A Hard Row to Hoe: Farming on the Brazilian Amazon Frontier under Incomplete Property Rights[*]

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Abstract

Many farmers in the Brazilian Amazon do not have clear titles to their land. Therefore, using an infinite-horizon representative agent model, this paper analyzes how improved property rights influence the farmer's investment in the land, as well as the farmer's consumption and debt. Specifically, the model examines three channels through which these variables are affected. Two involve the expenditure the farmer incurs to defend the land claim, and the third involves the interest rate premium the farmer faces when borrowing without a clear title to the land. Since investment itself can strengthen the farmer's claim to the land, improved property rights can reduce over-investment in the land, depending on some key parameter values.

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1. Introduction

No single paper can analyze the entire economy of the Brazilian Amazon. In terms of size, the Brazilian Amazon covers 1.6 million square miles (or 4.1 million square kilometers). From the urban centers of Manaus and Belém to remote Indian reservations, 22.4 million people reside within its borders. Accordingly, this paper focuses on farmers along the economic frontier of the Brazilian Amazon. The frontier consists of those areas on the fringes of population centers or in new settlements. On the frontier, farmers have access to markets, though some may be informal, but they probably do not have well-established formal property rights. Arguably, it is on this frontier that most socio-economic and environmental change is occurring in the Amazon, which certainly makes it worthy of analysis. Accordingly, this paper will examine the impact of improved property rights on the farmer's investment, consumption, and debt.

Although expropriation should not be a concern for small-scale farmers as it is for large-scale farmers, property rights do matter for them as well, certainly with regard to their ability to avoid or minimize conflict, sell or rent the land, or access credit. Property rights are not all-or-nothing, though. The degree to which property rights are established can vary from place to place and from one time to another, depending on formal and informal institutions. On the frontier, informal property rights can be established to varying degrees by the use of the land, a sales receipt, a tax bill, or boundary demarcation, for example. Even when someone has a formal title to the land, the person does not have complete property rights if the right is not reasonably enforced through the government or a competing title has been issued by another level of government, as is

sometimes the case in Brazil. Certainly, the farmer's investment and welfare will depend on the degree to which property rights are established.

A number of studies have examined the impact of land titling on such variables as land values, investment, labor supply, access to credit, and beliefs. Galiani and Schargrodsky (2007) provide a partial list of these studies, but also note that the studies either ignore the endogeneity of property rights or "address it by exploiting standard exclusion restrictions or variability in the regional timing of policy interventions." Endogeneity can arise with investment, for example, because a farmer may find it easier to secure property rights after investing in the land. Once property rights are secured though, uncertainty is reduced, and the farmer has a further incentive to invest.

This paper seeks to consider the issue in a different way and thereby avoid the endogeneity problem. Instead of presuming that the farmer will increase investment to *improve* property rights, the paper examines the expenditure the farmer needs to make to *defend* his or her property claim when property rights are incomplete. Survey results from Alston, Libecap and Mueller (1999) support the notion that farmers on the frontier of the Brazilian Amazon do indeed expend resources to defend their land claims (113).

By incorporating a parameter for the degree to which property rights are established into the model introduced below, the paper can examine the arguably realistic states of world between no property rights and complete property rights. Specifically, for more complete property rights, the model allows the farmer to spend less to defend his or her claim. The model also incorporates access to credit, which will depend on the degree to which property rights are established as well.

The paper examines both the steady state impact and transitional dynamics following an improvement in the degree to which property rights are established on such variables as consumption, investment and debt. As a result, the analysis provides clarity regarding the various channels through which property rights affect these variables.

2. The model

To address the issue at hand, I develop a model in which the representative farmer produces output with physical capital according to the function:

$$Q = F\left(K\right), \tag{1}$$

where Q and K represent output and the capital stock, respectively. The production function $F\left(K\right)$ is increasing in the level of capital available at the beginning of the period.

The farmer chooses consumption $\left(C\right)$ and investment to maximize utility over the infinite horizon:

$$\int_0^\infty U\left(C\right)e^{-\beta t}dt,\ U' > 0,\ U'' < 0,$$

subject to the agent's budget constraint

$$\dot{D} = C + I + \psi\left(I - \delta K\right) + E\left(\rho, K\right) + r_d D - F\left(K\right) \tag{2}$$

and the law of motion for capital

$$\dot{K} = I - \delta K, \tag{3}$$

where β denotes the fixed time preference rate, δ denotes the depreciation rate of the capital stock, r_d denotes the interest rate charged on the farmer's debt $\left(D\right)$, and an

overdot denotes a time derivative. Moreover, the total purchases of capital goods is represented by $I+\psi\left(I-\delta K\right),$ the sum of realized net investment I and a nonnegative and strictly convex adjustment cost $\psi\left(I-\delta K\right)$.

