, although specific evidence for Nicaragua is not available, in different contexts many other studies have not found a significant relationship between crop choice and measures of soil quality (Besley 1998, Goldstein and Udry 1999), or between soil quality and tenure status (Shaban 1987).

3.2 Main Results

Basic Specification.

The first column of table (2) reports the cross-section estimates (equation (2)). The results suggest that, in line with both theories, trees are more likely to be grown in owner-cultivated plots.[17] Also, richer farmers are more likely to grow trees and, when significant, the coefficient on livestock value is negative, suggesting that trees and animal husbandry are substitutes. The results also show that trees are more likely to be grown by farmers who belong to some social association/group and by farmers who live in large villages and/or villages that are close to the market, which presumably derives from the fact that tree crops are mostly grown for commercialisation rather than home consumption.

The second column of table 2 presents the empirical estimates of equation (3), that it includes farmer's fixed effects. The results show that, even controlling for every source of heterogeneity, land distribution matters: a given farmer is more likely to grow trees on the

[17] It could be argued that the result derives from omitted variable bias since land ownership might be a choice variable. The fixed effects estimates below suggest that this is not the case. Nevertheless, to address this issue in the larger sample I have controlled for whether owners have bought their plots or whether they have received it in inheritance or after a land reform. Although ownership might still be endogenous even if the farmer has not bought the plot (e.g. because among sons only the best farmers inherit the family plot), if results derive exclusively from the endogeneity of ownership we expect the coefficient of ownership to change when acquisition mode is controlled for as the endogeneity problem is more serious when the farmer has bought the land. However, the results, available from the Author upon request, show that the coefficient of ownership is unchanged and the mode of acquisition does not enter significantly.

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.

Column (3) presents the estimates of equation (4), i.e. it includes village fixed effects to control for differences in land quality as discussed above. As expected, the point estimates of the ownership variable and wealth are slightly lower, but not significantly so. This then suggest that although the ownership variable might proxy for village level non-observables, this accounts for a small part of its effect on the choice of crop mix.[18]

Finally, in the cross-section estimates the dependent variable is *mix*, which equals one when the farmer grows at least one tree. As explained above, this variable overestimates the number of farmers who grow tree crops and thus provides a lower bound estimate of the effect of ownership on crop choice. To obtain an estimate of the upper bound I estimated equation (2) using *mainmix* (=1 if one of the two main crops is a tree) as the dependent variable (column (4)). As expected the relative impact of ownership on crop choice is much stronger in this case. Evaluating at the sample mean, if the plot is farmed by its owner, the probability of there being at least one tree is about 20% higher while the probability of trees being a main crop doubles.

Does ownership matter less when farmers are poor?

Both models predict that landownership should not affect crop choice when the farmer is very poor and, according to the limited liability story, when the farmer is very rich either. To test this prediction I have split the sample in five subsamples along wealth quintiles. The result presented in Table 3 show that indeed landownership does not matter when the farmer is poor (i.e. when he belongs to the 1st and 2nd quintiles) but it does when the farmer is rich. Note that, when significant, the coefficient of *owner* is larger in the subsamples than it was in the entire sample, suggesting that the previous estimate of the effect of landownership on crop choice was biased downwards by the presence of poor farmers. Note also that, in line with the predictions of the limited liability model, landownership has a no effect on crop choice when the farmer is rich. This, however, might be due to the low variance of the ownership variable: 90% of farmers in the fifth quintile are owners.[19]

Testing between models.

Table 4 estimates whether the impact of wealth on crop choice differs according to whether the plot is cultivated by the owner or by a tenant. Column (1) includes an interaction term between wealth and the ownership variable, whereas columns (2) and (3) estimate equation

[18]I also experimented with other individual specific variables such as number of years farming the same plot, wife's education, household's composition, whether the farmer received technical assistance, whether the farmer belonged to a producers' group, whether the farmer had reported to be credit constrained. None of these were significant.

[19]The remainder of the distribution is as follows:
1st quintile: 30% owners; 2nd quintile 50% owners, 3rd quintile 60% owners, 4th quintile 70% owners.

[2] for tenants and owner-cultivators separately. The evidence suggest that, in this context, the inefficiency seems to derive from the inability to commit rather than from limited liability. According to the latter, wealth should affect crop choice regardless of whether the farmer owns the land or not. The results instead suggest that wealth only matters when the farmer owns the land: the interaction term is positive and significant while the wealth coefficient is not significant in column (1). Moreover, the coefficient is significantly different from zero in the owner-cultivators subsample alone.

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[20] and where the present Consititution and Reform Laws favour small owner-cultivators and makes it difficult to evict long-term tenants.[21] As a consequence most tenancy contracts in the sample are short-term (see Table 5).

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. 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 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)).[22]

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: the relationship between tenants and landlords does not affect crop choice.

That wealth affects crop choice for owner-cultivators suggest that credit markets are im-

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

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

[22] 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.

perfect. The imperfection can derive, as illustrated by the theoretical models, either from limited liability or from the inability to commit. From the questionnaire we learn that only 20% of farmers are currently in debt (see Table 6). 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. Not surprisingly, wealthy farmers are more likely to not need or want loans.[23]

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.[24] 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 suggest 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[25] so that no definite conclusion can be drawn at this stage.

