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Abstract

This paper analyses the impact of farm productivity as well as farm size on deforestation in Brazil. A two step econometric approach is adopted. A bootstrapped *translog* stochastic frontier that is a posteriori checked for functional consistency is used in order to estimate technical efficiency of which estimates are introduced in a land use model to assess the impact of productivity and farm size on deforestation. Analysis of agricultural census tract data suggests that technical efficiency has a non-linear (convex) effect: less and more efficient farms use more land for agricultural activities and so they have a positive effect on deforestation. However, the majority of farms are on the ascendant slope so that efficiency implies more deforestation in Brazilian Legal Amazon. Moreover, farm size has a robust negative effect on deforestation. Contrary to many studies, this result suggests that small farms convert more natural (forested) land into agricultural land than large ones.

Keywords: Tropical deforestation, Productivity, Farm size, Stochastic frontier model, Land use model, Brazil.

JEL codes: Q12, Q24

1 Introduction

The depletion of the Brazilian forest has drawn attention for a long time and been the subject of numerous studies (Pfaff, 1999; Andersen et al., 2002; Chomitz and Thomas, 2003; Margulis, 2004; Araujo et al., 2009; Pacheco, 2009a). This is of particular importance since most Brazilian policy makers are aware that Brazil's future is closely linked with environmental issues. To date, serious concerns exist that are related to the loss of biodiversity, climate change, local ecological disturbances as degradation of fresh water source or degradation of soil fertility and erosion (Soares-Filho et al., 2006; Salati et al., 2007).

The literature devoted to deforestation drivers allows distinguishing three categories of factors (Geist and Lambin, 2002).The first one is related to "underlying causes". In this category, demographic factors (Southgate et al., 1990; Cropper and Griffiths, 1994), macroeconomic factors (Arcand et al., 2008), income levels (Bhattarai and Hammig, 2001; Culas, 2007), income distribution (Koop and Tole, 2001), technological factors, government policies (Andersen and Reis, 1997; Margulis, 2004; Pacheco, 2006; Bulte et al., 2007) and institutional factors (Southgate and Runge, 1990; Mendelsohn, 1994; Deacon, 1994; Barbier, 2004; Araujo et al., 2009) as well as cultural factors are highlighted. These factors are mainly related to economic policies and social process[1].

The second causes are proximate representing "human activities or immediate causes at local level" (Geist and Lambin, 2002, p.143). Infrastructure extension (Pfaff, 1999; Margulis, 2004; Pfaff et al., 2007; Kirby et al., 2006), agricultural expansion (Angelsen, 1999), cattle ranching activities (Caviglia-Harris, 2005), agricultural income diversification (Perz, 2004), community's management schemes (Alix-Garcia et al., 2005), wood extraction and commercial logging (Otsuki et al., 2002) are considered as proximate sources of deforestation.

Besides, intermediate causes condition the relationship between proximate and underlying causes. These intermediates ones are considered as pre-disposing environment factors i.e geographical features (rain, soil quality, forest fragmentation...)(Chomitz and Gray, 1996; Chomitz and Thomas, 2003; Margulis, 2004; Kirby et al., 2006; Pfaff et al., 2007).

This paper contributes to the economic inquiry on the drivers of deforestation at the farm level[2]

[1] Barbier and Burgess (2001), Angelsen and Kaimowitz (2001) provide an exhaustive review of the literature.

[2] Browder et al. (2004) provide a review of the literature on determinants at farm level (Pichón, 1997; Godoy et al., 1997) according three different models: the neoclassical economic tradition (NET), the household life cycle (HLC) (Walker and Homma, 1996; Perz and Walker, 2002) and the political ecology approach. Our study is more linked to the first model in which a farmer manages his production in order to maximize his utility under some constraints and so agricultural land use (i.e the level of deforestation) depends on the profitability of land conversion explained by some production

and goes beyond existing literature by examining whether there exists a clear and unambiguous link between agricultural efficiency and deforestation. Put differently the question is whether efficient agricultural producer in the Amazonia have also sound environmental practices. Many papers analyse the effect of efficiency and reveal that inefficient farms (i.e with an extensive production) deforest more without estimate empirically the effect of productivity (Otsuki et al., 2002; Bulte et al., 2007; Keil et al., 2007). For example, Godoy et al. (1997, p. 978) explain that an "increase [of] the productivity of land (...) create(s) incentives to cut less forest". However, a potential increase of productivity can create incentives to cut more tree if an efficient farm is in a context of relatively poor valorisation of the environment. The main idea of this paper is to show that an efficient producer can increase its propensity to deforest because he does not take account the environment so that cleared land costs are low. Therefore, this kind of farmer increases an activity in which he is efficient i.e agriculture and so deforests (Boserup, 1965; Angelsen, 1999). Angelsen (1999) explains theoretically that in an open economy and an open access model[3], an increase in output productivity enhances agriculture expansion i.e deforestation. Besides, Pacheco (2009b, page 40) argues that "wealthier farmers not only tend to deforest more in absolute terms but also show a slightly greater propensity to deforest whatever their production system" by using a clustering analysis and creating a wealth index[4]. In other words, producers exploit extensive margins when they exist, before turning to intensive margins. Therefore, this study estimates econometrically a potential impact of productivity on agricultural expansion i.e on deforestation. To our knowledge, only Jones et al. (1995) have analysed empirically this effect in the Brazilian context. They find that the stock of cleared land is lower in farms with a higher productivity in cattle and cultivated land but that productivity has no effect on the pace of cleared land (Jones et al., 1995, p.179-180).

Several studies also analyse the effect of farm size on deforestation at the farm level and often conclude on a positive effect of farm size. Walker et al. (2002) compile results from 15 farm level models and find that the farm size has a positive effect on deforestation. This link is however indirect since there exists a correlation between farm size and agricultural land use (Browder et al., 2004). For example, there is often a positive correlation between specialized production systems like cattle

variables (like productivity, farm size, output composition).

[3]In this model (his model four), there is an open access regime and property rights are defined by forest clearance. This model is particularly well-defined for the Brazilian context (Angelsen, 1999, page 190).

[4]This index is derived from three measures (the number of cattle, number of lots of land, and property size in hectares) and two indices (an index of equipment and an index of durable goods owned by the household). However, the concept of wealthy is particularly large and our study only puts forward the effect of productivity and farm size.

production with farm size implying a positive correlation between farm size and extensive production. Pacheco (2009a) finds also that smallholders tend to less deforest than medium-large-scale ones because these small farmers have diversified their incomes. In others words, the relation between farm size and deforestation is linked with production systems. To our knowledge, there is no estimate of the marginal effect of property size on the agricultural use of land owned by a farmer i.e when the production system is controlled.

