Protected areas, local governments, and strategic interactions: The case of the ICMS-Ecológico in the Brazilian state of Paraná

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Abstract

The ICMS-Ecológico is an ecological fiscal transfer mechanism implemented in Brazil in the early 1990's in order to reduce biodiversity loss. The mechanism enables states to reward municipalities for the creation and management of protected areas and is of particular interest since it is a partly decentralized system, which works without any external financing and with only moderate transaction costs. Nevertheless, as the benefits of decentralization can be undermined by interactions among agents, we present an analytical framework discussing the impact of interactions among local governments on the effectiveness of a decentralized mechanism aimed at encouraging the creation of protected areas. We test for the presence of interactions among Brazilian municipalities in their decisions on whether or not to create conservation units in the state of Paraná between 2000 and 2010 through the estimation of a Bayesian spatial Tobit model. Our empirical investigation reveals strategic substitutability in municipalities conservation decisions, which raises implications for the design of the mechanism and its impact on biodiversity protection.

Keywords: Land use, Biodiversity, Fiscal federalism, Interactions, Bayesian spatial Tobit model, Brazil

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1. Introduction

Development policies implemented in Brazil from the late 1960's to the mid 1980's were considered as "very aggressive with little regard to the environmental consequences" (Andersen et al., 2002). However, the international community's growing interest in environmental problems, along with the worsening of Brazil's economic situation led to a change in policy making in the late 1980's. Indeed, several programs sprang up with the purpose of promoting sustainable development (see for example Di Bitetti et al., 2003 on biodiversity management and Feres and da Motta, 2004 on water management). This consideration of environmental issues in development policies was of the utmost importance since Brazil is recognized as one of the planet's major reserves of forests and biodiversity. Myers et al. (2000) point out that Brazil is estimated as hosting one-sixth of the earth's endemic plant species, to cite but just one example.

Although political will at the federal level is an important factor in environmental protection, the state of biodiversity is mainly influenced by local activities. A primary solution to protect flora and fauna at the local level is the establishment of protected areas (PAs). However, PAs involve local conservation costs in terms of land use restrictions despite the fact that they simultaneously generate both local and global conservation benefits. These global benefits constitute positive externalities which are not taken into account by local entities, leading to an under–provision of the environmental public good (Perrings and Gadgil, 2003, Ring, 2008b, Barton et al., 2009, among others).[4] To internalize externalities and ensure the provision of local public goods in developing countries, a primary solution has been to reward conservation through payment. The payment helps internalize the problem on the cost side by compensating municipalities for foregone opportunities, i.e., potential revenues lost due to conservation measures (Kumar and Managi, 2009). In addition, the sovereignty of nations makes payments the only mechanism likely to be effective and implementable at the global level (Farley et al., 2010). Ring and Schröter-Schlaack (2011) explain that conservation can be rewarded through two major kinds of economic instruments: payment for environmental services (PES) and ecological fiscal transfers.

[4]The literature on the effectiveness of protected areas in terms of biodiversity conservation and avoiding deforestation is substantial thanks to the growing availability of remotely sensed data on forest cover. At a global level, using matching techniques, Nelson and Chomitz (2011) and Joppa and Pfaff (2011) argue that protected areas are effective in reducing deforestation. Country-specific examples reporting that protected areas are associated with lower deforestation rates include Belize (Chomitz and Gray, 1996), Brazil (Chomitz and Thomas, 2003; Adeney et al., 2009; Soares-Filho et al., 2010), Costa Rica (Andam et al., 2008; Pfaff et al., 2009), Indonesia (Gaveau et al., 2009b,a), Peru (Oliveira et al., 2007) and Thailand (Cropper et al., 2001). Some papers also argue that the effectiveness of protected areas can depend on who own the protected area (Pfaff and Robalino, 2012). For Acre, in the Brazilian Amazon, Pfaff et al. (2014) find that states owned protected areas are implemented further from areas with high deforestation pressure from private actors, compared to federally protected areas.

Wunder (2005) describes PES as a 'voluntary' and 'conditional' transaction between a buyer and a seller of ES. PES mechanisms have been extensively studied in the literature as demonstrated by the several special issues on PES published in this journal in recent years (and emblematized by the articles of Engel et al. 2008, Muradian et al. 2010, and Farley and Costanza 2010). In this paper, we are interested in a second kind of mechanism designed to reward local actors for conservation initiatives, namely ecological fiscal transfers. Fiscal transfer schemes consist in redistributing public revenues through transfers from national and subnational governments to local governments (Ring et al., 2011). The purpose of ecological fiscal transfers can be to compensate local government for the management of existing PAs or to incite local government to create new PAs. Ecological fiscal transfers are interesting since they constitute a relatively new, innovative and poorly studied conservation instrument.

The first mechanism of this type to be created is the Brazilian ICMS-Ecológico (ICMS-E; "*Imposto sobre Circulacão de Mercadorias e Servicos - ecológico*" or "*Ecological value added tax*"), an intergovernmental ecological fiscal transfer which redistributes VAT revenues from state to municipalities, and that is used today in about half of the Brazilian states. The mechanism aims at reducing biodiversity loss by stimulating the creation and management of protected areas. Reaching this objective is made possible in two ways; (i) by rewarding municipalities for hosting state and federal PAs, and (ii) by inciting municipalities to create new PAs. The mechanism has several interesting features. First, it is a partly decentralized system, which implies that decision-makers benefit from more accurate information. Second, the mechanism is implemented without any external financing (the redistributed funds are collected from taxes on goods and services in the state concerned). Finally, the transaction costs are only moderate since the mechanism builds on an existing institutions for funds redistribution (Vogel, 1997, Ring, 2008b). As a result, the ICMS-Ecológico is considered to be of particular interest and numerous researchers have called for further analysis on the mechanism (Ring, 2008b, Kumar and Managi, 2009, Barton et al., 2009, Farley et al., 2010 and Ring et al., 2011, among others).

