Ecological Fiscal Incentives and Spatial Strategic Interactions : the Case of the ICMS-E in Paraná

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Résumé

The ICMS-Ecológico is a fiscal transfer mechanism from states to municipalities, implemented in the early 1990's in Brazil, in order to reward municipalities for the creation and management of protected areas. This paper investigates the efficiency of this mechanism by testing for the presence of spatial interactions between Brazilian municipalities in their decision to create conservation units in the state of Paraná between 2000 and 2010. We analyze the behavior of municipalities through a land use model and test the highlighted mechanisms by estimating a spatial tobit model. Estimation results reveal strategic substitutability in municipalities conservation decisions.

Keywords : Spatial interactions, Fiscal federalism, Land use, Biodiversity, Brazil.

JEL codes : D73, Q23.

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1 Introduction

Development Policies implemented in Brazil from the late 60's to the mid 80's were considered as "very aggressive with little regard to the environment." However, the growing interest of the international community for environmental problems and the worsening of the economic situation in Brazil led to a change in this in the late 80's (Andersen et al. 2002). Indeed, several programs sprang up with the purpose of promoting sustainable development (see for example Feres & da Motta (2004) on water management). This change was of the utmost importance since Brazil is recognized as a major reserve of forests and biodiversity. Myers et al. (2000) point out that Brazil is estimated to host one-sixth of the endemic plant species of the Earth, to cite but just one example.

Among the programs developed to promote sustainable development, the ICMS-Ecologico or ICMS-E ("*Imposto sobre Circulacão de Mercadorias e Servicos - ecológico*" or "*Ecological value added tax*") is of particular interest. It is a fiscal transfer mechanism implemented in order to promote land conservation at the local level. It is not only designed for Amazonian states [1] but also aims at protecting Atlantic forests, threatened by fragmentation (see Brooks & Balmford (1996), Brooks et al. (1999) or Putz et al. (2011) for example).

The ICMS-E is an intergovernmental fiscal transfer from state to municipalities, used today in about half of the Brazilian states. It rewards municipalities for the creation of protected areas (namely conservation units, CUs) and watershed reserves. One reason for its implementation was the demand from municipalities hosting federal or state managed protected areas to be compensated for the opportunity cost of providing this public good. Yet it also aims to act as an incentive to create new protected areas managed at the municipal level.

Since its implementation in the early 90's, the ICMS-E is a real success in terms of CUs creation. In 2000, the areas under protection had already increased by 62.4% in the State of Minas Gerais and by 165% in the State of Paraná (May et al. 2002). Moreover, the mechanism has several interesting features. It is a decentralized system, which imply that decision-makers benefit from a better information, the mechanism is implemented without external source of financing (the funds redistributed are collected from goods and services tax in the concerned state) and at very low transaction cost [2]. This way, it has been claimed that the ICMS-E could be an alternative to other instruments such as pollution permits or pigovian taxes, notably

1. Such as *Avanca Brasil* for example (Andersen et al. 2002).

2. According to Vogel (1997), in 1995, in the state of Paraná, 30 million dollars were redistributed to the municipalities for an administrative cost of only 32 thousands dollars.

for the implementation of commitments in international environmental agreements (see Farley et al. (2010)).

Despite its attractiveness, very few studies have been carried out on the ICMS-E. Grieg-Gran (2000) analyzes which municipalities are better off with the ICMS-E reform. She finds mixed evidence. She points out that until 2000, only 60% of the municipalities of Rondonia and Minas Gerais with protected areas benefited from the introduction of the ICMS-Ecologico. Furthermore, May et al. (2002) provide some interesting state level statistics for the Paraná and Minas Gerais states as well as several inspiring case studies [3]. Finally, Ring (2008) highlights the appeal of the ICMS-E by providing a clear description of the mechanism along with trends and macro level statistics on the creation of CUs in the three states mentioned above.

However, although these three studies are informative and highlight the strengths of the ICMS-E, no one questioned the efficiency of the mechanism. Yet, the ICMS-E is a decentralized policy, and as stated by Oates & Portney (2003), the efficiency of a decentralized policy implies the absence of interactions between agents. However, as we will see in our theoretical part, there are several reasons for expecting municipalities to influence each other when deciding to create CUs or not and that there is a risk of a race to the bottom, i.e., competition between counties [4] to attract economic agents which leads to the setting-up of lax environmental standards.

Therefore, the aim of this paper is to investigate whether or not there are interactions between municipalities when they set the propensity of their lands under protection. We collected data on the ICMS-E for 399 municipalities of the state of Paraná from 2000 to 2010. This state constitutes a case of primary interest because it was the first to adopt the considered mechanism in 1991 and a pioneer in introducing a quality-weighting factor for the redistribution of the ICMS-E.

The contributions of this paper are diverse. We build a new database thanks to the reports released by the IAP (Instituto Ambiental do Paraná). We adapt a land-use model from Chomitz & Gray (1996) to the problematic of setting aside lands for protection and assess its validity through the bayesian spatial tobit estimator proposed by LeSage (1999), LeSage (2000) and LeSage & Pace (2009). The spatial Bayesian tobit model allows us to test the presence of interactions between municipalities in their conservation decisions. Negative spatial interactions between municipalities are found, suggesting that the profitability hypothesis applies and that conservation behavior are strategic substitutes.

3. They interviewed several mayors, asking them why they used the ICMS-E mechanism.

4. The terms county and municipality will be used indistinctively in the rest of the paper.

The paper is organized as follows. Section 2 discusses the context in which the ICMS-E was implemented in the Brazilian state of Paraná. Section 3 presents the theoretical model of land use and Section 4 the estimation strategy while we analyze our results in Section 5. Section 6 concludes with possible policy implications.

2 ICMS-E and conservation units in Paraná

2.1 Presentation of the ICMS-E

Brazil is a federal country with 27 states which capture most of their revenue from tax on the circulation of goods and services, i.e., a value-added tax (VAT), named the ICMS tax (*Imposto sobre Circulacão de Mercadorias e Servicos*). They have to return 25% of their revenue collected from sales taxes to municipalities following certain criteria. Three quarters of this redistribution is defined by the federal constitution (the main criterion is the added value created by each municipality), but the Article 158 of the Federal Constitution states that the remaining 25% (i.e., 6.75% of the total) is allocated according to each state's legislation (for instance based on population size or health expenditures).

In 1992, the state of Paraná (see the geographical map 1, page 24, on Brazilian states) was the first to introduce ecological criteria in the redistribution of the ICMS-E. The state rewards municipalities for having protected areas (biodiversity) and watershed reserves (water quality) within their boundaries[5]. The initiative was followed by several states[6] and this new fiscal incentive tool is now called ICMS-Ecológico.