The effect of agricultural productivity and farm size on deforestation is estimated on census-tract-level data from the Censo Agropecuario 1995-96. This census permits to analyse the behaviour of each farm present in the Legal Amazon[5] between 1995-1996 and to avoid an aggregation bias. In fact, these data allow to estimate the level of technical efficiency thanks to dis-aggregated data on agricultural activities. Then, to assess the link between deforestation and productivity, a two step method is implemented. In the first step, technical efficiency is estimated from a stochastic production frontier model (Aigner et al., 1977). Secondly, in the second stage, the estimated technical efficiency is considered as a determinant of deforestation as well as farm size in a land use model following Chomitz and Gray (1996) and Chomitz and Thomas (2003). Moreover, in this model, effects of determinants of land use are studied so we equate an increase in agricultural land with deforestation.

The paper is organized as follows. Section 2 briefly describes the Legal Amazon and its historical background. Data, the stochastic production frontier model and the land use model are discussed in section 3. Section 4 analyses the econometric results followed by a conclusion in section 5 which discusses the main results and tries to bring some explanations linked to Brazilian context.

2 Tropical deforestation and agricultural technical efficiency: background

The Brazilian Legal Amazon (BLA) is an administrative area, created in 1953 to reduce the relevant economic, demographic and natural heterogeneities in Brazil[6]: the BLA has 20 million inhabitants of the 170 millions Brazilians in 2000 (source: IBGE ; see figure 1, page 23) on more than half of the territory. This demographical heterogeneity was more important before the implementation of

[5]This administrative area was created in 1953 and regroups nine states which are Acre, Amazonas, Amapa, Para, Rondõnia, Roraima and Tocantins (North region), Mato Grosso (Center-West region) and Maranhão (North-East region).

[6]An important heterogeneity of population within the BLA is also highlighted. Para and Maranhão concentrate more than half of the population (10 millions (source: IBGE , see figure 1, page 23).

development policies, since the 60s. The BLA population represented 8% of the total population in 1970 while it was of 12% in 2000. The demographical growth of BLA was more important mainly as a result of development policies.

In the 60s, the military government begun to considered economic and political objectives. The main one was a military and strategical one to discourage as well incursions from neighbours that the formation of domestic guerilla opposition. However, the second incentive was to provide land to people landless peasant in order to deal with demographic pressures.

Development policies have consisted in building of roads, colonization and land titling projects. The regional development policies of the Amazon Legal started in 1966 with the first phase called ”Operation Amazonia”. There are seven phases and the last one, *Avança Brasil*, started in 2000 with the aim to conciliate development and environment[7]. However, the regional development policy has been very criticized because of important resulting deforestation. As a consequence of this policy some 35 million ha were deforested between 1970 and 1995. In mid-nineties, nearly 10 percent of the BLA area was deforested, compared to 2.5%, in 1975. During this period, the growth of deforestation was 18 000 km^2 per year. More recently, the last phase was particularly criticized. Indeed, according to the Brazilian National Institute of Space Research (INPE, Instituto Nacional de Pesquisas Especiais), the annual cleared area increased from 18 226 (in 2000) to 27 379 km^2 (in 2004)[8]. However, since 2005, an improvement can be noticed as the annual cleared surface decreases: from 18 759 (2005) to 11 224 km^2 (2007).

Another important issue in the Brazil Legal Amazon is the very uneven land distribution. The president Fernando Enrique Cardoso (1995-2002) implemented a proeminent agrarian reform continued by the president Lula since 2002. This reform consists in ”maintaining and stimulating a modern agricultural sector that finally produced for the best interests of the larger society, while using welfare programs, including land reform, to ameliorate the worst social effects of agricultural modernization and provide some relief to a conflict-ridden countryside” (Pereira, 2003, p.48). The policy’s aim was to modernize agricultural sector by allowing landless or small landowners to have or secure land. In others words, this agrarian reform tried to secure property rights which can reduce deforestation (Araujo et al., 2009).

[7]These phases were implemented between 1971 and 2000. The second, third and fourth step (during the 70s and 80s) aimed to increase the regional development by colonization and big infrastructure projects. The nineties phases were oriented toward more environmental considerations.(Andersen et al., 2002, Chap. 2).

[8]During the nineties, the average of annual cleared land was between 12 000 and 16 000 km^2 INPE.

Recently, the Brazil's climate change plan, adopted in 2008 and implemented in 2009 by president Lula, implies to reduce global warming by stimulating high efficiency, maintaining a high proportion of renewable energy in the electricity production, encouraging the use of biofuels in the transportation sector, and reducing deforestation. In this last issue, the goal is drastically downsize illegal deforestation and then to eliminate the net loss forest in 2015 (a tree planted for a tree cut).

The Brazilian regional development policy have influenced the economical behaviour of farmers. However, the question is not so much whether this policy has increased agricultural efficiency but rather how this policy has changed conditions i.e if the opportunity cost associated with agricultural activities has been modified by regional development policies. By the way, beyond to increase deforestation by colonisation project, road networks or infrastructure projects, regional development policies affect agricultural productivity by influencing the agricultural modernization and the relation between agricultural inputs (Reis and Blanco, 1997). Several channels can be highlighted to explain this effect. For example, the improvements in market accessibility, lower rural wages or a reduction of agricultural prices inputs (like fertilizer, credit availability) modify profitability of agricultural option as well as the degree of substituability/complementarity of inputs. Firstly, these changes can enhance extensive shifting cultivation and so deforestation because of agricultural activities are more profitable than conservative forestry activities. Secondly, for example, an efficient farmer, with no constraint to achieve their labor and capital inputs, can increase their land use in order to improve his profitability given that natural environment is less valorized. In this case, more efficiency can increase deforestation because of land is a complementary of labor and capital. In a more valorized environment context, land is less used whereas labor and capital can be increased for an efficient farmer. Therefore, the intensive margin will be use before the extensive one in this context (Angelsen, 1999). However, it is not the Brazilian case with a less valued natural environment and an open access to land.

3 Methodology and conceptual framework

3.1 The 1995-1996 *Censo Agropecuário*

The dataset come from the *Censo Agropecuário* that was conducted in 1995 by the Brazilian Institute of Geography and Statistics (IBGE-Instituto Brasileiro de Geografia e Estatística). The census used covers the Legal Amazon (BLA) made up of all the states in the Northern region of Brazil plus parts of the states of Maranhão and Mato Grosso (see 1, page 23).