The degree to which property rights are established ρ enters the model in two ways, first through the expenditure the representative farmer incurs to defend the property claim $E\left(\rho,K\right)$ and second through the interest rate charged on the farmer's debt. To elaborate, the parameter ρ takes a value on a scale from 0 to 1, where $\rho=0$ represents no established (formal or informal) property rights and $\rho=1$ represents fully established formal property rights. The nonnegative expenditure function $E\left(\rho,K\right)$ is decreasing in both ρ and K. Of course, if formal property rights are fully established, then the farmer does not need to make any expenditures to defend the property claim, $E\left(1,K\right)=0$.

The interest rate faced by the farmer equals a base interest rate plus two premiums. Specifically,

$$r_d = r^* + Z\left(n\right) + \Upsilon\left(\rho\right). \tag{4}$$

The first premium, $Z\left(n\right),$ is a function of the debt-to-output ratio, $n\equiv D/Q,$ and ensures convergence to a stationary equilibrium. Assuming that $Z\left(n\right)$ is strictly increasing, the farmer's creditworthiness improves as its debt-to-output ratio declines. The latter premium, $\Upsilon\left(\rho\right),$ is meant to capture the interest rate channel through which property rights affect the farmer's investment and welfare. The premium is decreasing in the

degree to which property rights are established. For fully-established formal property rights, $\rho = 1$, the premium equals zero.

2.1. Solving the model

The solution to the representative farmer's optimization problem provides the following first-order conditions:

$$U_C = -\lambda_1, \tag{5}$$

$$\lambda_2 = -\lambda_1 \left(1 + \psi'\right), \tag{6}$$

$$\dot{\lambda}_1 = \lambda_1 \left(\beta - r_d\right), \tag{7}$$

$$\dot{\lambda}_2 = \lambda_1 \left[F_K - E_K - \delta - \beta\left(1 + \psi'\right)\right], \tag{8}$$

where λ_1 and λ_2 are the multipliers associated with the budget constraint and the law of motion for capital, respectively. Moreover, F_K and E_K represent the derivatives of the production function and the expenditure function with respect to capital.

2.2. Steady state equilibrium

In the long run, the economy converges to a stationary equilibrium determined by the following steady-state conditions:

$$\begin{gathered} I = \delta K, \\ F\left(K\right) = C + I + E\left(\rho, K\right) + r_d D, \\ \beta = r_d = r^* + Z'\left(n\right) + \Upsilon'\left(\rho\right), \\ F_K = E_K + \beta + \delta. \end{gathered}$$

These equations can be solved for the steady-state changes in the capital stock, debt and consumption.

3. Steady state analysis

Given the equilibrium conditions above, a change in the degree to which property rights are established affects the steady-state values of the capital stock, debt, and consumption in the following ways:

$$\hat{K}^* = \frac{\rho E_{K\rho}}{K\left(F_{KK} - E_{KK}\right)}\hat{\rho}, \tag{9}$$

$$\hat{D}^* = \left[\frac{\rho F_K E_{K\rho}}{Q\left(F_{KK} - E_{KK}\right)} - \frac{\rho \Upsilon'(\rho)}{nZ'(n)}\right]\hat{\rho}, \tag{10}$$

and

$$\hat{C}^* = \frac{\rho}{\gamma}\left[\frac{\beta E_{K\rho}\left(1 - nF_K\right)}{Q\left(F_{KK} - E_{KK}\right)} + \frac{\beta \Upsilon'(\rho)}{Z'(n)} - \frac{E_\rho}{Q}\right]\hat{\rho}. \tag{11}$$

The direction and magnitude of the changes depend in part on the values of the second derivates E_{KK} and $E_{K\rho}$. If E_{KK} and $E_{K\rho}$ are positive, then a one-unit increase in the capital stock reduces expenditures more when the capital stock is small and property rights are not well established. This diminishing returns argument seems plausible and will be explored further.

Specifically, if diminishing returns exist for production as well, then equation (9) clearly shows that improved property rights reduce the capital stock across steady states. With better property rights, the farmer relies less on capital to defend the land claim, discouraging overinvestment.

