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# PRODUCTION EFFICIENCY SOURCES OF SETTLERS UNDER BRAZILIAN LAND REFORM IN NORTHEAST REGION

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# PRODUCTION EFFICIENCY SOURCES OF SETTLERS UNDER BRAZILIAN LAND REFORM IN NORTHEAST REGION

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***SUMMARY**: The model of Brazilian land reform is based on settlements of families without land, in unoccupied public lands, or by expropriation of unproductive estates. The market assisted land reform programs are considered complementary instruments of land reform. They are used to provide credit for land purchase by groups of landless farmers directly from the land market. The aim of this paper was to measure the profit efficiency, considering two different mechanisms of land access. In this paper, analysis of profit efficiency was performed using the stochastic frontier analysis. The frontier of production was estimated based on Cobb-Douglas production function. The data set represents the states: Bahia, Ceará, Maranhão, Pernambuco and the north region of Minas Gerais. The overall efficiency estimates were 0.3163. The efficiency estimates were 0.3678 for the farmers assigned by expropriation, and 0.3537 for the farmers with market land access. The production showed decreasing gains with the major partial elasticity for land. The positive efficiency effect sources are: off-farm labor, collective labor, location in superior soil class county areas, location in Maranhão and Ceará states, age of head of household, crops with irrigation or flood, and use of machinery. The negative efficiency effect sources are: outer incomes and family consumption of its own production.*

***Keywords**: Land Reform, Stochastic Frontier Analysis, Production Efficiency.*

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# PRODUCTION EFFICIENCY SOURCES OF SETTLERS UNDER BRAZILIAN LAND REFORM IN NORTHEAST REGION

## 1 INTRODUCTION

Land reform remains a current topic in light of the tensions caused by the concentration of land and lack of alternative employment for the population that still lives in rural areas and depends on land access and working the land to survive. According to IBGE (2006) data, approximately 13% of Brazilian rural establishments belong to land reform settlements. The challenge is to turn land access into new job opportunities and new possibilities for overcoming rural poverty, based on the best use of local capacity and potential of rural communities. Land reform can increase economic efficiency by transferring unused and unproductive lands to households with potential to put these resources into the productive sphere.

The Northeast region of Brazil has the highest concentration of rural poverty in the country, and is therefore a target of various programs of land redistribution, as the National Institute of Colonization and Land Reform (INCRA), the National Program for Land Credit (PNCF), and its pilot program, Cédula da Terra. There are municipalities like Crateús in the hot semi-arid region of Ceará, with 37 land reform settlements, which justifies the results reached by many authors, that this type of productive organization can cause a huge impact on certain areas (Leite *et al*., 2004). It is a region where small-scale production undergoes a double challenge: 1) create conditions to minimize the negative effect of climate on production, 2) allow markets that emphasize the skills inherent in small production, or strengthening marketing channels, making use of socioeconomic and cultural aspects of family farming (Buainain *et al*., 2000).

Land reform policy in Brazil is performed by two complementary mechanisms of access to land. The first refers to the expropriation of rural properties, which is the official policy of agrarian reform in Brazil. The second refers to market assisted land access, which is considered a land reform tool complementary to land redistribution.

The National Land Reform Program (PNRA) is based on the mechanism of expropriation of unproductive estates for the settlement of landless families or small farmers, in order to enforce the constitutional provision of the social function of land. The legislation

ensures compensation to the expropriated owners for the value of real estate. The families settled on the land receive a donation for installation, housing, and access to credit via the National Program for Family Agriculture (PRONAF) at subsidized rates and special conditions. The National Institute of Colonization and Agrarian Reform (INCRA) is responsible for the selection of the beneficiaries, setting boundaries of individual plots, and deployment of productive and social infrastructure of the settlement (roads, schools, health centers, etc.) Beneficiaries are considered emancipated after the implementation of infrastructure, when the settlers are able to support themselves (Buainain *et al*., 2000).

Mechanisms of market assisted land access, including the Cédula da Terra Program, provide credit to groups of landless farmers, to negotiate and acquire, together in associations, their own properties. The beneficiaries are empowered to make decisions on the use of funding resources, the strategy of distributing lots amongst the families, the use of individual parcels and common lands; which state governments supervise. The state government guarantees the settlers' ownership of the property, technical assistance for productive projects and community investments. The land is acquired by a credit transaction, with payment terms of 20 years, and minimum grace period of three years, which may be extended depending on the regional agro-climatic constraints (Buainain *et al*., 2000).

To build a policy that could reduce rural poverty, access to land should be combined with availability of resources and infrastructure, which is necessary due to the relations of complementarity and synergy of productive assets, especially for small and under capitalized farmers (De Janvry and Sadoulet, 1995; Alcântara, 2010).

The characteristics of property rights over the distributed assets are important to the governance structure, which in turn affects the incentives for the development of productive activities with efficiency and sustainability (Hart, 1997; Bardhan *et al*., 2001, Banerjee *et al*., 2001). Having overcome the restrictions of land access, there is then the need for productive development to overcome conditions of poverty. This leads to the discussion of performance and production efficiency (Deaton, 1997).

The objective of this paper is to estimate the efficiency according to the mechanisms of land access and evaluate the overall effect of sources of production efficiency of beneficiary families of land reform. The dataset covered the states of Maranhão, Ceará, Pernambuco, Bahia and northern Minas Gerais area. The analysis was performed using a stochastic frontier analysis of production efficiency under the Cobb-Douglas functional form.

