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PRODUCTION EFFICIENCY OF FAMILY FARMS AND BUSINESS FARMS IN THE BRAZILIAN REGIONS

Denise Imori
Department of Economics, FEA - University of São Paulo
E-mail: denise.imori@usp.br

Joaquim José Martins Guilhoto
Department of Economics, FEA - University of São Paulo; REAL, University of Illinois; and CNPq Scholar
E-mail: guilhoto@usp.br

Fernando Antonio Slaibe Postali
Department of Economics, FEA - University of São Paulo
E-mail: postali@usp.br

RESUMO: Este trabalho tem como objetivo analisar a eficiência técnica dos estabelecimentos agropecuários do Brasil e de suas regiões, utilizando como base os dados do Censo Agropecuário 2006. Mais especificamente, procura comparar as eficiências técnicas dos estabelecimentos rurais familiares em relação aos de caráter patronal, considerando-se as diferenças regionais no país. Para tanto, estimaram-se, sob diferentes hipóteses, fronteiras estocásticas de produção e, simultaneamente, modelos de efeitos de ineficiência. Com isso, foi possível mensurar as eficiências técnicas dos estabelecimentos rurais, bem como analisar as influências de fatores relacionados ao ambiente produtivo, permitindo a indicação de políticas públicas voltadas ao aperfeiçoamento do desempenho dos produtores. Nas estimações empíricas, observou-se menor eficiência técnica para os estabelecimentos familiares. Em termos regionais, destacou-se, no que concerne à eficiência técnica dos estabelecimentos patronais, a região Sul do país, a qual também apresentou, ao lado do Centro-Oeste, os índices mais elevados para os estabelecimentos familiares, em média. Quanto à influência do ambiente produtivo, obteve-se que a educação formal e o acesso a crédito sobressaem como importantes fatores para a eficiência técnica da agropecuária brasileira.

Palavras-Chave: Fronteiras Estocásticas; Censo Agropecuário; Desenvolvimento Regional.

Classificação JEL: D24; Q12; R11.

ABSTRACT: This paper aims to analyze the technical efficiency of farms in Brazil and its regions, based on the data from the 2006 Census of Agriculture. More specifically, it seeks to compare the technical efficiency of family farms in relation to business farms, considering the regional differences in the country. To do so, one simultaneously estimated, under different assumptions, stochastic production frontiers and inefficiency effects models. Thus, it was possible to measure the technical efficiency of farms, as well as analyze the influence of factors related to the production environment, allowing the indication of public policies aimed at improving the performance of producers. In the empirical estimation, it was observed, as expected, lower technical efficiency for family farms. In regional terms, with respect to the technical efficiency of business farms, the South region of Brazil stood out, also presenting, along with the Midwest region, the highest efficiency rates for family farms, on average. Regarding the influence of production environment, it was found that formal education and access to credit are noteworthy as important factors for the technical efficiency of Brazilian agriculture.

Keywords: Stochastic Frontiers; Census of Agriculture; Regional Development.

JEL Code: D24; Q12; R11.

1. Introduction

Despite its modernization and consequent integration to markets (either as a supplier of inputs for the agro-industry or as a source of foreign exchange), Brazilian farming is still characterized by the poverty that afflicts considerable number of its producers. Among these, the family farms are of special concern – these are producers which hold limited areas and often have in their small scale an obstacle to participate in the modernization process of Brazilian agriculture.

Still, beyond their already recognized historical and social roles, the family farms are important also from an economic standpoint. Thus, evaluating their production performance is an urgent matter. In order to take full advantage of available inputs and existing technology, the focus is on the technical efficiency of these agricultural producers. Moving from the assumption that, like the others, they are economic agents concerned with the optimization of their earnings, one should analyze the exogenous factors that affect its productive performance in order to develop public policies that are designed to minimize existing inefficiencies.

Another important point is that in a country such as Brazil, characterized by a vast and diverse territory under different aspects, it would be expected that the performance of agricultural producers, be they family farmers or not, is marked by inequalities at the regional level – the objective conditions of production vary for various reasons, intra-and inter-regionally. Therefore, this issue should also be considered when evaluating the technical efficiency of agriculture in the country.

1.1. Context

In 2005, according to Helfand *et al.* (2009), the proportion of poor people in rural Brazil reached impressive 46% – almost two times higher than the poverty level found nationally. Since labor income represented 75% of total income in rural areas and having in view the low likelihood that the growth of transfers seen in recent years in the country is sustainable, in order to reduce poverty and rural inequality continuously, the essential implication is that public policy should aim to pro-poor sources of rural incomes. In this context, policies that contribute to the competitiveness of the family farms seem to be very important.[1]

In a context where resources are generally scarce and the opportunity to develop or adopt better technologies is still limited, the agricultural economy of the country and, in particular, the relief of rural poverty could greatly benefit from the analysis on the technical efficiency of rural establishments. The presence of significant levels of inefficiency suggests that there are opportunities for expanding production using the existing levels of inputs and technology (NISHIMIZU; PAGE, 1982).

In this framework, this work aims to address the central issue of technical efficiency of family farms. The Brazilian family farming, in addition to its traditional role in absorbing labor and producing food, has more recently been recognized as a relevant wealth generating complex, considering not only the rural and regional economies, but the country as a whole (GUILHOTO *et al.*, 2010).[2] Thus, the analysis of technical efficiency of family farms is highly appropriate, since, as

[1] On July 24, 2006, Law No 11.326 was enacted, establishing guidelines for the formulation of the National Policy for Family Farming and Family Ventures, thus, providing the legal framework for family farming. According to Law No 11.326, only farmers or rural entrepreneurs that simultaneously meet the following requirements can be considered "family farmers": a) Do not hold, on any account, area larger than four fiscal modules; b) Use predominantly labor of their own families in economic activities of their establishment; c) Have their income predominantly originating from economic activities linked to the establishment; d) Run their establishment with their family. Thus, following the current legal framework in Brazil, this study will use the above definition for family farming. The remaining establishments will be characterized as business farms.

[2] According to Guilhoto *et al.* (2010), in 2006 the GDP of Brazilian agribusiness exceeded the value of R$ 675 billion (in 2009 value), which corresponded to 24% of total national GDP. From this total, over 30% had their origin in the production of household establishments. Thus, the complex composed by household farming, which includes production

pointed by Abramovay (1997), its dynamism does not depend on supposedly "cultural" characteristics of its farmers, but on the same factors that affect the performance of rural producers in general. Following the indications of Schultz (1964), it is of great importance the incentives and possibilities that producers face in order to accomplish their agricultural potential. It is, therefore, an economically important point to examine and evaluate means whereby family farm's production efficiency can be enhanced.