In Paraná, the law implemented awarded 5% of ICMS revenue to municipalities in proportion to their protection of watersheds and conservation areas (also called "conservation units" (CUs)). Half of this (2.5%) is used to reward municipalities for the creation of CUs. These CUs can be publicly managed (federal, state or municipal level), privately owned or managed by public-private partnerships (such as *reserva particular do patrimônio natural*, RPPN). It is worthy noticing that municipalities have no obligation to create and improve protected areas, but are simply rewarded depending on the extent to which they meet the criteria in comparison with other municipalities. Also, since only a fixed pool of money is available in any given year, the

5. See May et al. (2002, P.175) for a more complete presentation of the law making process in Paraná.

6. 14 other Brazilian states have already introduced the ICMS-E, including São Paulo (1996), Minas Gerais (1996), Rondonia (1996), Amapá (1996), Rio Grande do Sul (1998), Mato Grosso (2001), Mato Grosso do Sul (2001), Pernambuco (2001), Tocantins (2002) (see the official website of the ICMS-E, http ://www.icmsecologico.org.br/, and Verssimo et al. (2002), Ring (2008)).

municipalities compete with each other to receive the money. The other half (2.5%) is for those municipalities that have watershed protection areas which partly or completely provide services for public drinking water systems in neighboring municipalities [7]. The main motivation of this fiscal redistribution policy was initially to compensate municipalities for the opportunity costs of conservation areas (often decided by the central level, i.e., the state) and for protecting watersheds. But this policy created significant incentives for the creation of new protected areas which, in turn, allow to increase the number and area of both state and municipal protected areas.

2.2 The Municipal Conservation Factor

A stated before, the Paraná state was the first to use environmental criteria to redistribute the ICMS. It was also pioneer in taking into account of the quality of the protected areas (Farley et al. 2010, May et al. 2002). The state redistribute the ICMS according to a Municipal Conservation Factor (MCF), which is derived from the ratio of CUs on total area weighted by a quality factor.

The MCF has thus two components : a quantitative component and a qualitative one. The former is the percentage of municipal land area under protection in the total area of the county. The latter evaluates the quality of the conservation unit on the basis of variables such as the biological and physical quality, the quality of water resources in and around the CUs, how important is the CU in the regional ecosystem, the quality of planning, implementation, maintenance and the legitimacy of the unit in the community. This factor reflect also the improvements over time of CUs and also their relationship with the surrounding community [8]. The quality of each CU is assessed by regional officers of the Environmental Institute of Paraná (Instituto Ambiental do Paraná, IAP). Their evaluation is then expressed as a score balancing the quantitative ratio [9].

The Municipal Conservation Factor of the municipality i is calculated as follows (this part

7. See for instance the case of the municipality of Piraquara which have 10% of its territory covered by protected areas for biodiversity conservation and the remaining 90% used for conserving a major watershed to supply the Curitiba metropolitan region (1.5 million inhabitants) with drinking water (May et al. 2002, Ring 2008).

8. For instance, the quality factor of a CU will increase if the county creates buffer zones around this area.

9. The quality index is also assessed by exceeding compliance with extant agreements with municipalities ; development of facilities ; supplementary analysis of municipal actions regarding housing and urban planning, agriculture, health, and sanitation ; support to producers and local communities ; and the number and amount of environmental penalties applied, within the municipality, by public authorities (May et al. 2002).

is adapted from Loureiro et al. (2008, p.22-23) and Ring (2008)).

First is the calculation of the Biodiversity conservation coefficient (BCC_{ji}) of each CU j in the municipality i as follows :

$$BCC_{ij} = \left(\frac{Area\ CU_j}{Area\ municipality_i} \right) * FC_n, \tag{1}$$

where $Area\ CU_j$ and $Area\ municipality_i$ are respectively the area of the conservation unit j and the area of the municipality i. Each BCC_{ij} is multiplied by a conservation factor FC_n which is variable and assigned to protected areas according to management category n (see the table 4 page 25 in appendix for more information of the weighting factor of each protected areas).

Then each BCC_{ij} is assigned an ESC criterion to take into account the variation of the quality as follows :

$$BCCQ_{ij} = [BCC_{ij} + (BCC_{ij} * ESC)], \tag{2}$$

where ESC is the variation of the quality of the CU weighted by the management strategy and the nature of the protected areas, i.e., municipal, state, federal.

Then the municipal conservation factor (MCF_i) is based on the sum of each $BCCQ_{ij}$ in the municipality i as follows :

$$MCF_i = \sum_{j=1}^{J} BCCQ_{ij}. \tag{3}$$

where J is the number of CU in the municipality i [10]. Finally the biodiversity conservation coefficient or ecological index EC_i of the municipality i is

$$EI_i = \frac{MCF_i}{SCF}, \tag{4}$$

where the state conservation factor SCF is given by the sum of all municipal conservation factors (MCF) in the state :

$$SCF = \sum_{i=1}^{Z} MCF_i, \tag{5}$$

where the Z the number of municipalities in the state which receives funds from the ICMS-E.

This part present therefore how the funds are redistributed in the ICMS-E. The next sub-section offer an overview of the evolution of parks created following the implementation of the ICMS-E.

10. For instance, Curitiba had 15 conservation units in 2000.

2.3 Evolution of conservation units in Paraná

A brief overview of the evolution of the number of counties in the ICMS-E for municipal CUs between 2000 and 2010 is given by the figure figure 4, page 27 in the appendix. There were 174 counties in the ICMS-E in 2000 compared to 192 in 2010, i.e., receiving funds for the presence of CUs in their territory. The number of counties in the fiscal mechanism has thus increased by 22, while 4 counties have decided to leave the mechanism (i.e., convert their parks for economic uses).

As stated before, in our analysis, we focus only on the creation of parks managed at the municipal level, since it is only at this level that the municipality has full power on the creation or destruction of park. Therefore, more precisely, as shown by figure 3 (in appendix, page 27), the number of counties which have received funds for the creation of municipal parks has increased by 9 counties between 2000 and 2010 (57 in 2000 compared to 66 in 2010) over the 399 counties in the dataset. In consequence, respectively 342 and 333 counties did not receive fiscal transfers from the ICMS-E for the creation of municipal CUs in 2000 and 2010. Moreover, it is worth noting that 4 counties no longer received funds from the ICMS-E, i.e., they converted municipal CUs for economic uses during the last decade, while 13 new counties received funds from ICMS-E for the creation of their first municipal CUs.

Finally, the figure 2 shows the evolution of the area of all CUs in hectare at the state level. It is found that the evolution of CUs can be divided into two periods. In the first decade, the creation of CUs increased sharply, while in the last decade (from 2000), the creation of CUs is found to increase more reasonably. From this, it can be assumed that the level of created CUs in the state of Paraná through the ICMS-E mechanism has reached a kind of stationary level. Of course, these figures concern all CUs, i.e., federal, state and municipal CUs and only the evolution of municipal CUs created, is relevant in our study. Unfortunately we do not have reliable data on the creation of municipal CU's before 2000. However, from our data between 2000-2010, it is found that the evolution of the number of municipal CUs follows the same trend than all CUs.

