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ANALYSIS

The Brazilian intergovernmental fiscal transfer for conservation: A successful but self-limiting incentive program

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ABSTRACT

Brazil's ecological intergovernmental fiscal transfer (ICMS-E) is a conservation incentive for protected areas (PAs). It redistributes tax revenues to reward municipalities for hosting PAs. To quantify its impact on the creation of state and municipal PAs, we used panel regressions on a longitudinal municipality dataset that combined information on PA creation and ICMS-E implementation for the 1467 municipalities in 6 Brazilian states in the Atlantic Forest region that never changed borders, from 1987 to 2016. We found that the percent of the municipal area covered with state or municipal PAs increased as a consequence of ICMS-E implementation. However, the magnitude of this effect declined as the ICMS-E revenue is shared more widely due to the expansion of PAs that reduced the gain from new PAs. We also found that ICMS-E policy primarily spurred the creation of PAs with less restrictive rules – similar to IUCN category V reserves – mainly by municipalities. For more restrictive PAs with higher local costs for municipalities, ICMS-E promoted state-proposed PAs but not municipal PAs. Our results suggest that states used ICMS-E to incentivize local implementation of their conservation preferences, including strict conservation, while municipal governments responded mostly with low-cost actions to increase their revenues.

1. Introduction

Intergovernmental fiscal transfers are public-finance instruments that can be used to support the provision of public goods by assisting in the internalization of spatial externalities (Ring, 2008). Brazil has innovated by using an intergovernmental fiscal transfer mechanism to emphasize environmental externalities in what is now called the Ecological Fiscal Transfer (EFT). EFT offer financial support for ecosystem-service production from locations that benefit from those services to where they are generated, similar to the motivation for payments for ecosystem services (PES) (Farley and Costanza, 2010; Ring, 2008). Higher levels of government transfer money to local administrations in order to compensate for the costs of, for instance, increasing biodiversity conservation (Loureiro, 2002) or more generally improving environmental quality (Gong et al., 2020) or reducing losses of ecosystem services. EFT has been described as a promising mechanism for environmental conservation (Farley and Costanza, 2010) and even has been suggested as the basis for a global mechanism to finance biodiversity conservation (Droste et al., 2019).

Ecological Fiscal Transfers are increasingly being adopted around the globe. Brazil first conceived and adopted an EFT for biodiversity conservation and was followed by Portugal (Santos et al., 2012); France has implemented similar program albeit on different spatial scales (Schröter-Schlaack et al., 2014); India has innovated by basing the revenue redistribution on forest cover and applying the rule to the whole country (Busch and Mukherjee, 2018) and China has identified ecological zones in which EFT was applied to avoid environmental degradation (Gong et al., 2020). EFT mechanisms were also proposed for other European countries such as German and Poland (Schröter-Schlaack et al., 2014) but not yet implemented.

The impacts of EFT, including different program designs, are now beginning to be evaluated. EFT for biodiversity conservation has shown positive effects on the increase of PA share at the state level in Brazil (Droste et al., 2017) and the ratio of municipal and national PAs in Portugal (Droste et al., 2018). India's EFT was expected to function as an incentive mechanism for state governments to raise investments on forestry; however, results were disappointing so far and forestry budgets as a share of total state budgets decreased by 16% after the

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implementation of the program (Busch et al., 2020). Results in China also enhanced the focus of the EFT as a compensation mechanism. Chinese EFT did not promote environmental improvements but has shown an effect against environmental degradation by reducing the so called "race-to-the-bottom" – i.e., when local governments relax rules for environmental protection in order to raise economic activity and improve their fiscal abilities (Cao et al., 2021).

Brazil's innovative fiscal transfer is mainly focused on raising the quantity of protected areas (PA), and in some cases the quality, by reflecting the area in PAs within the redistribution of tax revenues to local governments (from an added-value tax, the ICMS,[1] on the circulation of goods and services collected by states from municipalities, Fig. 1). The Brazilian ICMS-E ('Ecological ICMS') program allocates a fraction of ICMS tax revenue according to the municipal area designated as under legal conservation protection and gives higher weight to PA categories that impose higher restrictions (Loureiro, 2002).