3.3 Other Econometric Concerns and Robustness Checks.

The definition of wealth raises a number of concerns. First, since wealth does not include land value ownership might just be proxying for wealth, i.e. capturing the fact that owners can use the land as collateral, which gives them better access to credit and hence makes them more likely to grow trees. Land value is excluded in the wealth measure because it might be endogenous as trees might make a plot more valuable. Regardless of this, if ownership were just proxying for land value we would expect its coefficient to fall once land value is controlled for. Column (1) in Table 7 shows this is not so. The point estimate of the land ownership coefficient does not change when land value is included in the measure of wealth. Columns (3) and (4) show two more robustness checks on wealth definition. In column (3) the value of farm assets is excluded from the definition of wealth on the grounds that it too might be endogenous, which could be if trees required more expensive tools. Column (4) uses household durables, the most parsimonious definition of wealth.

Relatedly, wealth might be endogenous because since tree crops are more profitable, farmers who grow them might have become richer as a consequence. That is, the causality relationship might run from trees to wealth rather than the other way. More subtly, wealth endogeneity might be responsible for the different impact of wealth on crop choices in owned and rented

[23] About 30% of farmers in the fifth wealth quintile and about 10% in the first quintile state they do not need or want to borrow.

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

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

plots. That is, if one assumes that profits mostly accrue to the owner of the land, then trees would increase the wealth of owner-cultivators but not that of tenants.

To address these issues I have re-estimated equation [1] by 2SLS using wife's parents education and village characteristics as instruments for wealth. Village characteristics include: median land value from the survey and measures of education (% of literate, primary and secondary school), of religious fragmentation and of infrastructure (% of houses with direct water supply) from the 1995 Census. The underlying assumption is that farmers' wealth is likely to be higher in richer villages, that is villages with higher median land value and better infrastructure (proxied by educational achievements and house water supply). The identifying assumption is that the instruments are not variables of choice for the farmer and that they do not determine the farmer's crop choice, both of which seem reasonable. [26] Indeed, endogeneity could potentially arise if farmers were to sort themselves across village according to village characteristics. According to the Census, however, 95% of the resident population of was born in the villages under study. The 2SLS estimates are reported in column (2), Table 8: the coefficient of wealth is still positive and significant and that the other coefficients are unchanged. Interestingly, the wealth coefficient is much larger after instrumenting, which may indicate measurement error in the wealth variable. From the first stage regression (column (1)) we see that the instruments are a good predictor of wealth and have reasonable signs.[27] To test for overidentifying restrictions, I have regressed the second stage residuals on the instruments and other exogenous variables and then tested the significance of the instruments. The test, whose p-value is reported in the penultimate row of column (2) passes comfortably. Moreover, the Hausman test (last row of column (2)) fails to reject the null hypothesis of systematic coefficient difference, thus suggesting that wealth endogeneity might not be a serious issue in this case.[28] Also, results are robust to using the different definitions of wealth as in table 7. Finally, to check whether wealth is endogenous for owner-cultivators only, I have run the tests and 2SLS regression above for the sub-samples of owner- cultivators and tenants separately. Also in this case, the results suggest that the wealth effect appears not to be due to endogeneity.[29]

[26] As a further check I have experimented with different subsets of instruments. The results are robust to a number of different combinations, including dropping the wife's parents education variables that are, potentially, the most problematic.

[27] At the individual level, farmers whose father in law had formal education have higher wealth. At the village level, farmers who live in villages where the median land value is higher, where there is better infrastructure (proxied by water supply), where the percentage of primary and secondary school graduates is higher and that are more religiously homogeneous are wealthier. The negative coefficient on the percentage of literate can be interpreted together with the positive coefficients on primary and secondary school graduates as a proxy for poor education infrastructure. That is, a higher literacy rate coupled with a low primary school record might proxy for lack of schools in the village.

[28] A further concern is that livestock value and crop choice might be jointly determined. Results are robust to instrumenting for livestock value.

[29] The following robustness checks are not presented for reasons of space: (i) reproducing tables 2 to 8 for different definitions of the dependent variable; (ii) reproducing tables 2 to 8 for different definitions of wealth; (iii) excluding *distance to market* from the regressions. Reason for the latter being that a larger sample is

4 Related Literature

This paper relates to the large literature that analyses the impact of asymmetric information on agricultural productivity. Its contribution is twofold. First, it presents an explicit comparison of alternative ownership structures. Second, it analyses, both theoretically and empirically, one specific channel through which the pattern of land ownership affects productivity, namely the choice of contractible techniques.

Most of the existing literature aims to explain how the structure of tenancy contracts affects productivity on rented plots. The earlier literature focussed on explaining why sharecropping exists despite its inefficiency (Stiglitz (1974), Shetty (1988), Eswaran and Kotwal (1984)). Most recent papers have analysed alternative incentive mechanisms and other contractual dimensions. These include the impact of eviction threats on effort and non-contractible investment (Banerjee, Gertler and Ghatak (2001), Banerjee and Ghatak (2001), Dutta, Ray and Sengupta (1989)); the use of contract length as an incentive mechanism for non-contractible investment (Bandiera (2001)); and the role of sharecropping in the context of multitasking (Botticini (1999)).

The empirical literature on tenancy contracts provides evidence that contractual structure affects productivity as suggested by the theory. Using data from six villages in three Indian States, Shaban (1987) shows that farmers produce less output per acre on sharecropped plots than on their own plots. Banerjee, Gertler and Ghatak (2001) show that increased tenure security had a positive impact on agricultural productivity growth in West Bengal. Laffont and Matoussi (1995) show that Tunisian sharecroppers are less productive than fixed-rent tenants.