However some states are fully covered by tropical forest (like Amazonas and Acre States) and other are partially covered by tropical woods (Mato Grosso and Maranhão). However, every agricultural conversion of a natural area is considered as deforestation. Therefore, a farm in Mato Grosso which converts a savannah area in an agricultural area has the same impact on deforestation that a farm in Acre which converts a tropical forest area into an agricultural area. More precisely, there is the same impact in terms of biodiversity but not in terms of cleared trees (Angelsen, 1999; Andersen et al., 2002). In other words, as noted by Angelsen (1999, pages 187-188), the model ”implicitly assume that all agricultural expansion takes place into forested areas, which in reality is not the case. Thus in empirical work one should not equate an increase in agricultural land with deforestation. Nevertheless, agricultural expansion is the main source of deforestation, and is therefore worth studying for understanding the causes of deforestation”[9].

Besides, the dataset consists in ”representative farms” which encompass farms which have the same size (15 types of size) and land tenure (owner, sharecropper, renter or occupant) located in one county. 893 129 farms are regrouped in 14 724 ”representative farms” involving an average of 61 farms per ”representative unit” (Chomitz and Thomas, 2003; Helfand, 2004).

3.2 Estimated technical efficiency with a stochastic production frontier model

In order to estimate productive efficiency, a production function is used i.e only technical efficiency is analysed[10]. A non-optimal use of production factors which can be put forward for agricultural Brazilian farmers (constraints on labor and credit markets are strong) implies a technical inefficiency well-known as X-inefficiency (Leibenstein, 1966).

Considering that a producer i uses multiple inputs X to produce a single or a multiple output Y, a production function can be written to represent a particular technology: $Y_i = f(x_i)$, where $f(x_i)$ is called a production frontier. On the frontier the producer produces the maximum output for a given set of inputs or uses the minimum set of inputs to produce a given level of output. In standard

[9] Andersen et al. (2002, P.12-13) point out that ”transitional areas are just valuable as the dense forest in terms of both biodiversity and biomass record stored”.

[10] Farm productivity can be generally decomposed into two elements: a dynamic and a static one. The first element is related to technical progress and the second one to productive efficiency. To analyse the first element, it is necessary to have time series. Our data set does not allow us to have a temporal dimension so only farm's productive efficiency may be analysed. In fact, the 1985 census could have be used to have a temporal dimension but the 1995 census was completely different from previous census (see Andersen et al. 2002, p.45-47 for more details).

microeconomic theory there is no inefficiency in the economy implying that all production functions are optimal and all firms produce at the frontier. But if markets are imperfect, producers can be pulled beneath the production frontier.

An ouptut-oriented measure of technical efficiency (more output with the same set of inputs) gives the technical efficiency of a farmer i as follows:

$$TE_i(x, y) = [\max \phi : \phi y \leq f(x_i)]^{-1} \tag{1}$$

The parameter ϕ is the maximum output expansion with the set of inputs x_i.

An ouptut-oriented measure of technical efficiency is estimated under three auxiliary hypothesis. Firstly, equation 1 is applied into an econometric model as (Kumbhakar and Lovell, 2000, p.64):

$$Y_i = f(X_i; \beta).e^{-U_i} \tag{2}$$

where Y_i is a scalar of output, X_i a vector of inputs used by the producer $i = 1, ..., N$ and $f(X_i; \beta)$ is the production frontier[11] where β is a vector of technology parameters to be estimated. U_i are non-negative unobservable random variables associated with the technical inefficiency of production which follows an arbitrary distribution[12].

Secondly, a stochastic production frontier is used (Aigner et al., 1977; Meeusen and van den Broeck, 1977) so that the error term has two components: random shocks V_i (not attributed to the relationship between inputs and output) and the inefficiency U_i[13]. Therefore, the equation 2 becomes:

$$Y_i = f(X_i; \beta).e^{-U_i}.e^{V_i} \tag{3}$$

Where V_i represent random shocks which are assumed to be independent and identically distributed with a normal distribution, mean zero and unknown variance. Under that hypothesis, a producer beneath the frontier is not totally inefficient because inefficiencies can also be the result of random shocks (like climatic shocks).

[11] The production frontier has the traditional properties of monotonicity, continuity and concavity (Fuss and McFadden, 1978, p.226-227).

[12] We choose alternatively the half-sided normal distribution or the exponential one.

[13] A deterministic frontier implies a one way error term which is the inefficiency. The gap to frontier is only due to inefficiency.

Since TE_i is an ouptut-oriented measure of technical efficiency, a measure of TE_i is:

$$TE_i = \frac{Prod_{obs}}{Prod_{max}} = \frac{f(X_i;\beta).e^{-U_i}.e^{V_i}}{f(X_i;\beta).e^{V_i}} = e^{-U_i} \tag{4}$$

The technical efficiency is, then, estimated using the stochastic frontier model given by the equations 3 and 4.

Thirdly, the production function is modelled using a transcendental logarithmic ("Translog") specification. The translog specification is preferred to a Cobb-Douglas form (Diewert, 1971) because of its flexibility implying no restrictions on coefficient's substitutability (factor substitutability is equal to one in a Cobb-Douglas case)[14].

The traditional translog specification used follows the general form[15] (Christensen et al., 1971):

$$ln(Y_i) = \beta_0 + \sum_{j=1}^{4}\beta_j ln(X_{ij}) + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4}\beta_{jk} ln(X_{ji}) ln(X_{ki}) - U_i + V_i \tag{5}$$

Where $i = 1, ..., N$ are the farmer unit observation; $j, k = 1, 2, ..., 4$ are the applied inputs; $ln(Y_i)$ is the logarithm of the output of the farmer i and $ln(X_{ij})$ is the logarithm of the jtm input applied of the ith individual; and β_j, β_{jk} are parameters to be estimated[16].

The final empirical model estimated in the translog case is

$$\begin{aligned} Output_{i,c} = \beta_0 + \beta_1.Labor_{i,c} + \beta_2.Land_{i,c} + \beta_3.Livestock_{i,c} + \beta_4.Purchased_{i,c} \\ +\beta_5.Labor_{i,c}^2 + ... + \beta_9.Labor_{i,c} * Land_{i,k} + ... + \lambda - U_{i,c} + V_{i,c} \end{aligned} \tag{6}$$

Which represents the relationship between output and inputs for the producer i in the county (municipality) c and where λ is a state fixed effect.

The output is an aggregated output variable of three categories: animal production (cattle, chickens,...), harvest production (soybean, corn, coffee...) and plant production (wood,...). It is the gross value of agricultural output (for more details see annex *B.1*)[17](Helfand, 2004).