The next section of this paper presents the econometric specification of the stochastic frontier model. The empirical application of the model is presented in section 3, which has the variables used for the production factors, and the variables used to explain inefficiency measurement. In section 4 we present a descriptive analysis of socioeconomic characteristics beneficiaries for both mechanisms of land access. It is followed by a discussion of the results, pointing out the main sources that affect production efficiency. The paper ends with a conclusion about the expected differential effects, depending on the mechanisms of access to land.

## 2 MODEL SPECIFICATION

The measurement of productive efficiency proposed by Farrell (1957) is considered as a ratio between observed production and potential production obtained by optimizing inputs and outputs. This optimization can be achieved by maximizing the production given a quantity of inputs, or by minimizing the inputs given an observed output level. It may even be the result of a combination of both.

Productive efficiency incorporates two components. The technical component refers to the physical quantities of observed inputs and outputs. The allocative component refers to the effect of prices on the combination of proportions of inputs and outputs. Allocative efficiency refers to the ability of combining inputs and outputs in optimal proportions under the prevailing prices. Productive efficiency refers to a situation in which technical and allocative efficiencies are combined (Battese and Coelli, 1995; De Janvry and Sadoulet, 1995; Vicente, 2002).

Stochastic frontier analysis was selected because it allows the comparison of production efficiency among firms at a given point in time, considering both the estimated differential efficiency and the random (residual) error, without the need to assume that firms were operating at full technical efficiency.

The model of stochastic frontier production of Battese and Coelli (1995) was applied only to one moment in time, which is a particular specification of the general model used for panel studies. It can be specified as:

$$Y_i = \mathbf{x}_i\boldsymbol{\beta} + \left(V_i - U_i\right), \; i = 1,\ldots,N \tag{1}$$

where $i$ refers to the $i^{th}$ production unity (firm);

$Y_i$ is the logarithm of output;

$\mathbf{x}_i$ is the vector (1 x k) of the logarithm of inputs (land, labor and capital);

$\boldsymbol{\beta} = (\beta_0, \beta_1, \ldots, \beta_{K-1})$ is the vector (k x 1) of unknown parameters;

$V_i$ represents the residual, considered independent and identically distributed (i.i.d.) with distribution $V_i \sim N(0, \sigma_V^2)$ and;

$U_i$ represents technical inefficiency and has distribution $U_i \sim N^+(m_i, \sigma_U^2)$, where $m_i = \mathbf{z}_i \boldsymbol{\delta}$ and $\mathbf{z}_i$ is the vector of variables representing the characteristics of the firm that can influence the productive inefficiency ($\boldsymbol{\delta}$).

The maximum likelihood function is explained as a function of the variance of the parameters of the model $\sigma^2 = \sigma_U^2 + \sigma_V^2$, in which the portion of variance that explains inefficiency is defined as $\gamma = \sigma_U^2 / (\sigma_U^2 + \sigma_V^2)$. The model yields a better fit when $\gamma$ approaches 1, because most of the deviations of the frontier are explained by the component of technical inefficiency ($U_i$).

A common criticism about stochastic frontier analysis is that there is not a prior justification for assuming a particular distribution form for technical inefficiency effects ($U_i$). Distribution problems are observed under zero-mode distributions like half-normal form. Zero-mode distribution implies a bias toward low inefficiency levels, as most part of $U_i$ tends to be near zero (Coelli *et al*., 1998). In applying this model, it is assumed truncated-normal distribution for the technical efficiency effects, which is a generalization of the half-normal distribution (Stevenson, 1980). Truncated-normal distribution alleviates the problems of zero-mode distributions, because it allows for a wider range of distributional forms, including non-zero mode forms. This specification corresponds to Model 2 of Frontier 4.1 software, used to estimate the parameters of the model (Coelli, 1996; Coelli and Henningsen, 2011).

In equation (1), $U_i$ is the measure of inefficiency. The goal is to explain the model efficiency ($TE_i$) as a random component, which is determined by the ratio between the observed production and the potential production frontier for each firm ($TE_i = Y_i / Y_i^*$). The estimated technical efficiency is given by:

$$TE_i = f(\mathbf{x}_i; \boldsymbol{\beta}).\exp(V_i - U_i) / [f(\mathbf{x}_i; \boldsymbol{\beta}).\exp(V_i)] = \exp(-U_i) \quad (2)$$

Stochastic frontiers are usually estimated on Cobb-Douglas functional form, but alternative functional forms, like the quadratic transcendental logarithmic function (*translog*), have also been

used. Cobb-Douglas is easy to estimate, it is simple, however it brings with it restrictive properties. It has constant input elasticities, constant returns to scale, and the elasticities of substitution are equal to one. *Translog* form has been an interesting alternative to Cobb-Douglas because it imposes no restrictions upon returns to scale or substitution possibilities, but it has the drawback of being susceptible to multicollinearity and degree of freedom problems (COELLI *et al*., 1998).

## 3 EMPIRICAL APPLICATION

This study used part of the database produced by Buainain *et al*. (2002). The database contains 1322 records, considering only beneficiaries of agrarian reform. There are 644 records relating to beneficiaries of the PCT program and 678 records relating to the settlers of the INCRA program. Of this total, 1059 records were used, of which 512 represent the beneficiaries of the PCT beneficiaries and 547 settlers of INCRA. The main reason for the disposal of some records was the lack of information, particularly for the variables used in the production function, cultivated area of the lot, labor and production costs. The data used refers to the period of production between August 1999 and July 2000.

The empirical application of the model is built using variables that represent the production function, considering the production as the dependent variable and the production factors (land, labor and capital) as independent variables. It is also necessary to specify the vector of variables used to capture the effects of the sources of inefficiency.