3 Conceptual framework

The ICMS-E implies that counties have to choose between the preservation of the natural areas and their conversion into other economic uses such as agriculture. In order to analyze the determinants of these choices, an economic land use model is developed (following Chomitz &

Gray (1996), Pfaff (1999), Chomitz & Thomas (2001), Arcand et al. (2008))[11]. The starting point is the dual nature of the model implying the simple assumption that each land is allocated between alternative uses to maximize returns. In this model, the profitability of each use is compared to made the decision concerning the land allocation. In particular, we try to identify how a county is influenced by neighboring counties. From this model, a county-level, land-allocation decision rule is derived which provides the econometric equation to be estimated.

3.1 Basic land-use model

Following Chomitz & Gray (1996) and Pfaff (1999), we assume that a county can choose their land allocation from a binary framework. It is assumed that the county can be defined as an economic agent which could decide the land use allocation of each of its plots. This way, this model differs from an aggregated plot-level decision rule model into a county-level model (Pfaff 1999).

At any point in time, a county will decide to allocate a plot of land between different land uses to maximize profit :

$$\max \pi_{ij}^{l} = P_{ij}^{l} Q_{ij}^{l}(I_{ij}^{l}) - R_{ij}^{l} I_{ij}^{l}, \tag{6}$$

where π_{ij}^{l} is the profit of the parcel i in the county j of a given land use l, P_{ij}^{l} are plot-level prices for the vector of feasible outputs from the given land use l, Q_{ij}^{l} is the vector of all outputs produced from the land use l, I_{ij}^{l} is the vector of inputs used in all types of production from the land use l, and R_{ij}^{l} are plot-level prices for the vector of inputs used.

Given the dual nature of the model, there are two possible land uses (protected, i.e., the creation of a municipal CUs, or unprotected, i.e., the conversion of a forested land). Optimal input choice yields to maximise π_{ij}^{l} and the county level decision rule regarding land use allocation is

$$\max_{l} V_{ij}^{l}, \tag{7}$$

where

$$\max_{l} V_{ij}^{l} = \max_{l|I} \pi_{ijt}^{l}. \tag{8}$$

Thus, the county decision concerns the choice of the land use to have the maximum profit from its land use. Put differently, the clearing decision will be in a static view : $Choose_{ij}^{l} =$

11. See also Kaimowitz & Angelsen (1998) for a review of models used to study deforestation and Nelson & Geoghegan (2002) for a review of the literature concerning the land use based deforestation model

$protected \qquad \text{if} : V_{ij}^{protected} > V_{ij}^{unprotected}$.

The municipality j will decide to preserve its plot i, i.e., create a CUs, only if the maximum profit generated from the conservation is higher than the maximum profit resulting from the conversion option.

This decision-rule based on the comparison of the maximum profit of each land use depends obviously on the prices of both inputs and outputs used in each land use. For instance, a decreasing price of the input used in the land use option *unprotected* leads to an increase of the profit associated with this land use. In this case, the county will be relatively better off if it decides to convert its natural land. Thereby, prices by influencing the magnitude of each profit have an impact on the decision rule which can be modelled as follows :

$$Choose_{ij}^{l} = protected \qquad \text{if } D_{ij}^{protected}(P_{ij}^{l}, R_{ij}^{l}) > 0,$$

where

$$D_{ij}^{protected}(P_{ij}^{l}, R_{ij}^{l}) = V_{ij}^{protected}(.) - V_{ij}^{unprotected}(.).$$

This representation of the land allocation decision-rule allows economic factors to be integrated into the explanation of land use through their links with both input and output prices.

3.2 Observed variables and spatial interactions

3.2.1 Observed economic factors

The land use decision-rule is thus determined by $P_{i,j}^{l}$ and $R_{i,j}^{l}$ which are plot-level output and input prices. Put differently, this is the differential between the prices of each land use option which will determine the land allocation. However, we cannot observe them directly so we use closed county-level variables. Thus, the solution will be to use proximate variables which affect the differential prices and so in turn the land allocation decision. In the case of P_{ij}, the best way to approximate output prices at plot-level will be to have them at county-level P_j. Unfortunately, we have none of these variables so local output demand variables are used such as the county population pop_j (as a scale measure of the potential local market for cleared economic activities), the share of industry in the total county's activities ind_j (as a measure of development projects), the share of agricultural activities in the total county's activities agr_j (as a measure of local agricultural food demand) and the income level in a county inc_j as a measure of the economic development. All of these variables are assumed to have an impact on the differential output prices in favor of an increase of the *unprotected* option. Moreover, the effect of the variable *income* (per capita) could be more ambiguous since richer counties could be better off preserving their forests for ornamental purposes. To test this idea, the quadratic term of *income* will be used. Thus, (1) poorer counties are assumed to be more inclined to do parks since their comparative advantages to proceed in *unprotected* activities are lower than richer counties, and (2) richer counties are also assumed to create more parks. The quadratic term $incsq_j$ is thus assumed to be negative, i.e., the income effect on the creation of parks is concave.

In the case, of $R_{i,j}$, local input supply variables are used such as the rural density (per km^2) rur_j (as a measure of the rural wage) and the urban density (per km^2) urb_j (as a measure of the urban wage). These two variables are found to be proxies variables impacting the differential input prices in favor of *unprotected* activities. Put differently, these variables have a negative effect on the propensity to create parks by strengthening the opportunity cost of the *protected* option.

Lastly, we assume that the area of other CUS (federal and state), named FED_j could have an impact on the land allocation decision-rule through the differential prices. Given that the area of a county is by definition fixed, more non-municipal CUs increases the scarcity of the land. In this context, the effect of the land allocation decision is ambiguous. Assume that the land scarcity increases the land price. This pushes the economic agent to not invest in this county since the cost for *unprotected* option goes up. The municipality knowing that can decide to protect the land and create a CUs to earn money from the ICMS-E. Alternatively, an increase in the land price could attract only the more efficient agents into the county pushing this latter to convert their forested land into potential productive land for agriculture and industry.

3.2.2 Spatial interactions

The aim of this work is to test for the presence of neighboring effects in the decision to create municipal CUs in a county. This issue is particularly relevant since the ICMS-E is a decentralized system, and as Oates & Portney (2003) state, one condition for decentralization to be optimal is the absence of interactions between agents. Testing the presence of interaction is therefore crucial to assess the efficiency of the mechanism.