To understand the behavior of debt and consumption across steady states as represented by equations (10) and (11), three channels through which property rights affect the farmer will be explored. The first channel is the investment channel introduced

above: Improved property rights reduce the amount of capital needed to defend the land claim, discouraging overinvestment. With less investment, the farmer does not acquire as much debt, but also does not produce as much output to generate as much consumption.

The second channel is the interest rate channel: Improved property rights lower the interest rate premium faced by the farmer, which encourages the farmer to consume more initially. The higher associated debt though reduces consumption across steady states.

The remaining channel, which will be called the expenditure channel, pertains only to the change in steady-state consumption: Improved property rights reduce the amount the farmer needs to spend to defend the land claim. Accordingly, more can be spent on consumption goods. Note that both the investment and expenditure channels work through the expenditure function, but the latter one more directly.

The direction and magnitude of change in debt and consumption across steady state depends on which of these three channels dominates. However, this can not be known without calibrating the model.

4. Calibration of the model

Before proceeding to numerical simulations, functional forms for production, the adjustment cost to investment, interest rate premiums, and the expenditures to defend property rights are chosen, as well as the associated parameter values. For production, capital and a fixed quantity of labor are combined according to the Cobb-Douglas function

$$Q \equiv F\left(K\right) = K^{\alpha}, \tag{12}$$

where α is the cost share of capital. With regard to investment, the adjustment cost function is chosen so that investment incurs increasing marginal cost:

$$\psi = v\left(I - \delta K\right)^2 / 2.$$

The parameter v can be related to observed parameters via equation (6). More specifically, since $-\lambda_2/\lambda_1$ represents the Tobin's q in the model, equation (6) can be written as $q = 1 + \psi'$. Therefore, in steady state,

$$v = \psi'' = 1/\delta\Omega K, \tag{13}$$

where $\Omega \equiv \hat{I}/\hat{q}$ is the *q*-elasticity of investment spending. Furthermore, to capture the characteristics of the two interest rate premiums described in section 2, they are given the following functional forms:

$$Z\left(n\right) = x_1\left(e^n - 1\right) \tag{14}$$

and

$$\Upsilon\left(\rho\right) = x_2\left(e^{1-\rho} - 1\right), \tag{15}$$

where x_1 and x_2 are non-negative constants.

The chosen functional form for the expenditure to defend property rights,

$$E\left(\rho, K\right) = x_3\left(1-\rho\right)K^{-\sigma},\ x_3 \geq 0,\ \sigma \geq 0, \tag{16}$$

requires more explanation. Given the nonnegative constant x_3, this function has the necessary characteristics for the expenditure function set forth in section 2, namely $E\left(\rho, K\right) \geq 0,\ E\left(1, K\right) = 0,\ E_\rho < 0$ and $E_K < 0$. With this functional form, the model can also examine the impact of a change in property rights when the investment channel is weak, strong, or nonexistent, depending on the value of the parameter σ.

Presumably, if the investment channel does exist, $\sigma > 0,$ then an increase in the capital stock reduces the expenditure more when property rights are not well established or the capital stock is small than when the opposite is true. Consistent with this presumption, the chosen functional form for the expenditure has positive second derivatives E_{KK} and $E_{K\rho}$.

The values of the parameters for these equations and the rest of the model are specified in accordance with available real-world data, empirical evidence, and theory. In particular, the time preference rate (β), the depreciation rate (δ) and the intertemporal elasticity of substitution (τ) are set at 0.1, 0.05 and 0.25, respectively, based on research using Brazilian data by Issler and Piqueira (2000), among others. The income share of capital (α) is derived from equation (8) in steady state to be $\alpha = (\beta + \delta)k - \sigma\varepsilon,$ which is consistent with the numerical value provided by Brazilian economists Ellery, Gomes and Bugarin (2001). Furthermore, estimates for the *q*-elasticity of investment spending (Ω) mostly lie between 0.2 and 2.3.[1] For this study, a value of 2 is chosen for Ω, given that smaller values result in very slow speeds of adjustment.

The output shares of capital (k), debt (n), consumption (γ) and expenditure to defend claim to property (ε) are a little more difficult to pin down. Following Ellery (2002) though, a capital-output ratio of 2.7 is used. Regarding the debt-output ratio, access to credit appears to be more difficult in Brazil than in other countries. "Credit currently only amounts to 25 percent of GDP in Brazil, compared with 60 percent in Chile and more than 70 percent in many developing countries" (Santos, 2005).

