Getting Institutions "Right" for Whom? Credit Constraints and the Impact of Property Rights on the Quantity and Composition of Investment

Michael R. Carter and Pedro Olinto

Property rights reform is typically hypothesized to boost investment through investment demand and credit supply effects. Yet when the credit supply effect is muted, property rights reform would be expected to induce liquidity-constrained farms to reduce investment in movable capital even as they increase investment in attached capital. This expectation is corroborated by econometric analysis of panel data from Paraguay. While all farmers experience a positive investment demand effect, liquidity-constrained producers correspondingly reduce their demand for movable capital. Given an estimated pattern of wealth-biased liquidity constraints, property rights reform will get institutions "right" for only wealthier producers.

Key words: agricultural investment, capital constraints, property rights.

The proposition that legally secure and complete individual property rights over land boost investment and growth has been examined in historical, theoretical, and empirical literature. This proposition suggests that property rights are a key to unlocking of potential economic growth in low-income and transitional economies. In addition, if legally insecure property rights weigh most heavily on low-income households, then public policy designed to enhance the security of individual property rights over land would seem to be a "win-win" policy that promotes both economic growth and income equality.

However, this optimistic "win-win" scenario is correct only if property rights reform suffices to relax the constraints that limit small-farm investment and productivity growth. If not, then the results of property rights reform could be disappointing. Reform would thus get institutions "right" for medium- and large-scale producers, but not for small-scale producers.

The effects of legally secure property rights on investment are typically hypothesized to occur through a security-induced investment demand effect (households increase investment when they perceive a reduction in the likelihood of losing the land in which they might sink attached capital); and, a collateral-based credit supply effect (lenders become more willing to make loans when assured that land pledged as collateral is secure and free of competing claims).[1] While the investment demand effect should be at least as favorable for small-scale as for large-scale producers, the credit supply effect will tend to favor larger-scale producers if there are intrinsic wealth biases in rural credit markets.[2] Separate

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[1] In addition, it has been hypothesized that the right to transfer land to other producers relaxes a terms-of-trade effect (Besley) or an investment regret effect (Carter and Yao), especially in areas where off-farm opportunities are expanding quickly.

[2] Boucher and Carter develop a theoretical rationale for wealth biases in rural capital market. Empirical work by Bell, Srinivasan, and Udry, Kochar, and Mushinski find evidence that such biases are indeed at work. Weak access to capital, which raises the shadow price of capital, will also tend to make individuals discount the future more heavily, which in turn will reduced desired levels of investment. This consideration, along with any other factors that may make poor individuals discount the future more heavily than

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identification of investment demand and credit supply effects is thus needed to explore the hypothesis that property rights reform has differential effects across producer wealth classes.

To date, the empirical analysis of property rights reform has relied upon reduced form methods that cannot distinguish investment demand from credit supply effects. Focusing on the impacts of property rights reform, this article builds on work that examines economic behavior under credit constraints (e.g., Feder et al., 1990) and develops panel data econometric methods to separately identify demand and supply effects. Separate identification of these two effects promises to clarify the inconsistent empirical support for the hypothesis that legal tenure security boosts investment. The empirical literature tends to find that the impact of formally secure property rights on investment is weakest in areas where formal credit markets are weak and customary tenure institutions are strong (e.g., Bruce and Migot-Adholla and Feder and Akihiko). It is unclear whether this finding simply reflects the absence of credit supply effects or whether investment-depressing tenure insecurity is simply not a problem in these areas (as Platteau argues).[3]

In addition, the methods developed in this article permit exploration of the sensible but often overlooked proposition that if credit supply effects fail to relax binding credit constraints, then investment in fixed assets induced by property rights reform will reduce investment in expropriation-immune movable assets. When such countervailing portfolio effects take place, the income effects of property rights reform will be muted compared to what would be expected based on the increase in fixed investment alone. These observations also suggest that the qualitative studies asking farmers what new investments they would undertake if they were to receive tenure security (e.g., Prosterman) overstate tenure security effects because they fail to ask farmers what they would do *less of* if they increased fixed investment.

The remainder of this article is organized as follows. The next section develops a two-period model highlighting the demand, supply, and portfolio effects of property rights on investment in the presence of liquidity constraints. The subsequent section identifies the primary problems confronting consistent estimation of the model, and devises a panel data-based, regression-trimming strategy to deal with them. The Paraguayan study area and data are then introduced. Econometric analysis of the data indicate that while legal tenure security has a positive and significant demand effect for fixed capital, liquidity-constrained producers are correspondingly estimated to reduce their demand for movable capital as tenure security increases. In contrast, liquidity-unconstrained producers increase the size of their aggregate capital stock even as they shift its composition. Because the estimated pattern of liquidity constraints is wealth biased, these results imply that property rights reform will have differential effects across wealth classes and will get institutions "right" only for a wealthier subset of producers.

A Two-Period Model of the Demand, Supply, and Portfolio Effects of Property Rights Reform

This section develops a model of the impact of tenure insecurity and capital constraints on the overall level and composition of agricultural capital. We assume that there are two types of capital. The first, K_a, is immovable capital that is lost in the event that land is forfeited in a dispute. The second, K_m, is movable capital that is not lost when land is forfeited or taken away. We assume that in every production period, the agricultural household takes its capital stocks and land (T) as given and allocates short-term variable inputs to maximize income. Let $\pi_t^*(K_a, K_m \mid T)$ be the present value of the restricted profit function that corresponds to the short-run production problem for period t. To keep matters simple, we assume that capital lasts two production periods and that the decision to invest in capital takes place prior to the initial production period in accordance with the following problem

$$\begin{aligned}\operatorname*{Max}_{K_a, K_m, B}\ & \pi_1^*(K_a, K_m \mid T) \\ & + E\left[\pi_2^*(K_a, K_m \mid T)\right] - (K_a + K_m) \\ & - rB + r(W - K_a - K_m + B)\end{aligned}$$

the rich, could offset the presumption that the demand effects favor less wealthy households.

[3] In an important variation on this theme, Brasselle, Gaspart, and Platteau note that in some environments, weak tenure security may actually induce (over) investment in land as producers try to deepen their claim on a piece of land by establishing tree crops or other investments that locally make the land redistribution proof. In this case, provision of effective formal tenure security might actually reduce investment in attached capital.

subject to

$$K_a + K_m \leq W + B$$
$$B \leq S(h, T)$$
$$E\left[\pi_2^*\right] = \hat{\xi}(h)\pi_2^*(0, K_m) + (1 - \hat{\xi}(h))\pi_2^*(K_a, K_m)$$

where $\hat{\xi}$ is the probability that land (and its attached capital) will be lost in a dispute. This probability is a nonincreasing function of h, an indicator of tenure security. The term W is the farm's initial liquid wealth. Wealth that is not used to purchase capital goods earns a rate of return r. The term B is the amount the farm borrows at the interest rate r. The amount the farm can borrow is limited by its land assets, T, and the legal security of the rights it holds over its land, h. The farm's nonnegative ration of credit is given by $S(h,T)$, with $S_1, S_2 \geq 0$.