The interactions between a county and its neighbors can evolve in two directions. On the one hand, the level of CUs in a county and one of its neighbors could be strategic complements. Indeed by decreasing its conservation index, the municipality offers firms and peasants an easier climate to make profits and to extend their activities. Moreover, a new firm could vote with its feet (Tiebout 1956) and choose the municipality where the environmental standards are lower to settle down. This way, a race to the bottom could be observed [12].

On the other hand, if we think in terms of the profitability of the two options, conservation and exploitation, we could expect conservation decisions to be strategic substitutes. The creation of new CUs by a county could have two effects. Firstly, since municipalities compete for a fixed pool of money, when a given municipality creates new CUs, it decreases the amount transferred by the state for each CUs, thus decreasing the profitability of the conservation option. Secondly, the creation of new CUs decreases the stock of lands available for economic production in a particular area. Then, it increases the value of plots available for economic production and then the profitability of the exploitation option. A municipality could therefore decide to increase its supply of land for economic agents (by decreasing its number of CUs), in order to attract peasants and firms when its neighbor is decreasing its supply. We could therefore expect protection decisions to be strategic substitutes.

From our theoretical framework, the land-allocation decision-rule for the plot i in the county j becomes :

$$D_{ij}^{unprotected}(Q_k^{protected}, FED_j, pop_j, ind_j, agr_j, inc_j, incsq_j, urb_j, rur_j). \tag{9}$$

where $Q_k^{protected}$ is the level of CUs in the neighboring county k which is assumed to influence the profitability of the *protected* and *unprotected* options.

A land use decision-rule such as equation 9 leads to the equation which will be estimated and presented in the following section 4.1.

4 Empirical strategy

4.1 Econometric model and data used

To estimate the presence of interactions between municipalities in their conservation decisions, we borrow the methodology used in the tax-competition and public spending literature (see for example Case et al. (1993), Brueckner (2003), Lockwood & Migali (2009) or Rota-Graziosi et al. (2010)). We estimate a Spatial AutoRegressive (SAR) model, where the spatially lagged endogenous variable is a weighted sum of neighbors' decisions, such as :

12. In practice, there is no means to distinguish between a race to the top and a race to the bottom, but only to find strategic complementarity between decisions. However, our theoretical analysis leads us to think that if decisions are effectively strategic complements, they will lead to a race to the bottom.

$$P^* = \rho W P^* + \beta X + \epsilon \tag{10}$$

where P^* is a $N \times 1$ vector of the propensity to create a municipal CUs by a county. N is the number of municipalities in the sample, here 399. X is a $M \times N$ matrix of our M explanatory variables influencing the differential potential profit between land use conversion and land conservation previously defined (pop, ind, agr, inc, $incsq$, rur, urb and FED) and β is a vector of their corresponding coefficients. ϵ is a $N \times 1$ vector of residuals. WP^* is a spatially lagged endogenous variable, where W is a $N \times N$ contiguity matrix of which each element w_{jk} takes the value of 1 if two counties share a common border, 0 otherwise (where j identifies a municipality different from municipality k). Hence, ρ capture the presence of interactions between municipalities.

The dependent variable is latent, i.e., cannot be observed for $p^* < 0$. Indeed, there is a large number of zero observations in our sample. In 2010, 342 municipalities over 399 do not create municipal CUs. It is hard to think that each municipality is in exactly the same situation. We can therefore argue that censoring is at stake and that there exist negative profits unmeasured by our dependent variable. Therefore, we have :

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

where $p_{j,t}$ is the observed dependent variable. Following Chomitz & Gray (1996), we account for this censoring using a tobit model, where the conditional distribution of $p_{j,t}$ given all other parameters is a truncated normal distribution, constructed by truncating distribution from the left at 0.

Finally, the following expanded form of the spatial autoregressive tobit models is :

$$\begin{aligned} p^*_{j,t_{2010}} &= \rho \sum_{j \neq k}^{J} w_{jk} p^*_{k,t} + \beta p_{j,t_{2000}} + \delta FED_{j,t_{2010}} + \alpha_1 pop_j + \alpha_2 ind_j + \alpha_3 agr_j + \alpha_4 inc_j \\ &+ \alpha_5 incsq_j + \alpha_6 urb_j + \alpha_7 rur_j + \alpha_8 Curitiba + \mu_r + \vartheta_{i,t_{2010}}, \end{aligned} \tag{11}$$

where the observed dependent variable, $p_{j,t_{2010}}$, is the MCF of municipal parks of county j in 2010 defined in section 2.2.

$p_{j,t_{2000}}$ represent the initial MCF in 2000. $FED_{j,t_{2010}}$ is MCF of other CUs (federal and state CUs) in the county i in 2010. pop_j, urb_j and rur_j are respectively the average annual population growth, urban density and rural density between 2000-2010. ind_j (agr_j) is the average ratio between the GDP of industrial (agricultural) activities and the total municipal GDP between 2000 and 2008. inc_j is the annual average GDP per capita between 2000 and 2008 and $incsq_j$, its squared equivalent. *Curitiba* is a dummy variable which takes a value of 1 for the capital of Paraná namely Curitiba and 0 otherwise to control for the strong differences of this county compared to the others. μ_r is a micro-region dummy representing a legally defined administrative area consisting of groups of municipalities bordering urban areas. This dummy allows to ckeck for unobserved fixed effects shared by same neighboring counties. In the state of Paraná, 39 micro-regions are censused for 399 counties.

Data concerning CUs ($p_{j,t_{2010}}$, $p_{j,t_{2000}}$ and $FED_{j,t_{2010}}$) are taken from the ICMS-E official website [13]. All other variables come from the IPEA DATABASE [14] (see table 5 page 28 in appendix for more information on descriptive statistics).

4.2 Estimator

The estimation of parameters from spatial autoregressive tobit model represent a computational challenge and cannot be done via analytic methods, such as maximum likelihood. Therefore we rely on the bayesian approach developed by LeSage (1999), LeSage (2000), LeSage & Pace (2009) and applied by Autant-Bernard & LeSage (2011).

In this approach, the unobserved negative profits associated with the censored 0 observations are considered as parameters to estimate. The model is estimated via MCMC (Monte Carlo Markov Chain) estimation procedure. The procedure uses the Geweke m-steps Gibbs sampler to produce draws from a multivariate truncated normal distribution in order to generate the unobserved negative utilities associated with the censored 0 observations [15] [16].