Unlike these previous studies, which exclusively analyse the determinants of productivity on rented plots, this paper explicitly compares owned and rented plots. Such direct comparisons are rare in the literature mostly because it is implicitily assumed that transferring ownership to the farmer would eliminate the problems deriving from information asymmetry and achieve efficiency. One exception is Mookherjee (1997) who recognises that land redistribution *per se* does not guarantee first best since if the farmer needs to borrow, information asymmetries might affect the outcome even when he owns the land. In the same line as Mookherjee (1997), this paper explicitly models the contractual relationship between owner-cultivators and lenders.

Another point of departure from the existing literature is that the present paper analyses a specific mechanism through which land distribution might affect agricultural productivity, that is the choice of contractible techniques. Recognising that asymmetric information has an effect on the choice of contractible inputs over and above its effects on effort has two main advantages. First, it makes clear that the effect of land distribution on productivity might be stronger than if based on differences in effort alone. Second since, unlike effort, techniques are

available (1304 instead of 1172). Results are robust to these alternative specifications.

observable the predictions of the theory can be tested directly.

Both Braverman and Stiglitz (1986) and Banerjee, Gertler and Ghatak (2001) explicitly model the choice of contractible techniques but focus exclusively on the case in which the landowner delegates the cultivation of its plots. Braverman and Stiglitz (1986) show that if landlords can only employ pure sharecropping contracts[30] they may want to resist some specific innovations which increase output a little but lower the marginal product of effort by a lot. The intuition is that since the landlord is bound to a pure sharecropping contract, in order to extract the surplus from the innovation and keep the tenant at his reservation utility, he must necessarily lower the tenant's share. Lowering the tenant's share, however, reduces incentives and can ultimately make the landlord worse off. Banerjee, Gertler and Ghatak (2001) endogenise contractual structure in the context of a principal-agent model with limited liability. They show that, since limited liability imposes a constraint on the set of feasible contracts, equilibrium effort is low and landlords are less likely to make contractible investments complementary to effort when the tenant is poor.

The existing evidence on the relationship between land distribution and the choice of contractible techniques is quite slim. Feder et al (1985) report that studies of HYV adoption in India show no clear pattern. Bharadwaj (1974) analysis of Indian farm management data, however, shows that most of the productivity differential between small family and large rented farms can be attributed to different crop choices.

Finally, this paper also relates to the literature that studies whether formal, better defined and/or more complete land rights affect investment incentives and technology adoption. In theory better private rights should enhance tenure security and hence promote investment both because they facilitate the access to credit and because, as opposed to communal rights, they guarantee that the investor capture the full marginal benefit of his effort. Besley (1995), for instance, finds that better-defined rights promote investment in trees in a region of Ghana. Besley (1998), however, surveys the existing evidence and shows that, in some cases, property rights have been found to be irrelevant for investment. This paper and the literature above share the focus on incentives for contractible investments. Unlike that literature, however, this paper focusses on the distribution, rather than the definition, of property rights on land.

5 Discussion and Conclusions.

This paper has presented two theoretical arguments that illustrate how the distribution of property rights on land may affect the choice of production techniques and, through this, agricultural productivity when output depends on non-contractible effort. The first argument is based on limited liability which makes incentive provision costly and thus discourages the use of techniques that are complementary to effort. The second relies on the fact that land owners

[30] That is, if non-contingent payments are ruled out.

cannot commit to output contingent contracts which limits borrowing when the farmer owns the land and makes incentive provision impossible when the farmer does not, and therefore also discourages the use of techniques that are complementary to effort. In both cases the outcome can be inefficient regardless of the distribution of property rights, but it is generally more efficient when the farmer owns the land.

The empirical analysis of crop choice in rural Nicaragua shows that, in line with both theories, owner cultivators choose a riskier, more effort intensive and more profitable crop mix. The analysis also shows that the inability to commit, rather than limited liability, seems to be the main source of inefficiency.

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 follows from the fact that long-term commitments are typically more difficult to adhere to. An interesting question is whether limited liability would be the binding constraint when the feasible techniques have the same time horizon. Second, landlords may 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 the past land has been expropriated in favour of tenants and where most tenancy contracts are indeed short term.

Although productivity is higher when farmers own the land, tenancy is quite common and land sales are not frequent. Data on land transactions are needed to establish which factors, other than productivity, determine land value and hence land sales. In particular, it would be interesting to assess to what extent land sales are constrained by registry imperfection and title uncertainty and to what extent they are limited by credit constraints or political reasons.

Finally, the analysis also suggest that redistributing land to farmers would foster agricultural productivity because it improves the choice of effort and of other inputs that are complementary to it. Since the inability to commit seems to be the main cause of inefficiency, any kind of land reform that makes tenancy more secure or promotes the use of long term contracts would be similar to land redistribution in terms of its effect on the choice of effort and production techniques.

6 Appendix: Models

6.1 First Best

The problem is:

$$\max_{e,t,c_b} L = p(e)[g(t) - b(t)] - p(e)q(e) + b(t) - c_b - t + \lambda \left[p(e)q(e) + c_b - d(e) - u_i\right]$$

The first order conditions w.r.t. (e, t, c_b) are:

$$p'[g(t) - b(t)] - d' - (1-\lambda)pq' = 0 \tag{4}$$

$$p(e)[g' - b'] + b' - 1 = 0 \tag{5}$$

$$\lambda = 1 \tag{6}$$

Substituting the third equation into the first one shows that (e, t) which solve this problem are the same as first best. $c_b = u_i + d(e^*) - p(e^*)q(e^*)$ from the IR constraint.