Since its implementation in the early 90's, the ICMS-E appears to have been a real success in terms of CU creation. By the year 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). However, the environmental effectiveness of the ICMS-E has not been explicitly addressed in the literature. In terms of biodiversity conservation, "this relates to the increase in quantity and quality of the various categories of protected areas in the relevant jurisdiction having implemented the fiscal transfer scheme" (Ring et al., 2011, p.105). When municipalities are compensated for hosting federal or state level PAs, the fact that compensation occurs through a fiscal transfer mechanism should not be instrumental in determining the success of conservation initiatives. However, the other purpose of the ICMS-E is to incite municipalities to create protected areas. Thus, even if prior to the implementation of the ICMS-E, the creation of protected areas was almost exclusive to the state or the federal governments, this decision has now been partly decentralized and entrusted to municipalities. Beyond the additional conservation units (CUs) created, the advantage of decentralization is that municipalities benefit from better information on conservation costs than do higher levels of governments.[5] Nevertheless, as stated by Wallace Oates, the benefits of decentralization can be undermined by interactions among agents.[6] With respect to the ICMS-E, this threat was first underlined by Ring (2008a), who wrote: *"Despite the general suitability of many land-use issues for being assigned to lower governmental levels, spatial externalities may require different, more appropriate solutions."*

Interactions occur if a PA's creation by a municipality affects the utility that a neighboring municipality gets from the creation of a new PA. On the one hand, strategic complementarity among municipalities' decisions, which which exists when the utility gained from the creation of a PA by a given municipality increases with the creation of PAs by its neighbors, could lead to a race to the bottom in PA creation, ultimately resulting in a low overall level of area under protection in the state. On the other hand, strategic substitutability among municipalities' decisions, which exists when the utility gained from the creation of a PA by a given municipality decreases with the creation of PAs by its neighbors, may slow down the increase in the volume of PAs created and impede the creation of biodiversity corridors. Yet, according to Wilson Lourerio from the State Environmental Agency of Paraná, a good rule of governance for the ICMS-E is to "stimulate opportunities for achieving connectivity between forest fragments, with the objective of creating biodiversity corridors."[7] Therefore, testing the nature of (horizontal) interactions among municipalities in conservation decisions is essential in assessing the mechanism's effectiveness.[8]

In this paper, we contribute to the literature in several ways. First, we present an innovative conservation mechanism implemented in Brazil in the early 1990's, the ICMS-E. Second, we propose an analytical framework aimed at understanding the source and impact of interactions among local government in a decentralized mechanism aimed at creating PAs. Third, we test for the presence of interactions among municipalities in their decisions to create PAs in the state of

[5]Protected areas are called conservation units in Brazil.

[6]See for instance Oates and Portney (2003).

[7]As interpreted by Peter May in Ring et al. (2011).

[8]See Fredriksson and Millimet (2002) for another example of testing for the presence of horizontal interactions in the case of environmental criteria.

Paraná over the 2000-2010 period. Finally, we identify negative spatial interaction, a rare result in the spatial econometric literature.

Section 2 presents the ICMS-E under study along with existing international ecological fiscal transfers. Section 3 describes how the mechanism was implemented in the pioneering state of Paraná. Section 4 presents the conceptual framework aimed at understanding the nature of interactions among municipalities in their decisions to create PAs. Section 5 details our empirical strategy, while results are analyzed in Section 6. Finally, Section 7 concludes.

2. Ecological fiscal transfers

2.1. International experiments

To date, only Brazil and, more recently, Portugal have implemented intergovernmental fiscal transfers for biodiversity conservation. In other countries, these kinds of transfers have only been proposed.

Köllner et al. (2002) provide a method designed to calculate cantonal biodiversity and introduce a proposal to integrate biodiversity into the Switzerland's fiscal transfer system. Ring (2002) points out that in Germany the financing of ecological functions (e.g., sewage disposal, water supply and waste disposal) is integrated into intergovernmental fiscal relations at the local level through conditional grants. However, the author calls for systematic integration of ecological functions into the various fiscal equalization laws at the local level in order to deal with the under-provision of environmental public good. Hajkowicz (2007) computes an index of environmental protection needs that could form the basis of fund allocation under fiscal equalization in Queensland, Australia. The author uses a multiple criteria analysis to calculate this need index from multiple sustainability indicators. Kumar and Managi (2009) discuss the role of intergovernmental fiscal transfers in the public provision of environmental services in the case of India. They argue that the genesis of environmental degradation in India may be found in the incentive structure of governance and suggest that lump-sum fiscal transfer and matching (earmarked) grants should be developed both as compensation and incentive for Indian municipalities providing environmental services. In the case of Indonesia, Irawan et al. (2014) suggest that intergovernmental fiscal transfers may help in channelling REDD+ payments to local governments.

Finally, Portugal followed Brazil's lead in 2007 and introduced a new scheme of fiscal transfers for biodiversity conservation that compensates municipalities for land-use constraints imposed by the designation of protected areas or Natura 2000 sites. Santos et al. (2012) discuss the effects of this scheme and identify winning and loosing municipalities by comparing the new scheme with its predecessor and highlighting changes in fiscal revenues for selected municipalities in relation to their designated conservation areas.

Apart from these international experiences experiments, the Brazilian case is the first and the most advanced application of the integration of ecological functions into intergovernmental fiscal transfers. Thus, studying this early experiment can be of use for the future development of ecological fiscal transfer mechanisms.

2.2. The emergence of the ICMS-E

Brazil is a federation whose 27 states capture most of their revenue from taxes on the circulation of goods and services, i.e., a value-added tax (VAT) called the ICMS (*Imposto sobre Circulacão de Mercadorias e Servicos*). According to certain criteria, states must return 25% of collected sales taxes revenue to municipalities. Three quarters of this redistribution is defined by the Federal Constitution (the main criterion is the added value created by each municipality) but 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 (based on, for instance population size or health expenditures).

In 1992, the state of Paraná, was the first to introduce ecological criteria into the redistribution of the ICMS. The state rewards municipalities for having protected areas (biodiversity) and watershed reserves (water quality) within their boundaries.[9] In Paraná, the law stipulates that 5% of the ICMS revenues redistributed to municipalities should be in proportion to their environmental performance. The initiative was adopted by several states and this new fiscal incentive tool is now called the ICMS-E.[10]

2.3. Existing studies on the impact of the ICMS-E

The existing empirical studies on the ICMS-E focus on the states of Paraná, Minas Gerais and Rondonia, which are among the first states to have introduced the ICMS-E. Grieg-Gran (2000) assesses the effects of the ICMS-E in Minas Gerais and Rondonia and finds that both the compensation and incentive objectives have been achieved in these two states. In terms of the redistributive impact of the mechanism, results are more mixed, but in the state of Minas Gerais, the introduction of the ICMS-E slightly increased the share of revenues obtained by the

[9] See May et al. (2002, p.175) for a more complete presentation of the legislative process in Paraná.