In Brazil, PAs are created ('gazetted') by multiple levels of government: federal (national PAs), state (state PAs), and local/municipal (local PAs). Each local PA may generate ecosystem services at multiple spatial scales (i.e., local, state, and national levels) but its economic opportunity cost (Venter et al., 2014) typically falls on the municipality where the PA is located. Thus, municipalities may resist efforts by federal or state government to gazette new PAs. Resistance may be less meaningful with respect to federal proposals because the president has greater discretion than does a state's governor (Kopas et al., 2018). Yet municipal resistance may play a crucial role in the fate of state proposals. In this context, the ICMS-E was conceived to work as a compensatory mechanism that municipalities receive for hosting protected areas (Loureiro, 2002; May et al., 2002).

Since municipalities can receive compensatory ICMS-E financial transfers for hosting PAs, state governments can use the ICMS-E as an element in negotiations with municipal governments over state PA proposals. Compensatory revenue is based on the proportion of the municipal area covered by PAs, positively weighted by the restrictiveness of PA protection (Loureiro, 2002; May et al., 2002). Additionally, for most states implementing ICMS-E, municipal PAs also count in the formula's PA area. For such states, the ICMS-E is expected to stimulate local municipal governments to voluntarily set aside areas for conservation (Sauquet et al., 2014; Droste et al., 2017) because they directly benefit from the program's distribution of revenues. Thus, the ICMS-E is expected to increase the area under environmental protection either through reduced resistance to the creation of new state protected areas (compensation) or increased local government initiatives for creating new municipal areas (incentive) (Fig. 1).

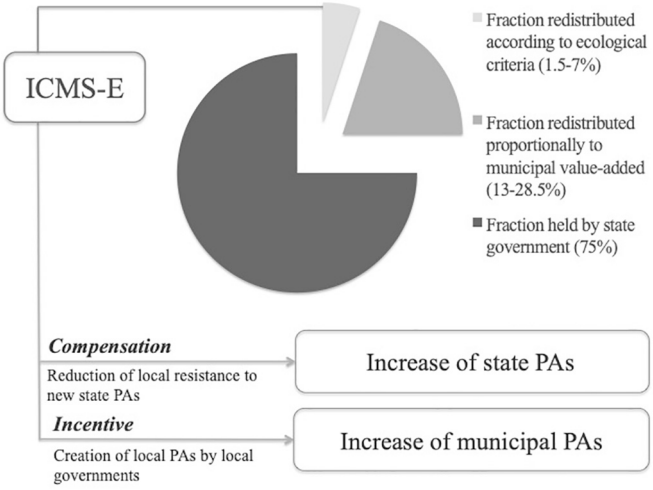

Fig. 1. The Ecological ICMS redistribution mechanism and two possible ways it is expected to impact area under legal conservation protection.

However, there are also other efforts to create new PAs in Brazil. The total area of PAs increased enormously from the 30's up to now, and the majority of them were gazetted between 1980 and 2009 (Vieira et al., 2019). Broadly, that rise was driven by multiple factors including the strengthening of environmental institutions and rise in management capacity (Drummond et al., 2011), re-establishment of democracy (Abman, 2018), increased international financial and technical support (MMA, 2010; The World Bank, 2012) and an increasingly engaged civil society (Oliveira, 2005). ICMS-E instruments began in 1991 as a new factor in PA growth, initially in the southern state of Paraná. While ICMS-E may well spur PA creation, given all of these other factors in PA growth it remains unclear whether the ICMS-E instrument *per se* actually raised PA area (Ferraro, 2009).

To isolate the impact of ICMS-E from other factors in PA growth, we employ a counterfactual approach using econometric tools to estimate changes in PA area without ICMS-E and then compare those with the observed changes with ICMS-E. Counterfactual approaches are common in impact evaluations within health or education policy studies, (Angrist and Pischke, 2008) and are also a best practice for environmental policy evaluations (Baylis et al., 2015; Ferraro, 2009). To our knowledge, only two studies have used a similar approach to explore the efficacy of ICMS-E.[2] Silva Júnior et al. (2013) detected no significant effect on the creation of new PAs in a comparison of Pernambuco state (ICMS-E since 2002) with the control group of Bahia, Alagoas and Paraíba states (Silva Júnior et al., 2013). However, the author observed the years of 2003 and 2004 only, which may be too short a time period to detect significant changes in PA creation. Droste et al. (2017), for a larger set of states and a longer time period (1991-2009), link larger numbers of both state and municipal PAs to the implementation of ICMS-E policy. However, their analysis was at the state level, which greatly limits the number of units that can be considered empirically, while also ruling out any exploration of the relative impacts of ICMS-E on municipal-level PA creation, or the differential impacts of ICMS-E on PA creation at different administration levels. Our work seeks to address these gaps.