6.2 The Limited Liability Model

I assume that L has full bargaining power and that he pays for t. The problem then is:

$$\max_{c_g, c_b, t}\{p(e)(g(t) - c_g) + (1-p(e))(b(t) - c_b) - t\} \text{ s.t.}$$

$$p'(e)[c_g - c_b] - d'(e) = 0 \tag{IC}$$

$$p(e)c_g + (1-p(e))c_b - d(e) \geq u \tag{IR}$$

$$c_b + w - s \geq 0 \tag{LL}$$

Plugging in the IC and rearranging terms the lagrangian of the problem is:

$$\begin{aligned}\max_{e,t,c_b} L &= p(e)[g(t) - b(t)] - p(e)q(e) + b(t) - c_b - t + \lambda\left[p(e)q(e) + c_b - d(e) - u_i\right] \\ &\quad +\theta\left[c_b + w - s\right]\end{aligned}$$

The first order conditions w.r.t. (e, t, c_b) are:

$$p'[g(t) - b(t)] - d' - (1-\lambda)pq' = 0 \tag{7}$$

$$p(e)[g' - b'] + b' - 1 = 0 \tag{8}$$

$$\lambda + \theta = 1 \tag{9}$$

There are three possible cases:

CASE 1. LL does not bind, IR does.

In this case $\lambda = 1, \theta = 0 \rightarrow$in equilibrium (e^*, t^*, c_b^*) satisfy:

$$\begin{cases} p'(e^*)[g(t^*) - b(t^*)] - d'(e^*) = 0 \\ p(e^*)[g'(t^*) - b'(t^*)] + b'(t^*) - 1 = 0 \\ p(e^*)[g(t^*) - b(t^*)] + c_b^* - d(e^*) = u_i \end{cases}$$

That is, $(e^*,\ t^*)$ are at first best. This is an equilibrium as long as the LL does not bind, that is for $w + u_i \geq s + p(e^*)[g(t^*) - b(t^*)] - d(e^*)$

CASE 2. Both LL and IR bind.

In this case $0 < \lambda < 1, 0 < \theta < 1 \rightarrow$in equilibrium $(\hat{e}, \hat{t}, \hat{c}_b)$ satisfy: $\begin{cases} p(\hat{e})q(\hat{e}) - d(\hat{e}) = u_i + w - s \\ p(\hat{e})[g'(\hat{t}) - b'(\hat{t})] + b'(\hat{t}) - 1 = 0 \\ \hat{c}_b = s - w \end{cases}$

CASE 3. LL binds, IR does not.

In this case $\lambda = 0, \theta = 1 \rightarrow$in equilibrium $(\tilde{e}, \tilde{t}, \tilde{c}_b)$ satisfy:

$$\begin{cases} p'(\tilde{e})[g(\tilde{t}) - b(\tilde{t})] - d'(\tilde{e}) - p(\tilde{e})q'(\tilde{e}) = 0 \\ p(\tilde{e})[g'(\tilde{t}) - b'(\tilde{t})] + b'(\tilde{t}) - 1 = 0 \\ \tilde{c}_b = s - w \end{cases}$$

The solution is feasible as long as the IR does not bind, that is for $w + u_i \leq s + p(\tilde{e})q(\tilde{e}) - d'(\tilde{e})$

Summing up, the solution depends on $w + u$ as follows:

$w + u_i \geq s + p(e^*)[g(t^*) - b(t^*)] - d(e^*)$	e^*, t^*	case 1
$s + p(\tilde{e})q(\tilde{e}) - d'(\tilde{e}) < w + u_i < s + p(e^*)[g(t^*) - b(t^*)] - d(e^*)$	$\hat{e},\ \hat{t}$	case 2
$w + u_i \leq s + p(\tilde{e})q(\tilde{e}) - d'(\tilde{e})$	$\tilde{e},\ \tilde{t}$	case 3

Proof of Result 1.

First note that for any u, $\frac{de}{dw} \geq 0$. To see this note that $\lambda^* = 1 > \hat{\lambda} > \tilde{\lambda} = 0$. From (4) it follows that $e^* > \hat{e} > \tilde{e}$. Also $\frac{de^*}{dw} = \frac{d\tilde{e}}{dw} = 0$ while $\frac{d\hat{e}}{dw} = \frac{1}{pq'} > 0$. Taking the total differential of the FOC$_t$ we see that $\frac{dt}{de} = -\frac{p'[g'(t) - b'(t)]}{p[g'' - b''] + b''} > 0$ since $[g'(t) - b'(t)] > 0$ and the denominator is <0 from the second order conditions for a maximum.

Proof of Result 2.

Recall that when the farmer owns the land his reservation utility is larger or equal than the reservation utility of the tenant $(u_1 \geq u_{2,})$, because if an agreement is not reached the farmer can cultivate the land based on his own resources while the tenant cannot. Note that in case 2 (i.e. when both IR and LL bind), the equilibrium level of effort is given by $p(\hat{e})q(\hat{e}) - d(\hat{e}) = u_i + w - s$ which implies that $\frac{d\hat{e}}{du} = \frac{1}{pq'} > 0$. Taking the total differential of FOC$_t$ we see that $\frac{dt}{de} = -\frac{p'[g'(t) - b'(t)]}{p[g'' - b''] + b''} > 0$ since $[g'(t) - b'(t)] > 0$ and the denominator is <0 from the second order conditions for a maximum.