[10] As of October 2013, 16 other Brazilian states have 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 ICMS-E official website, http://www.icmsecologico.org.br/, Veríssimo et al., 2002, and Ring, 2008a).

poorest municipalities. May et al. (2002) provide a presentation of the functioning of the ICMS-E to understand how and under what conditions the mechanism works and observe that in the state of Paraná and Minas Gerais, areas under protection increased respectively by 165 and 62.4 percent between 1991 and 2000. They also report that "the main incentive to create new CUs, according to local mayors, has been the potential for increased financial flows." In a reflexion on ecological fiscal transfers, Ring (2008a) also studies the effects of the ICMS-E in terms of newly created CUs and concludes that municipalities in Paraná and Minas Gerais have developed a strong interest in designating new CUs. Finally, Ring et al. (2011) provide a presentation of the ICMS-E, as well as several definitions for analyzing the strengths and weaknesses of the mechanism (e.g., environmental effectiveness).

The literature highlights that the Brazilian experiment helps to compensate for land-use restrictions and to incite local governments to engage in more conservation activities. However, the impact of interactions among municipalities has not been addressed in the literature. Thus, additional research along this line is needed. Before attempting such analysis, the next section presents how the mechanism was implemented in the state of Paraná.

3. Implementation of the ICMS-E in the state of Paraná

3.1. The state of Paraná

As previously noted, the state of Paraná was the first to use environmental criteria to redistribute the ICMS. It was also a pioneer in integrating the quality of protected areas into the fiscal transfer rule (May et al., 2002, Farley et al., 2010). Indeed, it is the only state that has developed such a sophisticated weighting scheme. Therefore, we have chosen to focus our study on this state.

Paraná is the ninth largest state in terms of area, totaling at 199,314.9 square kilometers, and has a population of nearly 10 million people (in 2010). On average, the agricultural sector represents 30% of the municipalities' GDP. In terms of GDP per capita, Parana's approximately 4,100 USD GDP per year (in 2010) ranks seventh in the country.[11]

In the state of Paraná, of the 5% of the ICMS revenues redistributed to municipalities in proportion to their environmental performance, 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 worth noting that municipalities have no obligation to create

[11]See http://www.ipeadata.gov.br/.

and improve protected areas but are simply rewarded depending on the extent to which they meet the criteria in comparison to other municipalities. The other half (2.5%) of the pool of money redistributed according to environmental criteria is for those municipalities with watershed protection areas that provide complete or partial services for public drinking water systems in neighboring municipalities. The next section presents the index used to measure the "environmental performance" of each municipality in terms of CU creation.

3.2. The Municipal Conservation Factor

The state redistributes the ICMS according to the relative Municipal Conservation Factor (MCF) of a municipality compared to the sum of overall MCFs in the state. The MCF is derived from the ratio of CUs to total municipal area weighted by a quality factor.

The MCF thus has two components: a quantitative and a qualitative one. The former is the percentage of municipal land area under protection in the total area of the county (the extensive measure of protection). The latter evaluates the quality of the CU on the basis of variables, such as biological and physical quality, including the quality of water resources in and around the CU, the quality of planning, implementation and maintenance, the CU's importance in the regional ecosystem, and the legitimacy of the unit in the community (the intensive measure of protection).[12] These factors also reflect improvements made on CUs over time as well as their relationships with the surrounding areas.[13] The quality of each CU is assessed by regional IAP (Instituto Ambiental do Paraná) officers whose evaluation is then used to generate a score weighting the quantitative ratio.[14]

More precisely, the MCF of the municipality i is calculated as follows (this part is adapted from Loureiro et al., 2008, p.22-23, and Ring, 2008a).

First it depends on the ratio of protected areas to total land of the municipality. The CU_ratio of each CU j is calculated in municipality i as follows:

$$CU\_ratio_{ij} = \left(\frac{Area\ CU_j}{Area\ municipality_i} \right), \quad (1)$$

[12] See Farley et al. (2010).

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

[14] According to May et al. (2002), the quality index is also assessed regarding to "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".

where $Area\ CU_j$ and $Area\ municipality_i$ are the area of the CU j and the area of municipality i respectively. At this step, the protection index depends only on a quantitative component.

Then, the CU_ratio_{ij} is first weighted according to management category n of the protected area (see Loureiro et al., 2008, p.73, for more information on the weighting factor FC_n of each protected area). This gives us the Biodiversity Conservation Coefficient BCC_{ij}:

$$BCC_{ij} = CU\_ratio_{ij} * FC_n. \tag{2}$$

Next each BCC_{ij} is assigned a QCU criterion, assessed by regional officers of the IAP, accounting for the variation of the "quality" of protected area, the management strategy and the nature of the protected areas, i.e., municipal, state, federal.

$$BCCQ_{ij} = BCC_{ij} * QCU, \tag{3}$$

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

$$MCF_i = \sum_{j=1}^{J} BCCQ_{ij}, \tag{4}$$

where J is the number of CUs in municipality i[15].

Finally, the money is strictly redistributed according to the value of the ecological index EI_i of municipality i, such as:

$$EI_i = \frac{MCF_i}{SCF}, \tag{5}$$

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

$$SCF = \sum_{i=1}^{I} MCF_i, \tag{6}$$

where I is the number of municipalities in the state receiving funds from the ICMS-E. The financial statements of the ICMS-E, which take the form of a fact sheet per municipality and

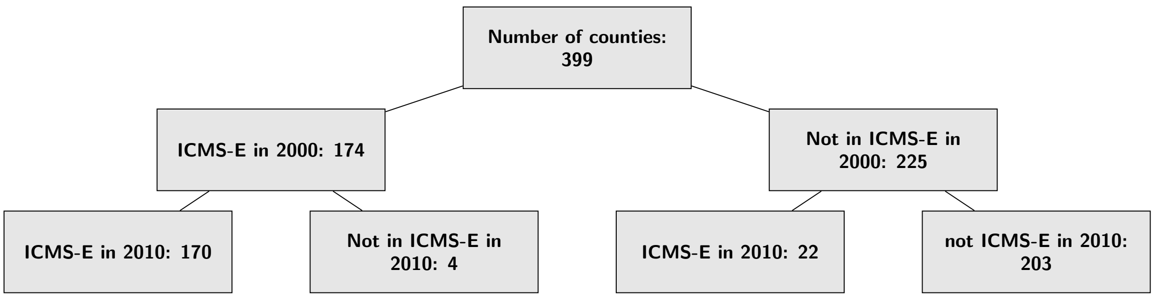
[15] For instance, Curitiba, the capital of the state, had 15 CUs in 2000.

per year, specify the area of the PAs, the quality index, and the amount of money received for each PA. These fact sheets are available for the period from 2000 to 2010 on the ICMS-E official website. We collected this data in order to lead the subsequent empirical analysis.