4.3 Interpretation of the coefficients estimated

Coefficients from a SAR model cannot be interpreted directly. Indeed there is an implicit form behind the model presented in equation 10. It can be rewritten as :

13. Data downloadable on this website http ://www.icmsecologico.org.br/.
14. Data downloadable on this website http ://www.ipeadata.gov.br/.
15. The m-steps correspond to the number of draws. Following LeSage & Pace (2009), considering our sample size(N=399), we choose m=10 even if could be relatively computationally challenging.
16. In addition, to produce estimates that will be robust in the presence of non-constant variance of disturbances (heteroscedasticity) and outliers, it is assumed that, in the development of the Gibbs sampler, the hyperparameter r that determines the extent to which the disturbances take on a leptokurtic character is stated at 4 as suggested by LeSage (1999).

$$P^* - \rho W P^* = \beta X + \epsilon \tag{12}$$

$$P^*(I_N - \rho W) = \beta X + \epsilon \tag{13}$$

$$P^* = (I_N - \rho W)^{-1}\beta X + (I_N - \rho W)^{-1}\epsilon \tag{14}$$

As we can see from equation 14, $\frac{\partial p^*}{\partial x'} \neq \beta$, but $\frac{\partial p^*}{\partial x'} = (I_N - \rho W)^{-1}\beta$. This occurs because of the spillovers generated by the decisions of neighboring counties. To interpret the coefficients of a spatial model, the researcher has to calculate the direct impact of a variable, its indirect impact and the total impact (equal to the direct impact plus the indirect one). Indeed, a change on an explanatory variable in a particular region will affect the p^* value of this region (direct impact), but also the other regions because of the spatial spillovers (the indirect impact). Computation details of these impacts are clearly described in (LeSage & Pace 2009, p.33-39).

5 Results

5.1 Neighboring effects and created CUs

We estimated the influence of neighbors decision as well as several economic indicators on the propensity of creating parks by a municipality. The Biodiversity Conservation coefficient used by the state of Paraná to redistribute the ICMS-E is used as dependent variable. In all regressions, the contiguity spatial weight matrix is used to represent the prior strength between two counties. Our results come from the estimation of a baysesian spatial tobit model using 1 step in the gibbs sampler and 1000 draws in the MCMC procedure [17]. Our main results are presented in table 1, where the first column present the value of the coefficients (β), the second colmun the value of the direct impact of the explanatory variable, the third column the indirect impact and the fourth the total impact.

17. With 10% of the draws used as burn-in.

Table 1 – Spatial interactions and MCF

	Dependent variable : MCF 2010			
n=1000, m=1				
Variable	Coefficient	*Direct*	*Indirect*	*Total*
ρ	-0.007961**			
	(0.015)			
MCF2000	2.147355***	2.159819***	-0.017943**	2.141876***
	(0.000)	(0.000)	(0.036)	(0.000)
FED2010	0.046348	0.04671	-0.000395	0.046315
	(0.408)	(0.417)	(0.502)	(0.417)
pop	-0.000087	-0.000099	0.000001	-0.000098
	(0.732)	(0.718)	(0.724)	(0.718)
agr	-0.120156***	-0.121699***	0.001038*	-0.120661***
	(0.000)	(0.000)	(0.071)	(0.000)
ind	-0.045715	-0.046228	0.0004	-0.045827
	(0.130)	(0.129)	(0.273)	(0.129)
inc	0.007792	0.007482	-0.000067	0.007415
	(0.763)	(0.773)	(0.790)	(0.773)
incsq	-0.002343	-0.00224	0.00002	-0.00222
	(0.699)	(0.714)	(0.744)	(0.714)
rur	-0.000506	-0.000507	0.000004	-0.000503
	(0.193)	(0.212)	(0.317)	(0.212)
urb	-0.000005	-0.000005	-0.000000	-0.000005
	(0.738)	(0.725)	(0.739)	(0.725)
Curitiba	-0.22267***	-0.223891***	0.001851*	-0.22204***
	(0.004)	(0.004)	(0.080)	(0.004)
intercept	-0.033999			
	(0.277)			

*Notes : ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients are in parentheses. n correspond to the number of draws and m to the number of steps in the gibbs sampler. We allow for heteroscedasticity in the error terms by setting the value of the hyperparameter r to 4.*

Negative spatial interactions between counties are found ($\rho < 0$) suggesting that a county is more inclined to create municipal CUs if their neighboring counties decrease the number of their CUs. This way, this result points out that the hypothesis of profitability, predicted by the theoretical model, seems to be at stake in the choice of creating municipal CUs in the state of Paraná between 2000 and 2010. This way, it is more profitable for a county to convert its natural land for agricultural or industrial activities if their neighboring counties have preferred to create CUs and be awarded by the ICMS-E. The design of the ICMS-E is an explanation of these behaviors since the pool of money is fixed, thus leading a county to not be incited to enter into the mechanism and so to be more inclined to convert its natural land for economic purposes. This result is linked to the descriptive statistics proposed in section 2.3 and could explain the stable trend in the creation of municipal CUs in the last decade after a strong upward trend in the first years of the implementation of the ICMS-E. Concerning the other economic factors assumed to have an effect on the land allocation rule-decision of a county (through their effects on the differential profit between land uses option), the population variables have the expected negative coefficient but are not significant. Moreover, the structure of the county's economy is found to be important to explain the propensity to create municipal CUs. In fact, the more the share of agriculture is important in the municipal activities, the less the propensity to create municipal CUs. This result points out the role of economic activities in the propensity to create CUs. More developed counties in terms of agricultural activities can be more encouraged to develop their activities to earn money from the ICMS which awards counties on the basis of their created value added. Besides, the Table 2 provides the estimated direct, indirect and total effects of each explanatory variable. Recall that direct impact can be interpreted as a marginal impact, the indirect one as a spatial spillover effect and total one as a summary measure of the total impact associated with changes in each explanatory variable. All significant effects previously presented (for population growth and the weight of agriculture and industry) are found to be mainly direct effects. However, we observe indirect effect effect of lower magnitude and of the opposite sign, which is due to the substitutable nature of conservation decisions.

5.2 Robustness checks

5.2.1 Taking only account of the size of protected areas

As our first robustness check, we use a different measure of the environmental performance of a county. Indeed, the Municipal Conservation Factor used to redistribute the ICMS-E is equal to the ratio of protected areas on total area of a county, weighed by a measure of the intensivity of the protection, the "quality factor". We choose to use only the ratio of protected areas on total land - the quantity tatio - as dependent variable. This will allow us to check the robustness of our first result (the substitutability in conservation decisions) and to see is the driving forces tested influence the way a country choose to improve its protection of land (i.e., in an intensive or extensive manner). Table 2 presents results for the quantity ratio as dependent variable.