Moreover, one cannot ignore that the family farmers are inserted in a scenario marked by historic land concentration in Brazil (GUANZIROLI *et al.*, 2001). Illustrating the persistence of such context there is the observation that in 2006 the family farms accounted for approximately 84.4% of the number of establishments in the country, but occupied only 24.3% of its agricultural area (IBGE, 2010). Given this context, this study of the potential of family farming was complemented by a joint analysis of the production of business establishments – so, following this approach, the measure of technical efficiency of family agricultural establishments has its results compared to those of business farms.

It is also evident the need for considering regional differences inside Brazil in the analysis. In addition to the natural conditions, the territory of the country is heterogeneous by other factors such as those relating to its historical occupation (BUAINAIN, 2007). Thus, especially keeping in view the nature of this activity, when studying the performance of agriculture one should consider the problems and peculiarities of Brazilian regional diversity. This is a point that this paper intends to highlight, investigating the efficiency of both types of agricultural establishments in the Brazilian regions.

This paper also sought to deal with an issue that has been emphasized by the international literature about technical efficiency of agriculture – especially when focusing family farmers – but (according to what we know at the time of this writing) not yet addressed by studies on the Brazilian case. It is the consideration of income earned in off-farm activities as part of the product valuation of farmers. As will be shown later, this study sought to contemplate this aspect through the estimation of a stochastic frontier model where the output variable includes wages earned in off-farm activities. The justification for considering the income earned in off-farm activities is based primarily on the following points (PAUL *et al.*, 2004; CHAVAS *et al.*, 2005; OLSON; VU, 2007): i) such activities would use common inputs to rural production, and ii) affect the economic performance of producers. In this context, as stated by Guanziroli *et al.* (2001) about the Brazilian family farming scenario, the possibility to generate income outside the family production unit is a factor that can determine the capacity of accumulation and thus the viability of any production system.

Having in mind what has been presented in this Introduction, it can be stated, more succinctly, that the present study has the motivation that improving the dimensioning of Brazilian agriculture, pointing out its strengths and limitations, is critical to the effectiveness of public policies and institutional innovations. Thus, the overall goal is the analysis of technical efficiency of agricultural establishments in Brazil, based on data from the Census of Agriculture of 2006, distinguishing family farms and business farms, and indicating factors that can explain differences in productive performance.

To this end, this paper is organized as follows, in addition to this Introduction: section 2 presents the methodology used in the empirical analysis. A brief review of literature on the technical efficiency of Brazilian agriculture is made in section 3. Section 4, in turn, explores the database used in the present work. The results are analyzed in section 5. Then, the last section presents some final comments.

of family-run crops and livestock, and the sectors that relate to these rural activities, represented in 2006 approximately 7% of the Brazilian economy in terms of value added.

2. Methodology

For a comprehensive explanation on microeconomic production theory, and on the development of the methodology of stochastic frontier analysis, see Kumbhakar and Lovell (2000).[3]

2.1. Stochastic frontier production functions model

The stochastic frontier production model was independently proposed by Aigner *et al.* (1977) and by Meeusen and van der Broeck (1977), in the following formulation:

$$Y_i = \exp(x_i\beta+V_i-U_i) \quad (1)$$

In the above expression, Y_i represents the output of the ith firm, x_i is the vector corresponding to the inputs, β is the vector of unknown parameters,V_i is a symmetric random disturbance representing statistical noise and U_i is a non-negative random variable associated to the technical inefficiencies. The model defined above is called "stochastic frontier function" because the production values are delimited superiorly by the stochastic variable $\exp(x_i\beta+V_i)$. The random disturbances V_i may be positive or negative, so that the production according to the stochastic frontier varies in relation to the deterministic part of the model, $\exp(x_i\beta)$.

As indicated by Queiroz and Postali (2010), the economic logic of this model lies in the fact that the production process is subject to two random economically distinguishable disturbances, U_i and V_i. The term U_i reflects the assumption that the production of a firm cannot be above the level indicated by its frontier of potential production, given its inputs. In turn, the random disturbance V_i indicates that the production frontier may randomly vary between companies or over time for the same firm.

2.1.1. Stochastic frontier model incorporating a model for technical inefficiency effects

According to Kumbhakar and Lovell (2000), the analysis of production efficiency should have two components. The first is the estimation of a stochastic production frontier that would work as reference to evaluate the technical efficiency of the producer. The objective of this first component would be to analyze the efficiency of producers using their inputs, under certain assumptions about their behavior. The other component emphasized by the authors and more recently widely in the literature regarding productivity, corresponds to the inclusion of another group of factors in the analysis, which are not outputs or inputs, but affect the performance of producers. The objective of this component is relating changes in performance of producers to variations in factors that are exogenous to their choice and that usually characterize the economic environment in which they operates. Note that the inclusion of these factors in the analysis allows us to analyze the role of public policies relating to technical efficiency (IGLIORI, 2005). Following a significant volume of empirical studies involving stochastic production frontiers, this study employed the methodology proposed by Battese and Coelli (1995). Accordingly, we describe below the stochastic frontier model incorporating a model for technical inefficiency effects as proposed in their article.[4]

The authors consider the following stochastic frontier production function for panel data:

$$Y_{it} = \exp(x_{it}\beta+V_{it}-U_{it}) \quad (2)$$

[3] One should also note the possibility of adopting non-parametric techniques for the analysis of technical efficiency, among which the DEA (Data Envelopment Analysis) methodology is prevalent in the literature. It involves the use of linear programming methods to construct a convex sectional border above the data points, and measures of technical efficiency are then calculated. A more complete presentation of this methodology can be found in Coelli *et al.* (2005).

[4] However, we point out that our study used cross-sectional data, given the unavailability of Census data for family farming for the other years for which the research was published.

In the above expression, Y_{it} denotes the output of the ith firm (i = 1, 2, ..., N) in the t-th period (t = 1, 2, ..., T). x_{it} is the vector (1 x k) of production inputs, which may include other control variables. β is the vector (k x 1) of parameters of the production frontier to be estimated. It is assumed that V_{it}s are i.i.d. random disturbances such that $V_{it} \sim (0,\sigma_V^2)$ and they are independently distributed from the U_{it} terms. In turn, U_{it}s are nonnegative random disturbances that represent technical inefficiencies of production and are assumed to be independently distributed. It is assumed that U_{it}s are obtained by truncation, at zero, of a normal distribution with mean $z_{it}\delta$ and variance σ^2, where z_{it} is a vector (1 x m) of explanatory variables for the technical inefficiencies and δ is a vector (m x 1) of parameters to be estimated. Therefore, the inefficiency effect of the stochastic frontier model, U_{it}, can be defined by the following specification:

$$U_{it} = z_{it}\delta + W_{it} \quad (3)$$

The random variable W_{it} is defined by the truncation of a normal distribution with zero mean and unknown variance, σ^2, so that the truncation point is given by $-z_{it}\delta$, that is, $W_{it} \geq -z_{it}\delta$ and $U_{it} \geq 0$.