The inequality constraints for this problem define two important regimes. The first is the unconstrained regime in which the financing constraint does not bind such that $W + B > K_a + K_m$. The first-order conditions for this regime are

$$(1a) \quad \kappa_a \equiv \partial\pi_1^*/\partial K_a + (1 - \hat{\xi})\partial\pi_2^* \times (K_a, K_m)/\partial K_a = (1 + r)$$

$$(1b) \quad \kappa_m \equiv \partial\pi_1^*/\partial K_m + \hat{\xi}\partial\pi_2^*(0, K_m)/\partial K_m + (1 - \hat{\xi})\partial\pi_2^*(K_a, K_m)/\partial K_m = (1 + r)$$

where κ_a and κ_m are the expected total marginal products of capital. Denote the solutions to this unconstrained problem as

$$(2a) \quad K_a^u = K_a^u(r, h \mid T)$$

$$(2b) \quad K_m^u = K_m^u(r, h \mid T).$$

Note that these unconstrained demand functions for agricultural capital depend only on prices and technologies and do not depend on the household's borrowings or on its endowment of liquid wealth, W.

In addition to this unconstrained solution, the problem above admits a solution in which the finance and borrowing constraints bind. In this case, $W + S = K_m + K_a$, permitting movable capital to be determined residually from the choice of attached capital and the liquidity constraint: $K_m = W + S - K_a$. In this case, the maximization problem reduces to a single choice variable and the first-order condition reduces to $\kappa_a = \kappa_m$. Denote the solution values for this constrained problem as

$$(3a) \quad K_a^c(W + S(h, T), h \mid T)$$

$$(3b) \quad K_m^c(W + S(h, t), h \mid T).$$

Note that these constrained-optimum capital stocks depend on the liquid wealth endowment, the credit ration, $S(h,T)$, and directly on the degree of tenure insecurity. Finally, define the endogenous shadow price of liquidity $\tilde{r}(W + S(h, T), h \mid T) = \kappa_a - 1$, such that for the liquidity-constrained producer

$$(4) \quad \kappa_a = \kappa_m = (1 + \tilde{r}).$$

Figure 1 displays this equilibrium for the liquidity-constrained producer. The width of the horizontal axis is given by the available liquidity, $W + S$. The K_a is measured from the left origin, and K_m is measured from the right. Any point along the axis exactly exhausts the available liquidity. For the relatively low level of tenure security given by h_0, the optimum-constrained capital portfolio is denoted by point A in the figure where expected rates of return are equalized between the two types of capital. Denote the shadow price of liquidity as $\tilde{r}_0$ for this low-security equilibrium capital allocation.

Figure 1 can also be used to illustrate the effect of an increase in tenure security from h_0 to h_1. This security increase boosts expected returns to attached capital such that κ_a shifts to the northeast as shown by the dashed line. While the increase in tenure security potentially has a secondary effect on κ_m (via a nonzero cross partial between K_a and K_m in the profit function) we assume this effect is zero for purposes of the figure.[4] If the increased tenure security has no liquidity or credit supply effect, the new liquidity-constrained equilibrium will shift to point B and will be characterized by a higher level of attached capital, a lower level of movable capital, and a higher shadow price of liquidity, $\tilde{r}_1$.

If liquidity expands to S' with enhanced legal tenure security, the width of the x-axis in figure 1 increases as illustrated by the dashed right-hand y-axis. Graphically, the κ_m curve shifts

[4] Including a nonzero cross-partial effect between K_a and K_m can be incorporated easily into the figure for the capital constrained case as every level of K_m corresponds to a unique level of K_a. However, in the unconstrained case discussed below, inclusion of a nonzero cross partial between K_a and K_m requires a graph-cluttering shift in the K_m following an increase in tenure security. The inclusion of this cross-partial effect would not affect the qualitative nature of the results in either case.

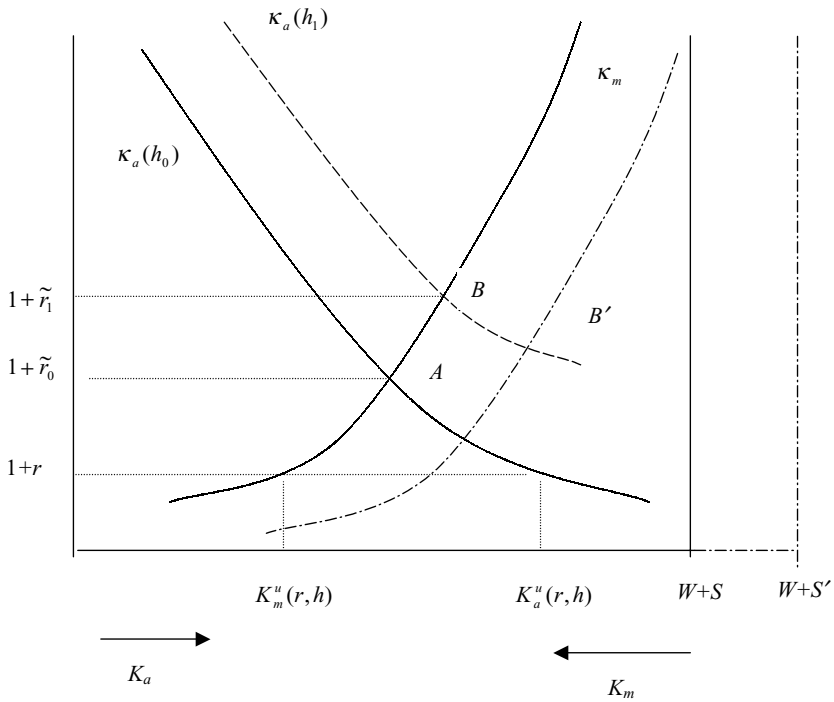

Figure 1. Portfolio effect of property rights reform for credit-constrained producer

to the right as shown by the dotted line as it is measured from the origin of the right-hand axis. Assuming that the farm remains in the liquidity-constrained regime after the increase in tenure security and liquidity, the new equilibrium would be at point B'.

Figure 1 can also be used to illustrate the liquidity-unconstrained equilibrium. Since the available liquidity no longer matters for this case, we will drop the interpretation of the width of the horizontal axis as indicating the total available liquidity. Given a market price of capital of r, desired stocks of the two capitals will be as shown. As can be seen, capital stocks of these levels would not be affordable for the liquidity-constrained household.