3.3. Evolution of conservation units in Paraná

An overview of the evolution of the number of counties (municipalities)[16] in the ICMS-E for all CUs between 2000 and 2010 is given by Figure 1. There were 174 counties in the ICMS-E (i.e., receiving funds for the presence of CUs in their territory) in 2000, compared to 192 in 2010. The number of counties that benefit from the fiscal mechanism thus increased by 22 in 10 years, while four counties decided to convert their land under protection for other uses.[17]

Figure 1: Evolution of the number of counties in the ICMS-E between 2000 and 2010



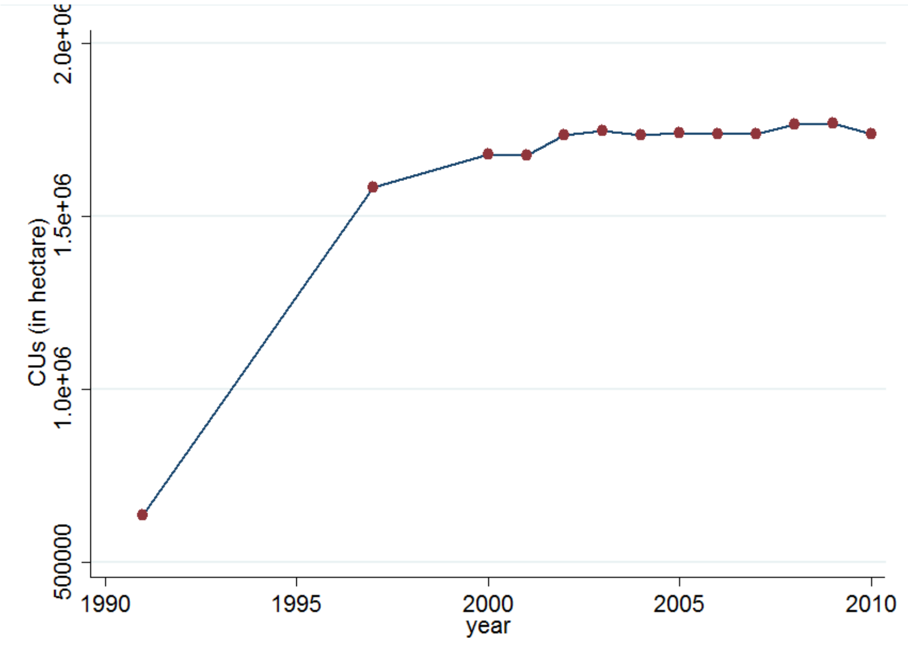
Source: drafted by authors.

Finally, Figure 2 shows the evolution of the area of all CUs by hectare at the state level. The evolution of CUs can be divided into two decades. In the first decade, the number of CUs created increased sharply, while in the second decade (from 2000), it increased more moderately. It appears that the number of CUs created through the ICMS-E mechanism has somewhat leveled out in the last decade.

[16]The terms "county" and "municipality" will be used interchangeably throughout the rest of the paper.

[17]The four municipalities concerned are: Marumbi, Palmital, Sao Jorge do Oeste, and Tibagi. There are two possible explanations for this. Either the PA has been completely destroyed, or the IAP agents have made the quality factors go down to 0. As pointed out by Ring et al. 2011, p.100), "If a protected area is badly managed or just a 'paper park', the transfers associated with it may in theory even drop to zero."

Figure 2: Evolution of the areas (in hectare) of all conservation units (federal, state and municipal), in the state of Paraná, between 1991 and 2010.



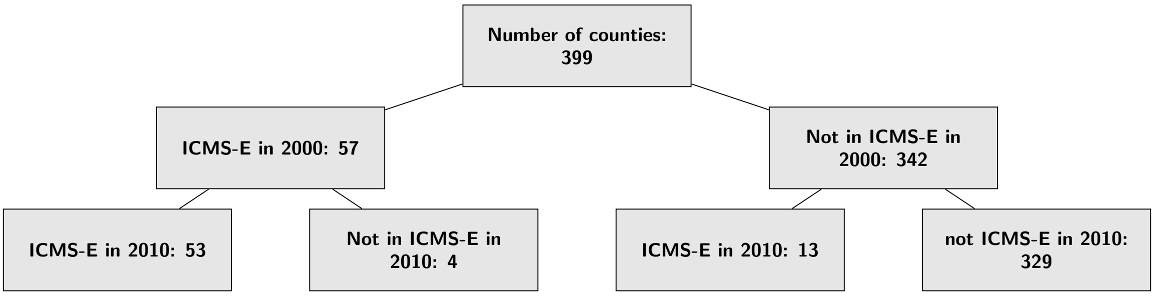
Source: Authors' calculation from May et al. (2002), Grieg-Gran (2000) and authors' collected data.

3.4. Municipal protected areas in the state of Paraná

As explained in the previous section, a PA can be managed at the federal, state or municipal level. In this paper, we focus only on the creation of PAs managed at the municipal level, since it is only at this level that the municipality has full power over the creation or destruction of a PA. We are, therefore, primarily interested in the CU_ratio and the MCF index for municipal PAs.

As shown by Figure 3, the number of counties that received funds for the creation of municipal PAs increased by nine between 2000 and 2010 (57 in 2000 compared to 66 in 2010) across the 399 counties in the dataset. As a consequence, 342 in 2000 and 333 in 2010 counties did not receive fiscal transfers from the ICMS-E for the creation of municipal CUs. Moreover, it is worth noting that four counties have converted their municipal CUs for economic purposes during the last decade, and no longer receive funds from the ICMS-E, while 13 new counties received funds from the ICMS-E for the creation of municipal CUs. In terms of the volume of muncipal PAs created, we observe an increase greater than 80% between 2000 and 2010.

Figure 3: Evolution of the number of counties in the ICMS-E for municipal CUs from 2000 to 2010



Source: drafted by authors.

In addition, as we can see in Table 1, for the 66 counties that received the ICMS-E for municipal PAs in 2010, the average area of municipal PA per county was about 1,172 hectares, representing on average 2 percent of the municipality's area. By comparison, the federal and state managed PAs for which 165 counties received the ICMS-E covered about 10,030 hectares on average per county (11 percent of the total municipal area).

Table 1: Summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Municipal CU	1,171.67	3,665.87	1.4	22,760.00
Ratio of Municipal CU on total area	0.02	0.06	0	0.22
Observations		66		
Federal and state CU	10,030.03	24,534.67	1.72	213,265.20
Ratio of Federal and state CU on total area	0.11	0.19	0	0.99
Observations		165		

Notes: Conservation Units (CU) are measured in hectares for the year 2010.

Now that we have presented the ICMS-E, in the next section, we will study one condition for the effectiveness of the mechanism, namely the interactions among municipalities in their decisions to create PAs.

4. Analytical framework

4.1. Definition of interactions

As explained in the introduction, interactions among municipalities occur if a PA's creation by a municipality affects the utility that a neighboring municipality gets from the creation of a new PA. The interactions between a municipality and its neighbors can evolve in two directions.