[14] A likelihood ratio test (LR) was implemented in order to test the functional form of the production function. In all tests, restrictions can be rejected at a very low confidence level so that the translog specification can be preferred. Details available upon request.

[15] We use a negative sign in order to show that the term $-U_i$ represents the difference between the best efficient firm (on the frontier) and the observed firm.

[16] Similarity conditions are imposed i.e $\beta_{jk} = \beta_{kj}$. Moreover, production frontier requires monotonicity (first derivatives i.e elasticities between 0 and 1 with respect to all inputs) and concavity (second derivatives negatives). These assumptions should be checked *a posteriori* by using the estimated parameters for each data point.

[17] This is not the added value but the output because intermediary inputs are used in our model.

Four inputs are taken into account[18]. The variable *Labor* includes all the persons who work in the farm. There are both family and hired labor and all are measured in full-time equivalent unit. The input *Stock lives* is the stock of animals in cattle equivalents. *Land* represents the total area (in hectares) held by a farm. All kind of land were aggregated: crops, pasture, productive land that was not being used (fallow) but also land which was not used for agricultural issue (forest, woodland and useless land). As Helfand (2004), *Purchased* inputs are the expenditures of feed and medicine for animals, fertilizer, chemicals (such as pesticides and herbicides), seeds and fuel[19].

However, a survey data is used and there can be proximity effects implying a correlation between producers behaviours in a same area. Therefore, error terms are correlated so that standard errors and the analysis of the significance of coefficients are biased. To avoid this potential spatial correlation between farms, errors terms are bootstrapped (200 replications) (Wooldridge, 2002, p. 378-379).

3.3 A land use based deforestation model

The analysis of deforestation is done following the land conversion model of Chomitz and Gray (1996). The basic assumption of this model is that a farmer allocates his plot either to an agricultural activity or leave it uncleared i.e under forest[20].

In other words, the propensity to clear land i.e the proportion of deforested land (p) depends on the potential profits ($\pi(X)$) per hectare from converting the natural land to agricultural use. Potential profit depends on X, a vector of farm level explanatory variables.

A traditional structural form of this model is the tobit (Chomitz and Gray, 1996; Dolisca et al., 2007):

$$p^*_{i,c} = \alpha X_{i,c} + \vartheta_{i,c} \tag{7}$$

Where $p^*_{i,c}$ is the latent dependent variable of farmer i in the county c explained by $X_{i,c}$, a set of explanatory variables influencing the potential profit. $\alpha = (\alpha_1...\alpha_k)'$ is a vector of unknown parameters and $\vartheta_{i,c}$ is the error term. The dependent variable is latent i.e it cannot be observed for $p^*_{i,c} < 0$, so

[18]For more details, see descriptive statistics in table 4, page 26 and annex B for *Labor* and *Stock lives* inputs.

[19]The number of tractors (in equivalent 75 hp) had been introduced but removed given that it does not respect theoretical assumptions of monotonicity and concavity. However, results do not change with this input. Results available upon request.

[20]The use may be agricultural (annual or peri-annual harvest, livestock, fallow or planted forest) or natural (the land remains natural i.e natural forest or natural pasture).

we have,

$$p_{i,c} = 0 \quad if \quad p^*_{i,c} \leq 0$$
$$p_{i,c} = p^*_{i,c} \quad otherwise$$

where $p_{i,c}$ is the observed dependent variable.

In other words, farmers with unprofitable areas belong to the same group so that the observed dependant variable is censored at 0.

Finally, the estimated model is:

$$p_{i,c} = \alpha_0 + \alpha_1 TE_{i,c} + \alpha_3 TE^2_{i,c} + \alpha_4 Size_{i,c} + \alpha_2 X_{i,c} + \varepsilon_{i,c} \tag{8}$$

Where $p_{i,c}$ is the observed dependent variable defined by the agricultural land ratio of farmer i in the county c. This is a ratio between agricultural land use (crops, cattle, planted pasture, short fallow) and all land uses. A ratio equals to 1 involves that a farmer uses all his land for agriculture. TE is technical efficiency estimated from stochastic production frontier model. *Size* represents the average size of each individual farm in the representative farm. It is a coded variable defined in the table 2, page 25[21]. X regroups a set of covariates in four categories[22]: *land tenure* (owners (62 percent), sharecroppers (26 percent), renters (9 percent) and occupants (3 percent), see table 3, page 25 for more details), *output composition* (peri-annual crops, annual crops, plant production, animal,...), *public goods* (cooperative, financing, technical assistance and electricity) and the last category focuses on *technology* (artificial insemination, irrigation, soil conservation, ...). This last category allows to control for some credit and capital market imperfections.

The expected sign of the coefficient of efficiency is difficult to highlight. The literature often concludes that an intensive farm deforests less that an extensive one but in the Brazilian case, even an efficient farm can exploit the extensive margin before the intensive margin. In other words, a more efficient agricultural unit deforests more than a less efficient one. Hence, the sign of this coefficient can be positive. However, if the sign is negative (other things equal, including agricultural land), it is expected that increasing efficiency curtails deforestation. In other words, an inefficient farm would have an extensive production.

[21] I dropped all farms in the 16th code (only 0,02 percent of all farms) because these farms do not declare their size.
[22] For more details, see descriptive statistics in table 4, page 26.

However, the relationship between technical efficiency and deforestation may be non-linear and convex. Indeed, a poorly efficient farm compensates for these inefficiencies by increasing abundant factors, i.e land. However a more efficient farmer can use this efficiency to invest and acquire new land. The non-linear effect is introduced with the term TE_i^2 and α_3 represents the non-linear effect of the technical efficiency. A positive sign induces a convex effect and therefore a strong effect on deforestation both when efficiency (inefficiency) is low (high) and high (low). The relevant question is actually whether an efficient farmer with an intensive production will stop his expansion or accelerate deforestation (Angelsen and Kaimowitz, 2001) and so if he exploits extensive margins when there exist, before turning to intensive margins. This kind of situation can occur in the Brazilian case characterized by an open economy and an open access to land in which an increase in output productivity enhances agriculture expansion i.e deforestation Angelsen (1999).