Proof of Result 3.

Denote by u_1 the reservation utility of the farmer when he owns the land. $u_1 = \max\{u_2, \Pi(w)\}$ where u_2 is the reservation utility of the tenant and $\Pi(w)$ are cultivation profits when the farmer does not borrow. Note that as long as $w > s + t^* - b(t^*)$ the farmer does not need to borrow and chooses the first best level of (e, t). Note also that $s + t^* - b(t^*) < s + p(e^*)[g(t^*) - b(t^*)] - d(e^*) - u_2$ since, by definition, cultivation at first best is better than the outside option (i.e. $p(e^*)[g(t^*) - b(t^*)] + b(t^*) - t^* - d(e^*) > u_2$). Thus when farmers are rich, that is for $w > s + p(e^*)[g(t^*) - b(t^*)] - d(e^*) - u_2$, first best can be achieved regardless of the distribution of property rights.

When $w < s - b(t^*)$ and the farmer does not borrow he can invest at most $\bar{t} = w + b(\bar{t}) - s$.

Then $\frac{d\Pi}{dw} = \frac{d\Pi}{de}\frac{de}{dw} + \frac{d\Pi}{dt}\frac{dt}{dw}$. Using the envelope theorem the first term equals zero while the second is $p(\bar{e})[g'(\bar{t}) - b'(\bar{t})] + b'(\bar{t}) - 1 < 0$ since $\bar{t} < t^*$. Then either $\Pi(w) > u_2$ for any w or there is a w' s.t. for $w < w'$ $\Pi(w) < u_2$. In the second case for any $w < w'$ the solution is the same regardless of the distribution of property rights. If $\Pi(w) > u_2$ for any w, on the other hand, there will be a w'' s.t. for $w < w''$, $\Pi(w) + w < s + p(\tilde{e})q(\tilde{e}) - d'(\tilde{e})$, which implies that regardless of the distribution of property rights the solution will be $(\tilde{e}, \tilde{t})$ and, as shown above, $\frac{d\tilde{e}}{du} = 0$. It follows that property rights matter only for intermediate wealth levels.

6.3 Non-contingent contracts model

As above, I assume that L has full bargaining power and that he pays for t. The problem then is:

$$\max_{c_g, c_b, t} \{p(e)(g(t) - c_g) + (1 - p(e))(b(t) - c_b) - t\}$$

s.t.

$$p'(e)[c_g - c_b] - d'(e) = 0 \qquad (IC)$$

$$p(e)c_g + (1 - p(e))c_b - d(e) \geq u \qquad (IR)$$

$$c_g = c_b \qquad (NC_L)$$

$$\begin{cases} c_g = g(t) - R \\ c_b = b(t) - R \\ R - w \leq b(t) \end{cases} \qquad (NC_F)$$

Where NC_L rules out output contingent payments when L owns the land and NC_F rules out output contingent payments when F owns the land. The latter constraint imposes that the farmer repays a fixed amount, i.e. regardless of the state of the world, and that the repayment minus the cash advance he can offer on t. That is, the wealthier the farmer, the less he needs to borrow.

CASE 1 L owns the land.

When L owns the land the IC becomes $-d'(e) = 0$, implying that F will choose the minimum level of effort, implying that $p(\underline{e}) \rightarrow 0$.

The lagrangian of the problem is then:

$$\max_{c_b, t} L = (b(t) - c_b) - t + \lambda(c_b - d(\underline{e}) - u)$$

The Focs are:

$$b'(t) - 1 = 0 \qquad (10)$$

$$-1 + \lambda = 0 \tag{11}$$

$\rightarrow$in equilibrium (t, c_b) satisfy: $\begin{cases} b'(t) - 1 = 0 \\ c_b - d(\underline{e}) - u = 0 \end{cases}$

CASE 2 F owns the land.

When the farmer owns the land and $w > t^*$, the farmer chooses first best (e^*, t^*) and does not need to borrow. If, on the other hand, $w < t^*$ the farmer can ask for a loan. In this case, the lagrangian of the problem is:

$$\max_{R,t} L = R - t + \lambda [S(t) + t - R - S(w)] + \theta[b(t) + w - R]$$

where $S(t) = p(e(t))[g(t) - b(t)] + b(t) - d(e(t)) - t$ denotes total surplus evaluated at t and $e(t)$ satisfies the $IC : p'(e)[g(t) - b(t)] - d'(e) = 0$. The outside option of the farmer is equal to $S(w) = p(e(w))[g(w) - b(w)] + b(w) - w - d(e(w))$,that is the utility the farmer would get if he were to can cultivate the land based on his own financial resources w. Note that $\frac{dS}{dw} = p[g'(w) - b'(w)] + b'(w) - 1 > 0$ since $w < t^*$.

The first order conditions are:

$$1 - \lambda - \theta = 0 \tag{12}$$

$$-1 + \lambda S' + \lambda + \theta b' = 0 \tag{13}$$

There are three cases:

Case 2.1 NC does not bind, IR does.

In this case $\lambda = 1$, $\theta = 0 \rightarrow$ in equilibrium, R^* and t^* satisfy:

$$\begin{cases} S'(t^*) = 0 \\ S(t^*) + t^* - R^* - S(w) = 0 \end{cases}$$

That is, first best can be achieved and the lender extracts all the additional surplus, i.e. $R^* - t^* = S(t^*) - S(w)$. This is an equilibrium as long as $t^* - w \leq b(t^*) - (S(t^*) + S(w))$, i.e. as long as the loan required to finance first best t is not too large.