Finally, note the unconstrained demand for agricultural capital evaluated at the endogenous shadow price of liquidity defined by (4), $\tilde{r}$, would just equal the constrained demand for capital:

$$(5a)\quad K_a^u(\tilde{r}(W+S,h),h\mid T)=K_a^c(W+S,h\mid T)$$

$$(5b)\quad K_m^u(\tilde{r}(W+S,h),h\mid T)=K_m^c(W+S,h\mid T).$$

Using these expressions, the total impact of tenure security on the desired liquidity-constrained holding demand for capital stock of type j can be decomposed as

$$(6)\quad \frac{dK_j^c}{dh}=\left[\partial K_j^u/\partial h\right]+\left[\partial K_j^u/\partial\tilde{r}\right]\left[\partial\tilde{r}/\partial h\right]+\left[\partial K_j^u/\partial\tilde{r}\right]\left[\partial\tilde{r}/\partial S\right]\left[\partial S/\partial h\right].$$

Note that the first term on the right-hand side of (6) is the direct, security-induced demand effect. The second term is an investment-depressing, endogenous shadow price of liquidity effect. The third term is the credit supply effect of land title. For movable and other types of capital for which the direct investment demand effect is small (i.e., $\partial K_j^u/\partial h\approx 0$), the sign of (6) will depend on the latter two terms. If credit supply effects are negligible for a credit-constrained household ($\partial S/\partial h\approx 0$), then (6) is expected to be negative for movable capital, indicating that tenure security crowds out investment in this asset.

The Econometric Model and Estimation Strategy

This section derives a strategy for estimating the theoretical model of desired capital stocks using panel data. For household i in period t, consider the following linear approximation

to the liquidity-unconstrained capital demand equations given in (2)[5]

$$(7) \qquad K_{it}^{u} = r_{it}\boldsymbol{\psi}_1 + \boldsymbol{X}_{it}\boldsymbol{\psi}_2 + [\gamma_i + \varepsilon_{it}]$$

where $\boldsymbol{\psi}_1$ and $\boldsymbol{\psi}_2$ are vectors of structural parameters, and the row vector $\boldsymbol{X}_{it}$ denotes observable characteristics that affect the economic returns to capital (such as tenure security, farm size, relative prices, technology, and market access). The term γ_i denotes latent, but time-invariant individual characteristics influencing desired capital stock. The random disturbance, ε_{it}, is assumed to meet the usual assumptions.[6]

In most empirical situations, an experimental or other exogenous process does not determine tenure status. Instead, individuals choose to invest in the legal and other procedures necessary to obtain secure tenure. The latent characteristics captured by γ_i (e.g., farming skill) may increase returns to investments in both tenure security and agricultural capital, suggesting that γ_i will not be orthogonal to r_{it} or to $\boldsymbol{X}_{it}$. It thus is vital to control for γ_i to avoid contaminating the estimates of the effect of tenure security with the effect of these latent characteristics.

The shadow price of liquidity for households in the constrained regime (defined above) can be linearly approximated by

$$(8) \qquad \tilde{r}_{it} = \boldsymbol{X}_{it}^{r}\boldsymbol{\alpha} + \left[\gamma_i^{r} + \varepsilon_{it}^{r}\right]$$

where $\boldsymbol{\alpha}$ is an unknown parameter vector, the $\boldsymbol{X}_{it}^{r}$ are the observable explanatory variables, and γ_i^{r} is a latent time-invariant factor. As with regression (7), we assume that ε_{it}^{r} is a random error that is orthogonal to the explanatory variables, whereas γ_i^{r} may not be.[7]

Taking advantage of the relationship given by (5), we can express the liquidity-constrained demand for capital as the unconstrained demand evaluated at the endogenous shadow price of liquidity given by (8)

$$(9a) \qquad K_{it}^{c} = \left[\boldsymbol{X}_{it}^{r}\boldsymbol{\alpha} + \gamma_i^{r} + \varepsilon_{it}^{r}\right]\boldsymbol{\psi}_1 + \boldsymbol{X}_{it}\boldsymbol{\psi}_2 + \gamma_i + \varepsilon_{it}.$$

Collecting terms we rewrite (9*a*) as

$$(9b) \qquad K_{it}^{c} = \boldsymbol{Z}_{it}\boldsymbol{\beta} + \tilde{\gamma}_i + \tilde{\varepsilon}_{it}$$

where the vector $\boldsymbol{Z}_{it}$ is the concatenation of X_{it}^{r} and $\boldsymbol{X}_{it}$; $\boldsymbol{\beta}$ is a vector of reduced form parameters; and, $\tilde{\gamma}_i = \gamma_i + \boldsymbol{\psi}_1\gamma_i^{r}$ and $\tilde{\varepsilon}_{it} = \varepsilon_{it} + \boldsymbol{\psi}_1\varepsilon_{it}^{r}$. The reduced form parameter in (9*b*) relating tenure security to desired investment corresponds to the total derivative defined by (6) since it incorporates both liquidity effects (from $\boldsymbol{\alpha}$) and investment demand effects (from ψ_1).[8]

Data from farms that are liquidity-unconstrained will be used to identify the structural parameters in (7), while liquidity-constrained observations will be used to estimate the reduced form parameters in (9*b*). Switching between the liquidity-constrained and - unconstrained regimes is endogenous and depends on the demand (D_{it}) versus the supply or ration (S_{it}) of liquidity or credit to each individual household i at time t. The binary liquidity constraint indicator variable, d_{it}, takes on the value one when demand for liquidity exceeds the supply

$$(10) \qquad d_{it} = \begin{cases} 1 & \text{if} \quad D_{it}\left(\boldsymbol{V}_{it}^{D}, \upsilon_i^{D} \mid \boldsymbol{\delta}^{D}\right) \\ & \qquad - S_{it}\left(\boldsymbol{V}_{it}^{S}, \upsilon_i^{S} \mid \boldsymbol{\delta}^{S}\right) = \boldsymbol{V}_{it}\boldsymbol{\delta} \\ & \qquad + \upsilon_i + \mu_{it} \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

where demand and supply are functions of observable variables ($\boldsymbol{V}_{it}^{D}$ and $\boldsymbol{V}_{it}^{S}$), latent, time-invariant effects (υ_i^{d} and υ_i^{s}), random time-varying disturbances (μ_{it}^{D} and μ_{it}^{S}); and, parameter vectors $\boldsymbol{\delta}^{D}$ and $\boldsymbol{\delta}^{S}$. For notational convenience, we use $\boldsymbol{V}_{it}$, υ_i, and $\boldsymbol{\delta}$ as shorthand for the full set of demand and supply variables and parameters, while μ_{it} is the resulting regression time-varying disturbance. Define the credit constraint probability, ρ_{it}, as

$$(11) \qquad \begin{aligned} \rho_{it} \equiv E(d_{it}) &= \Pr(d_{it} = 1) \\ &= \Pr(\mu_{it} \geq -\boldsymbol{V}_{it}\boldsymbol{\delta} - \upsilon_i) \\ &= \Phi(-\boldsymbol{V}_{it}\boldsymbol{\delta} - \upsilon_i) \end{aligned}$$

where Φ is the cumulative distribution function which monotonically increases in the linear index, $\boldsymbol{V}_{it}\boldsymbol{\delta}$.