α_4 measures the size effect which is expected to be negative. Indeed, a small farm can have a high discount rate involving a great agricultural land use[23]. Agricultural producers use the most abundant factor if they are constraint in the use of other factors (Boserup, 1965; Angelsen and Kaimowitz, 2001). Moreover, other interesting explanation of this negative effect can be found in the specific Brazilian context of land distribution. In BLA, a very important inequality in land distribution driven by a political scheme can explain this negative effect. Some authors (Pereira, 2003; Andersen et al., 2002) put forward this great heterogeneity in land distribution. In fact, large farmers can receive lands from the state without paying from them, then they receive fiscal incentives to produce, but they produce anything and they simply hold the land without paying from them (Pereira, 2003, p.56). In this context, small ones have to acquire land titles by developing the land, living on it, and cultivating it (Andersen et al., 2002, p.32).

However, there is an other important issue: *the abundance of land*. The idea is that farmers convert their forested plots because lands are very abundant and open accessed. Boserup (1965) emphasizes this idea to explain the drop in deforestation in Europe. County fixed-effects are introduced in order to control for the abundance of land. Moreover, transportation cost as well as climate features (precipitation levels) are controlled by these *municipios* fixed-effects.

[23] These farmers do not take into account the long term negative effect of an important land use on productivity.

4 Results

4.1 Technical efficiency estimation

The first part of the study concerns the econometric estimation of technical efficiency with a translog specification common to all farmers. In other words, the technology used and the technical relationship between inputs and output(s) are supposed to be the same for all farmers.

The maximum likelihood estimator is used to estimate technical efficiency with Stata 10 and the command *frontier*. We use two possible distributions for efficiency : a half-normal law (col.1 to 3 table 6, page 28) and an exponential law (col.4 to 6 table 6, page 28). Standard errors are corrected by bootstrapping (200 iterations). State fixed-effects are controlled with state dummies. The aim of this step is to estimate efficiency in order to use it in a second step. Therefore, technical efficiency has to be significant.

[see table 6, page 28 around here]

The first result is the significance of technical efficiency in all regressions. In other words, the model seems to be relevant to analyse and use technical efficiency as a regressor in the land use model. Indeed, if the estimated efficiency had not been significant in the stochastic frontier model, our specification would have been imperfect. Moreover, the share of efficiency ”half-normal” in the random deviation is more important than the share of efficiency ”exponential”. In order to deal with this heterogeneity, Spearman’s rank correlation coefficients are used. We want to determine if the choice between these distributions is important. The Spearman’s coefficient between efficiency estimated by a half-normal distribution and by an exponential one is 0.99 so that these two estimates of efficiency are very close. However, an analysis of descriptive statistics of efficiency reveals that the average is 0.56 with a half-normal distribution and 0.66 with an exponential distribution. This result suggests a substantial difference in means. Therefore, the choice of the distribution of efficiency can influence the results of the land use model. In order to choose between an half-normal distribution and an exponential one, we run two measures for comparing maximum likelihood models. These two measures are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). In all specifications (i.e with or without state dummies, bootstrapping or not), the exponential distribution is preferred to the half-normal one (see table 5, page 27)[24].

[24]These results hold in the Cobb-Douglas case. Details available upon request.

[see table 5, page 27 around here]

The second important step is to analyse the relevance of our model. Hence, we check the theoretical consistency of our estimated efficiency model by verifying that marginal products are positive and decreasing (monotonicity). In other words, if these theoretical criteria are jointly empirically validated, then the obtained efficiency estimates are consistent with microeconomic theory and can be used as determinant in the land use model.

As the coefficients of the translog functional form allow no direct interpretation[25] in the magnitude and significance of individual output elasticities, the latter were computed for all inputs at the sample mean (from coefficients of col.6). Brazilian agricultural production depend more strongly on purchased inputs (0.65) and labor (0.39). These findings suggest that efficiency gains are most likely with respect to purchased inputs and labor. The total contribution of production factors is more than 1 (1.02) implying increasing return to scale.

Finally, the model seems to be correctly specified because the returns to scale are positive (in all specifications) and the condition of monotonicity seems to be respected[26]. In other words, the production technology and the inputs used are relevant. Hence our specification seems to be good and we can suppose that the technical efficiency estimated is appropriated because this element is in fact the part not-explained by the model

4.2 Land use determinants

Two statistical problems linked to spatial correlation and generated regressors must be considered. Firstly, Deaton (1997) brings spatial correlation into light when survey data are used. Indeed, households in a single cluster (for example the county) live near one another, and are often interviewed at the same time (survey teams are often in one county at the same time). Moreover, farmers in a same county are engaged in the comparable agricultural activities because comparable soil qualities, pests or weather effects as well... Estimations are thus amenable to this spatial correlation: inefficient

[25]It is important to note that the coefficient estimated in the translog specification is not the input's elasticity and so the result cannot be easily interpreted as in the constant-elasticity Cobb-Douglas case. In others words, the elasticities of mean output with respect to the j^{th} input variable is calculated at the means of the log of the input variable and their second order coefficients as follows:

$$\frac{\delta lnY}{\delta X_j} = \beta_j + 2.\beta_{jj}\overline{lnX_j} + \Sigma^4_{j \neq k}\beta_{jk}\overline{lnX_k} \tag{9}$$

.

[26]However, at the mean sample, the marginal productivity of size is negative. This result does not validate the theoretical predictions but seems to be relevant. In fact, land is more a political or illegal attribute than an economic input in the brazilian case suggesting that it does not contribute normally to agricultural production.

estimation may be suspected. A clustering approach allows to consider that all farmers in the same county are spatially correlated. So, we deal with the similarity between people within the same cluster (municipality). In addition, county fixed effects are used.

For the second problem, the use of the estimated technical efficiency creates a potential generated regressor bias which could bias the estimate of the standard errors downward and so the estimation is not efficient. However, Pagan (1984) (theorem 7, page 233) show that estimates of the variance of residuals used like regressor (here technical efficiency) are correct[27]. In other words, the standard errors of technical efficiency are efficient and "*t-statistic* are "right".

[see table 7, page 29 around here]

The *first column* consider only a linear effect of technical efficiency which follows an exponential law in the first column[28]. Productivity has a positive and significant effect so that more efficient farms convert more natural plot into agricultural land[29]. The size has a negative and significant effect.

The second column does not consider county fixed-effects but introduces a **non-linear effect of efficiency**. *Efficiency*^{2} has a positive and significant coefficient at the one percent level and *Efficiency* is negative so that these results imply that there is a convex-effect of productivity on deforestation. Size effect does not change. A substantial result of this regression is that agricultural conversion is not driven by state fixed effects and so by natural areas surrounding farms. In other words, the proeminence of the stock of natural forested land does not condition the effect of productivity and farm size on agricultural expansion.