The production of the beneficiaries of land reform programs is characterized by a composition of a diverse set of agricultural products. The variable used to represent the production was the total value of agricultural production, in Brazilian Reais (R$). The main crops grown were cassava, beans, rice, corn, peanuts, squash, cotton, coconut, cocoa, orange, passion fruit, yams, cattle, goats, sheep, poultry and forages. The area used by farmers represented the land factor, considering the areas planted with seasonal crops and permanent areas of forestry farming, pasture, forage planting, and also small areas of the family's home yard. Labor days were considered as working days applied to production, for the aforementioned time period of August 1999 to July 2000. The use of capital was represented by the costs of inputs, services, and other production costs.

The set of variables for the inefficiency term was constructed from variables that represent: (i) the farmers of the group sample, in which INCRA identifies the beneficiaries of expropriating land reform, and PCT identifies the beneficiaries of market assisted land

reform; (ii) the scale of production, to show the control of effects of scale on efficiency; (iii) soil quality indicator; (iv) the production strategies in terms of composition of the productive structure and income sources; (v) the technological components of production systems; (vi) access to technical assistance and credit and (vii) human capital in terms of qualifying characteristics of the workforce and the allocation of family labor.

The empirical model follows the original specification of Battese and Coelli (1995) by applying the natural logarithm (base *e*). The production function for the Cobb-Douglas stochastic frontier is defined as:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(Land_i) + \beta_2 \ln(Labor_i) + \beta_3 \ln(Input_i) + (V_i - U_i) \tag{3}$$

where *i* refers to the $i^{th}$ production unit (firm);

$Y_i$ s the total value of agricultural production in Brazilian Reais (R$);

$Land_i$ is the total area used with temporary and permanent crops, pastures and other areas of intensive farming (ha);

$Labor_i$ refers to the number of working days during the whole year of production;

$Input_i$ refers to expenses for variable inputs, in Brazilian Reais (R$);

$\beta_0$ to $\beta_3$ are the parameters to be estimated;

$V_i$ is the component for the residual (random effects, measurement errors and errors by omission of variables) and;

$U_i$ captures the effects of variables associated with the technical inefficiency of production.

The term for the technical inefficiency ($U_i$) is given by:

$$\begin{aligned} U_i = \delta_0 \quad & +\delta_1(PCT_i) + \delta_2(MG_i) + \delta_3(MA_i) + \delta_4(CE_i) + \delta_5(BA_i) \\ & +\delta_6(UsedArea_i) + \delta_7(PSoilA_i) + \delta_8(PSoilB_i) \\ & +\delta_9(PConsumption_i) + \delta_{10}(PCollectiveProduction_i) \\ & +\delta_{11}(PCollectiveLabor_i) + \delta_{12}(POuterIncome_i) \\ & +\delta_{13}(POffFarmLabor_i) + \delta_{14}(Livestock_i) \\ & +\delta_{15}(Machines_i) + \delta_{16}(PurchasedSeeds_i) \\ & +\delta_{17}(Fertilizers_i) + \delta_{18}(Lowland_i) + \delta_{19}(Irrigation_i) \\ & +\delta_{20}(Credit_i) + \delta_{21}(TechAssistance_i) \\ & +\delta_{22}(Age_i) + \delta_{23}(Schooling_i) \\ & +\delta_{24}(LocalMigration_i) + \delta_{25}(StateMigration_i) \end{aligned} \tag{4}$$

where *i* refers to the $i^{th}$ production unit (firm);

$PCT_i$ receives the value 1 for the beneficiaries of the Cédula da Terra program and 0 for the beneficiaries settled by land expropriation;

$MG_i$ receives a value of 1 for the state of Minas Gerais and 0 for others;

$MA_i$ receives the value 1 for the state of Maranhão and 0 for others;

$CE_i$ takes the value 1 for the state of Ceará and 0 for others;

$BA_i$ receives the value 1 for the state of Bahia and 0 for others;

$UsedArea_i$ refers to cropland, pastures, and other areas of farming (ha);

$PSoilA_i$ refers to the proportion of municipal land with better soil;

$PSoilB_i$ refers to the proportion of municipal land with medium quality soil;

$PConsumption_i$ is the ratio of the value of production used for family consumption and the total value of production;

$PCollectiveProduction_i$ is the ratio of the value of collective production and the total value of production;

$PCollectiveLabor_i$ is the ratio of working days used for collective activities and the total days worked by the family during the whole production year;

$POuterIncome_i$ is the ratio between the amount of income earned in activities outside the lot and settlement, and the total amount of income earned;

$POffFarmLabor_i$ refers to the ratio of working days of activities off the lot and off the settlement, and the total days worked by the family in during the whole production year;

$Livestock_i$ is assigned the value 1 for the presence of livestock and zero for absence;

$Machines_i$ takes the value 1 for the use of mechanical force in production;

$PurchasedSeeds_i$ receives the value 1 for the use of purchased seeds;

$Fertilizers_i$ takes the value 1 for the use of fertilizers, in particular chemical fertilizers;

$Lowland_i$ assigned the value 1 for the cultivation conducted in lowland areas;
$Irrigation_i$ assigned the value 1 for irrigated;

$Credit_i$ registers the value 1 for those receiving credit, excluding the regular funding of land reform programs;

$TechAssistance_i$ registers the value 1 if the beneficiary has received technical assistance;

$Age_i$ refers to age of the head of household in years;

$SchoolingYears_i$ represents the years of formal schooling of household head;

$LocalMigration_i$ assigned the value 1 when there was migration between municipalities but within the state, and 0 for the absence of migration;

$StateMigration_i$ assigned the value 1 when there was migration between states, but not within the state, and 0 for the absence of migration, and;

$\delta_0$ a $\delta_{25}$ are unknown scalar parameters, the coefficients of inefficiency to be estimated.