On the one hand, the decision to create PAs by a county and the one of its neighbors could be strategic complements, meaning that the utility gained from the creation of a PA by a given municipality increases with the creation of PAs by its neighbors. On the other hand, the decision to create PAs by a county and the one of its neighbors could be strategic substitutes, meaning that the utility gained from the creation of a PA by a given municipality decreases with the creation of PAs by its neighbors. Indeed, arguments exist for both possibilities, and we will expose these arguments in the following paragraphs. To develop and present our arguments, we consider that with a given plot, a municipality can choose between two options: designating an area as either *protected* or *unprotected*. A protected area means the creation of a municipal PA whereas an unprotected area refers to the development of economic activities (industry, agriculture, logging, etc).

4.2. Sources of interactions

A strategic complementarity in municipalities' conservation decisions would mean that a municipality has an interest in following the decisions of its neighbor. This could be motivated by three primary factors. First, according to the Tiebout theory of "voting with the feet" (Tiebout, 1956), a new firm could choose to establish itself in the municipality where the environmental standards are lower. This could lead to a race to the bottom between municipalities in an attempt to attract the firm. Second, a farmer could choose the county where his farm's potential development is higher (i.e., where there are less protected areas). Therefore, this could lead the municipalities to compete again based on this criterion. Finally, as pointed by Andam et al. (2007), the establishment of PAs in a county can lessen the development of local market infrastructure (such as transport), which could then reduce the profitability of economic activities in neighboring counties due to the lack of infrastructure development in a particular region. The spillovers from the creation of a PA in one municipality can thus be positive and induce the creation of a PA in the neighboring municipality.[18]

However, if we think in terms of the profitability of the two options, i.e., the development of economic activities and the creation of PAs, we could also expect the decisions to be strategic substitutes that could come through four channels. First, the creation of a PA in one municipality could constrain economic activity and lead to a worker surplus in this municipality. The displacement of the worker surplus to the neighboring municipality could bring down the wage level and favor the decision to develop economic activities over the protection option. Second,

[18] Or to put it differently, the development of infrastructures can exacerbate deforestation (see for example Pfaff, 1999).

the creation of new CUs decreases the stock of lands available for economic production in a given municipality and therefore, increases the demand for these lands in neighboring municipalities. Depending on the relative profits from economic activities, the municipalities could be incited to increase their supply of land for economic activities (by decreasing their number of CUs) in order to attract farmers and firms while their neighbors are creating protected areas. We could, therefore, in this case again expect protection decisions to be strategic substitutes. Moreover, an example which is traditionally highlighted in studies on deforestation leakages is that in which the creation of a PA in a municipality decreases the availability of the wood resources in this municipality and then increases logging in neighboring municipalities (a phenomenon also referred to as outsourcing by Aukland et al., 2003). The creation of PAs in a municipality will therefore favor the destruction of PAs or the reduction of incentives to create new PAs in neighboring municipalities. Finally, a PA is also a public good that the local population can enjoy. Yet, the distance between two municipalities is relatively small, and citizens from one municipality can go to a neighboring municipality to enjoy the recreation of a PA. A municipality can thus decide to "free ride" and create less PAs if neighboring municipalities are providing this local public good.

4.3. Implications of interactions

The absence of interactions among municipalities would indicate that a municipality is deciding to set its land under protection or to develop economic activities, disregarding the action of neighboring municipalities. Strategic complementarity in conservation decisions could lead to a race to the bottom or a race to the top in PA creation. A race to the bottom would ultimately result in a low overall level of area under protection in the state, whereas a race to the top would result in a high level of area under protection. Strategic substitutability among municipalities' decisions would raise two threats to the effectiveness of the mechanism: it could (i) slow down the increase in the volume of PAs created and (ii) impede the creation of biodiversity corridors.

In light of the arguments expounded above, we could expect conservation decisions to be independent, strategic substitutes or strategic complements. The following section deals with the empirical strategy implemented in order to identify the nature of strategic interactions among municipalities.

5. Empirical strategy

5.1. Econometric model and data used

As explained by Anselin (2001) the spatial lag model, or spatial autoregressive model (SAR), is appropriate when the focus of interest is the assessment of the existence and strength of spatial interaction. We therefore estimate a SAR model, where the spatially lagged endogenous variable is a weighted sum of neighbors' decisions, such as:

$$P^* = \rho W P^* + \beta X + \epsilon, \tag{7}$$

where P^* is a $K \times 1$ vector of the propensity to create municipal CUs by a county. K is the number of municipalities in the sample, here 399. X is a $M \times K$ matrix of our M explanatory variables influencing the choice between the protected and unprotected options and β is a vector of their corresponding coefficients. ϵ is a $K \times 1$ vector of residuals. WP^* is a spatially lagged endogenous variable, where W is a $K \times K$ contiguity matrix of which each element w_{ik} takes the value of 1 if two counties share a common border, 0 otherwise (where i identifies a municipality different from municipality k). Hence, ρ captures the presence of interactions between municipalities.

The dependent variable is latent, i.e., cannot be observed for $p_i^* < 0$. Indeed, there is a large number of zero observations in our sample. In 2010, 333 municipalities out of 399 did not host municipal CUs. Having 0% of municipal CUs is a corner solution; it does not mean that every municipality is in precisely the same situation. Consequently, censoring is at stake and there exist negative profits unmeasured by our dependent variable. Therefore, we have:

$$\begin{cases} p_i = 0 \quad if \quad p_i^* \leq 0 \\ p_i = p_i^* \quad if \quad p_i^* > 0 \end{cases} \tag{8}$$

where p_i is the observed dependent variable. Following the traditional approach in land use studies initiated by Chomitz and Gray (1996), we account for this censoring using a Tobit model, where the conditional distribution of p_i, given all other parameters, is a truncated normal distribution constructed by truncating distribution from the left at 0.[19]

[19]Since our degree of censoring is high (83%), one could suspect a poisson or selection (Heckit) model to be more consistent with the data generating process. However, our dependent variable is continuous, not discrete. Furthermore, there is no plausible structural explanation for the non-creation of municipal CUs. Indeed, there is no minimum level of CUs required to receive the ICMS-E (the smallest PA in our sample is about 1.4 hectares) and a municipality can request registration of a protected area at any time. Therefore, the estimation of a Tobit model was deemed the best choice for our analysis.