[1] Studies include Abel and Blanchard (1986) Engel and Foley (1975), Hayashi (1982) and Summers (1981).

Considering that this number does not include informal credit, but also that the poor, rural farmer may have even less access to credit than the average Brazilian, high and low values are chosen for n of 0.1 and 0.4. For the percent of output spent to defend the property claim, Alston, Libecap and Mueller (1999) surveyed Amazonian settlers regarding "what activities they undertook regularly to maintain their [property] claims" (111). The most common response was the clearing of boundaries, which on average took the settler five and a half to six days per year. Other activities pursued by some settlers included having their sales receipts for the land notarized, hiring a topographer to map their borders, building markers on their boundaries, making multiple trips to government offices to petition for titles, attending community meetings and paying membership to a community organization to signal that a claim was recognized by the community.[2] For a rough estimate of the total cost of maintaining and strengthening land claims, the authors aggregated the total time spent by each of seven settlers toward these ends. The amount of time ranged from 6 days to 30 days, with an average of 13.4 days (113). Assuming the farmer works six days per week all year, the average farmer is thus spending 4.28 percent of the time devoted to work maintaining or strengthening the claim to land. Thus, a conservative value of 0.04 is chosen for ε. Given the values of k, n and ε, the agent's budget constraint (2) in steady state, $\gamma = 1 - \delta k - \beta n - \varepsilon$, implies realistic values for the consumption share of output (γ) of 0.785 and 0.815.

The remaining parameters concern the functional forms for the interest rate premiums and the expenditure to defend the property claim, namely x_1, x_2 and σ. Since

[2] The farmer may also have to bribe government officials to defend the land claim, though Alston, Libecap and Mueller did not indicate that this was an issue for the settlers they surveyed.

the interest rate premium $Z(n)$ exists merely to ensure convergence to a stationary equilibrium, x_1 is set at a low value of 0.02. The other interest rate premium, $\Upsilon(\rho)$, however, is meant to capture the interest rate channel, whereby the degree to which property rights exist affects investment through the interest rate. Assuming the impact is moderate, the parameter x_2 is given the value 0.05, which means that at most, the interest rate premium is 8.6 percent. However, to allow for the possibility that the credit channel does not exist or is small, values for x_2 of zero and 0.02 are also considered. Finally, for larger values of σ, a increase in the capital stock will have a larger impact on reducing the expenditure necessary to defend the claim to property. Consequently, values of zero and one are chosen for σ, which allows for the possibilities that a one-unit change in the capital stock leads to no change, a 0.015 unit decrease, or a 0.030 unit decrease in expenditure, respectively, for given values of ε and k.

5. Results of numerical simulations

With the model calibrated, steady-state changes, as well as the transitional dynamics, can be better understood through numerical simulations. In particular, the transitional path of the model, which has been solved in the appendix, provides insights regarding the initial change in consumption and investment. As would be expected, improved property rights lead to higher initial growth in consumption and investment for larger values of x_2. Because the interest rate falls by a greater percentage, the farmer is better able to tilt spending toward the present. Also as expected, improved property rights

reduce the need for capital to help the farmer defend the land claim. The immediate decline in investment frees funds for consumption.

Although the initial change in consumption is positive, consumption falls across steady states for most combinations of parameter values. To understand the difference, one must first understand the steady-state change in debt. Numerical simulations show that the change in debt is nonnegative across steady states, except when x_2 is very close to zero. Consequently, if the interest rate channel exists, improved property rights tend to do more to encourage borrowing through lower interest rates than they do to reduce the need for debt-financed capital.

Since debt rises across steady states for almost all combinations of parameter values, debt servicing leaves fewer funds available for consumption. Nonetheless, when the parameters x_2 and σ both take low values, consumption rises. To understand this, recall that the interest rate does not fall as much when x_2 is small, which discourages the farmer from incurring as much debt. Also, the capital stock does not fall as much when σ is small, which results in higher output and consumption than would have occurred otherwise. Thus, when the interest rate and investment channels are sufficiently weak, consumption rises across steady state due to reduced expenditures required to defend the land claim. Moreover, since consumption rise initially and falls across steady state for most combinations of parameter values, the welfare implications of improved property rights should be considered further.