The variables $INCRA_i$ (beneficiaries settled by the expropriation land reform), $PE_i$ (State of Pernambuco) and $PSoloC_i$ (soils with low level of quality) were omitted to avoid perfect multicollinearity (Verbeek, 2004).

The descriptive statistics for the set of variables used in the model are presented in the next section.

## 4 DESCRIPTIVE STATISTICS

We proceed to the descriptive analysis of variables used in the model for both groups of beneficiaries, PCT and INCRA (Table 1). Results refer to the production yield from August/1999 to July/2000. The comparison between the characteristics of farmers under expropriation and market assisted land access are based on statistical tests applied to the difference of distributions of means (Mann Whitney Wilcoxon) and frequency (Chi-squared).

Considering the production factors, beneficiaries of the state led program by expropriation (INCRA) did better on the total value of production (R$ 2426.14), which includes production for consumption. They used larger area (7.61 hectares) and were more labor intensive (638.69 days of labor per year). The beneficiaries of market assisted land access program (PCT) yielded R$ 1784.92, using the average of 5.78 hectares and 557.30 labor days for the period 1999/2000 (Table 1).

The model has two *proxy* variables for environmental characteristics: state and soil quality. The differences between PCT and INCRA proportions are larger in Maranhão (MA) and Ceará (CE). Maranhão has higher proportion of INCRA settlers (20.66%) compared to the proportion observed of PCT (15.04%). The inverse occurs in Ceará, where the proportion of PCT settlers is higher (36.33%) than INCRA (26.69%). State led settlements (INCRA) occurred under higher frequency in counties with higher proportion of soils of regular quality (36.00%), while market led settlements (PCT) were more frequent in counties with higher proportion of soils of better quality (47.64%).

Collective projects were observed with lower intensity in the INCRA settlements as compared to the PCT settlements. The proportion of labor days applied to collective activities was 7.93% for INCRA farmers and 15.07% for PCT beneficiaries. The part of collective production was

lower for state led settlers (11.28%) compared to the market led ones (18.14%).

The use of technology for production reveals lower production intensity for the state led settlers. INCRA settlers had lower frequency of use of machines (25.05%); use of purchased seeds (36.93%); use of chemical fertilizers (38.03%); lowland cropping (17.18%); and use of technical assistance (35.83%). The production technology of PCT settlers was characterized by the use of machines in 33.40% of the households; use of purchased seeds by 46.29% farmers; use of chemical fertilizers by 45.70%; lowland cropping frequency of 22.27%; and 52.15% of farmers used technical assistance.

Table 1: Average of production factors and inefficiency sources of beneficiaries of INCRA and PCT, 1999/2000.

| Variable | PCT (n=512) | | | INCRA (n=547) | | | Mann Whitney Wilcoxon Test | | $\chi^2$ Test | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Median | Mean | Standard Deviation | Median | W | p-value | $\chi^2$ | p-value |
| Production value (R$) | 1784.92 | 2473.93 | 1040.64 | 2426.14 | 4370.61 | 1144.29 | 130894 | 0.0062 | - | - |
| Used area (ha) | 5.78 | 6.12 | 4.00 | 7.61 | 8.11 | 4.22 | 128139 | 0.0168 | - | - |
| Labor days | 557.30 | 430.84 | 448.50 | 638.69 | 440.85 | 561.00 | 120077 | 0.0001 | - | - |
| Costs (R$) | 496.16 | 1047.97 | 172.65 | 558.54 | 1538.09 | 178.00 | 139827 | 0.9671 | - | - |
| MG (proportion) | 0.1016 | 0.3024 | - | 0.1316 | 0.3384 | - | - | - | 2.3122 | 0.1284 |
| MA (proportion) | 0.1504 | 0.3578 | - | 0.2066 | 0.4052 | - | - | - | 5.6716 | 0.0172 |
| CE (proportion) | 0.3633 | 0.4814 | - | 0.2669 | 0.4428 | - | - | - | 11.4123 | 0.0007 |
| BA (proportion) | 0.2266 | 0.4190 | - | 0.1974 | 0.3984 | - | - | - | 1.3448 | 0.2462 |
| PE (proportion) | 0.1582 | 0.3653 | - | 0.1974 | 0.3984 | - | - | - | 2.7770 | 0.0956 |
| High quality soil (ratio of county area) | 0.4764 | 0.3916 | 0.4387 | 0.3907 | 0.3181 | 0.3404 | 155367 | 0.0020 | - | - |
| Regular quality soil (ratio of county area) | 0.2822 | 0.3499 | 0.1065 | 0.3600 | 0.3107 | 0.2819 | 110461 | 0.0000 | - | - |
| Low quality soil (ratio of county area) | 0.2414 | 0.2927 | 0.0885 | 0.2493 | 0.2889 | 0.1469 | 137910 | 0.6670 | - | - |
| Consumption (ratio of production) | 0.5515 | 0.3233 | 0.5620 | 0.5427 | 0.3371 | 0.5476 | 142286 | 0.6501 | - | - |
| Collective production (ratio of production) | 0.1507 | 0.2704 | 0.0000 | 0.0793 | 0.2096 | 0.0000 | 164114 | 0.0000 | - | - |
| Collective labor (ratio of labor days) | 0.1814 | 0.2276 | 0.1000 | 0.1128 | 0.1859 | 0.0377 | 169767 | 0.0000 | - | - |
| Outer income (ratio of income) | 0.3824 | 0.3391 | 0.3480 | 0.3483 | 0.3269 | 0.2905 | 147335 | 0.1388 | - | - |
| External labor (ratio of days) | 0.1143 | 0.2080 | 0.0000 | 0.1020 | 0.1889 | 0.0000 | 143776 | 0.3911 | - | - |
| Livestock (proportion) | 0.6113 | 0.4879 | - | 0.6984 | 0.4594 | - | - | - | 8.8791 | 0.0029 |
| Animal labor (proportion) | 0.0762 | 0.2655 | - | 0.0658 | 0.2482 | - | - | - | 0.4312 | 0.5114 |
| Machines (proportion) | 0.3340 | 0.4721 | - | 0.2505 | 0.4337 | - | - | - | 8.9458 | 0.0028 |
| Purchased seeds (proportion) | 0.4629 | 0.4991 | - | 0.3693 | 0.4831 | - | - | - | 9.5473 | 0.0020 |
| Fertilizers (proportion) | 0.4570 | 0.4986 | - | 0.3803 | 0.4859 | - | - | - | 6.4105 | 0.0113 |
| Lowland cropping (proportion) | 0.2227 | 0.4164 | - | 0.1718 | 0.3776 | - | - | - | 4.3257 | 0.0375 |
| Irrigation (proportion) | 0.0469 | 0.2116 | - | 0.0420 | 0.2009 | - | - | - | 0.1453 | 0.7031 |
| Technical assistance (proportion) | 0.5215 | 0.5000 | - | 0.3583 | 0.4799 | - | - | - | 28.6145 | 0.0000 |
| Credit (proportion) | 0.4844 | 0.5002 | - | 0.4534 | 0.4983 | - | - | - | 1.0202 | 0.3125 |
| Local migration (proportion) | 0.6602 | 0.4741 | - | 0.6965 | 0.4602 | - | - | - | 1.6049 | 0.2052 |
| Migration between states (proportion) | 0.2695 | 0.4442 | - | 0.2340 | 0.4238 | - | - | - | 1.7747 | 0.1828 |
| Age of the head (years) | 41.4981 | 10.8820 | 40.0000 | 43.0713 | 11.9792 | 42.0000 | 129457 | 0.0334 | - | - |
| Schooling of the head (years) | 1.8398 | 2.1513 | 1.0000 | 1.6527 | 2.0497 | 1.0000 | 145913 | 0.2176 | - | - |
| Age of the settlement (years) | 2.0020 | 0.2382 | 2.0000 | 3.2102 | 1.2380 | 3.0000 | 57482 | 0.0000 | - | - |