Battese and Coelli (1995) propose to use the method of maximum likelihood estimation to obtain simultaneously the parameters of the stochastic frontier (β) and of the model of inefficiency effects (δ). Therefore, it is used the parameterization of Battese and Corra (1977), replacing σ_V^2 and σ^2 by $\sigma_S^2 = \sigma^2 + \sigma_V^2$ and $\gamma = \sigma^2/\sigma_S^2$ in the maximum likelihood function. The maximum likelihood function and its partial derivatives with respect to the estimation parameters of the model (β, δ, σ_S^2 and γ) are presented in Battese and Coelli (1993).

The technical efficiency (TE) of each firm in each period can be defined by the ratio Y_{it}/Y_{it}^*, where Y_{it}^* is output on the efficient frontier (i.e., when $U_{it}=0$). Therefore:

$$TE_{it} = \frac{\exp(x_{it}\beta + V_{it} - U_{it})}{\exp(x_{it}\beta + V_{it})} = \exp(-U_{it}) = \exp(-z_{it}\delta - W_{it}) \quad (4)$$

The prediction of technical efficiencies is based on their conditional expectation, given the assumptions of the model. This result is also presented in Battese and Coelli (1993).

2.2. Definition of regional areas

One may question the hypothesis that the technological structure of farmers and the effects of exogenous factors on their production are identical in all regions of Brazil, which is assumed when estimating the stochastic production frontier and its model for technical inefficiency effects using all observations in the country. To overcome this potential problem, one can perform the estimations separately for each region, with the same parameters used for the national model. However, against such segregation of the analysis account the fact that, using it, the results regarding the technical efficiency indices are not comparable between regions. With those points in view, the present study aimed to address the issue about the regional heterogeneity including regional dummies in the specification of the model for technical inefficiency effects. The regional definition used here differs from the usual division of the Brazilian space in great regions, aiming to aggregate similar municipalities in terms of the characteristics of their agriculture.[5]

[5] Thus, five regions in the country were considered. In the North region, the municipalities of Legal Amazonia were included, with the important exception of those belonging to the state of Mato Grosso. Therefore, in the present work, the North region is composed of the municipalities of Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, Tocantins, and western Maranhão. In the Northeast region, the municipalities included those from the area of operation of the Superintendence for the Development of the Northeast (SUDENE), with the exception of those from Maranhão and already included in the North. Thus, within this work, the Northeast region includes the municipalities of eastern Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia and northern Minas Gerais and Espírito Santo. The third region, Southeast, includes other municipalities of Minas Gerais and Espírito Santo, São

3. Literature review

Since it was theoretically proposed in the late 1970s, the stochastic frontier model has been applied in several studies related to agriculture, under various assumptions and having as subject of study the performance of producers in different countries and regions.[6]

In the recent literature on Brazil,[7] Igliori (2005) employed the methodology Battese and Coelli (1995) to analyze the technical efficiency of farmers of the Legal Amazon. For this, the author employed data of 257 regions resulting from aggregating municipalities, based on the Census of Agriculture of 1996.

Magalhães *et al.* (2011) applied the methodology of Battese and Coelli (1995) on primary data to assess the determinants of technical inefficiency of 308 beneficiaries of the land reform program Cédula da Terra in five states in the Northeast region, between the years 2002 and 2003. Among their results, Magalhães *et al.* (2011) point out that labor was the factor that essentially determined production. Regarding the variables of the model for inefficiency effects, beyond the state dummies, only that for establishments' self-consumption was significant. The non-significance of the other variables, however, also point to important elements for understanding constraints on the production of the beneficiaries. In particular, according to the authors, they were expending resources to obtain precarious technical assistance which, combined with generally low levels of education, did not provide good results to the establishments.

More recently, Lambais *et al.* (2012) extended the analysis of the program Cédula da Terra to panel data, comprising 181 families in the years 2000 and 2006. The authors observed small gains in technical efficiency of producers between the two years. Positive effects on efficiency were provided by animal labor, and the presence of livestock. The negative effect of self-consumption, found in Magalhães *et al.* (2011) was confirmed, accompanied by the negative effect of the proportion of income earned outside the establishment, and the use of purchased seeds. Therefore, the use of this new panel data changed some of the results of Magalhães *et al.* (2011), but confirmed its main conclusions.

Magalhães *et al.* (2012) analyzed the question about the effects of different mechanisms of land access (expropriation of rural land or market assisted land access) on efficiency of farmers. Employing a database that included both recipients of the program Cédula da Terra and farmers that were settled by INCRA, the authors rejected the hypothesis of gaps in productive efficiency due to different mechanisms of land access.

Other studies also focused on the application of the methodology of stochastic production frontiers to data from the Census of Agriculture of 2006.[8] Loures and Moraes (2013a) analyzed the efficiency of farmers of Minas Gerais, employing also data from the Census of Agriculture of 1996. The frontiers were separately estimated for each year. In the period, the authors observed many changes in the efficiency ranking of the Minas Gerais' mesoregions.

Employing data from the Census of Agriculture of 2006, comprising 558 homogeneous microregions of Brazil, Almeida (2012) aimed to investigate the existence of differences in technical efficiency of small, medium and large agricultural establishments. Using Chow tests and analysis of dummy variables applied to initial estimates, the author concluded that the regions and the different

Paulo, and Rio de Janeiro. The South region comprises all the municipalities of Santa Catarina, Paraná, and Rio Grande do Sul. Finally, the Midwest region includes the municipalities of Mato Grosso do Sul, Mato Grosso, and Goiás.

[6] For an extensive literature review on the technical efficiency of agricultural establishments, we suggest the following studies: Battese (1992), Bravo-Ureta and Pinheiro (1993), Thiam (2003), Bravo-Ureta *et al.* (2007).

[7] It should be pointed out that the problem of technical efficiency of agriculture in the Brazilian regions was also addressed by the use of alternative methodologies, especially the DEA. Some of this papers: Helfand and Levine (2004), Nogueira (2005), Barros (2011), Loures and Moraes (2013b), Barbosa and Sousa (2013), Barbosa *et al.* (2013).

[8] We also point out the work of Felema *et al.* (2013), which applied partial productivity measures. The authors analyzed the net productivity of labor and land in Brazil, and identified production factors that influence these productivities. The present work is distinguished by applying a methodology that simultaneously considers the use of multiple inputs in the production and analyzes the effect of external factors that are not inputs or products on the technical efficiency of producers.

farm size strata were characterized by their own production functions. Thus, estimates were presented for each of the five geographical regions of Brazil, as well as for each size stratum. From his results, the author concluded that the Schultz's hypothesis of "poor but efficient" could not be rejected for all Brazil, despite rejecting it for small establishments with less than 10 ha of area in the Midwest region, and for the stratum under 50 ha in the North region.

A very important aspect to be highlighted in the literature review is that different authors with different subjects and databases have addressed the problem of measuring the performance of agricultural producers in quite different ways. The specification that was adopted in this paper was based on the literature concerning the technical efficiency of agriculture, but was also limited by the available database, as shown below.