The third column is our preferred specification and considers a non-linear effect of efficiency. The results remain the same concerning the convex effect of efficiency and the negative effect of size. The quadratic term has a positive and significant coefficient at the one percent level i.e a convex effect of technical efficiency on deforestation. An increase of 1 percent of efficiency induces an increase of nearly 0,02 percent of the agricultural ratio[30]. Moreover, an increase of 10 percent of the

[27]Two conditions are necessary. The first one is that the residuals of the two equations are independent and the second is that the predicted variable in the first equation is not used (here the predicted output).

[28]To further test the robustness of my results, an another estimator was used: the quantile regression estimator. Standard errors are bootstrapped in order to avoid the spatial correlation problem. The convex-effect of productivity is robust to this change of estimator as well as the negative effect of farm size. Those results are not presented here but they are available upon request.

[29]Efficiency as well as efficiency^2 can be endogenous. To avoid this potential problem, we did some Spearman's rank correlation coefficients between efficiency and the residuals of each regression. In the majority cases efficiency (and so efficiency^2) is independent of the residuals (details available upon request).

[30]We have at the mean efficiency, $\frac{\delta ratio}{\delta efficiency} = \delta efficiency + 2 \times \delta efficiency^2 = -0,228 + 2 \times 0,186 \times \overline{efficiency} = 0,02$ where coefficients are elasticities.

mean efficiency (from 0.66 percent to 0.73 percent) implies an increase of nearly 0.86 percent of the agricultural ratio in the translog specification[31]. Further, the reversal point is obtained for an efficiency of 61 percent so that there is an optimal efficiency allowing to reduce deforestation[32]. Moreover, only 25 percent of farms have an efficiency lower than 61 percent. In other words, many farms are on the ascendant slope which implies actually that more efficiency induces more agricultural use of natural plot. Besides, farm size has a robust negative effect. In this specification, a one standard deviation average increase in farm size decreases dependent variable of 0,03.

In the *column four*, technical efficiency estimated from a half-normal law is introduced. The effect of size remains strongly negatively significant and the non-linear effect of efficiency remains positive and significant.

Finally, in all regressions, renters, sharecroppers and illegal occupants convert more natural land than owners. This result implies that property rights allow to reduce deforestation i.e an owner is more likely to implement more long term activities. Temporary crops and cattle activities (Caviglia-Harris, 2005) are the two main types of production to contribute to deforestation. Lastly, the cooperative and the funds received (Margulis, 2004) seems to reduce the agricultural pressure on natural land.

5 Conclusion

The aim of this paper is to assess the effect of farm productivity and farm size on deforestation using a census-tract-level data from the Censo Agropecuario 1995-96. This census allows us to analyse the behaviour of each farm present in Legal Amazon between 1995-1996. Besides, a two step approach is implemented to assess this link. The first one is to estimate the productivity with a stochastic production frontier model which allows to assess the technical efficiency of each ”representative farm”. In the second step, this estimated efficiency is introduced in a land use model in order to study determinants of deforestation at farm level data.

We find that productivity, approximated by an estimated technical efficiency, has a convex effect on deforestation. We can say that less and more efficient farms convert more natural plot into agricultural land. On the one hand, less efficient units can have some constraints on labour or credit market[33] and

[31] With coefficients of the column 3 of table 7, page 29 and after transformation in order to have elasticities, we have: $\Delta ratio = [1.068 - 0.228 \times 0.73 + 0.186 \times 0.73 \times 2] - [1.068 - 0.228 \times 0.66 + 0.186 \times 0.66 \times 2] = 0.01$ or an increase of 0.86 percent of the agricultural ratio.

[32] Around this level of efficiency, a marginal increase of efficiency does not increase agricultural expansion.

[33] Considering that we control for some technology and public good access, our results are mainly driven by imperfections

so cannot optimally use their factors (labour and capital). This kind of farms use the more abundant factor: the land. For those farmers, the input land is a substitute of others constrained inputs. On the other hand, the more efficient farms have no constraint. They can use labor and capital optimally and so can use more land. For efficient farmers, land is a complement input of labor and capital. Moreover, the reversal point is for an efficiency ranging from 61 percent but less than 25 percent of Brazilian farmers in Legal Amazon have a productivity lower than 61 percent in 1995. Hence, the majority of farms are on the ascendant slope. This result implies actually that Brazilian farmers convert more natural land into agricultural plot when their efficiency increases. This result can be explained by the poor environmental valorization of Brazilian tropical forest and the problem of open access to land which push farmers to exploit their extensive margins before their intensive ones (Angelsen, 1999).

We also uncover that a small farm converts more land than a large one. This result was expected. Indeed, a small farm has more constraints than a large one. These constraints can enforce small farms to use more land. However, since we control for the level of efficiency, these constraints can occur only on the size because the two farms have the same efficiency level. In fact, a small farmer can have a high discount rate so that he is induced to convert natural land (Boserup, 1965; Angelsen and Kaimowitz, 2001). The very heterogeneous context of land distribution in BLA (Pereira, 2003; Andersen et al., 2002) can explained this result. Small farmers have actually not the right political connections to acquire land so that they must cultivate their plots to acquire them[34].

To conclude, our results can be explained by the Brazilian context. A poor environmental valorization and a very important inequality in land distribution can conditioned our findings. In this sense, an important improvement would be to use the new census 2005-2006 of IBGE. It would be interesting to have a temporal dimension allowing us to use more information to test the role of environmental valorization of forest. The recent regional policy of development(*Avança Brasil*) can actually improve this valorization allowing efficient farmers to have an intensive production which respects environment.

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on labor market. However, some others imperfections on credit and capital markets can occur and explain our results.

[34]The Brazilian agrarian reform developed by the president Fernando Henrique Cardoso (1995-2002) starting from 1995-1996 can not be analysed with our results.