At the municipality level, we employ a difference-in-differences approach to estimate the impact of ICMS-E on areas under legal protection. Focusing on the Atlantic Forest region in south and southeastern Brazil, we compare changes over time in municipalities from states that have implemented the ICMS-E (treatment group) to changes in comparable control states without the ICMS-E intervention. With a dataset of 1467 municipalities (and an expanded dataset with 2060 units used to check robustness), we explored three main questions: i) on average, does the ICMS-E influence the creation of new PAs?; ii) do the impacts of the ICMS-E program fall as the increase in total PA area over time dilutes its incentive for new PAs?; and iii) do those effects differ according to the level of government that is proposing the new PA as well as the PA type?

2. Theoretical model and hypothesis

The impact of EFTs depend on the program design and its interaction with the national and sub-national contexts. In the Brazilian case, state and municipal governments are differently positioned in the ICMS-E mechanism. State actors (i) decide to adopt ICMS-E, (ii) manage a larger area, i.e., the whole state (iii) benefit from environmental policy spillovers across municipalities, but (iv) do not receive the financial resources from ICMS-E. Municipalities (i) bear the costs of foregone land

[1] In Portuguese, *Imposto sobre a Circulação de Mercadorias e Serviços*.

[2] With a different method, de Paulo and Camões (2019a) investigated states engagement to the ICMS-E in Brazil and showed that the rate of program adoption raised in non-electoral years.

use due to PA creation, (ii) do not benefit as much from environmental policy accomplishments, but (iii) receive the ICMS-E money. The federal government does not have the same role as the states, facing entirely different incentives. Thus, we expect that choices should be different for state and municipal PAs.

H1. Outcomes are different for state-proposed PAs and municipal-proposed PAs.

Different PA categories imply different costs. Strict protection is more costly to implement than sustainable use reserves, for instance, considering all of the types of transaction costs related to paying for private land as well as persuading local people about a new land use arrangement (de Paulo and Camões, 2019b). Opportunity costs are probably the main costs and highly economically valued areas also likely promote more intense dispute over land use. In this context, an important point is that Environmental Protection Areas (APAs) do not require private lands to be expropriated or landowners to be indemnified. Expropriation costs are zero, so we expect APA creation to be preferred under the ICMS-E incentive. In addition, APAs can overlay with other PA categories, so they are not limited in space by the PAs within all other categories, but only by other APAs. Among all the PA categories, APAs certainly impose the least transaction costs.

H2. The rise in APAs under ICMS-E will be higher than for other PA categories.

Protected areas are not randomly assigned and their location is biased towards lands with low opportunity costs (Venter et al., 2014). For this program, within any PA category a bias towards lower opportunity costs is also expected, at least for municipal PAs (Droste et al., 2018). We expect that cheap PAs are created first and the remaining land for PAs has higher opportunity cost.

H3. Lack of space for new PAs has a negative effect on the creation of new areas.

Finally, the main criteria for redistributing the ICMS-E is the proportion of the municipality covered with protected areas (PAs) (federal, state or municipal, depending on each state law definition), weighted by PA category. The total amount of ICMS-E funds is divided across all municipalities competing for this resource (Loureiro, 2002). The amount received by each municipality hosting a PA depends on the total extension of PAs in the state and how much of that PA area is in other municipalities. As new PAs are created elsewhere within a given state, the share falls for a given municipality. Also falling as a result will be the magnitude of the rise in a municipality's share for any new PA it creates. Thus, municipalities that are considering the creation of new PAs are essentially competing for these funds with not only other localities but also their own past PA creation. Thus, the gains from a new PA falls as total PA area rises over time.

H4. The rise in PAs is smaller as marginal gain from an additional PA diminishes.

