The Implication of Property Rights for Joint Agriculture-Timber Productivity in the Brazilian Amazon

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ABSTRACT: This paper examines whether better property rights will increase joint productivity of agricultural and timber products in the Brazilian Amazon. Farrell output-based technical efficiency and technological progress measures are derived by using DEA (Data Envelopment Analysis) for Amazonian counties and are regressed on non-discretional variables such as land title. Land title is found to significantly improve the technical efficiency.

Key words: Technical efficiency, property rights, DEA, two-stage procedure

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1. Introduction

Poor property rights can cause both misallocation of resources and wasteful resource use. In the Brazilian Amazon, poor land management and less than utilization of opened area are often seen in areas under absentee or imperfect ownership and on public lands where government monitoring is not present. Since the 1980's, when logging activity rapidly expanded, the Brazilian Amazon has experienced migration of agropastoral producers who follow logging roads into the forests and clear forested sites (Uhl et al, 1991). When ownership is not well established, loggers tend to ignore the agricultural suitability of the land when they place logging roads. This unplanned land management can result in poor agricultural productivity. Furthermore, if poor property rights discourage intensive road building by loggers and hence intensive following-on land clearing, timber and agricultural productivity per unit land tends to be low.

Poor property rights can also discourage migration of efficient entrepreneurs and skilled labor. This can not only directly cause low labor productivity but also cause inefficient utilization of capital, resulting in poor productivity in both timber and agricultural sectors.

Given this situation, better property rights could increase joint agricultural-timber productivity if they induce more efficient use of land, labor and capital. If productivity could be increased, economic progress could occur with less extensive deforestation. This could provide more forest at a given level of development and produce environmental benefits for Brazil and other countries.

Using data for 257 counties in the Brazilian Amazon in 1985 and 1995, this paper will (1) develop measures of timber-agricultural joint productivity within the sectors that are directly associated with deforestation, and (2) measure effects of property rights on factor productivity in the timber and agriculture.

2. Property Rights and Productivity

The major causes of poor property rights in the Brazilian Amazon are imperfect title provision and a lack of legal enforcement on land ownership. Until the mid-1960's, when the large-scale colonization projects started, this area was covered by forest and was very sparsely populated. Further, most of the land was public domain. Then, the federal and state government transferred ownership of the land to private claimants so as to create an incentive for migration into the area. Low fees were established for titles to land claims[1] to attract landless farmers in the poor neighboring regions and urban entrepreneurs who were interested in the cattle business.

However, homesteaded area was always larger than area for which land titles were actually provided. For example, 73 percent of occupied area had formal titles in 1970 in the Legal Amazon (IBGE, 1970). Even when title was established, lack of legal support for the protection of property rights was severe in the earlier period of development (Schneider, 1995). Thus, property rights remained imperfect.

Illegal use of public land by loggers and small cultivators has also been common in the Brazilian Amazon. Government's regulation of the use of public land has been ineffective because high monitoring costs have discouraged the government from controlling use. Users of this land do not have an incentive to incur costs for gaining title—time for titling procedure, payment for the title, and concession fee—when the probability of being discovered using untitled land is small and benefits from legal occupancy are low. Poor property security consequently discouraged effective use of land and forced an increase in private expenditure for protection of property (Mendelsohn, 1994).

Having poor property rights can discourage efficient and sustainable land use. In the case of open access, the extreme case of weak property rights, soil and tree resources are mined. Farmers and loggers do not make joint production decisions, and land is not logged in a way that benefits agricultural production. Forested land with titles that is under absentee ownership is commonly rented or sold to logging companies according to the authors' field survey. Loggers' choice of site and placement of logging roads is not consistent with jointly efficient planning of timber and agriculture because the owner of the land is absent and hence does not monitor loggers' behavior.