4. Database

The data used in this study was obtained by request from the Center for Agrarian Studies and Rural Development (NEAD) to IBGE, who tabulated the municipality-level data from the Census of Agriculture of 2006, detailing the family farms from the municipal total. For reasons of confidentiality, the data regarding survey questions that were answered by less than 3 establishments were not disclosed. Thus, we could not consider all municipalities that were investigated by the Census of Agriculture of 2006.

4.1. Stochastic production frontier

The estimations used as output variable the total value of production of the establishments in 2006 and, alternatively, the sum of that value with the wages earned outside the establishment by rural producers.[9]

As production inputs, we considered four categories that are usual in the literature on technical efficiency of agriculture: labor, capital, land and other inputs. For the construction of the variable labor, we considered the guideline of Proger Rural, so it was measured in labor units employed by the establishment. As the capital, we considered the value of vehicles, tractors, machinery, and implements declared as assets by the producers. In the category of other inputs, we considered the expenses with fertilizers, soil amendments, seeds and seedlings, pesticides, animal medicines, salt and feed, and fuel. For land input, we considered the total area of establishments, which includes the area used for crops and pastures, but also that occupied by woods and forests, water bodies for aquaculture, constructions, and degraded or useless land.[10]

4.2. Model for technical inefficiency effects

The specification of the inefficiency effects model includes variables based on the literature concerning the technical efficiency of agriculture (GORTON; DAVIDOVA, 2004).[11] The first assessed variable, of central concern to the present work, it was the dummy indicative of the family character of the establishment. Thus, we evaluated the hypothesis that, conditionally to the other

[9] One should indicate, though, that this procedure implies the imposition of the hypothesis that both categories of activities (inside or outside the establishment) are considered as equally important by producers (Solís, 2005).

[10] One should point out that the inclusion of woods and forests, as well as areas unsuitable for agriculture, in the inputs used by producers is not trivial. Possibly such inclusion affects the answer to the main question of this research study, which is the difference between the technical efficiencies of family farms in relation to business ones. The reason is that, on average, these areas represent a larger percentage of the total area of business establishments: 31%, against 26% for family farms. This difference, significant at 1%, suggests that the inclusion of these areas possibly reduces the efficiency measure of business producers, since – as compared to the case where such areas were excluded – one is increasing the amount of inputs used by them without proportional return for their production value.

[11] Due to unavailability of data, variables suggested by the literature as related to technical efficiency of agriculture could not be considered. Among these variables, one can highlight those related to access to technical assistance and participation in associations.

variables included in the model, the category of the establishment (family or business) implies, on average, at different levels of technical efficiency.

The model also incorporated variables that are intended to indicate the effects of differences in the composition of output on the technical efficiency of agricultural establishments (HELFAND, 2003). The proportions of the total area of family or business farms in the municipality that were destined to livestock, to permanent crops or temporary crops were included as control variable.

In order to analyze the effect of human capital on the technical efficiency of agriculture, the model included a variable referring to formal education. This is the average years of schooling of people with more than 25 years in each municipality, as measured by the Population Census of 2000. Therefore, for reasons of data availability, we are not differentiating formal education of workers employed by family farms and business farms in the same municipality. The model also included the groups of years of management in the establishment indicated by producers in the Census of Agriculture of 2006. Note that such variable is indicative both of the experience as of the age of producers.

Among the structural factors, we sought to evaluate the effects of access to credit, land tenure status and environmental conditions on the technical efficiency of agricultural establishments. As the variable referring to credit, the model for inefficiency effects employed the proportion of establishments in each municipality and in each category (family or business) which received funding in 2006 through various agents (banks, credit cooperatives, suppliers, integrator companies, other financial institutions, NGOs, relatives, etc.).[12] Regarding the land tenure status, the specification of the model for inefficiency effects included the proportion of establishments in each municipality and in each category (family or business) which were owned by the producers, as opposed to they being renters, partners or occupants of the managed land.[13] Intending to further control by some environmental factors, the model included, besides the altitude of the municipality (taken from IBGE's register of cities and towns in 1998), controls related to rainfall and temperature (estimates of annual averages from 1961 to 1990 conducted by the Institute of Applied Economic Research, IPEA, from data base of the University of East Anglia).

Table 1 presents descriptive statistics for the representative establishments that were considered in this work, for Brazil as a whole. One realizes that representative business establishments presented, on average, much higher values for both the output variables and for those relating to inputs. It should be noted that, considering the partial productivity measure given by production per area, the family farms presented, on average, higher value: R$ 886.33 per hectare were produced, compared to R$ 549.58 per hectare in business farms. Regarding the variables of the model for inefficiency effects, Table 1 indicates that representative family establishments had, on average, greater portions of their area dedicated to agricultural crops. Family farmers presented, in 2006, higher average years of management of their establishments. On the other hand, a smaller proportion of family farmers, by municipality, were named as owners of their lands, in comparison with business producers.

It is also noteworthy that descriptive statistics for each region, here omitted for space constraint, showed a very diverse picture in Brazilian agriculture.

[12] In the present work, access to credit is considered exogenous, following the practice commonly adopted in the literature of agricultural economics (*e.g.* Solís *et al.*, 2009).

[13] As pointed by Igliori (2005), the importance of such control stems from the fact that owners, renters, partners and occupants have different property rights and pay different prices for the use of the land, which may impact the technical efficiency of their establishments.

Table 1 - Descriptive statistics, Brazil

		Family				Business			
		Mean	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**
Production Frontier	**Production value (R$ thousand)**	20.20	74.77	0.62	4 909.29	157.23	403.15	1.09	13 333.68
	Off-farm income (R$ thousand)	0.69	1.24	0.00	21.82	4.71	6.86	0.00	199.72
	Labor (units)	2.99	0.85	1.09	23.10	6.18	10.03	1.33	490.25
	Capital (R$ thousand)	16.67	19.24	0.13	507.70	114.59	326.36	0.17	9 948.33
	Other inputs (R$ thousand)	4.33	12.79	0.01	591.40	64.44	442.07	0.04	18 432.71
	Area (hectares)	22.79	18.49	0.85	222.83	286.10	441.27	2.67	8 617.09
Model for inefficiency effects	**Area - Livestock (proportion)**	0.45	0.23	0.00	0.97	0.44	0.24	0.00	1.00
	Area – Temporary crops (proportion)	0.21	0.19	0.00	0.97	0.19	0.21	0.00	0.99
	Area – Permanent crops (proportion)	0.08	0.12	0.00	0.92	0.06	0.11	0.00	0.85
	Education (average years of schooling)	4.01	1.26	0.81	9.26	4.02	1.26	1.04	9.26
	Experience (groups of management years)	3.39	0.25	1.66	4.00	3.28	0.26	1.52	4.00
	Credit access (proportion)	0.20	0.15	0.00	0.87	0.20	0.15	0.00	1.00
	Land owners (proportion)	0.79	0.18	0.00	1.00	0.86	0.14	0.00	1.00
	Altitude (meters)	419.27	289.23	0.00	1 505.00	420.17	288.93	0.00	1 505.00
	Rainfall - average (mm/month)	114.77	35.84	28.87	254.24	114.73	35.73	28.87	254.24
	Temperature - average (°C)	22.79	3.03	14.38	28.04	22.78	3.02	14.38	28.04
	Observations	5 215				5 198			

Source: research data.