Summarizing, we expect that (i) results are different for state and municipal PAs; (ii) APAs are the preferred PA under the ICMS-E incentive as this category of PA presents the least transaction cost among all of the PA categories in Brazil; (iii) the increase in any category falls as opportunity costs rise and land opportunity costs increase as the space for new PAs reduces; and (iv) the increase of new PAs diminishes as the marginal gain from creating an additional area of PA decreases because the slices of the ICMS-E cake shrink as more and more PAs are created.

3. Data and empirical strategy

3.1. Data

We consider six states in the Atlantic Forest region that implemented the ICMS-E (Paraná, Minas Gerais, São Paulo and Rio de Janeiro), as well as control states in the same regions (South and Southeast) where ICMS-E was not implemented at any point (Santa Catarina and Espírito Santo). São Paulo was in the control for municipal PAs because it does not include municipal PAs in the calculus of the ICMS-E redistribution. The observed period for all the regressions considering the creation of new PAs is 1987-2016. However, in the computation of our total PA areas we considered all of the PAs, even if they were created before 1987, in order to correctly account for the accumulated area of PAs in the municipality.

We gathered our PA data from two sources: (i) the National Conservation Units Register (*Cadastro Nacional de Unidades de Conservação*) of the Federal Ministry of the Environment, available in its website (MMA, 2021); and (ii) a survey of municipal reserves conducted by the *Ambiental 44 Informação e Projetos em Biodiversidade Ltda*, done in partnership with the NGO SOS Mata Atlântica (Pinto et al., 2017).[3]

The National Conservation Units Register includes all the categories of PAs that exist in Brazil – those being Strictly Restricted (SR), Sustainable Use (SU) and Indigenous Land (IL) – as well as all of the three public administrative levels – i.e., federal, state, and municipal – involved in creating PAs since the first PA was created within Brazil in the 1930s. While federal and state reserves are well-documented, municipal reserves are less so. Municipal reserves are created by local governments (municipalities) through decrees. The *Ambiental 44 Informação e Projetos em Biodiversidade Ltda* provides detailed information about the municipal protected areas in the Atlantic Forest region and is probably currently the best and the most updated source for municipal PAs. From both sources, we obtained the following information for all PAs: restriction category, year of creation, locality (municipalities where they are located) and area of the reserve. Using these data, we calculated the percent of the municipality area covered by each PA for 2060 municipalities in the Atlantic Forest region within the six states that we study.[4] Because municipalities may change their limits, our final database only considers 1467 municipalities for which limits are exactly the same over the observed period, based on the Minimum Comparable Area analysis (Ehrl, 2017).

We complemented those data with municipal variables collected by the *Instituto Brasileiro de Geografia e Estatística (IBGE)* (National Institute of Geography and Statistics). For agricultural yield, we used the weighted mean of the produced quantity and current average price paid to the producer, according to periods of harvest and commercialization of each product (freight, taxes and charges are not included in the price)[5] (IBGE, 2017a). Cattle beef production was based on the effective herd in each municipality divided by total municipal area (density of cattle) (IBGE, 2017b).

Beyond those controls, we hypothesize that two main factors can be expected to modulate any impact on PA creation due to the presence of the ICMS-E program: (i) the marginal gain per additional PA area as determined by the ICMS-E formula; and (ii) the remaining municipal area, i.e., physical space, available for new PAs. We created two variables to distinguish the effect of these two factors.

3.1.1. Marginal gain

We simply took the derivative of the ICMS-E's formula for the redistribution of funds to compute the gain from creating another bit of PA area (see Supplementary Material). This *marginal gain* varies greatly depending on the existing PA area, getting close to zero when there is

[3] PA dataset was obtained from the authors of the study.

[4] Municipalities created between 1995 and 2010 (IBGE, 2010) were excluded from the database.

[5] In this case, we updated values from their original currencies (Cruzados, Cruzados Novos, Cruzeiros, Cruzeiros Reais and Reais) to corrected US dollars, using dollar quotation for Brazilian currencies for the last day of each year, provided by the Brazilian Central Bank, and inflation information (based on Consumer Price Index), provided by the Bureau of Labor Statistics, US government.

already a lot of PA area, while starting essentially at one if a municipality is the first in the state to have a PA. We used a two-year lag, in terms of the areas used to compute the incentive, since the ICMS-E revenue division is based on the PAs existent two years before. Finally, because this is a slightly complex formula, and a non-linear one, we test robustness using the log of a municipality's PA share and just the share itself.