Poor property rights can also affect the quality of labor force and level of entrepreneur management. Schneider (1995) observes that people with lower opportunity costs (less educated) tend to arrive at the colonized area earlier than those with higher opportunity costs who tend to buy the land from these early comers in the Brazilian Amazon. Given that property rights evolve for land that is close to more developed centers, unskilled people will tend to occupy land under poorer property rights. Therefore, poor property rights can tend to correlate with a higher share of producers with poor skills, and with more environmentally damaging production practices.

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[1] The average land price in the Legal Amazon in 1975 was $74 in the 1985 US dollar. It implies that fees charged for acquisition of land title was low.

3. Methdology

Better property rights can be an important key factor in the development, possibly leading to a win-win situation where production is boosted without incurring further land clearing, and wasteful use of labor and capital. The following two steps are essential to pursue this hypothesis: (1) to define a measure of productivity, and (2) to provide a method to test this hypothesis.

We will analyze total factor productivity (TFP) with regard to labor, land and capital as a measure of productivity because these factors are fundamental inputs of production. TFP is a more appropriate measure of productivity than single factor productivity because these factors of production are substitutes and because property rights institution can affect use of all these factors. We will incorporate major primal products in the Brazilian Amazon that are associated with deforestation into the output vector. Our model can thus capture an entire framework that is related to land clearing. Our analysis focuses on variation of TFP, and our results for technical efficiency will be interpreted as TFP.

Data Envelopment Analysis (DEA) is a method to measure technical efficiency based on the piecewise-linear production frontier that is characterized by lines that envelope the data points. DEA has an advantage of being able to avoid specifying functional forms of production function. It can incorporate multiple inputs/outputs without aggregation by using linear programming where individual inputs/outputs enter in separate constraints associated with the envelopment condition. This technique is appropriate for modeling the highly complex multiple sector production structure in the Brazilian Amazon.

In the Brazilian Amazon, the major agricultural production includes cattle, rice, beans, cassava, corn, and banana. Total value of production of these crops accounts for 58 percent in 1985 and 32 percent in 1995 of the total agricultural products in this area.

Since industry and commercial sectors do not require a large area of land for their operation and since land requirement for housing is very small compared to the agropastoral area, it is reasonable to assume that cleared land is used mostly for agricultural production in the Brazilian Amazon. It is also assumed that most of labor and capital available in a given county is used to produce the above selected agricultural products and timber. The timber sector has increased its importance in the Amazonian economy. The value of log production grew to be as great as the total value of these six agricultural products in 1995.

Fundamental inputs are cleared land, H, labor, L, and capital, K. The output set of this technology is

(3.1) $$Y(L,K,H) = \{y^A, y^T : \{L,K,H\} \text{ can produce} \{y^A, y^T\}\},$$

where $y_A \in \Re_+^{MA}$ is an agricultural output vector and $y_T \in \Re_+$ is production of log. This technology is assumed to satisfy free disposability and convexity.

Land area that is already cleared by the previous period is denoted as H_{-1}, and it is assumed that such land will remain cleared in the current period. On the other hand, new farm land is assumed to be obtained with labor cost[2] (López and Niklitschek ,1991). Since level of timber production also facilitates land clearing, new land, $\Delta H \equiv H - H_{-1}$, can be defined as a function of L_{-1} and $y^T{}_{-1}$, labor use and timber output in the previous period, respectively. Thus, (3.1) can be rewritten as

(3.2) $$Y(L,K,H_{-1},L_{-1},y^T{}_{-1})=\{y^A,y^T:\{L,K,H_{-1},L_{-1},y^T{}_{-1}\}\text{ can produce}\{y^A,y^T\}\}$$

The Farrell technical efficiency for this technology is defined as

(3.3) $$TE=\min\{\lambda:\{y^A/\lambda,y^T/\lambda\}\in Y(L,K,H_{-1};L_{-1},y^T{}_{-1})\}$$