Case 2.2 *Both* NC and IR bind.

In this case $0 < \lambda < 1$, $0 < \theta < 1 \rightarrow$ in equilibrium, $\hat{R}$ and $\hat{t}$ satisfy:

$$\begin{cases} b(\hat{t}) + w - \hat{R} = 0 \\ S(\hat{t}) + \hat{t} - \hat{R} - S(w) = 0 \end{cases}$$

Case 2.3 NC does not bind, IR does.

In this case $\lambda = 0$, $\theta = 1 \rightarrow$ in equilibrium, $\tilde{R}$ and $\tilde{t}$ satisfy:

$$\begin{cases} b'(\tilde{t}) = 1 \\ b(\tilde{t}) + w - \tilde{R} = 0 \end{cases}$$

This is an equilibrium as long as $\tilde{t} - w \geq b(\tilde{t}) - (S(\tilde{t}) + S(w))$.

Proof of Result 4:

From the solution of Case 2 above, it can be seen that t^* is an equilibrium if and only if $t^* - w \leq b(t^*) - (S(t^*) + S(w))$, i.e. as long as the loan required to finance first best t is not too large. Next, it can be easily shown that $t^* > \hat{t} > \tilde{t}$. Substituting the expression for S in the Foc for t:

$$p(g'(t^*) - b'(t^*)) + b'(t^*) = 1$$
$$\lambda p(g'(\hat{t}) - b'(\hat{t})) + b'(\hat{t}) = 1$$
$$b'(\tilde{t}) = 1$$

The results follows from the fact that $\lambda > 0$ and that $p(g'(t) - b'(t)) > 0$. Finally, note that $\frac{dt^*}{dw} = 0$, $\frac{d\tilde{t}}{dw} = 0$ and $\frac{d\hat{t}}{dw} = \frac{1+S'(w)}{1+S'(\hat{t})-b'(\hat{t})} > 0$.

Proof of Result 5.

From the analysis of Case 1, the Foc for t when L owns the land is $b'(t) = 1$,while at first best $p(g'(t^*) - b'(t^*)) + b'(t^*) = 1$. The result follows from the fact that e and t are complements, i.e. $p(g'(t) - b'(t)) > 0$.

Proof of Result 6.

Comparing Cases 1 and 2, we see that t is the same (i.e. $\tilde{t}$:$b'(\tilde{t}) = 1$) when the farmer who owns the land is poor enough, i.e. $w + S(w) \leq \tilde{t} - b(\tilde{t}) + S(\tilde{t})$. Result 4 shows that $\frac{dt_F}{dw} \geq 0$ while $\frac{dt_L}{dw} = 0 \rightarrow \frac{d(t_F - t_L)}{dw} \geq 0$.

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Figure 1. Technique Choice under Limited Liability