5. Results

5.1. Parameter estimates and hypothesis testing

Following the recommendation of Battese and Broca (1997), we used a general specification for the model as a starting point and tested a simpler formulation within a formal framework for hypothesis testing. In this work, the most general form of the stochastic production frontier is a translog function.

The results of the maximum-likelihood estimates for the parameters of the stochastic production frontier and the model for technical inefficiency effects are shown in Table A1, in the Annex. Models I and II employed the sum of the value of production of the establishments and wages earned in off-farm activities as the output variable, adopting, respectively, the functional forms translog and Cobb-Douglas. In turn, the Models III and IV incorporate only the production value as output variable, also adopting the functional forms translog and Cobb-Douglas, in that order.

After obtaining these estimates by maximum-likelihood, we proceeded to carry out several tests of hypotheses in order to evaluate the alternatives considered for the production technologies. The results are shown in Table 2. The test groups 1, 2 and 3 made use of the likelihood ratio, λ.[14]

In short, besides the statistical significance of the parameter γ indicating that the stochastic production frontier approach proved to be more appropriate than the model of average production function, results of tests of hypotheses presented in Table 3 indicate that: i) the translog functional form provided a better representation of the production frontier than the Cobb-Douglas specification and satisfied the theoretical consistency conditions in mean data point[15]; ii) the model for inefficiency effects was to be incorporated into estimations; iii) the levels of the explanatory variables jointly affect the estimated technical efficiencies; iv) choosing the output variable did not affect the ranking of the estimated technical efficiencies. Taking up this in mind, the following analysis will focus on the results of the estimations obtained under Models I and III, which adopted a translog functional form for the production frontier, included the model for inefficiency effects of Battese and Coelli (1995) and considered different variables representing output (sum of the value of production of

[14] Through it, it is possible to compare the likelihood functions under alternative hypotheses (SOLÍS, 2005). If the null hypothesis, H_0, is true, then $\lambda=2\ln[L(H_0)/L(H_1)]$ is asymptotically distributed as a chi-square random variable (or mixed chi-square) with the number of degrees of freedom equal to that of restrictions being tested (BATTESE; COELLI, 1995). If the null hypothesis involves $\gamma=0$, then λ has a mixed chi-square distribution, given that $\gamma=0$ is a value at the border of the parameter space for γ. The critical values for the tests in this case can be found in Kodde and Palm (1986).

[15] Namely: a) monotonicity; b) diminishing marginal productivity; c) quasi-concavity.

establishments plus wages earned in off-farm activities and only the value of production, respectively).

Table 2 – Hypothesis testing of stochastic production frontier models

Test	Null hypothesis	Test Statistic	Conclusion
1) Cobb-Douglas x Translog			
Model I x Model II	$\beta_{ij}= 0, \forall$ i,j	625.38	Reject H_0
Model III x Model IV		611.79	Reject H_0
2) No inefficiency effects in the production function			
Model I		1729.27	Reject H_0
Model II	$\gamma = \delta_0=\delta_1=\ldots=\delta_{19}=0$	1939.11	Reject H_0
Model III		1701.44	Reject H_0
Model IV		1968.47	Reject H_0
3) Variables in the inefficiency effects model have no effect on the level of technical inefficiency			
Model I		1729.27	Reject H_0
Model II	$\delta_1=\delta_2=\ldots=\delta_{19}=0$	856.42	Reject H_0
Model III		1701.44	Reject H_0
Model IV		2046.09	Reject H_0
4) Spearman correlation			
Model I x Model II		0.973	
Model III x Model IV	Same ranking of	0.977	
Model I x Model III	technical	0.974	
Model I x Model without inefficiency effects	efficiencies	0.399	
Model III x Model without inefficiency effects		0.415	

Source: research data.

Returning to the analysis of parameter estimates of the stochastic production function, shown in Table A1, for Models I and III, we can point out that one should be careful when interpreting the estimated parameters, since they have little meaning per se for the translog function. Calculating the elasticities for each input would actually be of greater interest. The values of these elasticities (calculated at the mean data point) are presented in Table 3. In both Models I and III, the higher elasticity of the production frontier (at mean data point) corresponded to labor, followed by that of other inputs and that of capital.

Table 3 - Elasticities of production frontier in relation to inputs

	Model	
	I	**III**
Labor	0.509	0.549
Capital	0.272	0.290
Other Inputs	0.322	0.328
Land	0.136	0.164

Source: research data.

As pointed out by Barnes (2008), the measure of returns to scale can be obtained by summing these partial elasticities. In the case of Model I, we obtained a sum equal to 1.238, whereas for Model III it was equal to 1.330. Thus, in both Models, the sum obtained was greater than unity, indicating increasing returns to scale at the mean data point.

5.2. Technical efficiencies

This section is dedicated to analyzing the results of the estimation of technical efficiencies of representative establishments, obtained from the stochastic production frontiers under Models I and III. Such estimations were performed according to the expression (4). First, we analyze the results for Brazil as a whole, which are then segmented by region.

We observed that the choice of variable regarding the output brings changes that are not negligible as regards the distribution of technical efficiencies estimated considering each type of agricultural establishments. Note that under Model III, which does not consider wages earned in off-farm activities as part of their output, a larger number of representative family establishments presented technical efficiencies corresponding to superior intervals (compared to what was observed under Model I).

Under both Models, however, family farmers presented lower average technical efficiency than business farmers. The average technical efficiency indices of representative family establishments were 0.54, under Model I, and 0.60, under the Model III. This indicates that, on average, with the same levels of inputs and technology, the sum of production value of establishments and wages earned in off-farm activities, in the case of Model I, or the production value, in the case of Model III, could be increased in 46 percentage points and 40 points, respectively. These results, therefore, suggest that substantial gains could be achieved by family farmers, given the existing levels of inputs and technology employed by producers. In turn, the representative business establishments presented average technical efficiency indices of 0.74 and 0.71 in Models I and III, in that order.

Figure A1[16], in the Annex, shows the geographical distribution of estimated technical efficiencies. As would be expected given the high value of the Spearman correlation between Models I and III, shown in Table 2, the representations show up very similar.

The North region is the one that has the lowest average technical efficiency considering the family farms, under Models I and III – under both, we obtained the result that over 70% of family farmers have technical efficiency below 0.50. Regarding business establishments in the North region, although they are more efficient than family farms, they too could achieve substantial gains of output under both Models I and III – the estimated average technical efficiencies of these two models were, respectively, 0.60 and 0.57. Figure A1 highlights, however, that representative business establishments corresponding to some municipalities in northwest Rondônia, northern Pará and Amapá obtained technical efficiency indices above 0.80.