Source: Original data from Buainain *et al*. (2002).

Considering the characteristics of the head of household, the beneficiaries of the state led program are slightly older (43.1 years) compared to the head of household under the market led program (41.5 years).

The development of agriculture projects is strongly affected by its own maturity. The average for the age of projects area higher for INCRA, and one could expect a higher level of development of these projects. INCRA settlements age range varies from 1 to 6 years, and PCT program settlements are 3 years old at most. This issue was checked by the comparison of the characteristics of INCRA settlers grouped according to the age of the projects – younger projects up to 3 years old, and older ones with more than 3 years. Considering production factors, farmers from older projects used smaller areas for production and lower intensity of labor, with no difference of statistical significance for production itself. Considering the sources of inefficiency, older settlements had higher frequency of technical assistance and older farmers.

## 5 RESULTS

The average global efficiency was 0.3610, with a minimum of 0.1111, and maximum 0.8172 for the interval between 0 and 1. The estimate for the variance of the model parameters ($\sigma^2$) was statistically significant. The probability to reject the null hypothesis is less than 0.1%. The portion of variance due to inefficiency explanatory parameters ($\gamma$) can also be considered significant to a similar degree as the average before (Table 2).

The estimated value of the log-likelihood was -1530.1 (32 degrees of freedom). The model validation test is determined by the double of the difference between the log-likelihood estimates for the deterministic production frontier (estimated under full efficiency) and the stochastic frontier production (considering presence of inefficiencies and errors for measurement and specification). The log-likelihood for the deterministic frontier was -1691.4 (5 degrees of freedom). The value of the test, considering the distribution $\chi^2$ (27 degrees of freedom) was 322.6, which represents the distance between the frontiers – deterministic and stochastic – p-value below 0.1%. This means that the inefficiency model expresses a high level of statistical significance.

The first result to point out is about returns to scale. The production showed diminishing returns to scale considering the whole set of production factors. The overall elasticity was 0.4601. Land (*lnUsedArea*) was the factor with the greater partial elasticity, 0.3118. Labor (*lnLabor*) and inputs costs (*lnInputs*) had low elasticity level, of 0.0862 and 0.0620 respectively. It was observed statistical significance only for land and inputs costs. Land was the factor that contributed the most to the performance of production, almost four times the labor, and five times greater than inputs costs. This arrangement of factors

highlights the marginal role of labor and inputs in production, revealing a strategy of use of available land, and weak in labor and capital. However, the total elasticity under the unit indicates that the relationship between inputs and production value is less than proportional, so there is evidence that other variables may play an important role in production.