3.1.2. Lack of space for new PAs

Municipalities can run out of area for new PAs over time, creating a physical upper-limit on new PAs plus a likely indicator of rising opportunity costs for any new PAs. We calculated the accumulated percentage of total municipality area in PAs, for each municipality in each year. For concerns about space, however, it is crucial to distinguish PA categories, in particular the very unrestricted *Environmental Protected Areas (APAs)* versus all the other PA categories. Based on the National System for Conservation Units (in Portuguese *Sistema Nacional de Unidades de Conservação – SNUC*), APAs are typically very large areas that encompass both public and private lands. Further, their implementation does not displace resident population and does not restrict economical activities such as agriculture and mining (Federal Law 9985/2000 (BRASIL, 2000)). This is the most unrestricted PA category and in fact it can further overlay any other type of PA with the implication that any existing PAs do not in fact limit the area for APA creation. As the accumulated PA percentage increases, space for new PAs decreases, so we call this variable lack of space for new PAs and we calculated it separately for: i) all PAs except APAs; and ii) APAs exclusively. We expect that as the accumulated area of PAs in a municipality increases, the probability of creating new PAs will decline.

3.2. Empirical strategy

We tested whether the ICMS-E legislation affected the creation of new PAs. We did so separately for state-proposed and municipality-proposed PAs, as well as for APAs exclusively and for other PAs. To do this, we used a municipality-level panel data and a difference-in-differences regression of the form:

$$y_{m,t} = \beta_1 \,\mathrm{law}_{m,t} + \beta_2 \,\mathrm{law}_{m,t} \times \mathrm{MG}_{m,t} + \beta_3 \,\mathrm{space}_{m,t} + \beta_4 X_{m,t} + \theta_t + \alpha_m + \varepsilon_{m,t} \quad (1)$$

where y is the percentage of total municipality area covered with new PAs (state or municipal) in each municipality m in each year t; *law* identifies if a municipality is under ICMS-E law in t year; *MG* accounts for marginal gain for an additional PA fraction in the municipality, lack of *space* and X are control variables; θ denotes time effect and ε is the error term. We believe the revenue *MG* is only relevant when ICMS-E law is implemented. We allow the heterogeneous effect of *law* by interacting it with *MG* variable (although we also test for the average effect of the law by keeping only the *law* and test robustness for the interaction by including the revenue *MG* by itself). Our two main parameters of interest are: β_1 for the effect of the ICMS-E when *MG* is zero; and β_2 for the effect of the interaction between the presence of the ICMS-E law in the treatment states and the marginal gain from creating new PAs in a municipalities, which varies with the stock of prior PAs.

Additionally, because the area under agricultural land use on rural lands might reduce the opportunity costs of new PAs and thus chances of creating them, we controlled for both agricultural and cattle-beef production. We also checked for robustness: (i) testing for alternatives variables that account for the effect of the ICMS-E allotment, (ii) varying control variables, (iii) varying units, considering a larger sample by relaxing the geographical limit criteria, iv) checking for the parallel trends between treatment and control groups and also v) applying the approach proposed by Callaway and Sant'Anna (2020) to check if the assumptions of a difference-in-differences analysis hold in this case, with multiple treatment periods, when using a two-way fixed effect method (see Suplementary Information). All models were conducted in R (Version 3.4.2.) (R Core Team, 2017), using the PLM package (Version 1.6-6) for panel regression analyses (Croissant et al., 2008).

4. Results

In terms of the general trends for PA creation, we found that both state and municipal governments increased the areal extent of new PAs over time, with more areal gain in unrestricted APAs than other PA categories (Fig. 2).[6]

Those trends over time in PA creation, however, could well be fully independent of the implementation of ICMS-E. Thus, to explicitly test for ICMS-E's impacts on PA creation, our panel regressions remove the fixed differences between all our municipalities, as well as the average trends across time for the whole sample. We then compare changes in areal PA extent in places with and without ICMS-E implementation. We find that ICMS-E has, on average, a significant positive effect on the creation of both new state and new municipal PAs (note that this average is most easily seen in SI robustness checks (Table S3) without any interactions). Following our theory of impact for ICMS-E, however, our highlighted results do feature the interaction between the presence of ICMS-E and the marginal gains, for any government, from creating new PAs (Table 1).