The linear programming for deriving the inverse TE is

(3.4) $$TE^{-1}{}_k(y^A,y^T,L,K,H_{-1};L_{-1},y^T{}_{-1})=\max_{z_k,\theta}\{\theta: s.t. \sum_{j=1}^{J} z_j y^A{}_{mj}\geq\theta y^A{}_k, m=1,\ldots,6,$$
$$\sum_{j=1}^{J} z_j y^T{}_j\geq\theta y^T{}_k,\ \sum_{j=1}^{J} z_j L_j\leq L_k,\ \sum_{j=1}^{J} z_j K_j\leq K_k,\ \sum_{j=1}^{J} z_j H_{-1j}\geq H_{-1k},$$
$$\sum_{j=1}^{J} z_j L_{-1j}\leq L_{-1k},\ \sum_{j=1}^{J} z_j y^T{}_{-1j}\leq y^T{}_{-1k},\ z_j\geq 0, j=1,\ldots,J\}$$

Here, TE^{-1} is computed for a county k where $k=1, \ldots, J$. The terms, z_j are intensity variables. The non-negativity constraints for z_j is imposed for the convexity of output set. Constant returns to scale is assumed.

Implication of property rights on technical efficiency is then examined. The measure of property rights that is most commonly used in the empirical literature is land title (e.g. Lopez, 1995; Alston et al, 1996). Land title is an indicator of land tenure security that is based on legal support of the government or community-level recognition of ownership. Land title is also an indicator of the extent to which returns from land are accrued to a land holder. Therefore, having land title implies enforceability and disposability which are important elements of property rights.

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[2] Land maintenance costs such as soil improvement and pasture rejuvenation might not be trivial but tend to be small when compared with costs for land clearing.

Since we use aggregate data, a binary variable that represents having or not having a title, as is often used for household data, is not applicable. Instead, a ratio of area held by household with title to total county area is used. This measure represents an average degree of property rights to a county.

Once Farrell's technical efficiency (*TE*) is derived, this index will be regressed on property rights, market access and demographic variables. Explanatory variables will be chosen so that they are exogenous to the production structure and they are not correlated with the variables in the DEA stage. If they are, results of both first and second stage procedures will be biased (McCarty and Yaisawarng, 1993).

Some of these variables exogenous to the decision making units are, however, under government control. Therefore, policy implication will be derived from the result of the second-stage procedure.

Our second-stage procedure regression will follow the truncated regression (Tobit) model in McCarty and Yaisawarng (1993) since the dependent variable, TE^{-1}, is bounded from below at unity. The model will be specified as follows:

$$(3.5) \qquad TE^{-1}{}_k = r_k \beta + u_k \quad \text{if } TE^{-1}{}_k > 1$$

$$= 1 \qquad \text{if } TE^{-1}{}_k = 1,$$

where k denotes k^{th} county, r_k is a vector of explanatory variables, β is a vector of parameters and u_k is a random term that is assumed to follow a normal distribution with mean 0 and constant variance σ^2.

3. Data and Empirical Results

Data

Descriptive statistics for data used in empirical analysis are provided in Table 3.1. This data is for 257 Brazilian Amazon counties in the years 1985 and 1995. It is obtained from the DESMAT data set of the IPEA – Institute of Applied Economic Research. Inputs include capital, labor and cleared land, and lagged inputs include labor and timber production in 1985.