Table 2 – Spatial interactions and CUs ratio

	Dependent variable : CUs ratio in 2010			
n=1000, m=1				
Variable	Coefficient	*Direct*	*Indirect*	*Total*
ρ	-0.015591**			
	(0.049)			
ratiom2000	2.496689***	2.50393***	-0.042608*	2.461322***
	(0.000)	(0.000)	(0.055)	(0.000)
ratioFED2010	0.002393	0.001981	-0.000046	0.001935
	(0.917)	(0.930)	(0.920)	(0.931)
pop	-0.000238	-0.000225	0.000004	-0.000221
	(0.424)	(0.448)	(0.532)	(0.447)
agr	-0.158445***	-0.157292***	0.002696*	-0.154596***
	(0.000)	(0.000)	(0.080)	(0.000)
ind	-0.06142**	-0.059479**	0.001014	-0.058464**
	(0.039)	(0.049)	(0.204)	(0.049)
inc	-0.00736	-0.009311	0.000168	-0.009144
	(0.781)	(0.730)	(0.743)	(0.731)
incsq	0.002291	0.002695	-0.00005	0.002646
	(0.720)	(0.676)	(0.686)	(0.677)
rur	-0.000265	-0.000301	0.000004	-0.000296
	(0.448)	(0.417)	(0.510)	(0.417)
urb	-0.00015***	-0.00015***	0.000003*	-0.000148***
	(0.000)	(0.000)	(0.065)	(0.000)
Curitiba	0.269058***	0.269791***	-0.004644*	0.265147***
	(0.000)	(0.000)	(0.089)	(0.000)
intercept	0.033778			
	(0.310)			

*Notes : ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients are in parentheses. n correspond to the number of draws and m to the number of steps in the gibbs sampler. We allow for heteroscedasticity in the error terms by setting the value of the hyperparameter r to 4.*

Negative spatial interactions between counties are also found thus confirming the negative effects of neighboring counties on the propensity to create CUs for a county. Concerning the other economic factors, the negative effects of agricultural is still found suggesting that counties whom the economy is more base on agriculture are less prone to increase their level of CUs. Finally, the density of urban population is now a factor which threat protection. It is worthy to notice that this factor have an effect on the extensive component of protection, but no longer when it is weighed by the intensivity of the protection. Concerning the indirect effects (spatial externalities), two variables have a significant effect. First is the negative initial level of quality (in 2000) suggesting that the more was the initial level of neighbors, the less the propensity for the county to increase the quality of its CUs. The second significant indirect impact is the positive effect of agriculture. Thus, the greater the weight of agriculture in the neighbors of a municipality, the greater the propensity to create CUs in this county.

5.2.2 Checking the consistency of the estimator

Since the bayesian spatial tobit is a new estimator and that few researcher have used it, we provide several robustness tests on the estimator itself. Indeed, to our knowledge, it have been proposed in the article of LeSage (2000) and the manuals of LeSage (1999) and LeSage & Pace (2009), but to the best of our knowledge, have only been applied in Autant-Bernard & LeSage (2011).

The following regressions are run with different number of m-steps ($m = 1$, $m = 10$ or $m = 20$) of the Gibbs sampler process and different number of draws (n=1,000 ; 10,000). Robustness tests are made on the estimation procedure since the main computational challenge using a Bayesian framework is the state of some parameters such as the number of draws or the number of m-step used in the computation of the estimated negative utilities for the censored observations of the dependent variable (LeSage & Pace 2009).

The first robustness check on the number of steps in the Gibbs sampler process, aims at testing the accuracy of the computed vector of parameters which replaces the unobserved latent utility (here for $p^*_{j,t} < 0$) (LeSage & Pace 2009, p.287).

The second test consists in increasing the number of draws and comparing the inferences based on a smaller set of draws (here n=1,000) to those resulting from a larger set of draws (here n=10,000) in order to evaluate the stability in the parameter values found. The basic assumption is that if the inferences are identical, then the estimator can be assumed to be consistent.

Tables 3 provide results with the MCF coefficients as dependent variable for respectively 1, 10 and 20 steps of the Gibbs sampler process, with 1,000 and 10,000 draws . The spatial interactions are still found to be negative and significant as are the urban density, the agricultural ratio and the industrial one. The level of created CUs in 2000 is found to have a significant and negative indirect effect suggesting the presence of negative neighboring effects on the propensity to create CUs. Also, urban density is now found to have a significant positive indirect effect. This reinforces the role of urban density in the decision to create CUs. If the neighbor of a county has a strong urban density, the propensity to create CUs in this county will be stronger since this county could expect that its neighbor is not inclined to create CUs.

TABLE 3 – Consistency tests

	Dependent variable : MCF 2010					
m=	1		10		20	
n=	1000	10000	1000	10000	1000	10000
Variable						
ρ	-0.007961**	-0.005395**	-0.0093**	-0.00786**	-0.009105***	-0.00481*
	(0.015)	(0.014)	(0.018)	(0.029)	(0.001)	(0.075)
MCF2000	2.147355***	2.083261***	2.0062***	2.03212***	2.035416***	2.095744***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FED2010	0.046348	0.048372	0.0476	0.049377	0.040812	0.042334
	(0.408)	(0.361)	(0.299)	(0.332)	(0.408)	(0.418)
pop	-0.000087	-0.000195	-0.000000	-0.000111	-0.000000	-0.000122
	(0.732)	(0.435)	(0.827)	(0.652)	(0.999)	(0.623)
agr	-0.120156***	-0.120498***	-0.0978***	-0.110865***	-0.103823***	-0.112345***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ind	-0.045715	-0.047154	-0.0404	-0.044297	-0.047554*	-0.043165
	(0.130)	(0.101)	(0.106)	(0.106)	(0.068)	(0.127)
inc	0.007792	0.009978	0.0067	0.009938	0.012694	0.009026
	(0.763)	(0.711)	(0.776)	(0.697)	(0.593)	(0.723)
incsq	-0.002343	-0.00256	-0.0023	-0.002748	-0.003612	-0.002489
	(0.699)	(0.681)	(0.675)	(0.646)	(0.517)	(0.680)
rur	-0.000506	-0.00033	-0.0005	-0.000368	-0.000469	-0.000372
	(0.193)	(0.310)	(0.210)	(0.279)	(0.174)	(0.305)
urb	-0.000005	-0.000005	-0.000000	-0.000005	-0.000006	-0.000005
	(0.738)	(0.697)	(0.686)	(0.714)	(0.626)	(0.709)
Curitiba	-0.22267***	-0.208601***	-0.2005***	-0.20258***	-0.200199***	-0.211293***
	(0.004)	(0.005)	(0.001)	(0.003)	(0.002)	(0.004)
intercept	-0.033999	-0.028195	-0.0258	-0.036568	-0.029702	-0.028634
	(0.277)	(0.424)	(0.373)	(0.266)	(0.360)	(0.395)

*Notes : ***=significant at the 1 percent level, **=significant at the 5 percent level, *=significant at the 10 percent level. p-values associated to the reported coefficients are in parentheses. n correspond to the number of draws and m to the number of steps in the gibbs sampler. We allow for heteroscedasticity in the error terms by setting the value of the hyperparameter r to 4.*

6 Conclusion

The aim of this paper was to assess the efficiency of the ICMS-E by testing the presence of strategic interactions between Brazilian counties in the state of Paraná. It is a fiscal transfer from the state to municipalities on the basis of the performance of each county in the creation and management of CUs. This way, the ICMS-E can be viewed as a Payment for Environmental Services (PES).