The expanded form of the spatial autoregressive Tobit model is the following:

$$
\begin{aligned}
p_i^* &= \rho \sum_{i \neq k}^{K} w_{ik} p_k^* + \beta_1 MCFm2000_i + \beta_2 MCFfed2010_i + \beta_3 ind_i + \beta_4 agr_i + \beta_5 inc_i \\
&+ \beta_6 pop_i + \beta_7 urb_i + \beta_8 rur_i + \beta_9 Curitiba_i + \mu_r + \vartheta_i, \qquad (9)
\end{aligned}
$$

where the observed dependent variable p_i, is the MCF[20] of municipal PAs of county i in 2010 (the variable "MCFm2010"). The variable "MCFm2000" represents the MCF for municipal PAs in 2000 and is introduced to account for the initial conditions determined by the first decade of the mechanism's operation.

All other variables are control variables and are assumed to have an impact on the land allocation decision-rule (*protected*, *unprotected*). First $MCFfed2010_i$ is introduced, which is the MCF for other CUs (federal- and state-managed) in county i in 2010. This variable can have both negative and positive expected effects. Given that the area of a county is by definition fixed, more non-municipal CUs increase the scarcity of land. In this context, the effect of a land allocation decision is ambiguous. The creation of federal or state level PAs could decrease the amount of land to be potentially converted into municipal conservation areas. $MCFfed2010_i$ would therefore have a negative effect on p_i. However, we can assume that land scarcity increases land price, discouraging investment in this county since the costs for the *unprotected* option go up. Knowing this, the municipality may decide to protect the land and create CUs to obtain more money from the ICMS-E.[21]

The variables ind_i and agr_i, respectively, are the average ratio of the industrial GDP on the total municipal GDP between 2000 and 2008 and the average ratio of the agricultural GDP on the total municipal GDP between 2000 and 2008.[22] These variables measure development projects and are assumed to increase the opportunity costs of creating CUs. They are thus negatively linked to the propensity to create municipal PAs.

Income (inc_i) is the logarithm of the average of the GDP per capita between 2000 and 2008 (in 1,000R$). The variables pop_i, urb_i and rur_i are the average annual population growth, urban density (1,000 inhabitants per km^2) and rural density (1,000 inhabitants per km^2), respectively, between 2000 and 2010. These variables are proxies for labor supply and land demand and are expected to have a negative effect on p_i.

Curitiba is a dummy variable that takes a value of 1 for the capital of Paraná namely

[20] Defined in Section 3.2.
[21] This can be seen as a kind of vertical interaction.
[22] The year 2008 is the last year for which data are available.

Curitiba and 0 otherwise to control for the significant difference between this county and the others. Indeed, unlike others counties, Curitiba strongly desires to be a green city[23,24].

We also introduce micro-regional dummies (μ_r), which represent legally defined administrative areas consisting of groups of municipalities bordering urban areas. These dummies enable us to check for unobserved fixed effects shared by neighboring counties. In the state of Paraná, 39 micro-regions are censused for 399 counties.

Data concerning CUs (p_i, $MCFm2000_i$ and $MCFfed2010_i$) are taken from the ICMS-E's official website. All other variables come from the IPEA database (see Appendix A for summary statistics).[25]

5.2. Estimator

The estimation of parameters from the spatial autoregressive Tobit model represents a computational challenge and maximum likelihood is almost impossible to use due to multiple integrals in the likelihood function. Therefore, the econometrician must turn to simulation methods. We choose to rely here on the Bayesian approach developed by LeSage (1999), LeSage (2000), LeSage and Pace (2009), due to its computational simplicity and the ability to easily account for heteroscedasticity in the error terms in this framework.[26]

In this approach, the model parameters are estimated via the MCMC (Monte Carlo Markov Chain) procedure, with a chosen number of n draws such as estimator convergence is achieved. The posterior mean and standard deviation of parameters estimated at each draw are then used as parameter values in the displayed results. Furthermore, the unobserved negative profits associated with the censored 0 observations are considered as parameters to estimate. The procedure uses the Geweke m-steps Gibbs sampler, to produce a chosen number of m draws from a multivariate truncated normal distribution, in order to generate the unobserved negative profits associated with the censored 0 observations. This is repeated at each n draw.[27]

[23] Note that the 2011 UN-Habitat report quoted Jaime Lemer, the mayor of Curitiba: "The city is not the problem, it is the solution. And it is a solution for the problem of climate change." (United Nations, 2011)

[24] Note that in a standard cross section, this would be akin to dropping the observation. However, it is different in a SAR model, since the municipality behavior influences the other decision through the spatially lagged endogenous variable.

[25] Monetary variables are taken in constant values (2000R$).

[26] Our choice is similar to the one adopted by Albers et al. (2008) when studying the interactions between private and public PAs creation in the United States.

[27] 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, which determines the extent to which the disturbances take on a leptokurtic character, is stated at 4, as suggested by LeSage (1999).

6. Results

6.1. Neighboring effects and created CUs

We estimate the influence of neighbors' decisions, as well as several economic indicators, on a municipality's propensity to create PAs. The Municipal Conservation Factor, implemented by the state of Paraná to redistribute the ICMS-E, is used as dependent variable. As explained in Section 3.2, the MCF is derived from the ratio of CUs to total municipal area weighted by a quality factor. In all regressions, the contiguity spatial weight matrix is used to represent the prior strength between two counties.

As specified in the preceding section, the number of n draws have to be chosen such as convergence of the estimator is achieved. In our case, relying on a number of 100,000 draws appears to be a conservative choice, as shown in Appendix B.

Our results come from the estimation of a Bayesian spatial Tobit model using 100,000 draws in the MCMC procedure, with 10% of the draws used as "burn-in". Our main results are presented in Table 2, where the first column presents the value of the coefficients (ρ, β_k), the second column the value of the direct impact of the explanatory variables, the third column the indirect impact and the fourth the total impact. 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 (indirect impact). The total impact is equal to the sum of the direct impact and the indirect impact (LeSage and Pace, 2009, Elhorst, 2010).