6. Concluding remarks

This paper explores channels through which the degrees to which property rights are established affect the farmer's investment in the land. The paper, being applied theory in nature, was informed by empirical research in the literature and is meant to inform future empirical research. Certainly, empirical research could shed more light on informal markets, particularly with regard to how economic agents respond to differing degrees or types of property rights. Surveys may take this research in surprising, but important directions. Consider, for example, the work of Field (2007), which finds that Peruvian urban "households with no legal claim to property spend an average of 13.4 hours per week maintaining informal tenure security, reflecting a 14% reduction in total household work hours for the typical squatter family" and "are also 40% more likely to work inside of their home" (1563). Might rural farmers and particularly those on the frontier find it necessary to work on or near their own land to maintain their property claims, rather than consider seasonal migration? Answers to questions like this can help policymakers design and support institutions that improve the farmer's wellbeing.

Appendix: Solving for the transition path

In order to analyze the transitional dynamics of a change in the degree to which property rights are established, first-order conditions provide the time paths of consumption,

$$\dot{C} = \tau C\left(r_d - \beta\right), \tag{A.17}$$

and investment

$$\dot{I} = \left[r_d\left(1+\psi'\right) - F_K + E_K + \delta + \delta\psi''\left(I - \delta K\right)\right]\Big/\psi'', \tag{A.18}$$

where $\tau \equiv -U_C/U_{CC}C$ denotes the intertemporal elasticity of substitution. These equations can be linearized, along with (2) and (3), around the new steady state $\left(C^*, D^*, I^*, K^*\right)$ to generate the following system of first-order differential equations:

$$\begin{bmatrix} \dot{C} \\ \dot{D} \\ \dot{I} \\ \dot{K} \end{bmatrix} = \begin{bmatrix} 0 & \tau\gamma Z'(n) & 0 & -\tau\gamma n Z'(n) F_K \\ 1 & \beta + nZ'(n) & 1 & -\left[\beta + \delta + n^2 Z'(n) F_K\right] \\ 0 & Z'(n)/\psi'' F_K & \beta + \delta & X \\ 0 & 0 & 1 & -\delta \end{bmatrix} \begin{bmatrix} C(t) - C^* \\ D(t) - D^* \\ I(t) - I^* \\ K(t) - K^* \end{bmatrix},$$

where $X = \left[E_{KK} - F_{KK} - \delta\psi''(\beta + \delta) - nZ'(n) F_K / F(K)\right]/\psi''$. Therefore, on the saddlepath, consumption, debt and capital evolve according to

$$\hat{C}(t) = \hat{C}^* + \frac{n\left(Y_{12}e^{\eta_2 t} - Y_{11}e^{\eta_2 t}\right)}{\gamma\left(Y_{21} - Y_{22}\right)}\hat{D}^* + \frac{k\left(Y_{11}Y_{22}e^{\eta_1 t} - Y_{12}Y_{21}e^{\eta_2 t}\right)}{\gamma\left(Y_{21} - Y_{22}\right)}\hat{K}^*, \tag{A.19}$$

$$\hat{D}(t) = \left(1 + \frac{Y_{22}e^{\eta_2 t} - Y_{21}e^{\eta_2 t}}{Y_{21} - Y_{22}}\right)\hat{D}^* + \frac{kY_{21}Y_{22}\left(e^{\eta_1 t} - e^{\eta_2 t}\right)}{n\left(Y_{21} - Y_{22}\right)}\hat{K}^*, \tag{A.20}$$

and

$$\hat{K}(t) = \frac{n\left(e^{\eta_2 t} - e^{\eta_1 t}\right)}{k\left(Y_{21} - Y_{22}\right)}\hat{D}^* + \left(1 + \frac{Y_{22}e^{\eta_1 t} - Y_{21}e^{\eta_2 t}}{Y_{21} - Y_{22}}\right)\hat{K}^*, \tag{A.21}$$

where the system's negative eigenvalues are η_1 and η_2 and the system's eigenvectors are

$$\begin{aligned} Y_{1i} &= \tau\gamma Z'(n)\left(Y_{2i} - nF_K\right)/\eta_i, \\ Y_{2i} &= \psi'' F_K\left[\left(\delta + \eta_i\right)\left(\eta_i - \beta - \delta\right) - X\right]/Z'(n), \\ Y_{3i} &= \delta + \eta_i, \end{aligned}$$

when Y_{4i} is normalized to one.

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