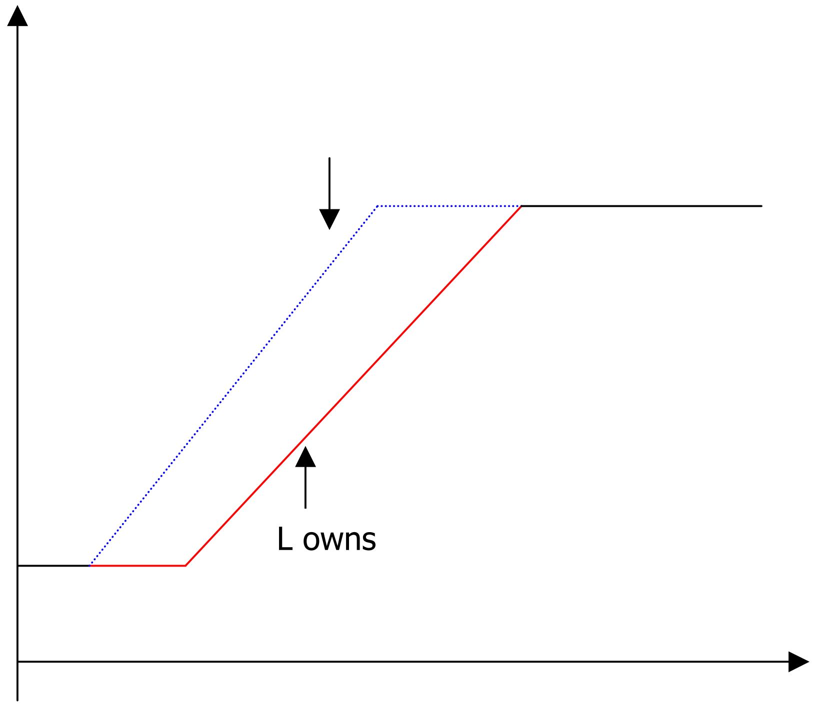

Figure 2. Technique Choice under Imperfect Commitment

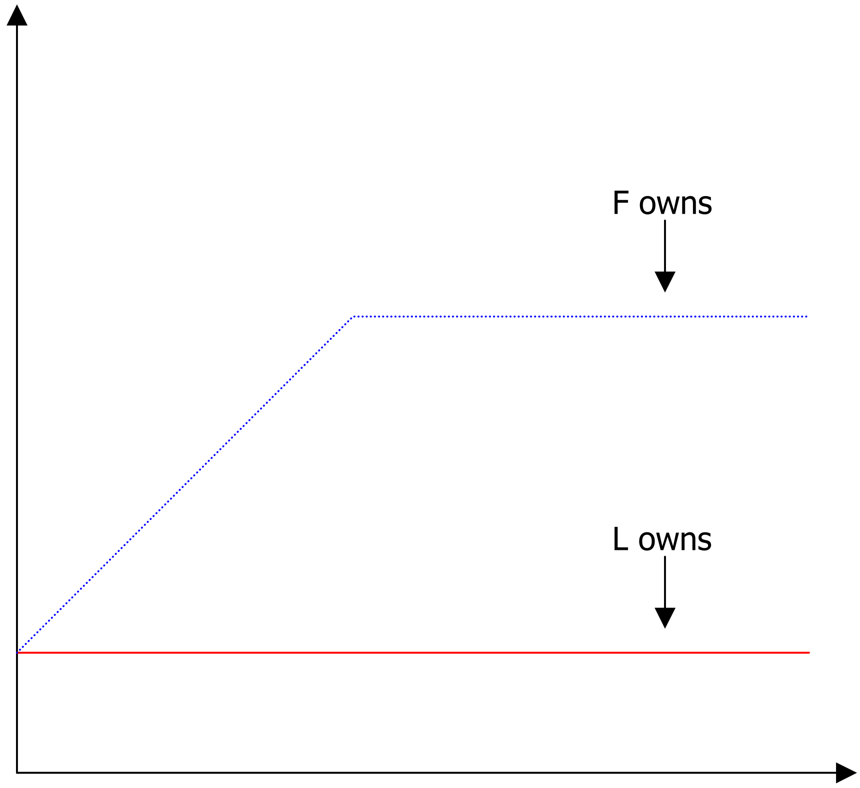

Table 1.1 Variables Means and Standard Deviations

	entire sample	owners	tenants	mean equality test-Pvalue	owner-cum-tenant
crop mix	.56	.62	.47	.00	
	(.49)	(.02)	(.02)		
mainmix	.08	.12	.03	.00	
	(.28)	(.01)	(.007)		
farmer owns plot	.59				
	(.49)				
farmer's wealth	28.3	39.6	11.6	.00	26.1
	(66.5)	(81.1)	(27.8)		(42)
livestock value	12.5	19.2	1.7	.00	10.1
	(49.1)	(61.5)	(14.1)		(27.6)
social capital	.47	.50	.42	.03	.59
	(.76)	(.78)	(.73)		(.72)
famer's age	46.2	48.5	42.7	.00	47.4
	(15.8)	(15.5)	(15.5)		(15.7)
farmer's sex	1.11	1.12	1,11	.55	1.05
	(.32)	(.32)	(.31)		(.23)
farmer's education	.46	.46	.45	.75	.37
	(.49)	(.49)	(.49)		(.48)
plot size (manzanas)	26.15	39.1	7.02	.00	
	(72.7)	(89.9)	(23.2)		
town size (1000 pers)	37.8	36.8	39.3	.44	42.5
	(59.1)	(58.3)	(60.3)		(37.2)
	1.86	1.88	1.82	.25	1.88
distance to market (hrs)	(1.00)	(1.02)	(.97)		(.92)
years farming plot	11.4	15.2	6.07	.00	
	(10.3)	(10.7)	(6.54)		
contract length			2.2		
			(2.8)		

Variables Definition
crop mix: dummy variable,=1 if the farmer grows a mix of trees (coffee, citrus, mangoes or bananas) and annual crops;
mainmix: dummy variable,=1 if trees are a main crop;
wealth: (value of house+durables+business assets+livestock + farm assets) in thousands of *cordobas*
education: dummy variable, =1 if the farmer has had some formal education; **social capital:** number of groups the HH belongs to; **plot size:** 1 manzana=0.69 hectares; **distance to market:** distance from farm to market-- village average.

Table 1.2: Main Crops

% of farmers growing:	*entire sample*	*owners*	*tenants*	*proportion equality test-Pvalue*
corn	77	78	76	.25
beans	59	60	57	.31
cassave	16	18	13	.03
millet	15	14	16	.23
citrus	37	39	32	.00
banana	17	20	14	.00
coffee	9	13	3	.00
mango	24	26	20	.00

Table 2: Land Distribution and Crop Mix: Basic Specification.

P-values in parenthesis.

	(1) cross-section	(2) household fixed effects	(3) cross section with village fixed effects	(4) cross-section with mainmix on LHS
farmer owns plot	0.13	0.18	.08	.09
	(.00)	(.00)	(.01)	(.00)
farmer's wealth*10^{-6}	.81		.77	1.3
	(.08)		(.06)	(.02)
livestock value*10^{-6}	-.63		-.43	-1.4
	(.34)		(.45)	(.03)
social capital	.06		.04	.01
	(.00)		(.04)	(.44)
famer's age	.001		.001	.00
	(.29)		(.21)	(.50)
farmer's sex	-.05		-.02	-.00
	(.15)		(.57)	(.92)
farmer's education	.02		-.00	.03
	(.55)		(.90)	(.03)
plot size*10^{-2}	-.04	-0.06	-.02	-.00
	(.11)	(.59)	(.27)	(.62)
village size	.41			.26
	(.01)			(.07)
distance to market	-.06			-.03
	(.00)			(.11)
town fixed effects	yes	no	no	yes
village fixed effects	no	no	yes	no
hh fixed effects	no	yes	no	no
Nobs	1172	167	1304	1173
R-squared	.10	0.08	.23	.13

Dependent Variable are **crop mix**=1 if farmer grows a mix of annual and tree crops (columns 1-3); **mainmix**=1 if tree is a main crop (column 4). **P-values** are based on robust standard errors - Huber/White/sandwich estimator- in columns 2 and 4, also controlling for clustering at the village level in columns 1 and 3.