Equations (7) and (9*b*), and (10) can be combined to form an endogenous switching

[5] The parameters and variables in (8) should include an additional subscript indicating type of capital (attached or movable). To reduce notational clutter, we suppress those subscripts, though the empirical work below does not restrict parameters to the same across types of capital.

[6] That is, we assume that $E[\varepsilon_{it} \mid r_{it}, \boldsymbol{X}_{it}] = 0$, $E[\varepsilon_{it}\, r_{it}] = 0$ and $E[\varepsilon_{it}, \boldsymbol{X}_{it}] = 0$.

[7] The term γ_i^{r} might include social connections that make both capital and secure tenure status cheaper to obtain.

[8] While similar to equation (7) in appearance, the parameters in (9*b*) are reduced from parameters and have a different interpretation than the structural parameters in (7).

regression for desired capital stock

$$(12)\quad K_{it} = \begin{cases} K_{it}^{c} = \boldsymbol{Z}_{it}\boldsymbol{\beta} + \tilde{\gamma}_i + \tilde{\varepsilon}_{it}, & \text{if} \quad d_{it} = 1 \\ K_{it}^{u} = r_{it}\boldsymbol{\psi}_1 + \boldsymbol{X}_{it}\boldsymbol{\psi}_2 + \gamma_i + \varepsilon_{it}, & \text{if} \quad d_{it} = 0. \end{cases}$$

Three difficulties confront the estimation of the parameters in (12):

1. *Unobserved Regime Switching* as the liquidity constraint indicator, d_{it}, is not observed.[9]
2. *Heterogeneity Bias* as each regression regime contains a latent, individual-specific, time-invariant variable that is likely to be correlated with property rights and other variables; and
3. *Selection Bias* as the (unobserved) regime-switching process is economically endogenous based on the demand and supply of liquidity.

We develop and implement a two-stage estimation strategy to deal with these problems. In the first stage, we use estimated liquidity demand and supply parameters that determine the constraint regime to replace the unobserved regime-switching variable with a consistent estimate of its expected value. In the second stage, we estimate the parameters in (12) via two alternative methods. The first method uses a conventional fixed effects differencing technique to (partially) control for heterogeneity and selection biases. The second, more conservative method adopts the regression-trimming and -weighting methods suggested by Honore and Kyriazidou and Kyriazidou and eliminates any residual biases associated with the first difference estimator.

Assuming for the moment that d_{it} and regime switching are observed, the switching regression (12) can be written as

$$(12')\quad K_{it} = d_{it}[\boldsymbol{Z}_{it}\boldsymbol{\beta} + \tilde{\gamma}_i + \tilde{\varepsilon}_{it}] + (1 - d_{it}) \times [r_{it}\boldsymbol{\psi}_1 + \boldsymbol{X}_{it}\boldsymbol{\psi}_2 + \gamma_i + \varepsilon_{it}].$$

Applying a conventional fixed effects or first difference transformation to (12′) yields

$$(13)\quad K_i^* = \left[\boldsymbol{Z}_i^*\boldsymbol{\beta} + \tilde{\gamma}_i d_i^* + \tilde{\varepsilon}_i^*\right] + \left[r_i^*\boldsymbol{\psi}_1 + \boldsymbol{X}_i^*\boldsymbol{\psi}_2 - d_i^*\gamma_i + \varepsilon_i^*\right]$$

where the $*$'s indicate time-differenced variables defined as follows

$$\begin{aligned} K_i^* &= K_{it} - K_{it-1} \\ d_i^* &= d_{it} - d_{it-1} \\ Z_i^* &= d_{it}\boldsymbol{Z}_{it} - d_{it-1}\boldsymbol{Z}_{it} \\ X_i^* &= (1 - d_{it})\boldsymbol{X}_{it} - (1 - d_{it-1})\boldsymbol{X}_{it} \\ r_i^* &= (1 - d_{it})r_{it} - (1 - d_{it-1})r_{it-1} \\ \tilde{\varepsilon}_i^* &= d_{it}\tilde{\varepsilon}_{it} - d_{it-1}\tilde{\varepsilon}_{it-1} \end{aligned}$$

and

$$\varepsilon_i^* = (1 - d_{it})\varepsilon_{it} - (1 - d_{it-1})\varepsilon_{it-1}.$$

Noting from (9*b*) that $\tilde{\gamma}_i = \gamma_i + \boldsymbol{\psi}_1\gamma_i^r$, the time-invariant, latent variable terms in (13) can be combined and the equation simplified as

$$(13')\quad K_i^* = \boldsymbol{Z}_i^*\boldsymbol{\beta} + r_i^*\boldsymbol{\psi}_1 + \boldsymbol{X}_i^*\boldsymbol{\psi}_2 + \left[d_i^*\boldsymbol{\psi}_1\gamma_i^r\right] + \left[\tilde{\varepsilon}_i^* + \varepsilon_i^*\right].$$

As inspection of (13′) reveals, this first difference approach has swept away the time-invariant component (γ_i) that directly affects desired investment. However, both of the error components in square brackets are sources of potential econometric bias. The terms in the first set of brackets can be a source of what will be termed residual heterogeneity bias, while the terms in the second set of brackets may be a source of residual selectivity bias.

As can be seen from (13′), first differencing will not eliminate the latent individual heterogeneity component, γ_i^r, affecting the shadow price of liquidity (and indirectly affecting investment) except where $d_i^* = 0\,\forall\, i$. Put differently, unless all observations stay in the same liquidity constraint regression regime over time, the first differencing method commonly used to control the latent characteristics in linear models will not completely eliminate the time-invariant latent terms and will expose ordinary least squares estimation of (13′) to "residual" heterogeneity bias if $E[\gamma_i^r \mid d_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}, r_{it}.] \neq 0$.[10]

In addition to this bias problem, OLS estimation of (13′) may be subject to selectivity bias unless the terms in the second square bracket have zero expectation conditional on the liquidity constraint regime

$$(14)\quad E\left[\tilde{\varepsilon}_i^* + \varepsilon_i^* \,\middle|\, d_{it}, d_{it-1}\right] = 0.$$

[9] The fundamental problem is that in the possible presence of nonprice loan rationing, observed loan transactions, or lack thereof, cannot be used to impute liquidity constraint status. While Barham, Boucher, and Carter discuss questionnaire strategies that may yield credibly observable indicators of liquidity constraint status, the data available for this study contain only the more routinely available variables that do not permit the construction of such indicators.