Table 2: Spatial interactions and MCF

Dependent variable : MCFm2010

Variables	Coefficients	*Direct*	*Indirect*	*Total*
Spatial lag (ρ)	-0.0064***			
	(-4.598)			
MCFm2000	2.8981***	2.8253***	-0.0188***	2.8065***
	(4.140)	(3.989)	(-2.825)	(3.989)
MCFfed2010	0.0403	0.0412	-0.0003	0.0409
	(0.474)	(0.499)	(-0.484)	(0.499)
popgr	-0.0042	-0.0043	0.0000	-0.0043
	(-0.103)	(-0.110)	(0.107)	(-0.110)
agr	-0.1766***	-0.1706***	0.0011**	-0.1694***
	(-3.588)	(-3.360)	(2.509)	(-3.360)
ind	-0.0625	-0.0604	0.0004	-0.0600
	(-1.401)	(-1.381)	(1.282)	(-1.381)
inc	-0.0060	-0.0059	0.0000	-0.0059
	(-0.270)	(-0.276)	(0.253)	(-0.2760)
rur	-0.8262	-0.7967	0.0053	-0.7914
	(-1.247)	(-1.232)	(1.140)	(-1.232)
urb	-0.0049	-0.0049	0.0000	-0.0049
	(-0.238)	(-0.245)	(0.230)	(-0.245)
Curitiba	-0.3482***	-0.3358***	0.0022**	-0.3336***
	(-2.779)	(-2.663)	(2.184)	(-2.663)
intercept	-0.0725			
	(-0.821)			
Micro-region dummies	yes			
Observations	399			

Estimation method: Bayesian spatial Tobit. Number of n draws: 100,000. Number of m steps in the Gibbs sampler: 1. Number of draws used as burn-in: 10,000. $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Asymptotic $t - stat$ associated to the reported coefficients are in parentheses.

Negative spatial interactions between counties are found ($\rho < 0$) suggesting that the creation of CUs by a municipality decreases the incentive of neighboring municipalities to create CUs. It appears more profitable for a county to use its land for economic activities if their neighboring counties have opted to create CUs and be rewarded by the ICMS-E.

Concerning the other factors assumed to have an effect on the land allocation rule-decision of a county (through their effects on the differential profit between land use options), the structure of a county's economy is found to be important in explaining its propensity to create municipal CUs. In fact, the higher the share of agriculture in a municipality is, the lower its propensity to create municipal CUs. Counties that are more developed in terms of agricultural activities may be more encouraged to develop their activities than to set their lands under protection. Finally, the population variables have the expected negative coefficients but are not significant.

Table 2 provides the estimated direct, indirect and total effects of each explanatory variable. We observe an indirect effect of lower magnitude and of the opposite sign compared to the direct effect, which is due to the substitutable nature of conservation decisions. For instance, we observe a positive indirect effect of the agricultural GDP, which means that an increase in the agricultural ratio in a given region will increase the creation of PAs in neighboring regions.

6.2. The extensive measure of protection

In this section, we use a different measure of the environmental performance of a county, choosing to use only an extensive measure of protection as dependent variable: the CU_ratio. The CU_ratio is the ratio of protected areas to total land. This allows us (1) to check the robustness of our first result (the substitutability in conservation decisions) and (2) to determine whether the driving forces tested influence how a county chooses to improve its land protection, i.e., in an intensive or extensive manner. Table 3 presents results for the CU_ratio as dependent variable.

Table 3: Spatial interactions and *CU_ratio*

Dependent variable : CU_ratiom2010

Variables	Coefficients	*Direct*	*Indirect*	*Total*
Spatial lag (ρ)	-0.0047***			
	(-3.068)			
CU_ratiom2000	2.5105***	2.5071***	-0.0123***	2.4949***
	(9.188)	(9.308)	(-2.681)	(9.306)
CU_ratiofed2010	-0.0215	-0.0200	0.0001	-0.0199
	(-0.541)	(-0.511)	(0.458)	(-0.511)
popgr	-0.0221	-0.0224	0.0001	-0.0223
	(-0.523)	(-0.539)	(0.501)	(-0.539)
agr	-0.2305***	-0.2270***	0.0011**	-0.2259***
	(-4.639)	(-4.530)	(2.236)	(-4.534)
ind	-0.0898*	-0.0881*	0.0004	-0.0877*
	(-1.940)	(-1.916)	(1.505)	(-1.917)
inc	0.0047	0.0046	0.0000	0.0046
	(0.205)	(0.207)	(-0.203)	(0.207)
rur	-0.6222	-0.6086	0.0030	-0.6056
	(-0.948)	(-0.943)	(0.846)	(-0.943)
urb	-0.1403***	-0.1406***	0.0007**	-0.1399***
	(-3.840)	(-3.904)	(2.236)	(-3.903)
Curitiba	0.2278**	0.2294**	-0.0011*	0.2283**
	(2.219)	(2.263)	(-1.696)	(2.263)
intercept	-0.012582			
	(-0.145)			
Micro-region dummies	yes			
Observations	399			

Estimation method: Bayesian spatial Tobit. Number of n draws: 100,000. Number of m steps in the Gibbs sampler: 1. Number of draws used as burn-in: 10,000. $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Asymptotic $t - stat$ associated to the reported coefficients are in parentheses.

Negative spatial interactions between counties are also found, thus confirming the negative effects of the creation of CUs by neighboring counties on a county's propensity to create CUs.

Concerning other factors, the negative effect of agricultural activities is still found, suggesting that counties whose economies are based more strongly on agriculture are less prone to increase their level of CUs. Interestingly, the density of urban population and the industrial GDP are now factors which threaten protection. It is worth noting that these factors have a negative effect on the extensive component of protection (the *CU_ratio*), but not when we take into account the intensity of the protection (the MCF). This suggests that both urban areas with high population density and industrial based economy counties care as much about the environment as others but choose to protect their land in an intensive rather than in an extensive manner. In other words, counties with a higher share of GDP generated by industrial activity (or counties with a higher urban population density) dedicate a smaller share of their land for protection but compensate by increasing the intensity of the protection. That is why these counties are not found to protect less when we study the MCF index (in Table 2), which is a measure reflecting both extensity and intensity of protection.

6.3. Discussion of the results

Our main result is that the interaction term, ρ, is negative and significant. This is a rare result in the literature. Daniel A. Griffith has devoted several papers to underlining the importance and the scarcity of finding negative spatial correlation (e.g., Griffith, 2006, Griffith and Arbia, 2010). Indeed, as he explains, there is almost always positive spatial correlation in the data–generating process and the researcher is unable to include all spatially correlated factors in the regression analysis (typical elements would be geographical or meteorological characteristics). In his effort to shed light on this problem (Griffith, 2006), the author censuses less than 10 studies finding negative spatial autocorrelation in the literature, the first being a study of the Phillips curve by Anselin (1988). Furthermore, Brady and Irwin (2011, p.495) argue that "the effect is only identified if the spatial lag parameter is negative." Hence, even if spatial econometrics results are often threatened by the fact that spatial interactions can be driven by spatial error correlation, this is not the case in our study, since we found negative spatial dependence. As a result, this study constitutes one of the few in the literature that identifies interactions through the use of spatial econometrics.