This fiscal scheme is important since it is a form of PES which can be implemented without external source of financing and at very low transaction costs. However, since the system is decentralized, its efficiency could be threatened by the presence of interactions between municipalities when they decide to set their lands aside for protection.

Therefore, this study tries to investigate if the behavior of neighboring counties in terms of created municipal CUs has an effect on the propensity for a county to create municipal CUs between 2000 and 2010 in the state of Paraná. The choice of the time-span analysis is motivated by the availability of data but is interesting due to the fact that, in this period, the level of created CUs seems to have reached a stationary level after a strong upward trend in the first decade of the implementation of the ICMS-E (1992-2000).

From a land use model and a spatial autoregressive Bayesian tobit model, the results suggest the presence of negative spatial interactions between counties. These negative spatial externalities can be explained by the hypothesis of profitability which states that the county will choose the use which maximizes its profit. In our case a municipality will prefer to develop economic activities, to attract peasants and firms from a neighbor who have decided to create CUs. The fact that in the ICMS-E a fixed pool of money is shared between counties explain and strengthen this effect.

The results do not highlight a race to the bottom between counties which would have finally questioned the efficiency of the ICMS-E. However, we observe strategic substitutability between conservation decisions which seems to lead the mechanism to reach an equilibrium. In a way, the mechanism seems to be efficient, because this result suggests that the behavior of municipalities is driven by an optimization process and that they integrate the decision of their neighbors in their calculus.

However, remark that there is no reason for the shared pool of money to lead to the optimal level of land set aside for protection. Moreover, it seems that municipalities do not intend to provide a public good but are more subject to a profitability calculus. This way, the design of the ICMS-E, via the definition of the quality weighting factor, seems crucial.

To conclude, the ICMS-E has had great success and has allowed to increase the number of CUs in Paraná. This experience should be viewed as a new and interesting tool to finance local public good without external funding, but being aware of the potential negative spatial interactions which can occur.

Références

Andersen, L. E., Granger, C. W. J., Reis, E. J., Weinhold, D. & Wunder, S. (2002), *The dynamics of deforestation and economic growth in the brazilian amazon*, Cambridge University Press.

Arcand, J.-L., Guillaumont, P. & Jeanneney-Guillaumont, S. (2008), 'Deforestation and the real exchange rate', *Journal of Development Economics* **86**(2), 242–262.

Autant-Bernard, C. & LeSage, J. P. (2011), 'Quantifying knowledge spillovers using spatial econometric models', *Journal of Regional Science* **51**(3), 471–496.

Brooks, T. & Balmford, A. (1996), 'Atlantic forest extinctions', *Nature* **380**(6570), 115.

Brooks, T., Tobias, J. & Balmford, A. (1999), 'Deforestation and bird extinctions in the atlantic forest', *Animal Conservation* **2**(3), 211–222.

Brueckner, J. (2003), 'Strategic interaction among governments : an overview of empirical studies', *International regional science review* **26**, 175–188.

Case, A. C., Rosen, H. S. & Hines, J. J. (1993), 'Budget spillovers and fiscal policy interdependence : Evidence from the States', *Journal of Public Economics* **52**(3), 285–307.

Chomitz, K. M. & Gray, D. A. (1996), 'Roads, land use, and deforestation : A spatial model applied to belize', *The World Bank Economic Review* **10**, 487–512.

Chomitz, K. M. & Thomas, T. S. (2001), 'Geographic patterns of land use and land intensity in the brazilian amazon', *World Bank Policy Research Working Paper* **No. 2687**.

Farley, J., Aquino, A., Daniels, A., Moulaert, A., Lee, D. & Krause, A. (2010), 'Global mechanisms for sustaining and enhancing pes schemes', *Ecological Economics* **69**(11), 2075–2084.

Feres, J. G. & da Motta, R. S. (2004), Country case : Brazil, *in* R. S. da Motta, ed., 'Economic instruments for water management : the cases of France, Mexico, and Brazil', Edward Elgar Publishing, pp. 97–133.

Grieg-Gran, M. (2000), ‘Fiscal incentives for biodiversity conservation : The icms ecologico in brazil’, *Discussion Papers IIED* (00-01).

Kaimowitz, D. & Angelsen, A. (1998), *Economic models of tropical deforestation : a review*, Cifor.

LeSage, J. (1999), *The theory and practice of spatial econometrics.*, 1 edn, Online Manuel.

LeSage, J. P. (2000), ‘Bayesian estimation of limited dependent variable spatial autoregressive models’, *Geographical Analysis* **32**(1), 19–35.

LeSage, J. & Pace, R. K. (2009), *Introduction to Spatial Econometrics (Statistics : A Series of Textbooks and Monographs)*, 1 edn, Chapman and Hall/CRC.

Lockwood, B. & Migali, G. (2009), ‘Did the single market cause competition in excise taxes ? evidence from EU countries’, *Economic Journal* **119**(536), 406–429.

Loureiro, W., Pinto, M. A. & Joslin Motta, M. n. (2008), ‘Legislao atualizada do icms ecolgico por biodiversidade’, *Governo do Paraná* .

May, P. H., Neto, F. V., Denardin, V. & Loureiro, W. (2002), *Selling Forest Environmental Services : Market-based Mechanisms for Conservation and Development*, Earthscan Publications, chapter Using fiscal instruments to encourage conservation : Municipal responses to the ecologicalvalue-added tax in Paraná and Minas Gerais, Brazil, pp. 173–199.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. & Kent, J. (2000), ‘Biodiversity hotspots for conservation priorities.’, *Nature* **403**(6772), 853–858.

Nelson, G. & Geoghegan, J. (2002), ‘Deforestation and land use change : sparse data environments’, *Agricultural Economics* **27**, 201–216.

Oates, W. & Portney, P. (2003), *Handbook of environmental economics*, Vol. 1, chapter The political economy of environmental policy, pp. 325–354.

Pfaff, A. S. (1999), ‘What drives deforestation in the brazilian amazon ? evidence from satellite and socioeconomic data’, *Journal of Environmental Economics and Management* **37**(1), 26–43.

Putz, S., Groeneveld, J., Alves, L., Metzger, J. & Huth, A. (2011), ‘Fragmentation drives tropical forest fragments to early successional states : A modelling study for brazilian atlantic forests’, *Ecological Modelling* **222**(12), 1986 – 1997.

Ring, I. (2008), ‘Integrating local ecological services into intergovernmental fiscal transfers : the case of the ecological icms in brazil’, *Land Use Policy* **25**(4), 485–497.