[10] Discussion earlier in this section gave reasons why this expectation may be nonzero.

In general, we might expect selectivity to be a problem in that farmers with connections, entrepreneurial zeal, and other latent characteristics that make them less likely to be credit-constrained may also directly boost their desired investment levels. However, note that the error terms in (14) have already been purged of any such characteristics that are time invariant (as connections and entrepreneurial zeal would seem to be). Any econometrically problematic selectivity could thus take place only through any remaining, time-varying latent characteristics. For this reason, we will refer to a violation of (14) as a problem of residual selectivity bias.

To gain further purchase on this residual selectivity bias problem, we follow conventional sample selection notation and denote the expected values of the underlying time-varying error terms in (14) as

$$(15a)\quad \tilde{\lambda}_{it} \equiv E[\tilde{\varepsilon}_{it} \mid d_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}, r_{it}]$$

and

$$(15b)\quad \lambda_{it} \equiv E[\varepsilon_{it} \mid d_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}, r_{it}].$$

For there to be no problem of residual selectivity bias, it must be the case that $\tilde{\lambda}_{it} = \lambda_{it} = 0$.

One approach to deal with these residual bias problems is to trim the sample by eliminating all observations that change regimes between time periods and for which $d_i^* \neq 0$ (see Honore and Kyriazidou and Kyriazidou). Trimming sweeps away the term $d_i^* \boldsymbol{\psi}_1 \gamma_i^r$ in (13′) and thereby eliminates the source of residual heterogeneity bias.

Trimming has the additional benefit of relaxing the conditions needed for selectivity bias to be eliminated. Without trimming, both (15*a*) and (15*b*) must have zero expectations to eliminate selectivity bias. With trimming, the error for each observation will either be of the form $\tilde{\varepsilon}_{it} - \tilde{\varepsilon}_{it-1}$ or $\varepsilon_{it} - \varepsilon_{it-1}$, and condition (14) can be replaced by the weaker condition that there will be no residual sample selection bias if

$$(16)\quad (\tilde{\lambda}_{it} - \tilde{\lambda}_{it-1}) = (\lambda_{it} - \lambda_{it-1}) = 0.$$

In words, this expression says that there will be no residual selectivity bias as long as the expected *difference* between the error terms (in the same liquidity constraint regime) is zero.

Note that we can evaluate the likelihood that (16) is met by writing the conditional expectations (15*a*) and (15*b*) as functions of the linear index predicting the shift between the liquidity constraint regimes

$$(17)\quad \tilde{\lambda} = \tilde{\Lambda}(\boldsymbol{V}_{it}\boldsymbol{\delta} + \upsilon_i) \text{ and } \lambda_{it} = \Lambda(\boldsymbol{V}_{it}\boldsymbol{\delta} + \upsilon_i)$$

where the arguments of the functions are defined in (10).[11] For those observations for which the linear index $\boldsymbol{V}_{it}\boldsymbol{\delta} + \upsilon_i$ does not change very much between the two periods, $(\tilde{\lambda}_{it} - \tilde{\lambda}_{it-1})$ and $(\lambda_{it} - \lambda_{it-1})$ in (15) will be small. These terms will also be small when there is little change in any monotonic transformation of the linear index, $\boldsymbol{V}_{it}\boldsymbol{\delta}$.

The liquidity constraint probability, $\rho_i = \Phi(\boldsymbol{V}_{it}\boldsymbol{\delta} + \upsilon_i)$, defined in (11) is one such monotonic transformation of this linear index. Exploiting the monotonicity of the cumulative distribution function, Φ, we can rewrite the selection terms in (17) as

$$\tilde{\lambda}_{it} \equiv \tilde{\Lambda}\big(\Phi^{-1}(\rho_{it})\big)$$

and

$$\lambda_{it} \equiv \Lambda\big(\Phi^{-1}(\rho_{it})\big)$$

we note that $(\tilde{\lambda}_{it} - \tilde{\lambda}_{it-1}) = (\lambda_{it} - \lambda_{it-1}) \approx 0$ when $\rho_{it} \approx \rho_{it-1}$. Noting that the selection bias for this class of problem disappears as the linear index governing regime switching does not change over time, Kyriazidou suggests weighting the data in inverse proportion to the distance between the two selection indices for two periods.

Combining these ideas we arrive at the two-stage estimation strategy to be used in this article. We first estimate (10) and construct estimates of the liquidity rationing probability, $\hat{\rho}_{it}$. We then we substitute these estimated $\hat{\rho}_{it}$'s for the d_{it}'s in (13′). In the analysis to follow, we offer two alternative second-stage estimators of the parameters in (13′):

1. *OLS First Difference Estimation*, in which (13′) is simply estimated using ordinary least squares. This estimator permits us to use all observations, but is subject to residual heterogeneity bias (as well as to selection bias if there are time-varying latent characteristics which enhance liquidity access and are correlated with property rights status and other explanatory variables).
2. *Trimmed Sample Estimation,* in which we eliminate observations that are likely to have changed regression regimes over time.

[11] Note that in the special case where the errors from the investment and liquidity constraint equations are joint normally distributed, (17) reduces to the familiar Mills ratio terms. We do not make that assumption in the analysis here.

Table 1. Property Rights, Credit, and Capital Stock

Has Formal Loan						
Attached capital	133.2	103.0	25.3	23.2	108.2	77.9
Movable capital	204.2	150.7	140.9	115.2	111.6	214.1
Formal credit	58.9	50.2	32.2	28.9	31.5	38.6
Informal credit	3.0	3.1	0.0	1.1	0.0	29.3
Farm size (hectares)	141.6	111.3	41.1	43.6	47.9	42.2
% titled or formal	94%	97%	94%	85%	0%	0%
Number of observations	34	48	5	6	4	5
No Formal Loan						
Attached capital	82.6	73.9	103.2	92.7	53.9	51.7
Movable capital	199.3	133.5	169.5	136.1	111.4	99.3
Informal credit	11.4	8.3	7.5	5.5	10.2	10.8
Farm size (hectares)	30.0	26.8	11.1	9.3	11.0	10.9
% titled or formal	93%	95%	90%	93%	0%	0%
Number of observations	79	86	85	65	41	38

Note: Current $US/hectare unless otherwise noted. For the purpose of this table, a household is considered titled if it owns at least some titled land, and formal if owns at least some formal document but no title. Other includes landless households (tenants) and squatters.