Table 3.1: Descriptive Statistics for Inputs/Outputs Variables in 1995

	Mean	Standard Deviation	Min	Max	Median
Cattle Produced (head)	24,100	81,389	0	820,873	3,686
Rice Produced (ton)	6,575	27,566	0	354,227	878
Maize Produced (ton)	6,914	39,798	0	460,889	561
Bean Produced (ton)	440	3,035	0	47,929	58
Cassava Produced (ton)	11,424	28,615	0	273,068	2,620
Banana Produced (ton)	222	577	0	5,555	45
Timber Produced (m3)	180,345	1,447,587	0	22,426,581	2,642
Capital (1985US$)	238,697	1,072,708	683	14,130,725	33,914
Labor in 1985	12,730	26,287	216	304,523	8,989
Labor in 1995	16,449	30,734	219	324,440	6,229
Cleared Land (km2) in 1985	976	3,017	1	29,893	205
Cleared Land (km2) in 1995	1,525	6,013	1	64,709	210
Area with Titles (ha) in 1985	394,026	1,190,281	285	12,948,954	101,794
Area with Titles (ha) in 1985	445,258	1,567,341	94	16,594,672	85,262
Population in 1985	51,239	121,907	1,406	1,072,580	19,890
Population in 1995	68,837	168,802	1,406	1,517,951	22,497
Density of Good Soil	1,264	4,701	0	42,138	0
Distance to State Seat (1,000km)	359	311	0	1,366	258
Area (km2)	19,749	49,952	105	361,329	3,542

Results

We derived an inverse TE from DEA models that are based on the technology defined (3.2). The mean of TE^{-1} is 1.6, the standard deviation is 1.0, the maximum is 9.7

and median is 1.3. The number of efficient units (TE^{-1}=1) is 75. It is 30 percent of the total number of samples.

Results from the second-stage procedure, in which TE^{-1} is regressed on the property rights and other exogenous variables in 1995 and 1985, are in Table 3.2. They generally meet a priori expectations. Technical efficiency increases with density of titled land and decreases with population density. Distance to state seat and soil quality are not significant in any of the cases. These estimates are consistent with our theory that better property rights encourage technically efficient resource use. Given that lagged labor and timber represent land clearing activity level, property rights variable can be thought of as affecting land clearing patterns. For example, under poor property rights, road building by loggers and land clearing for farming tend to be extensive. In such a case, efficient land use is hindered by the extensiveness of cleared land.

Population density worsens technical efficiency. Direct consequences of high population pressure are high demand for land and a greater labor force. These factors tend to increase pressure for land clearing where land clearing is not regulated.

Table 3.3 contains a simulation of change in outputs and their total value for a change in the two variables that are significant in the previous regression. The results suggest that total factor productivity improves by 13 % when land with titles increases by one percent. The simulated change in terms of revenue is US$ 500 million or 6 % of the total agricultural gross product in the Legal Amazon in 1995. They also suggest that total factor productivity decreases by 5.8 percent and that revenue decreases by 240 million when population increases by one percent. Since Farrell's input technical efficiency is inverse output efficiency under constant returns to scale, the results also suggest that a 13

% of reduction of input use is possible maintaining current level of outputs if land with titles increases by one percent. For example, 49,000 km2 of land clearing, which is one percent of total forested area could be avoided for producing the same amount of outputs.

Table 3.2: Second-stage Parameter Estimates

Model: Tobit; N=257

	1995	**1985**
	TE^{-1}	TE^{-1}
Intercept	1.607***	1.550***
	(0.144)	(0.140)
Density of Titled Land	-0.506**	-0.361**
	(0.230)	(0.183)
Distance to State Seat	-0.335	-0.341
	(0.242)	(0.235)
Population Density	0.003***	0.006***
	(0.001)	(0.001)
Density of Good Soil	-0.239	-0.245
	(0.352)	(0.346)
Log Likelihood	-338	-335

Inside parenthesis is standard deviation. *, **, *** denotes significance at 10%, 5% and 1 % level, respectively.

Table 3.3: Simulated Effects of the Exogenous Variables for the Legal Amazon

	1 % Change of Density of with Titles	**1 % Change in Population Density**
% Increase in output	12.6	-5.8
Increase in value output (1985US$)	506 million	-236 million

4. Conclusions

We found that provision of land title rights can induce a significant increase in total factor productivity. Such policies have to be adjusted regionally according the current degree of property rights and technical efficiency. Study shows that development effect of land titling is important in policy making where inefficiency in resource use is present but environmental regulation is costly as in the Brazilian Amazon. Doing so might lead to a win-win situation where agriculture and timber producers increase production while reducing current level of environmental damage.

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