Recalling the derivative of the ICMS-E formula, i.e., that as more PAs are created the marginal financial gains from creation of new PA area can fall to zero, we do not expect the law to have an impact in all conditions. The evidence supports this (Table 1's initial 2 rows). The law usually has no effect if the marginal gain is zero (2nd row), i.e., if PA area is already high. The evidence also supports our hypotheses about differential impact of ICMS-E across PA types. ICMS-E has greater impact when the formula's marginal gains are higher, i.e., when there are fewer existing PAs (1st row). There is an important difference across types of PAs, however. Municipal APAs, with very low local opportunity costs, continue to be created despite low gains.

While the regressions referenced above focus on whether government shifted behaviors, the pattern of our estimated ICMS-E impacts is similar when the regressions are weighted by total municipal area (approximating an 'average effect in areas', more closely tied to the program's objective; Table 2). Naturally, these magnitudes are different: e.g., the unweighted effect on state APAs is 32% higher than on municipal APAs, while the weighted effect on state APAs is three times that for municipal APAs. However, all of the following core findings hold: ICMS-E implementation does not impact PA extent if the marginal gains for an additional unit of PA area are very low; the impact of ICMS-E rises with the marginal gains in terms of revenue; and effects vary by PA type, given variation across type in the costs of protection.

Across Tables 1 and 2, we find strong support for the hypothesis that the limited remaining physical space within a municipality area available for new PAs plays an important role in this observed outcome, confirming that we need to control for this factor. With regard to other controls: we found agricultural production yield to have an almost zero but still significant effect on state PAs, both restricted and unrestricted; while the cattle-density variable seems to have no effect upon the creation of new PAs or APAs.

As robustness checks, we varied the specification for our interactions as well as the control variables (Tables S2 and S3) and, further, tested some alternatives for measuring the marginal gain for the creation of a new PA (Table S4). A typical interaction specification for ICMS-E and its marginal gain is presented in Table S2 and shows a similar effect pattern. Shifting other control variables also finds the same for ICMS-E impact (Table S3). Finally, for the gain from additional PA area, we shifted from

[6] This was the case up to mid 2000s but protected areas downgrading, downsizing and degazettement has increased in Brazil since then (Bernard et al., 2014).