For the Northeast region, we observed that its family farms could also achieve substantial gains in output, given their inputs levels and production technology, since they showed low technical efficiencies estimates, on average: 0.46 and 0.53 under Models I and III, respectively. As for representative business establishments, it was found that, under estimates of both Models I and III, the Northeast region had, on average, the lowest technical efficiencies. Also, it should also be indicated that this was the only region in which, according to the results of Model III, the average efficiency of representative family establishments was not inferior to that of business establishments, which presented average technical efficiency level of 0.52 (under Model I, 0.56). According to Figure A1, especially some representative business establishments regarding municipalities from São-Francisco valley in Bahia and from east Piauí presented low technical efficiencies. On the other hand, it is observed that the representative business establishments corresponding to areas closer to the coast showed considerably higher technical efficiencies under both Models.

The Southeast region was in middle position regarding its estimated technical efficiencies for representative family establishments, both under the Model I, as under the Model III – their average ratios were 0.58 and 0.64, respectively. Regarding the technical efficiency estimates for representative business establishments, one can indicate that the average value presented by the Southeast was lower only than in the South region (0.85 under Model I, 0.83 under Model III). According to Figure A1, the representative business establishments imbued with technical efficiencies higher than 0.90 in the Southeast region corresponded for municipalities located mainly in the areas of northeast of São Paulo, south of Minas Gerais (besides Uberaba and Uberlândia, in this state), and south of Rio de Janeiro.

As for the South and Midwest regions of the country, one can indicate that such regions have obtained technical efficiency indices to their family farms whose means were not statistically different

[16] In these Figures, the blank areas of the Brazilian territory correspond to municipalities whose data required for estimating the stochastic production frontier and the model for inefficiency effects were not available in the database.

and were higher than in other regions of the country, considering both Models I and III – the South had averages of 0.64 and 0.69, respectively, while the Midwest had averages of 0.66 and 0.71. For business establishments, as pointed out in the preceding paragraph, the South presented the highest average technical efficiency in the country – under both models, 0.89. It is noteworthy, in this region, the large proportion of municipalities whose representative business establishments had efficiency rates higher than 0.90: 54.20%, according to the Model I, 46.06%, according to the Model III. According to Figure A1, these municipalities were located, in the South region, especially in the western areas of their states. As for the Midwest, this region was found in an intermediate position for the technical efficiency of their representative business establishments (0.82 under Model I, 0.78 under Model III). Figure A1 indicates that the efficiency ratios above 0.80 corresponded mainly to municipalities of Mato Grosso do Sul and southern areas of the states of Mato Grosso and Goiás.

5.3. Model for inefficiency effects

We analyze now the estimated parameters for the models for technical inefficiency effects, included in Models I and III, whose results were presented in Table A1.[17] First, we evaluate the effects of the explanatory variables that are not dummies. Regarding the composition of production, the results for both Models I and III indicate that, over the category of area use that was omitted from the specification employed here (woods and forests, or land that is useless for agriculture) increasing the proportion of area for any of the other activities has positive and statistically significant effect on the technical efficiency of farms. This is an understandable result: everything else constant, the allocation of a greater proportion of the area for activities whose production more greatly contribute to the composition of the output variables of Models I and III would lead to greater technical efficiency measures.

The parameter refering to formal education was estimated to be negative and significant. This indicates that an increase in the number of years of schooling of the adult population of a given municipality would lead to greater technical efficiency of its agricultural establishments. This is a strong indication that, in agreement with what was theorized by much of the literature, also in the Brazilian agriculture education would act as a driver of technical efficiency, providing the processes for capturing information and making decisions by producers to be faster and well done (*e.g.*, Battese; Coelli, 1995; Battese; Broca, 1997; Abdulai; Eberlin, 2001; Solís *et al.*, 2009).

About the other component of human capital included in the model for inefficiency effects of the present work, the experience of producers, presented significant parameter (at 5% level of significance) only in Model III. That is, only in the model which did not consider wages earned in off-farm activities as part of the output variable of the stochastic frontier, the farmers' experience was significant and positively related to the technical efficiency of agricultural establishments. Thus, in the empirical application of Model III of this paper, there is evidence that the positive effect of experience on the producers' technical efficiency exceed unfavorable aspects that accompany their increasing age (WILSON *et al.*, 2001). However, the parameter on the producers' experience was not significant in the model for inefficiency effects included in Model I – it is not an isolated case in the empirical literature (*e.g.*, Sherlund *et al.*, 2002; Thiam, 2003; Paul *et al.*, 2004; Solís *et al.*, 2009).

One possible explanation for the lack of significance of the parameter referring to the producers' experience in the estimation of only Model I would be that getting salaries in off-farm activities – embodied in the output variable of that model – would be more substantial among younger producers. Possibly, such producers have more frequent access to jobs, both in rural establishments directed by others, and in urban areas, which expands its product as considered by Model I and, given the used inputs, also its technical efficiency. With this, the significant positive relationship observed

[17] In interpreting the effects of these variables, it should be indicated that, since in the model for inefficiency effects of Battese and Coelli (1995) the dependent variable is the element relating to the inefficiency error term (U_i), a negative parameter indicates that the respective variable favors technical efficiency.

in Model III between technical efficiency and producers' background would be less evident. The issue clearly deserves a more thorough study, which, however, is beyond the scope of this work.

Regarding access to credit, the estimation results of Models I and III suggested that it has positive influence on technical efficiency. Thus, as indicated by Helfand (2003), it seems that, in fact, in Brazil, access to credit would lead establishments to choose the most appropriate combinations of inputs and outputs, facilitating the employment of superior crop qualities and the gathering of information necessary for a better performance. This is a result, although not unanimous (*e.g.*, Battese; Broca, 1997; Solís *et al.*, 2009), also found in empirical applications concerning other regions (*e.g.*, Liu; Zhuang, 2000; Abdulai; Eberlin, 2001).

Similarly to the results obtained for the variable on producers' experience, the parameter of the variable referring to land tenure status was significant only in the model for inefficiency effects corresponding to Model III. In this model, where the wages earned in off-farm activities are not considered as components of outputs, the significant and positive relationship between the percentage of land owners in municipalities and technical efficiency suggested the validity of the idea that land ownership reduces risks and encourages investment in techniques that enable higher productivity (Gebremedhin; Swinton, 2003). However, the empirical application developed under the Model I did not find a statistically significant relationship between land tenure status and technical efficiency, which constitutes a recurrent result in literature (*e.g.*, Battese; Broca, 1997; Igliori, 2005).

The parameters of the variables that were included in the model as environmental controls were statistically significant in both Models I and III, suggesting that these factors actually influence the technical efficiency of Brazilian agriculture. Thus, on average, in Brazil, higher altitudes are associated with lower technical efficiencies. As to other environmental controls, it was observed that, on average and considering the country as a whole, higher temperatures are associated with lower technical efficiencies, with the opposite being true for rainfall.