This is equivalent to a weighting scheme w_i given by

$$(19)\quad w_i = \begin{cases} 1 & \text{if} \quad \hat{\rho}_{it} > 80\% \quad \forall t \\ & \text{or} \quad \hat{\rho}_{it} < 20\% \quad \forall t \\ & \text{and} \quad |\hat{\rho}_{it} - \hat{\rho}_{it-1}| < 20\% \\ 0, & \text{otherwise.} \end{cases}$$

Using these weights, only those observations that are very likely to have been in the same regime in both periods are kept for the analysis. While the OLS first difference estimator is subject to residual heterogeneity and selection biases, this latter procedure is insulated against these problems.

How and For Whom Does Tenure Security Work in Paraguay?

This section uses a farm-level panel data set collected in Paraguay to gauge how and for whom tenure security works. Paraguay remains one of Latin America's most highly agricultural economies, as well as one of its poorest. Similar to most of Latin America, the land distribution is dualistic, with numerous tiny farms coexisting with large production units controlling most of the agricultural area. Carter and Galeano and Carter and Salgado give more detailed information on agricultural and land issues in Paraguay. After first presenting a descriptive overview of the available panel data, this section goes on to estimate the switching regression model of desired capital stock.

Property Rights, Capital, and Credit in Paraguay

The panel data available for this study emerged from a stratified, multistage random sample of 300 producer households distributed across three distinctive regions of rural Paraguay: The traditional core "minifundia" zone of Paraguarí; the colonization zone of San Pedro; and the department of Itapúa, located in the frontier region with Brazil and where there has been significant agro-export growth. These 300 producer households were interviewed in 1991, and 248 were successfully reinterviewed in 1994.[12] Both interviews collected full production and income information as well as a detailed accounting of the modes of land access, property rights, and land transactions. Larger farms of more than 25 hectares of land were purposefully over-sampled to assure adequate representation of this important group of producers.

Table 1 presents some basic indicators drawn from the available data. The columns of the table report mean values for farms in three

[12] This 17% attrition rate appears to be the result of poor record-keeping in the first round of survey. The pattern of attrition shows no relation to observable variables such as land, wealth, or credit market participation, suggesting that the pattern of attrition was indeed random. It remains possible that the attrition was related to unobserved variables, with perhaps only the more skillful or entrepreneurial producers remaining in the survey. In this case, inference from this data should be understood for applying to the more entrepreneurial set of farmers who tend to survive over time, as opposed to applying to the full population of farmers who might be found at any single point in time. Inference about this former group is presumably no less interesting than that about the former. Moreover, the results detailed below that identify weaknesses in the small-farm sector would, if anything, be stronger if data on a nonattrited sample were available.

tenure security or property rights categories. The rows divide observations based on formal credit status. It should, of course, not be assumed that farms without formal loans are necessarily credit rationed. Nonetheless, splitting the data in this way permits us to get a sense for the data and the primary hypotheses to be investigated.

A farm is designated as "Titled" if at least some of its land is held with legally registered, mortgagable property rights. A farm is assigned to the "Formal" category if it did not qualify as titled but owned land emanating from colonization projects in the 1960s and the 1970s that assigned colonists legally secure, but inalienable and unmarketable property rights. Once an individual pays off colonization debts, land held under formal tenure is titled and the land becomes fully marketable (and mortgagable). In the analysis to follow, land in the formal category will be treated as having equal tenure security as titled land but as having potentially different collateral value. Over the study period, Paraguay had no general program of land titling, and those farms with titled land had to go through some trouble and expense to obtain and maintain their titles.

The "Other" tenure category in table 1 reflects the fact that rural Paraguay has been typified by a wide variety of tenure regimes, including significant informal squatting that developed given the country's historically long period of extreme land abundance. Land that is accessed under these more precarious regimes amounts to a significant share of land for farms in the smallest size strata. Less than 60% of the small farms sampled in 1991 either had, or were in the process of obtaining legal title to their land. This not atypical pattern in which legally unclear or insecure land access predominates in the small-farm strata underlies the perspective that property rights reform policies should differentially advantage the less well-off even as it promotes aggregate growth.

Observations in the northwest corner of table 1 have legal title to their land and were observed to have formal production loans. These farms have both high levels of attached capital per hectare compared to other farms,[13] and much higher loan levels. The key question to be investigated is whether or not these relatively high levels of credit and attached capital are the result of these farms' legal status per se. For example, note also that these farms are by far and away the largest in the sample, raising the question as to whether their favorable capital and credit indicators are a result of their tenure status, or their size in markets that are scale sensitive. It could of course also be that this descriptive association between title status, credit, and attached capital is a spurious reflection of the fact that all three variables are caused by a fourth factor (e.g., entrepreneurial zeal). In this case, the provision of title to randomly selected (not necessarily zealous) farmers would do nothing for credit access and agricultural productivity.

The panel data methods used here rely on the changes in household characteristics and behaviors over time to identify the impact of property rights on investment and credit access. While the sacrifice of between household variation to control for time-invariant, household-specific effects is likely to be statistically expensive, the data do exhibit intrahousehold variation over time in the key property rights variables. As can be gleaned from table 1, the number of farms in the title category rose from 112 to 132 from 1991 to 1994. In addition, some number of titled farms increased the amount of their farm area held under legally secure status.

Econometric Results

Table 2 presents first difference estimates for the switching regression functions for attached and movable capital given by equation (12).[14] An appendix available from the authors summarizes the estimation of the credit demand and supply functions used to construct the first-stage estimates of the credit constraint probability (ρ_{it}) used in (12). Following the regression strategy outlined earlier, results are presented for the full sample as well as for a trimmed sample excluding observations that are likely to have changed credit constraint status between 1991 and 1994. As discussed earlier, there are two types of legally secure land in rural Paraguay. The two types should offer similar security to the owner and hence have identical impacts on investment demand. Their credit supply effects may, however, be

[13] Attached capital includes buildings, fences, land improvements, and irrigation infrastructure. Movable capital is measured as stocks of machinery, equipment, and livestock.

[14] The results presented here are a parsimonious specification leaving out family labor variable and higher-order farm size measures that might be expected to control for differences in the shadow price of labor across households. With those variables included, the econometric results became unstable. The inclusion of household specific effect makes the exclusion of these variables not especially worrisome, as household labor scarcity would be expected to change relatively little over the sample period.