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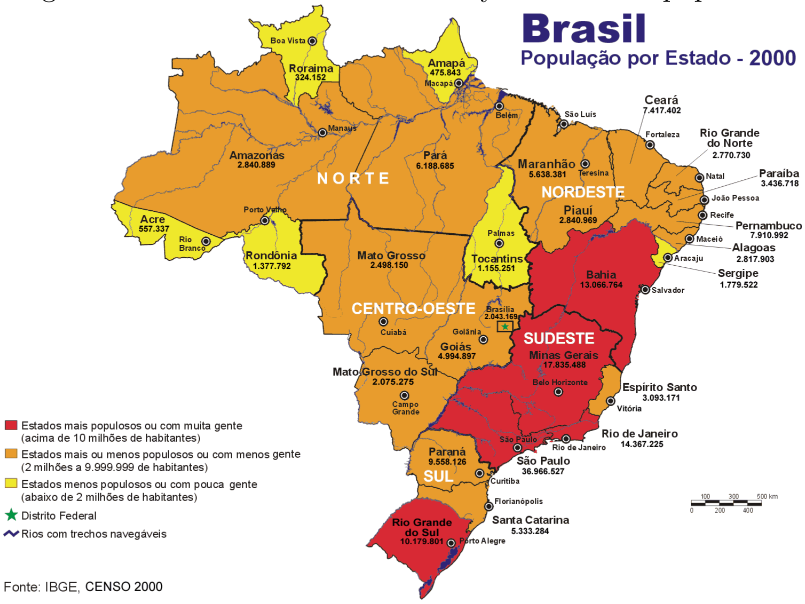
A Geographic maps

Figure 1: Brazilian states and density of Brazilian population



Source: IBGE

B Presentation of some variables

Output variable Output variable is defined by animal production, crop production and production of plants. Animal production value is an aggregate value of production of cattle, pigs, chickens, horses, sheep and goats and other animals. However, the value of the purchase of animals (cattle, pigs and chicken mainly) is deducted to reflect the fact that these animals can also be a source of inputs and not be recognized as a value produced.

85 % of of crop production is temporary (wheat, soybeans ,...) and 15% is permanent (coffee, bananas ,...). Finally, the production of plants includes the production of wood (forestry, 10 %), plants (horticulture, 12 %) and all productive plant extractions (78%). The output of each farm is represented in reais and transformed into logarithm.

Labor variable This variable includes all the persons who work in the farm. There are both family and hired labor and all are measured in full-time equivalent unit. We recorded a child under 14 years as half of an adult and a person in temporary employment as three quarters of a permanent worker.

Permanent employees over 14 years are recorded as an adult family member working all time in the farm. Finally, a child (under 14) working temporarily in the farm received a double weight and represents 38% (0.75*0.5) of a permanent worker. This variable is transformed into logarithm.

Cattle variable The stock of animals in cattle equivalents is used. We aggregated animals from their relative prices in Legal Amazon calculated from the database on the movements of purchases and sales of animals. The stock of each type of animal is weighted by the ratio between the price of a head (of a animal) and the price of a head of cattle. For example, 248.4 reais and 190.88 reais are respectively the price of a horse and the price of a cattle head. Therefore, the weighting factor is 0.77 for a horse (5.18: pigs, 209.76: chickens, 9.21: sheep and goats). Then, the stock of each animal is multiplied by its weighting factor and after each stock is added in order to have the input variable measuring the stock of animal in cattle equivalents (into logarithm).

C Descriptive statistics

Table 2: Size variable

Total area (hectare, ha)	Code	Total area (hectare, ha)	Code	Total area (hectare, ha)	Code
Less than 1 ha	1	Between 1 et 2	2	Between 2 et 5	3
Between 5 et 10	4	Between 10 et 20	5	Between 20 et 50	6
Between 50 et 100	7	Between 100 et 200	8	Between 200 et 500	9
Between 500 et 1000	10	Between 1000 et 2000	11	Between 2000 et 5000	12
Between 5000 et 10000	13	Between 10000 et 100000	14	More than 100000	15
Without notification	16				

Table 3: Descriptive Statistics of land tenure

Land tenure	Ratio			Size (code)			Output (reais)		
	Mean	Median	Stand. dev.	Mean	Median	Stand. dev.	Mean	Median	Stand. dev.
Owner	0.73	0.81	0.25	7.26	7	3.65	126 912	525 935	1 706 901
Renter	0.86	1	0.25	5.18	5	2.94	8 655	115 633	922 843
Sharecropper	0.82	1	0.27	4.78	4	2.86	4 547	37 970	120 615
Occupant	0.76	0.9	0.29	5.42	5	2.88	108 325	15 893	369 881

Table 4: Descriptive Statistics

Variables	Mean	Standard deviation	Median	Min	Max
Stochastic production frontier model					
Output (Reais)	321 856	1 318 644	42 847	1	61 815 322
Cattle (Nbr)	2 750	7 671	174	0	171 521
Labor (Nbr)	255	611	52	1	16 562
Surface (ha)	8 361	33 800	372	0.002	1 574 492
Purchased inputs (Reais)	62 436	500 142	2 518	0	27 417 804
Land use model					
Ratio	0.67	0.29	0.70	0	1
Size (coded variable)	6.24	3.46	6	1	15
Owners (=1)	0.52	0.50	1	0	1
Renters (=1)	0.13	0.34	0	0	1
Sharecropper (=1)	0.09	0.29	0	0	1
Occupant (=1)	0.26	0.44	0	0	1
Peri-annual crop (Reais)	151 491	1 139 290	8 200	0	61 048 403
Permanent crop (Reais)	26 475	127 743	1 027	0	5 287 537
Plant (Reais)	32 711	333 378	1 204	0	31 489 928
Cattle (Reais)	114 310	357 221	4 435	0	8 867 316
Hog and chicken (Reais)	21 184	177 456	1 706	-365 042	9 705 833
Other animals (Reais)	3 013	19 485	0	0	789 220
Financing (Reais)	25 623	241 833	0	0	1 108 2574
Dummy variables	Mean. part of farms if 1		Median	Min	Max
Cooperative (=1)	0.25		0	0	1
Tech. assist. (=1)	0.49		0	0	1
Electricity (=1)	0.60		1	0	1
Fertilizer (=1)	0.49		0	0	1
Pest and disease control (=1)	0.83		1	0	1
Soil conserv. (=1)	0.27		0	0	1
Insemination (=1)	0.78		1	0	1
Irrigation (=1)	0.17		0	0	1
Meca. force (=1)	0.46		0	0	1
Technical efficiency					
Distribution	Mean	Median	Standard deviation	Min	Max
Half-Normal	0.56	0.58	0.14	0.004	0.950
Exponential	0.66	0.70	0.15	0.0001	0.956

D Results

Table 5: Tests of Hypothesis on Distributional Form of Efficiency

Specification				Criteria		
Col. in table 6	State Dummy	Bootstrap.	Half or Exponent.	Likelihood	AIC	BIC
col.1	no	no	half	-17 547.3	35 140.6	35 314.4
col.2	no	yes	half	-17 547.3	35 140.6	35 314.4
col.3	yes	yes	half	-17 246.1	34 542.1	34 731.2
col.4	no	no	expo.	-17 125.7	34 297.3	34 471.2
col.5	no	yes	expo.	-17 125.7	34 297.3	34 471.2
col.6	yes	yes	expo.	**-16 735.4**	**33 532.9**	**33 767.3**