Concerning the dummy variables, first we analyze the results for the variable of central interest to the study, namely, that indicating the family (=1) or business (=0) character of the representative establishment. Table A1 shows, for both Models I and III, positive and statistically significant maximum-likelihood parameters for the dummy of family character. The results therefore suggest that, conditionally to the other variables in the model for inefficiency effects, the family character is negatively related to technical efficiency of agricultural establishments.

Concerning the relationship between the heterogeneity of each region, an important point is the examination of Figure A1 in comparison to the results that were obtained for the parameters relating to the regional dummies. It should be emphasized that, unlike the technical efficiency indices illustrated by Figure A1, the measured relationship between each variable in the model for inefficiency effects, including the regional dummies, and the performance of productive establishments is conditional to the other factors considered in the model.

Table A1 shows that, in Model I, we obtained a positive and significant (at 10% level) parameter for the dummy relative to the North region. Therefore, given the indicated controls, the agricultural establishments in the North were on average less efficient than those in the South (omitted in the specification). In turn, the parameter for the dummy of the Midwest region in the model for inefficiency effects of Model I was estimated as negative and statistically significant, indicating higher levels of technical efficiency, given the controls of the model.

In Model III, which considers as the output variable only the production value of establishments, some results concerning the regional dummies were different from those of Model I. The main difference refers to the statistical significance of the negative parameter for the dummy on the Northeast region in the model for inefficiency effects. Thus, in the case where one considers only the value of production as output variable, the Northeast region, given the factors of the model for inefficiency effects,[18] would be more positively related to technical efficiency of agriculture in

[18] I.e. conditionally to presenting values that were equal to those of the South region for variables concerning the composition of production, education, producers' background, land tenure status, access to credit, and environmental aspects.

relation to the South region. This is a result that directs to an important point for the frequent association between productive inefficiency and this Brazilian region. It is indicating that the low average technical efficiency of the Northeast region, illustrated by Figure A1, can be explained by disadvantages in terms of human capital and structural factors that influence the performance of farmers.

In accordance with Model I, also in Model III the agricultural establishments of Midwest region showed up, on average and given the controls in the model for inefficiency effects, more efficient than those of the South region. This is not a surprising result since, especially among business producers, agricultural production in this region, the Brazilian frontier of agricultural expansion (BAER, 2008), is guided primarily in technology-intensive and high market value commodities, especially soybeans (NEAD, 2010).[19]

6. Final remarks

The wider goal of this study was to analyze the technical efficiency of agricultural establishments in Brazil, based on data from the Census of Agriculture of 2006. In particular, we sought to evaluate the difference between the efficiencies of family and business farmers in the country – this point is important because, despite being marked by several restrictions on production, family farming plays major roles, from historical, social and economic standpoints. In order to do so, we applied the model of stochastic production frontier as presented by Battese and Coelli (1995). Thus, it was possible to simultaneously measure the technical efficiencies and assess how exogenous factors affect the producers' performances, so that it was possible to analyze the role of public policies on technical efficiency.

A main point among the results obtained in the study is that family farmers presented, on average, low performance relatively to business farmers. Also conditionally, considering factors related to human capital and structural conditions of production, the family character was related to lower technical efficiency. That is, those factors that affect agriculture as a whole, such as considered in this study, could not fully explain the gap in efficiency between groups of producers, both in Brazil and in their regions. This implies that public policies aimed at increasing the competitiveness of the farming family, by improving its technical efficiency, should preferably be designed in a specific way for these producers. In this context, it seems necessary to analyze and deal with likely market failures that are hindering the access of family farmers to inputs of better quality and higher value crops, in order to strengthen local economies.

Among the variables considered in the model for inefficiency effects, we highlight the effect observed for the formal education. Thus, we have that public policies focused on formal education of the general population significantly and positively affect the technical efficiency of the rural sector. It may be pointed out that, especially in a scenario marked by modernization of agriculture, the investment in education should be considered a central element in a strategy designed to improve the performance of rural production. In such scenario, we also highlight the implication of our results for the variable on credit access, which displayed a significant and positive relationship with technical efficiency. The development and availability of adequate lines of credit can be indicated as central for the competitiveness of producers, especially in markets of modern outputs.

At the regional level, among our results, there is the indication that the possibility of increasing technical efficiency through public policies that improve conditions for productive context is especially great for municipalities in the area of SUDENE. This is an important result, since it points

[19] It is also possible to regionally distinguish the effect of the family character of establishments on the technical efficiency through a specification of the model in which interactions between dummies for the family character and for the regions were included. Among the main results that were obtained with such specification, we have that in Model III, given controls of the model for inefficiency effects, excepting those located in the North region, in average family farms in the South are more technically efficient than those of other regions the country (in line with what would be expected given the historical development of family farming in the country), while their business farms are less efficient.

out tangible instruments to increase outputs, given the available inputs and technology, in a region where on average technical efficiencies are lower than those of other regions.

Even with limitations, some of which were already pointed out, it is thought that the present work has contributed to the discussion on the technical efficiency of Brazilian agricultural producers, as well as exogenous factors that affect its economic performance, providing support for the design of public policies more carefully aimed at minimizing the inefficiencies existing in the rural sector of Brazil and its regions.

An important observation to be made, finally, concerns the question about the sustainability of the alternative indicated in this work to the problem of rural poverty, namely, improving the performance of farmers, especially those of family character. Although increasing technical efficiency could in the short term compensate for push factors in poorer rural areas, easing the dynamics of emptying of labor, one should ask whether such an increase would be a sufficient and sustainable balance in the long term, especially as the opportunity costs for members of the family group increase with new opportunities in urban centers, especially the young people. Clearly, it is desirable to create better opportunities for producers and their families, so then other questions arise: how to integrate the rural labor to urban markets, in a secure way? What are the prospects for agricultural production, especially typically family crops? Among others, these questions are necessary for future studies about the Brazilian family farming.