Table 2. Switching Regression Results

	Full Sample				Trimmed Sample			
	Attached Capital		Movable Capital		Attached Capital		Movable Capital	
	Coefficients	Std Errors	Coefficients	Std Errors	Coefficients	Std Errors	Coefficients	Std Errors
Liquidity Unconstrained Regime								
Formal tenured area (Ha)	243[a]	132	−38	133	270[a]	148	−97	165
Farm size (Ha)	24	56	166[b]	67	23	63	188[b]	74
1994 time shift	663[a]	363	−493	962	746	458	−356	1077
Minifundia region time shift	−799[a]	483	1719	1900	−1308	860	3144	3428
Frontier region time shift	3002[a]	1588	14057[b]	4518	3103	1876	17082	5591
Liquidity Constrained Regime								
Formal tenured area (Ha)	262[a]	130	−188	129	**−87**	**60**	**−588**	**378**
Titled area (Ha)	236[a]	128	−291[b]	143				
Farm size (Ha)	20	52	358[b]	65	−8	40	−259	182
1994 time shift	156	126	215	327	224[a]	127	693[a]	402
Minifundia region time shift	−224	899	869	2439	25003	18130	10955	61752
Frontier region time shift	−791	2166	3162	5074	−10091	9613	−58029	64607
Intercept shift	−54	408	−217	1009	2191	2052	−11098	20049
Minifundia region shift	166	484	−599	1319	−12578	9098	−5853	30957
Frontier region shift	234	1135	−3066	2911	5001	4799	28841	32328
R^2	0.34		0.30		0.37		0.33	
Number of observations	246		246		141		141	

[a] Different from zero at the 10% level.
[b] Different from zero at the 5% level.

different. For households in the liquidity-unconstrained regimes, the two types of land should have identical effects and identify the investment demand effect of tenure security. For households in the liquidity-constrained regimes, the effects of these two types of land should be different, and both are included in the regression.

Initially, all liquidity-constrained regime equations were estimated without imposing any restrictions on the coefficients of titled and formal land. For the full sample regression, we reject the hypothesis that the coefficients of formal and titled land are the same. For the trimmed sample estimates, this hypothesis cannot be rejected and only the estimates restricting these coefficients to be the same are reported. Table 2 displays these restricted estimates in bold face.

The overall character of the results is quite striking using both the full and trimmed samples. Land tenure security appears to increase attached capital for both liquidity-constrained and liquidity-unconstrained farms. For unconstrained households—which identify the pure structural effect of tenure security on investment—the shift of one hectare of land from the insecure to the secure category (holding total farm size fixed) is estimated to increase total attached capital by \$243 to \$270 (the larger effect is the point estimate from the trimmed regression; the lower from the full sample estimation). Both of these estimates are different from zero at the 10% level.[15]

For the liquidity-constrained regime, an increase of one hectare of formal land is estimated to increase attached investment by \$262, while an increase in titled area is estimated to increase it by \$236.[16] Both of these coefficients are statistically different from zero at the 10% level. The modestly higher magnitude of the titled land estimate is unexpected, in that titled land might be expected to marginally relax the severity of the credit constraint, whereas formal land (which is not mortgagable) would not be. Interestingly, these estimates are very close to the estimates for the liquidity-unconstrained regime. As discussed earlier, these are reduced form coefficients mixing the pure tenure security effect with a liquidity or leverage effect.

While the impacts of legal tenure security on attached capital appear very similar across liquidity constraint regimes, its impact on the demand for movable capital is strikingly different. Consistent with the theoretical model, the estimated impact for liquidity-unconstrained farms is quantitatively small and statistically insignificant according to both the full sample and trimmed regressions. For households in the liquidity-constrained regime, the full sample results show a strong negative impact of formal tenure security on movable investments. The absolute value of these coefficients is similar to that of the increase estimated for attached capital, indicating that the increase in attached capital investment following tenure security is purchased at the cost of reduced holdings of movable capital for liquidity-constrained households.[17]

As predicted by the theoretical model, the positive effects of tenure security on investment are dampened by an unfavorable liquidity constraint effect for credit-constrained households leading to reduced stocks of movable capital. But for which type of households do these dampening effects occur? To gain insight on this problem, the estimated coefficients from the full sample were used to calculate the following expected tenure security investment effects for farms of different sizes

$$(18)\quad E[\Delta_j(x_{it})] = \left[\rho_{h=1}E\left(K^c_{jit}\right) + (1-\rho_{h=1})E\left(K^u_{jit}\right)\right] + \left[\rho_{h=0}E\left(K^c_{jit}\right) + (1-\rho_{h=0})E\left(K^u_{jit}\right)\right]$$

where $\Delta_j(x_{it})$ is the expected change in the stock of capital of type j as a farm with characteristics given by x_{it} would experience if it moved from having all of its land under insecure tenure ($h = 0$) to having all its land titled ($h = 1$). Notation indicating the conditioning of the credit rationing probabilities and the capital stock functions on x_{it} has been suppressed.

Figure 2 graphs (18) over a range of farm sizes. The two solid curves show the estimate of (18) for attached and movable capital. The dashed line shows the impact of title on the

[15] Note that if investment were a way to increase tenure security—as Braselle, Gaspart, and Platteau show that it is under the customary tenure systems of Burkina Faso—the sign of this effect could be negative. In Paraguay, there is no intact customary system that might create the basis for "insecurity-induced" investment.

[16] The figures reported in the text are the full sample estimates. The trimmed sample estimates are not statistically significant for this regime.

[17] As might be expected, the results using the trimmed regression lose significance as nearly half of the observations are eliminated. Nonetheless, the basic portfolio effect story remains in the trimmed sample results.