Table 2: Results of the stochastic frontier production model for the sample of beneficiaries of INCRA and PCT, 1999/2000 (n=1059).

| Group | Parameters | | Estimates | Standard Error | z-value | Pr(>\|z\|) | |
|---|---|---|---|---|---|---|---|
| Production Factors | $\beta_0$ | *Intercept* | 7,010013 | 0,343243 | 20,422900 | 0,000000 | *** |
| | $\beta_1$ | *lnUsedArea* | 0,311838 | 0,048128 | 6,479300 | 0,000000 | *** |
| | $\beta_2$ | *lnLabor* | 0,086217 | 0,052274 | 1,649300 | 0,099082 | . |
| | $\beta_3$ | *lnCosts* | 0,062058 | 0,011802 | 5,258500 | 0,000000 | *** |
| Inefficiency Sources | $\delta_0$ | *Intercept* | 1,972910 | 0,409160 | 4,821900 | 0,000001 | *** |
| | $\delta_1$ | *PCT* | 0,108257 | 0,134497 | 0,804900 | 0,420879 | |
| | $\delta_2$ | *MG* | -0,276835 | 0,224971 | -1,230500 | 0,218495 | |
| | $\delta_3$ | *MA* | -0,532408 | 0,210474 | -2,529600 | 0,011420 | * |
| | $\delta_4$ | *CE* | -0,455154 | 0,201685 | -2,256800 | 0,024023 | * |
| | $\delta_5$ | *BA* | -0,121415 | 0,201703 | -0,601900 | 0,547209 | |
| | $\delta_6$ | *UsedArea* | 0,009140 | 0,010982 | 0,832300 | 0,405252 | |
| | $\delta_7$ | *PSoilA* | -0,694920 | 0,222582 | -3,122100 | 0,001796 | ** |
| | $\delta_8$ | *PSoilB* | -0,348435 | 0,255322 | -1,364700 | 0,172351 | |
| | $\delta_{11}$ | *PConsumption* | 1,016835 | 0,207410 | 4,902500 | 0,000001 | *** |
| | $\delta_9$ | *PCollectiveProduction* | 0,047738 | 0,263255 | 0,181300 | 0,856103 | |
| | $\delta_{10}$ | *PCollectiveLabor* | -0,985079 | 0,345882 | -2,848000 | 0,004399 | ** |
| | $\delta_{13}$ | *POuterIncome* | 1,850644 | 0,240196 | 7,704700 | 0,000000 | *** |
| | $\delta_{14}$ | *POffFarmLabor* | -1,165857 | 0,337327 | -3,456200 | 0,000548 | *** |
| | $\delta_{12}$ | *Livestock* | -0,334447 | 0,155194 | -2,155000 | 0,031159 | * |
| | $\delta_{15}$ | *Machines* | -0,249249 | 0,148549 | -1,677900 | 0,093369 | . |
| | $\delta_{16}$ | *PurchasedSeeds* | 0,109953 | 0,130206 | 0,844400 | 0,398419 | |
| | $\delta_{17}$ | *Fertilizers* | -0,101433 | 0,150481 | -0,674100 | 0,500272 | |
| | $\delta_{18}$ | *Lowland* | -0,152372 | 0,161340 | -0,944400 | 0,344959 | |
| | $\delta_{19}$ | *Irrigation* | -0,536991 | 0,290458 | -1,848800 | 0,064491 | . |
| | $\delta_{20}$ | *Credit* | -0,121310 | 0,155026 | -0,782500 | 0,433912 | |
| | $\delta_{21}$ | *TechAssistance* | -0,138789 | 0,154639 | -0,897500 | 0,369451 | |
| | $\delta_{22}$ | *Age* | -0,016466 | 0,005738 | -2,869600 | 0,004110 | ** |
| | $\delta_{23}$ | *Schooling* | -0,007330 | 0,030475 | -0,240500 | 0,809925 | |
| | $\delta_{24}$ | *LocalMigration* | -0,119748 | 0,167980 | -0,712900 | 0,475924 | |
| | $\delta_{25}$ | *StateMigration* | 0,071975 | 0,149597 | 0,481100 | 0,630426 | |
| | $\sigma^2$ | *sigmaSquared* | 1,278227 | 0,128229 | 9,968400 | 0,000000 | *** |
| | $\gamma$ | *gamma* | 0,531073 | 0,084478 | 6,286500 | 0,000000 | *** |

Notes: . 10% of significance; * 5% of significance; ** 1% of significance; *** 0,1% of significance.
Source: Original data from Buainain *et al*. (2002).

***Sources of inefficiency***

There is no statistically significant evidence that the mechanism of market assisted land access (*PCT*) contributed to the efficiency of the settlers. Although there is no statistical

significance (p-value=0.4209) the positive sign indicates contribution to inefficiency (0.1083). This result is also an indication that the complementary variable, which represents land access by expropriation (*INCRA*), may have contributed negatively to the inefficiency.

In terms of geographical distribution, the parameters estimated for the states of Minas Gerais (*MG*), Maranhão (*MA*), Ceará (*CE*) and Bahia (*BA*) indicate that there were positive contributions to efficiency. The estimated parameters respectively were: -0.2768, -0.5324, -0.4551 and -0.1214, with statistical significance for only Maranhão and Ceará. Pernambuco (*PE*) contributed negatively to efficiency as expected, given its complementary role for the model. The drought that hit several regions of Pernambuco during the period of data collection (1999/2000) may explain, along with the problems of governance, and the socioeconomic position of the beneficiaries of this state, having very low levels of technical efficiency.

Soil quality in settlement projects municipalities was used to capture the effects of environmental characteristics along with the indicators of states. The variables refer to the proportion of the municipal area with three levels of soil quality – high, regular and low. The variables – high quality and regular quality (*PSoilA* and *PSoilB*) – contributed negatively to the inefficiency, -0.6949 and -0.3484 respectively, with significance only for high quality soils.

The area used for crops and pastures was introduced in hectares, to capture the scale effect on efficiency, which could be lost due to restrictions of the Cobb-Douglas function. The estimated coefficient was near zero (0.0091), without significant effect on efficiency. On average, farmers of PCT and INCRA occupied only 21.4% and 23.6% of the available average area, estimated at 27.0 ha and 32.3 ha. Therefore the degree of effective use of the land was not enough to develop economies of scale.