Rota-Graziosi, G., Caldeira, E. & Foucault, M. (2010), ‘Decentralization in africa and the nature of local governments’ competition : evidence from benin’, *CERDI-Working Paper* (2010.19).

Tiebout, C. M. (1956), ‘A pure theory of local expenditures’, *Journal of Political Economy* **64**, 416.

Verssimo, A., Le Boulluec Alves, Y., Pantoja da Costa, M., Riccio de Carvalho, C., Born, G. C., Talocchi, S. & Born, R. H. (2002), Payment for environmental services : Brazil, Technical report, Fundacin PRISMA.

Vogel, J. H. (1997), ‘The successful use of economic instruments to foster sustainable use of biodiversity : six case studies from latin america and the caribbean’, *Biopolicy* **2**.

7 Appendix

7.1 Paraná in Brazil

Figure 1 – Paraná in Brazil

Source : Encyclopaedia Britannica

7.2 Calculation of the ICMS-E : the conservation factor

TABLE 4 – Conservation factor FC_n for different management categories n of protected areas in Paraná

Management category	Federal	State	Municipal
Ecological research station	0.8	0.8	1
Biological reserve	0.8	0.8	1
Parks	0.7	0.7	0.9
Private natural heritage reserve (RPPN)	0.68	0.68	.
Area of relevant ecological interest	0.66	0.66	0.66
Forest	0.64	0.64	0.64
Indigenous area	0.45	.	.
Buffer zones (*Faxinais*)	.	0.45	.
Environmental protection area	0.08	0.08	0.08
Special, local areas of tourist interest	0.08	0.08	0.08

Source : Adapted from (Loureiro et al. 2008, p.73). A point (.) mentions that there is none CU of this nature. For instance, there is none municipal or state indigenous area.

7.3 Creation of CUs over time

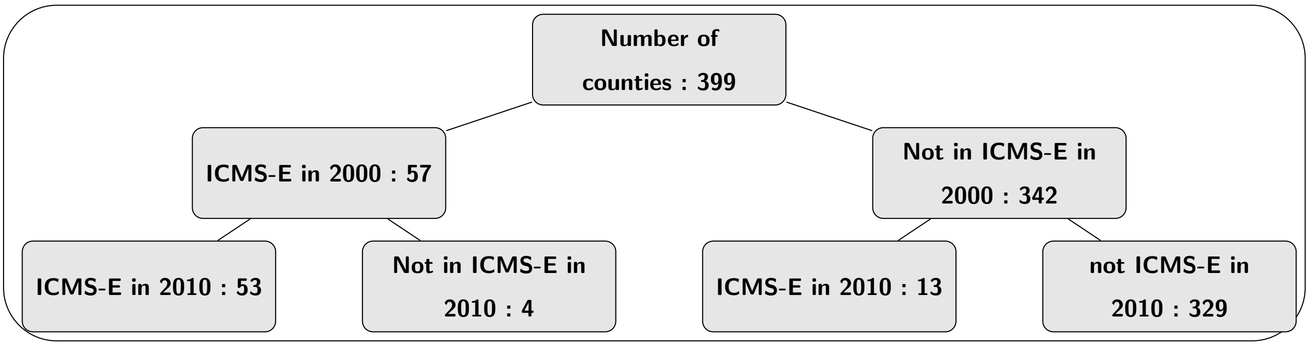
FIGURE 2 – Evolution of the creation of all CUs in Paraná between 1991 and 2010

Note : Evolution of the areas (in hectare) of all conservation units (federal, state and municipal) between 2000 and 2010.

Source : Authors' calculation from May et al. (2002) and Grieg-Gran (2000), and authors' collected data.

7.4 Descriptive statistics

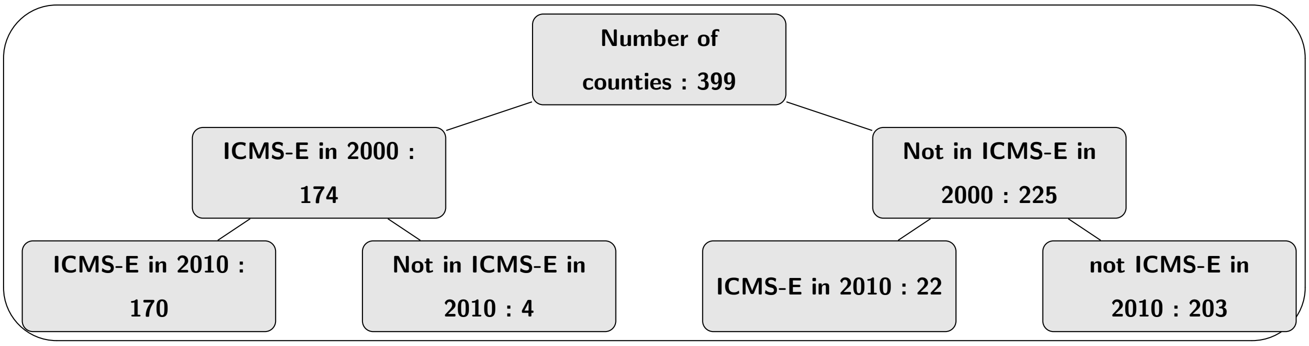
FIGURE 3 – Evolution of the number of counties in the ICMS-E for municipal CUs



Note : Evolutions between 2000 and 2010 of the number of counties concerning by the ICMS-E for the creation of municipal CUs.

Source : drafted by the authors

FIGURE 4 – Evolution of the number of counties in the ICMS-E



Note : Evolutions between 2000 and 2010 of the number of counties concerning by the ICMS-E, whatever the CUs.

Source : drafted by the authors

Table 5 – Summary statistics

Variable	Mean	(Std. Dev.)	Min.	Max.	N
CUs ratio (2010)	0.0034	(0.0238)	0	0.2175	399
Coefficient quality (2010)	0.0018	(0.009)	0	0.1272	399
CUs ratio (2000)	0.0018	(0.0156)	0	0.1993	399
Coefficient quality (2000)	0.0013	(0.0093)	0	0.1695	399
CUs ratio (Federal, State) 2010	0.0444	(0.1322)	0	0.9876	399
Coefficient quality (Federal, State) 2010	0.0135	(0.0386)	0	0.3254	399
Population growth	2.2483	(11.7301)	-38.4769	73.3038	399
Ratio agriculture	0.3051	(0.1484)	0.0004	0.6235	399
Ratio industry	0.1439	(0.1148)	0.0288	0.8336	399
Log GDP	1.6361	(0.3994)	0.8232	3.7569	399
Log GDP squared	2.836	(1.5153)	0.6777	14.1145	399
Rural population density	9.4345	(10.9149)	0	192.9066	399
Urban population density	51.1113	(233.5605)	0.8544	3918.803	399

Source : Authors' calculation.