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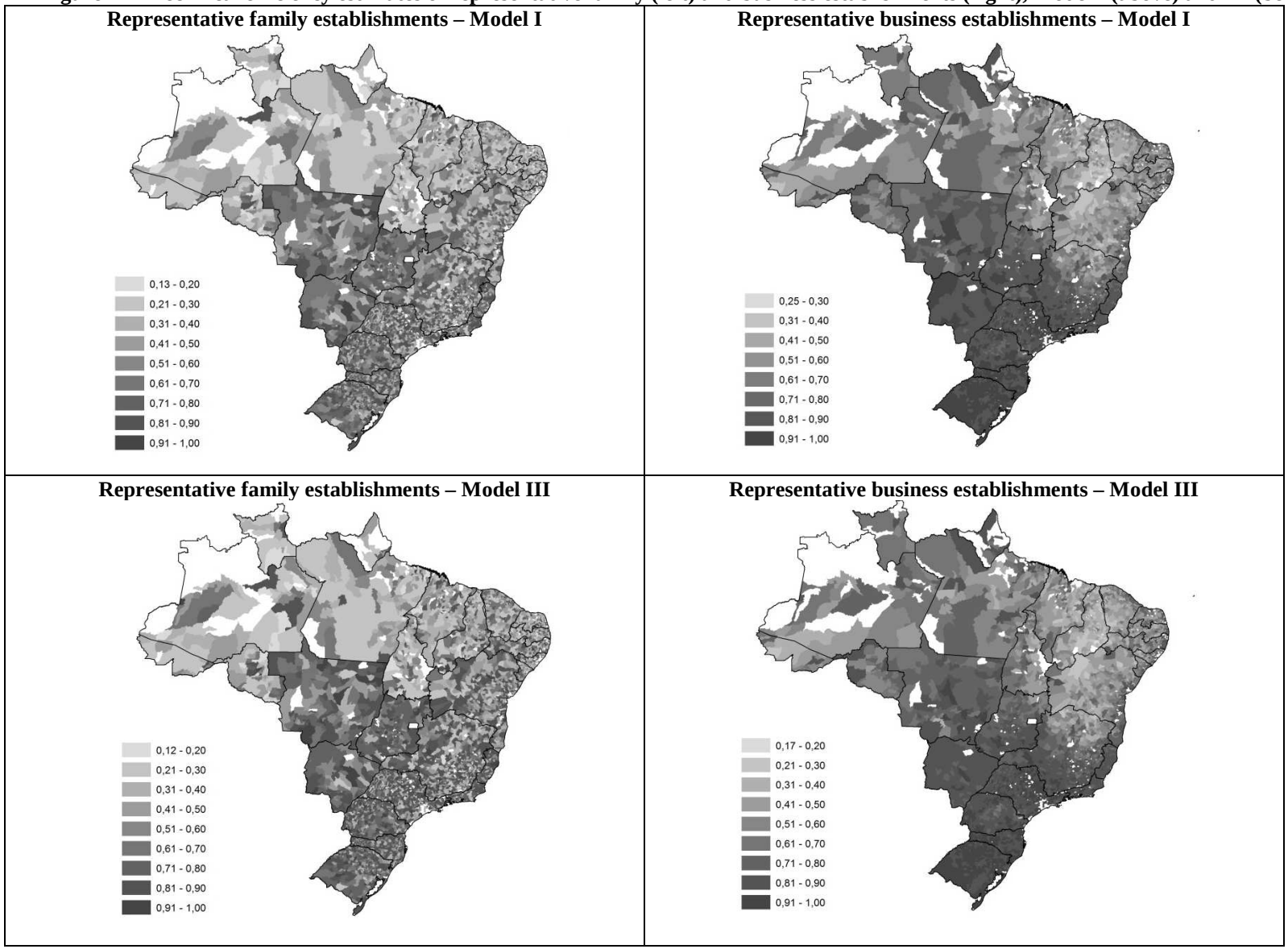
Annex

Table A1 – Parameter estimates of the stochastic production frontier with model for inefficiency effects - Models I, II, III and IV

		Model I			Model II			Model III			Model IV		
		Parameter	SD		Parameter	SD		Parameter	SD		Parameter	SD	
Production Frontier	Constant	1.377	0.103	***	1.472	0.056	***	0.985	0.095	***	1.144	0.048	***
	Labor	0.589	0.072	***	0.454	0.018	***	0.660	0.075	***	0.488	0.019	***
	Capital	0.464	0.030	***	0.316	0.009	***	0.551	0.031	***	0.349	0.009	***
	Other inputs	-0.238	0.024	***	0.225	0.007	***	-0.255	0.025	***	0.220	0.007	***
	Land	0.257	0.031	***	0.127	0.009	***	0.253	0.033	***	0.146	0.009	***
	Labor*Labor	-0.105	0.020	***				-0.112	0.021	***			
	Capital*Capital	-0.012	0.005	**				-0.014	0.005	***			
	Other inputs*Other inputs	-0.008	0.003	**				-0.009	0.003	***			
	Land*Land	-0.018	0.005	***				-0.015	0.005	***			
	Labor*Capital	0.001	0.020					-0.011	0.021				
	Labor*Other inputs	0.075	0.016	***				0.071	0.016	***			
	Labor*Land	-0.006	0.018					0.005	0.019				
	Capital*Other inputs	0.036	0.006	***				0.039	0.006	***			
	Capital* Land	-0.043	0.008	***				-0.052	0.008	***			
	Other inputs*Land	0.070	0.006	***				0.076	0.006	***			
Model for inefficiency effects	Constant	0.450	0.281	***	0.588	0.275	**	0.334	0.300	***	0.376	0.327	
	Family dummy	0.604	0.036	***	0.388	0.031	***	0.400	0.033	***	0.204	0.033	***
	Area - Livestock (proportion)	-0.290	0.062	***	-0.297	0.060	***	-0.362	0.062	***	-0.387	0.074	***
	Area – Temporary crops (proportion)	-0.313	0.076	***	-0.399	0.078	***	-0.483	0.077	***	-0.590	0.085	***
	Area – Permanent crops (proportion)	-0.561	0.105	***	-0.621	0.107	***	-0.797	0.113	***	-0.882	0.129	***
	Education	-0.263	0.013	***	-0.282	0.013	***	-0.312	0.015	***	-0.342	0.015	***
	Experience	-0.068	0.042		-0.102	0.045	**	-0.095	0.042	**	-0.131	0.051	**
	Credit access (proportion)	-0.558	0.102	***	-0.605	0.099	***	-0.582	0.108	***	-0.696	0.121	***
	Land owners (proportion)	-0.087	0.069		0.073	0.074		-0.179	0.072	**	-0.007	0.072	
	Altitude	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000	0.000	***
	Rainfall - average	-0.002	0.000	***	-0.001	0.000	***	-0.002	0.000	***	-0.001	0.000	***
	Temperature - average	0.062	0.008	***	0.070	0.008	***	0.089	0.009	***	0.102	0.010	***
	North	0.102	0.058	*	-0.050	0.058		-0.037	0.057		-0.204	0.062	***
	Northeast	-0.022	0.046		-0.251	0.045	***	-0.141	0.046	***	-0.383	0.049	***
	Southeast	0.048	0.042		-0.061	0.040		0.006	0.040		-0.118	0.044	***
	Midwest	-0.162	0.054	***	-0.307	0.059	***	-0.200	0.056	***	-0.402	0.061	***
	σ^2	0.432	0.009	***	0.455	0.009	***	0.487	0.010	***	0.519	0.011	***
	γ	0.170	0.023	***	0.167	0.025	***	0.182	0.024	***	0.198	0.025	***
	Log-likelihood	-10079.32			-10392.01			-10627.46			-10933.35		

Source: research data. Significance levels: * 10%, ** 5%, *** 1%.

Figure A1– Technical efficiency estimates of representative family (left) and business establishments (right), Model I (above) and III (below)



Source: research data.