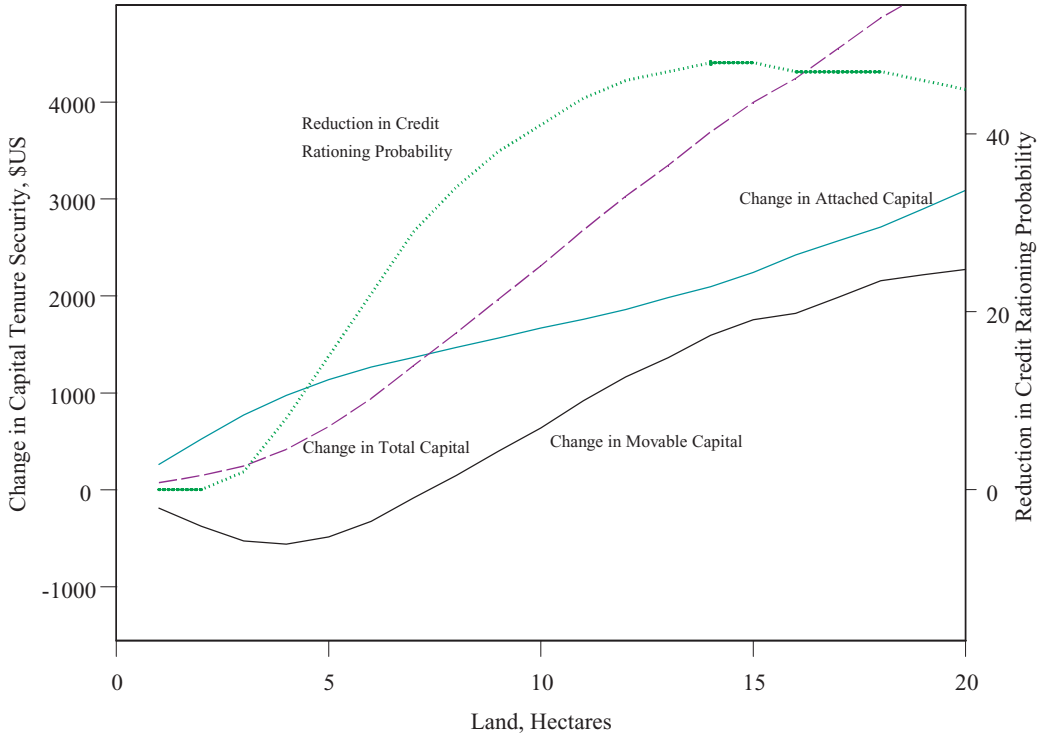

Figure 2. Heterogenous impact of property rights on investment

change for the total stock of capital (defined simply as the sum of attached and movable capital). As this figure shows clearly, the decline in desired movable capital accompanying legal tenure security for farms less than about 5 hectares in size offsets the increase in demand for attached capital such that total desired capital stock is flat over that range. Beyond that point, total capital begins to rise as increases in attached capital are no longer exclusively purchased at the cost of diminished movable capital.

The impacts of tenure security on capital thus show a land size or wealth bias. The reason for this finding can be seen in the dotted line in figure 2 showing the expected liquidity constraint effect of tenure security as a function of farm size. More formally, estimated credit supply and demand parameters are used to estimate the following expression

$$(19) \qquad \Delta_\rho(x_{it}) = \rho_{h=1}(x_{it}) - \rho_{h=0}(x_{it})$$

where $\Delta_\rho(x_{it})$ is the change in the credit rationing probability for a farm with characteristics x_{it}. Careful examination of figure 2 shows that the change in the estimated impact of land title on the credit rationing probability is zero for farms of less than about 3 hectares in size. For these farms, the estimated credit rationing probability is approximately 100% irrespective of legal tenure status. Beyond 3 hectares, the acquisition of land title begins to reduce that rationing probability, but it is not until a titled farm has in excess of 15 hectares that its rationing probability ($\rho_h = 1$) falls below 50%.[18] In terms of expression (10), it is at this farm size that titled farms are likely to be in the liquidity-unconstrained regime. Note, however, that even at farm sizes below 15 hectares, the shadow price of liquidity may be falling (though still above the market rate), inducing the estimated increase in total investment.

Summary and Policy Implications

While the literature on land tenure security and investment has often discussed the

[18] An *un*titled farm ($h = 0$) of 15 hectares has an estimated rationing probability of 91%. Beyond that size, the rationing probability for an untitled farm begins to decline, falling below 50% at a farm size of 35 hectares. It should be noted that in Paraguay—as in most of Latin America—large farms with hundreds and even thousands of hectares control most agricultural land. The credit supply effects of title thus appear most important for a mid-sized farm of 15 to 35 hectares.

potential investment demand and credit supply effects of land titles or other policies increasing tenure security, this article puts forward a model to show that for households that are constrained in their access to liquidity, the investment demand effect will itself induce an increase in the endogenous shadow price of liquidity. Unless offset by a buoyant credit supply effect that brings the shadow price of liquidity down, the net effect of an increase in tenure security could well be a decrease in the desired stocks of these capital goods that are movable and immune from expropriation in the event of land loss (and hence not directly influenced by investment demand effects). For producers for whom the credit supply effect is zero, an increase in tenure security will change the composition but not the quantity of agricultural investment. In this case, analysis of the effect of tenure security on investment in only attached capital will overstate the benefits of property rights reform. Who benefits from tenure security reform—and by how much—depends centrally on the interactions between investment demand and credit supply effects.

While the underlying theoretical model is straightforward, consistently estimating the endogenous switching regression it implies, confronts a number of difficulties. Taking advantage of the available panel data from Paraguay, this article has used regression-trimming procedures to control the latent characteristics that are likely to be correlated with both tenure status and with the endogenous selection into credit constraint regimes. Emerging from this estimation procedure are three key results:

1. Tenure security has a strong structural effect on the demand for attached capital, holding the price of liquidity fixed;
2. The credit supply effects of tenure security are nonexistent for the smallest farms and only become large for farms in excess of 15 hectares; and,
3. Tenure security thus induces a shift in the portfolio composition of capital for smaller farms (toward more attached capital), but only for larger farms is it estimated to enable an unambiguous increase in total capital stock.

For a country like Paraguay, where agricultural land is often held under a variety of legally tenuous arrangements and the small-farm sector which remains home to a majority of the country's population, these results hold several nuanced implications. First, it is clear that provision of tenure security does not get institutions "right" for all farmers. In particular, a generalized policy of land titling would be expected to disproportionately benefit larger-scale producers who experience both investment demand and credit supply effects and whose mass and composition of capital would be positively affected by such a policy. In this context it is important to note that in eastern Paraguay (the area exclusive of the large, arid, and thinly populated Chaco region), median farm size is less than 5 hectares. The finding that a farm must be of some 15 hectares to fully benefit from tenure reform implies that most households—especially low-income rural households—would at best experience only a muted set of benefits from tenure reform. Indeed, to the extent that the differential advantage created by tenure reform encourages land accumulation by larger farmers, the secondary or spillover effects could be negative for these poorer households.

Finally, it should be stressed that evidence that land titling would have socially skewed effects is not an argument against land titling. Instead it suggests that policy—if aimed at achieving broadly based agrarian growth—needs to be carefully sequenced, with prior, or at least simultaneous, attention given to credit market reform. Discussion of the options and institutions available to address financial market bias is beyond the scope of this article. However, the analysis here strongly suggests that attention needs to be given to these issues as an intrinsic part of land tenure reform lest a set of policies be designed that get institutions right only for a small, and already privileged subset of producers.

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