The outer income ratio and production for consumption, along with the low level of occupation of the available area, give a set of evidences that agricultural production may not be the main strategy for economic development of the settlers. It doesn't underestimate its role as the primary strategy to access the land though. Part of the explanation for the strategy of subsistence production can also be linked to environmental factors, underdevelopment of local markets, and restriction of access to local and regional markets; in particular due to lack of infrastructure for storage of production, and precarious access to urban centers (De Janvry and Sadoulet, 2004).

The strategy of supplementing income through outer income was the variable that most contributed to inefficiency (1.8506), while off-farm labor was the variable that most contributed to the efficiency (-1.1659), both with statistical significance. On one hand, the shift of focus from the management and design of the lot can compromise the productive efficiency; on the other hand, the off-farm labor can contribute to the experience of the farmer and can integrate them into the market, contributing to the development of technical and allocative efficiency (De Janvry and Sadoulet, 1995). While subsistence production is important for the family's food security, the focus of this strategy, coupled with the shift of focus to generate additional income via activities outside of the settlement, can point to future restriction of accumulation of capital necessary to overcome conditions of poverty through agricultural production.

The portion of the value of production from collective production did not affect the efficiency significantly, while the share of labor for the collective settlement activities contributed to the development of technical efficiency (-0.9851).

The seemingly incoherent gap between the effects of obtained production against the labor effort in collective activities may be the result of the allocation of surplus labor, but not exactly in the search for income derived from the collective access to productive assets. For beneficiaries of the PCT program, the share of production from collective activities (15.07%) corresponded almost to the double of that obtained by the settlers of INCRA (7.93%). For the proportion of work devoted to group activities, the proportions were 18.14% and 11.20%, respectively for PCT and INCRA.

Livestock farming can play dual role in the production system. On the one hand, the animals create a monetary reserve to face adverse conditions in the long run; on the other hand, it also provides quick access to food in the short term, such as the production of milk products. The negative sign of the variable indicated that the presence of livestock has contributed to resolve the inefficiency (-0.3344).

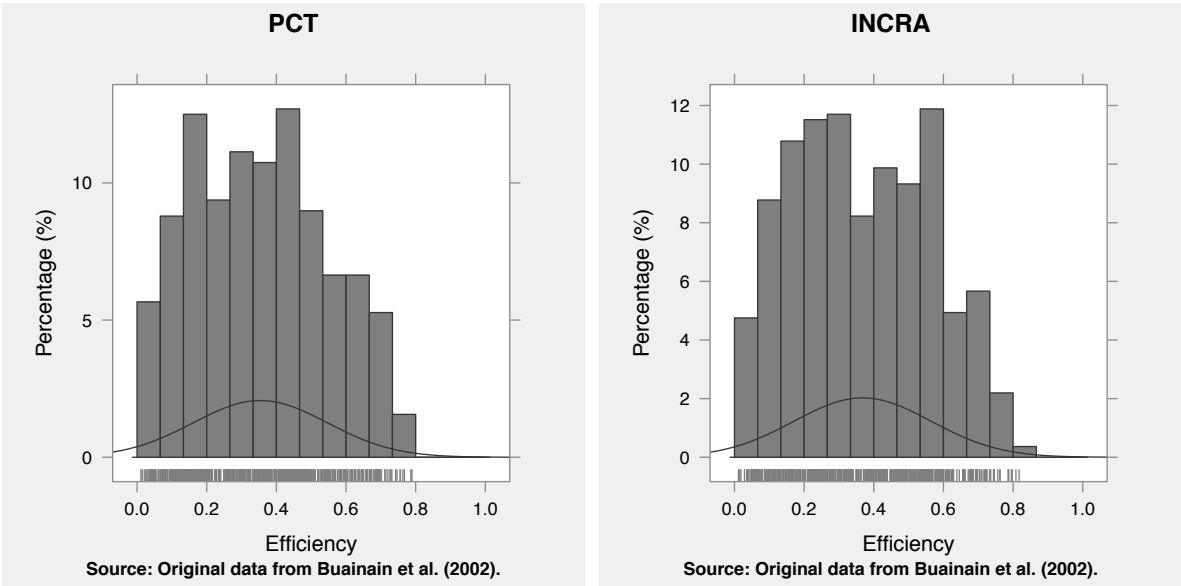
The most significant effects of technology refer to irrigated cultivation (-0.5370) and mechanical traction (-0.2492). The effects of lowland cultivation, chemical fertilizers, and seeds purchased were not statistically significant. The variables for access to technical assistance and credit also showed no statistically significant estimates. The estimated parameter for the head of household age was significant (-0.0165). However, there was no statistical significance for years of education, state and local migration.

There was no statistically significant difference observed between productive efficiency for PCT and INCRA farmers. The value of the efficiency index observed for the settlers of the PCT was 0.3537 and 0.3678 for farmers by INCRA (Table 2), and no statistical significance for the difference (p(t)=0.2381). Figure 1 presents the distributions of efficiency according to the mechanism of access to land.

Table 3: Estimated efficiency for the group of beneficiaries of PCT and INCRA, 1999/2000.

| Variable | N | Mean | Standard Deviation | Dispersion (%) | Standard Error | Lower Bound (95%) | Upper Bound (95%) |
|---|---|---|---|---|---|---|---|
| PCT Efficiency | 512 | 0,3537 | 0,1930 | 54,5581 | 0,0085 | 0,3369 | 0,3704 |
| INCRA Efficiency | 547 | 0,3678 | 0,1968 | 53,5163 | 0,0084 | 0,3513 | 0,3844 |
| PCT and INCRA Efficiency | 1059 | 0,3610 | 0,1950 | 54,0225 | 0,0060 | 0,3492 | 0,3727 |

Source: Original data from Buainain et al. (2002).