Table 3: Land Distribution and Crop Mix, by Wealth Quintiles

Dependent Variable is Crop Mix. P-values in parenthesis.

	1st	2nd	3rd	4th	5th
coefficient on land ownership variable	-.01	.12	.16	.17	.08
	(.91)	(.10)	(.04)	(.02)	(.90)

dependent variable is crop mix, other regressors are wealth, livestock value, farmer's age, sex and education, village size, distance to market and province dummies as above.

P-values are based on robust standard errors (Huber/White/sandwich estimator) controlling for clustering at the village level

Table 4: Wealth and Crop Mix, by Ownership Mode

Dependent Variable is Crop Mix. P-values in parenthesis.

	(1) full sample	(2) owners only	(3) tenants only	(4) owners only	(5) tenants only
farmer owns plot	.11	-	-	-	-
	(.01)				
farmer's wealth*10^{-6}	-.21	1.2	.06	1.2	1.3
	(.74)	(.00)	(.95)	(.00)	(.18)
farmer owns*wealth	1.4				
	(.03)				
livestock value*10^{-6}	-.96	-1.0	-1.6	-1.0	-6.9
	(.08)	(.10)	(.20)	(.09)	(.27)
social capital	.05	.05	.06	.05	.05
	(.00)	(.05)	(.01)	(.11)	(.13)
famer's age	.00	.00	.00	-.00	.00
	(.28)	(.55)	(.36)	(.60)	(.89)
farmer's sex	-.05	-.06	-.00	-.05	.01
	(.16)	(.20)	(.97)	(.37)	(.91)
farmer's education	.02	.05	-.02	.06	-.05
	(.54)	(.17)	(.63)	(.09)	(.31)
plot size*10^{-2}	-.04	-.03	-.00	-.04	-.01
	(.10)	(.18)	(.14)	(.07)	(.11)
village size	.40	.59	.15	.68	.28
	(.01)	(.00)	(.52)	(.00)	(.20)
distance to market	-.05	-.03	-.09	-.03	-.09
	(.00)	(.08)	(.00)	(.08)	(.01)
landlord belongs to the same family					-.02
					(.71)
farmer receives technical assistance				.02	.27
				(.57)	(.00)
length of contract					.03
					(.00)
years farming plot				.005	-.00
				(.00)	(.39)
farmer has title				.01	
				(.78)	
town fixed effects	yes	yes	yes	yes	yes
Nobs	1172	717	455	682	392
R-squared	.10	.11	.09	.13	.16

P-values are based on robust standard errors (Huber/White/sandwich estimator) controlling for clustering at the village level .

Table 5: Length of Tenancy Contracts

1 year	58.0
2 years	21.6
3 years	8.1
4 years	3.3
5 years	2.7
more than 5	6.2

Table 6: Farmers' Credit

did you ask for a loan or advance purchase?	yes: 19%	*why didn't you ask for a loan?*	no need	22.4
	no:81%		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 7: Different Measures of Wealth

Dependent Variable is Crop Mix. P-values in parenthesis.

	wealth=total value of assets	wealth=total value of assets-land.	wealth=total value of assets-land-farm assets	wealth= value of durables
coefficient on land ownership variable	.13	.13	.13	.13
	(.00)	(.00)	(.00)	(.00)
coefficient on wealth variable	.14	.81	.82	4.4
	(.05)	(.08)	(.08)	(.11)

P-values are based on robust standard errors (Huber/White/sandwich estimator) controlling for clustering at the village level.
Other regressors are wealth, livestock value, farmer's age, sex and education, village size, distance to market and province dummies as above.

Table 8: IV Estimates

	1st stage--LHS variable is **wealth*10^{-6}**	2nd stage--LHS variable is **crop mix**
farmer owns plot	.004	.10
	(.00)	(.01)
farmer's wealth*10^{-6}		5.4
		(.05)
livestock value*10^{-6}	1.1	-5.7
	(.00)	(.06)
social capital	.001	.05
	(.04)	(.01)
famer's age	.0003	-.00
	(.00)	(.89)
farmer's sex	-.001	-.03
	(.47)	(.30)
farmer's education	.006	-.02
	(.00)	(.64)
plot size*10^{-2}	.00004	-.01
	(.07)	(.04)
village size	-.01	.37
	(.04)	(.02)
distance to market	-1.6	-.04
	(.05)	(.08)
wife's father education	.01 (.05)	
wife's mother education	.00 (.90)	
village median land value	.001 (.06)	
literacy rate	-0.17 (.01)	
%of primary school graduates	.07 (.09)	
%of secondary school graduates	.19 (.02)	
%of people in houses with direct water supply	.02 (.12)	
religious fractionalisation	-.01 (.04)	
town fixed effects	yes	yes
Instruments=0 -P-value	.00	
Test of Overidentifying Restrictions-P-value		.73
Hausman Test-P-value		.99
Nobs	1148	1148
R-squared	.77	.03

P-values are based on robust standard errors (Huber/White/sandwich estimator) controlling for clustering at the village level.

Variables Definition:
wife's parents education =1 if they have some formal education.
religious fractionalisation=1 if less than 70% of the population belongs to the main religion.

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.