Furthermore, the coefficient ρ may appear relatively low. However, in their 2009 book, Le Sage and Pace do not provide a detailed discussion about the way to interpret this coefficient. In addition, in the first application of this estimator in 2011, Le Sage and Autant-Bernard do not interpret the magnitude of the coefficients either but compare only the magnitudes among coefficients. Furthermore, the existence of uncontrolled (positively) spatially correlated phenomena would have pushed us toward the finding of positive interactions while we find negative interactions. Thus, the coefficient we found is a lower bound estimate.

To go further on this last issue, we examine several alternative specifications of the model. The threat to the identification of a positive spatial interaction coefficient also threatens the identification of the magnitude of the negative spatial interaction coefficient. Indeed the presence of uncontrolled positively spatially correlated factors makes the coefficient a lower bound estimate. To illustrate this point, we show what happens when we withdraw several variables which allow us to purge for spatially correlated factors in Table 4.

Table 4: Variation of the spatial correlation coefficient

Dependent variable : MCFm2010

	Baseline model	Without agr	Without 5 micro-region dummies	Without 10 micro-region dummies	Without 15 micro-region dummies	Without micro-region dummies
Spatial lag (ρ)	-0.0064***	-0.0040***	-0.0027**	-0.0030***	-0.0027	0.0090
t-stat	(-4.598)	(-3.427)	(-2.578)	(-3.228)	(-1.343)	(0.604)

Notes: Estimation method: Bayesian spatial Tobit. Number of n draws: 100,000. Number of m steps in the Gibbs sampler: 1. Number of draws used as burn-in: 10,000. $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Asymptotic $t - stat$ associated to the reported coefficients are in parentheses. Other control variables included.

As shown by Table 4, when we withdraw controls, such as the "agr variable", the magnitude of the coefficient decreases. We successively withdraw micro-region dummies and we see that the magnitude of the coefficient diminishes when we withdraw the 5 and 10 last micro-region dummies (in alphabetical order). The coefficient turns non significant when 15 micro-region dummies are withdrawn. It even turns positive (but non significant) when all micro-region dummies are withdrawn.[28]

7. Conclusion

The aim of this paper is to assess the efficiency of the ICMS-E by testing the presence of strategic interactions between Brazilian municipalities in the state of Paraná. The ICMS-E is a fiscal transfer from the state to municipalities on the basis of the performance of individual municipalities in the creation and management of CUs.

This fiscal scheme is important since it compensates local government for hosting and creating PAs without any external source of financing and at moderate transaction costs. However, since the mechanism is partly decentralized, its effectiveness could be threatened by the presence of interactions between municipalities when they decide to set aside their lands for protection.

Therefore, this study attempts to investigate whether the behavior of neighboring municipalities in the state of Paraná had an effect on a municipality's propensity to create municipal CUs between the years 2000 and 2010. The results do not highlight a race to the bottom between counties which would have questioned the effectiveness of the ICMS-E. However, we do observe strategic substitutability between conservation decisions. This means that the utility gained from the creation of a PA decreased (or increased) if a neighbor created more (or less) protected

[28]We are grateful to an anonymous referee for this suggestion.

areas.

The mechanism appears to be effective, because our results suggest that the behavior of municipalities is driven by an optimization process and that municipalities take their neighbors' decisions into account when making their own decisions. However, there is no reason for the shared pool of money to lead to the optimal level of land set aside for protection. Thus, the design of the ICMS-E, via the definition of the quality weighting factor seems crucial.

Furthermore, a factor contributing to biodiversity loss in the state Paraná is forest fragmentation. The strategic substitutability in conservation decisions revealed by this study may indicate a threat to the ultimate success of the ICMS-E. These negative interactions could be an obstacle to the creation of a biodiversity corridor and could encourage forest fragmentation, which would conversely require strategic complementarities in decisions and the manifestation of a race to the top in environmental protection decisions. One way to achieve strategic complementarities could be to account for the creation of PAs by neighboring municipalities in the municipal conservation factor. Otherwise, the creation of biodiversity corridors will remain the exclusive responsibility of state or federal PAs.

To conclude, the ICMS-E appears to have fostered an increase in the number of CUs in Paraná over the last 20 years and should be viewed as an interesting tool for financing the provision of local public goods. However, the aim of ICMS-E is to preserve biodiversity. As such, the policy maker should be aware of the potential negative spatial interactions that can occur, since these could be obstacles to the creation of a biodiversity corridor and may prevent the ICMS-E from stopping the process of forest fragmentation currently threatening the state of biodiversity.

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Appendix A. Descriptive statistics

Variable	Mean	(Std. Dev.)	Min.	Max.	N
CUs ratio (Municipal) in 2010 ($CU\_ratiom2010$)	0.0034	(0.0238)	0	0.2175	399
Coefficient quality (Municipal) in 2010 ($MCFm2010$)	0.0018	(0.009)	0	0.1272	399
CUs ratio (Municipal) in 2000 ($CU\_ratiom2000$)	0.0018	(0.0156)	0	0.1993	399
Coefficient quality (Municipal) in 2000 ($MCFm2000$)	0.0013	(0.0093)	0	0.1695	399
CUs ratio (Federal, State) in 2010 ($CU\_ratiofed2010$)	0.0444	(0.1322)	0	0.9876	399
Coef. quality (Federal, State) in 2010 ($MCFfed2010$)	0.0135	(0.0386)	0	0.3254	399
Agricultural GDP/GDP (agr)	0.3051	(0.1484)	0.0004	0.6235	399
Industrial GDP/GDP (ind)	0.1439	(0.1148)	0.0288	0.8336	399
GDP per capita in 1,000R$ (inc)	5.647	(3.305)	2.278	42.817	399
Population growth (pop)	2.2483	(11.7301)	-38.4769	73.3038	399
Urban population density (urb)	51.1113	(233.5605)	0.8544	3,918.803	399
Rural population density (rur)	9.4345	(10.9149)	0	192.9066	399

Source: Authors' calculation based on data from the ICMS-E website http://www.icmsecologico.org.br/ and the IPEA website http://www.ipeadata.gov.br/. Monetary variables are taken in constant values (2000R$).

Appendix B. Assessing the convergence of the model

Dependent variable : MCFm2010

nb. n draws	1,000	10,000	25,000	50,000	75,000	100,000	125,000	150,000
coef. (ρ)	-0.0086**	-0.0082**	-0.0063**	-0.0067***	-0.0059***	-0.0064***	-0.0063***	-0.0062***
t-stat	(-2.285)	(-2.107)	(-2.495)	(-3.480)	(-4.619)	(-4.598)	(-4.705)	(-4.855)

Notes: Estimation method: Bayesian spatial Tobit. Number of draws used as burn-in: 10%. Number of m steps in the Gibbs sampler: 1. $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Asymptotic $t-stat$ associated to the reported coefficients are in parentheses. Control variables and micro-region dummies included.