Table 6: Results with the Translog specification

Output	(1)	(2)	(3)	(4)	(5)	(6)
Cattle	0.1***	0.1***	0.127***	0.11***	0.11***	0.134***
	(0.014)	(0.021)	(0.017)	(0.014)	(0.023)	(0.019)
Labor	0.709***	0.709***	0.696***	0.683***	0.683***	0.672***
	(0.02)	(0.021)	(0.023)	(0.019)	(0.021)	(0.023)
Surface	0.18***	0.18***	0.165***	0.169***	0.169***	0.155***
	(0.015)	(0.019)	(0.02)	(0.014)	(0.023)	(0.02)
Purchas. inputs	-.004	-.004	-.010	-.004	-.004	-.009
	(0.01)	(0.013)	(0.013)	(0.009)	(0.011)	(0.011)
Cattle^2	0.06***	0.06***	0.057***	0.065***	0.065***	0.059***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.007)	(0.006)
Labor^2	0.087***	0.087***	0.085***	0.101***	0.101***	0.097***
	(0.007)	(0.008)	(0.007)	(0.006)	(0.007)	(0.007)
Surface^2	-.019***	-.019***	-.018***	-.016***	-.016***	-.015***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.006)	(0.006)
Purchas. inputs^2	0.082***	0.082***	0.085***	0.084***	0.084***	0.088***
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Cattle*Labor	-.100***	-.100***	-.076***	-.112***	-.112***	-.082***
	(0.008)	(0.011)	(0.011)	(0.008)	(0.012)	(0.009)
Cattle*Surface	-.021***	-.021**	-.021**	-.025***	-.025**	-.023***
	(0.006)	(0.009)	(0.009)	(0.006)	(0.01)	(0.009)
Cattle*Purchas. inputs	-.024***	-.024***	-.030***	-.024***	-.024***	-.031***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.006)	(0.005)
Labor*Surface	0.047***	0.047***	0.036***	0.051***	0.051***	0.038***
	(0.007)	(0.009)	(0.009)	(0.007)	(0.01)	(0.009)
Labor*Purchas. inputs	-.098***	-.098***	-.108***	-.103***	-.103***	-.115***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)
Surface*Purchas. inputs	-.013***	-.013**	-.009	-.013***	-.013**	-.009
	(0.004)	(0.005)	(0.006)	(0.004)	(0.006)	(0.006)
Constant	6.161***	6.161***	6.034***	6.027***	6.027***	5.899***
	(0.045)	(0.061)	(0.06)	(0.042)	(0.048)	(0.056)
Obs.	14201	14201	14201	14201	14201	14201
χ^2 statistic	86783.99	120499.8	123410.6	96915.27	143606.6	98098.48
Log-likelih.	-17583.57	-17583.57	-17246.06	-17158.9	-17158.9	-16768.81
Sig-u (TE.)	0.89	0.89	0.912	0.514	0.514	0.523
Sig-v (errors.)	0.647	0.647	0.612	0.638	0.638	0.606
$H_0 : sigma_u = 0$	470.201***	470.201***	599.259***	1319.54***	1319.54***	1553.772***
Low of distribution	half-normal	half-normal	half-normal	exponential	exponential	exponential
Bootstrap.	no	yes	yes	no	yes	yes
Dummy "State"	no	no	yes	no	no	yes

Standard errors bootstrapped (200 rep.); *** p$<$0.01, ** p$<$0.05, * p$<$0.1

Table 7: Results with efficiency estimated from a translog specification

Dep. var.: Agricultural land ratio	(1)	(2)	(3)	(4)
Efficiency	0.054***	-.197**	-.231***	-.209***
	(0.018)	(0.09)	(0.071)	(0.074)
Efficiency^2		0.247***	0.272***	0.285***
		(0.086)	(0.067)	(0.074)
Size	-.046***	-.052***	-.047***	-.047***
	(0.001)	(0.001)	(0.001)	(0.001)
Renter	0.078***	0.114***	0.076***	0.076***
	(0.009)	(0.009)	(0.009)	(0.009)
Sharecropper	0.064***	0.09***	0.062***	0.062***
	(0.01)	(0.011)	(0.01)	(0.01)
Occupant	0.009	0.016**	0.009	0.009
	(0.006)	(0.007)	(0.006)	(0.006)
Temporary crop	0.049***	0.052***	0.047***	0.047***
	(0.016)	(0.019)	(0.016)	(0.016)
Permanent crop	0.0009	-.044**	-.004	-.004
	(0.019)	(0.022)	(0.019)	(0.019)
Plant	-.144***	-.284***	-.150***	-.151***
	(0.022)	(0.03)	(0.022)	(0.022)
Hog-chicken	-.068***	-.076***	-.075***	-.075***
	(0.022)	(0.027)	(0.022)	(0.022)
Other animals	-.071	-.310***	-.074	-.074
	(0.055)	(0.062)	(0.054)	(0.054)
Cooperative	-.008	-.015*	-.007	-.006
	(0.005)	(0.008)	(0.005)	(0.005)
Tech. assist.	0.01*	-.014*	0.01*	0.01*
	(0.005)	(0.007)	(0.005)	(0.005)
Electricity	0.035***	0.058***	0.035***	0.035***
	(0.006)	(0.007)	(0.006)	(0.006)
Financing	-.002***	-.002**	-.002***	-.002***
	(0.0006)	(0.0008)	(0.0006)	(0.0006)
Fertilizer	0.012**	0.015*	0.013**	0.013**
	(0.006)	(0.008)	(0.006)	(0.006)
Pest control	0.022**	0.051***	0.021**	0.022**
	(0.009)	(0.01)	(0.009)	(0.009)
Soil conservat.	0.032***	0.048***	0.032***	0.032***
	(0.006)	(0.007)	(0.006)	(0.006)
Artif. insem.	-.057***	-.044***	-.056***	-.056***
	(0.008)	(0.009)	(0.008)	(0.008)
Irrigation	-.017***	-.004	-.017***	-.017***
	(0.005)	(0.007)	(0.005)	(0.005)
Mech. force	0.035***	0.059***	0.035***	0.035***
	(0.005)	(0.007)	(0.005)	(0.005)
Const.	0.997***	0.948***	1.070***	1.063***
	(0.019)	(0.033)	(0.027)	(0.026)
Obs.	14201	14201	14201	14201
Log likel.	3592.906	794.168	3609.739	3613.507
Dummy	County	No	County	County
Distr. law (Eff.)	exponential	exponential	exponential	half-normal

Robust standard errors reported in parentheses (cluster by county); *** $p<0.01$, ** $p<0.05$, * $p<0.1$