(a) (b)

Figure 1: Distribution of beneficiaries according to efficiency mechanism and access to land, 1999/2000: (a) PCT (n=512), (b) INCRA (n=547).

***Descriptive statistics of farmers near to the frontier***

The differences between PCT and INCRA farmers near to the frontier were statistically significant for a small set of variables, including state, use of fertilizers, use of technical assistance and age of the settlement. Significant differences for the average efficiency estimates were not observed

according to the land access mechanism (0.7291 for PCT and 0.7356 for INCRA).

The stratum of efficiency near to the frontier had no PCT settlers for the states of Minas Gerais and Pernambuco. On the other hand, the frequency for INCRA settlers was 18.75% for Minas Gerais and 12.50% for Pernambuco. For the state of Ceará, the proportion of farmers in the PCT (61.90%) was greater than that of INCRA (21.88%).

The use of fertilizers was most often seen in the PCT group, in 76.19% of cases compared with 31.25% for the group of farmers from INCRA. The proportion of farmers with access to technical assistance was higher for the PCT group, 71.43% against 37.50% for the group of INCRA.

Although not a hallmark of farmers near the frontier considering the total sample, the average age of the projects was higher for the settlers through expropriation (INCRA), 2.8 years against 2.0 years of projects established through access to land through the market (PCT), virtually reproducing a feature of the sample.

Near the frontier, the differences between the characteristics of the farmers according to the access mechanism to the land tends to be lower when the comparison is made considering the set of observations of the stratum of 95% lower values of efficiency or even for the whole set of values in the sample. In conclusion, the degree of similarity between the farmers was higher.

## 6 CONCLUSION

The estimated average efficiency was 0.3163 for the overall set of farmers. The index value for the PCT settlers was 0.3537, while for the INCRA settlers was 0.3678, with no statistical significance for the difference between the two. This rejects the hypothesis of differentiation in productive efficiency between the mechanisms of access to land by expropriation and market assisted land access.

The production showed diminishing returns to scale considering the whole set of production factors. Land was the factor that contributed the most to the performance of production, almost four times the work and five times greater than production costs. This arrangement of factors of production shows the marginal role of labor and inputs in production, revealing a strategy of farming based on partial use of available land, low intensity of labor and capital usage.

The sources of the efficiency offer a coherent explanation for the behavior of efficiency as a function of the productive structure. The first result of the model confirms the existence of inefficiency, indicating that there was a set of discriminating variables. The variables that contributed negatively to the inefficiency, therefore positively for efficiency,

were the proportion of labor allocated to activities outside the settlement, the proportion of labor allocated to group activities, the location of projects in municipalities with the largest area of land with high soil quality, location of projects in the states of Maranhão and Ceará, and age of the head of household. Irrigation and the use of machinery in productive activities are variables in set of secondary level of statistical significance. The variables that contributed negatively to efficiency were the proportion of outer income activities and proportion of the value of production for family consumption.

Labor can be considered the resource more readily available and relatively inexpensive in family production units, a prevalent feature of land reform beneficiaries. Surplus labor, coupled with lack of financial resources to develop the available land, both are marginally diminishing contribution to production. It may explain in part the reversal effects on efficiency of the labor allocated to collective production inside the settlement and off-farm activities. If the surplus labor would be allocated for their own production, the marginal contribution to production could present a negative sign. The second striking feature of production systems present in land reform settlements is the subsistence production for the family, which contributed negatively to the efficiency of production. Production for home consumption on the one hand is indispensable for the food security of the family and their livelihoods. This means a composition of a production system in terms of products of low elasticity of consumption, therefore, with limited incentives to expand production. Adding precarious access to local markets due to limitations on transportation of production, or even absence of local markets, diminishes incentives to increase production as well.

The inefficiency is not explained according to the mechanism of access to land; however, individuals nearby the frontier have a set of characteristics that differentiate them from others. Farmers near the efficiency frontier fully combine the intensification of production relative to the absence of the main sources that contributed negatively to the efficiency. On the one hand, production systems at the frontier are characterized by higher production value, more intensive use of capital (inputs costs), a greater proportion of labor for collective production, increased frequency of observations for livestock, use of machinery, and cultivation in lowland and irrigated areas. Indicators of lower intensity of participation in this stratum of producers were located in the state of Pernambuco, located in municipalities where the proportion of the area was lower for soils of low quality and low rate of outer incomes in the composition of total income.

Indicators of human capital, except for age of the head of household, are virtually absent in terms of effects on efficiency. There were no significant effects for the years of schooling, migration between municipalities within the state and migration between states. The effects of the age of the head of household should be interpreted with care, in part because they can carry the effects of age of the settlements itself.

The quality of the settlement projects was evaluated indirectly, according an indicator of soil quality areas relative to the municipal agricultural area. The results obtained indicate that positive effects on the efficiency were observed in the presence of high quality soil, and farmers near the frontier are characterized by sitting in areas with lower proportion of low quality soils. So there is indirect evidence that the quality of the projects makes a difference considering the efficiency of the farmers.

There are limits to interpretation of the results, due to the adverse effects of the early stages of projects, and due to incomplete conditions necessary for the settlements' full development of productive activities. The results also show that there is room to grow, in terms of scale, improving performance and productivity, and improving production efficiency.

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