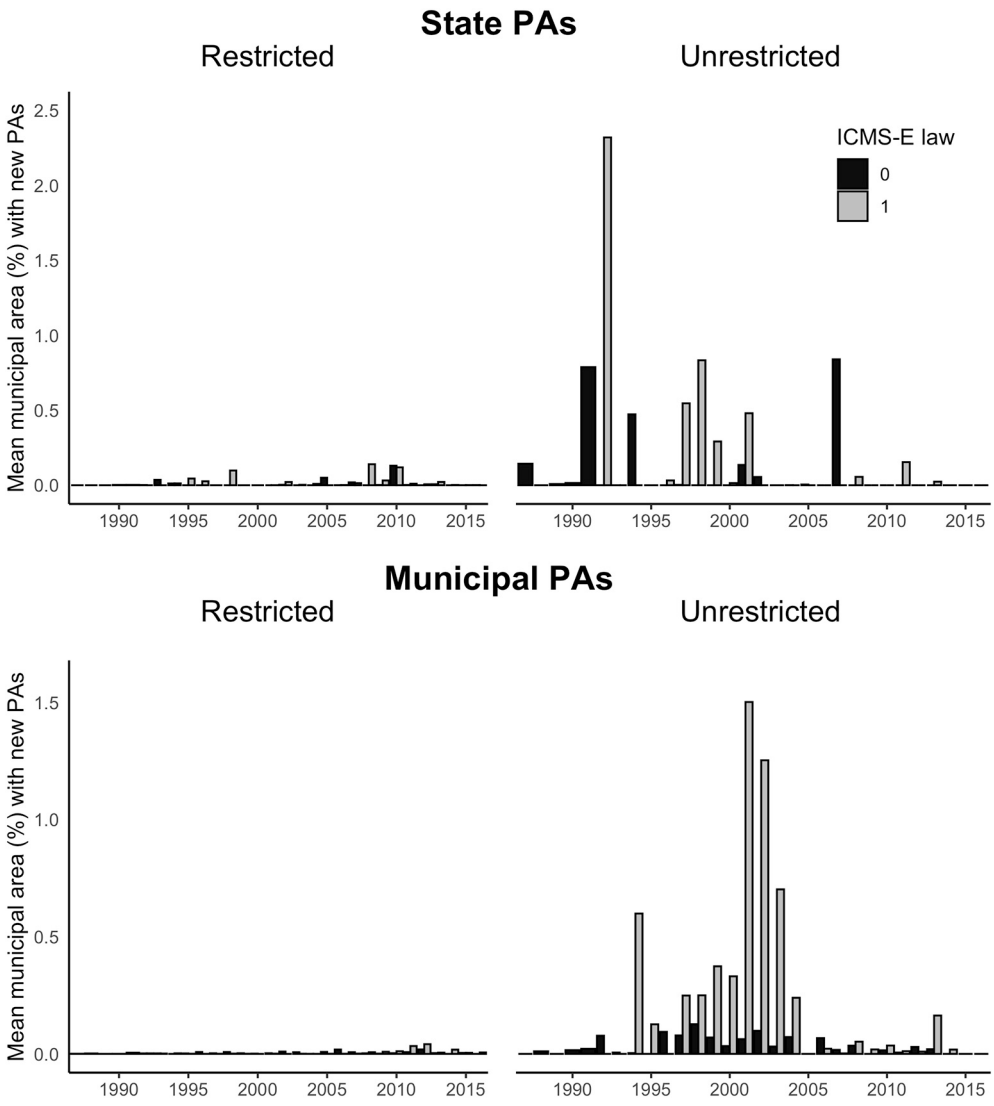

Fig. 2. The creation of new PAs per year under or not implemented ICMS-E law, as the mean of individual municipal area percentages covered with new PAs, over time for state and municipal, restricted and unrestricted PAs.

the marginal gain derivative to directly using the share of PA area that features in the ICMS-E formula (note that this implies one value per state per year versus individual values for each municipality) both logged and linear. In this form, the share rises as the PA cover in the state rises, so it has a negative effect on marginal gains. Thus, when there are few other PAs (share is small), the law has most impact. The interaction of law with share is negative. We also varied sample including a set of municipalities that had their limits changed over time and the observed patterns are the same (Tables S5 and S6). We apply the Callaway and Sant'Anna (2020) approach to our simple model in order to see how consistent is the use of two-way fixed effect (TWFE) regressions in our case. We found that the core assumptions appear to hold (see Supplementary Information).

5. Discussion

Our results show that the ICMS-E revenue-redistribution instrument promoted PA creation. That said, its redistribution formula limited the incentives: creating a new PA earns relatively less, approaching zero on the margin, as the stock of existing PAs keeps rising. Our results demonstrate the implications of that: impacts vanish, i.e., the ICMS-E no longer effectively incentives PA creation, when the stock of PAs gets high enough that the gains no longer justify incurring the opportunity cost.

We also showed that ICMS-E had its largest impact for PAs that imposes the least restriction on land use, implying low local costs (*Environmental Protected Areas – APAs*). Impacts are relatively large for APAs whether they are proposed by the state or by a municipality itself. For state proposals, the effect of ICMS-E on APAs is almost 7 times higher than for other PAs (Strictly Protected and Sustainable Use), despite the low weight attributed to APAs in the formula used to redistribute ICMS-E funds. Thus, it appears that low PA costs do matter. Finally, we find that ICMS-E's effects differ not only across PA categories but also by administrative levels responsible for PA creation. This too is consistent with costs mattering since for low enough costs, municipalities may accept low gains.

The ICMS-E formula effectively creates a race: municipalities creating PAs early get almost all of the early resources. This dynamic too may incentive APAs (once again despite their lower weight in the ICMS-E's rational formula), since they can be created rapidly given their flexibility, e.g., ability to overlap with existing land-use designations, and generate some income for municipalities. As political decisions are known to be influenced by short-term electoral incentives (Burgess et al., 2012; Ruggiero, 2018), in this case we can imagine a municipal

Table 1
ICMS-E impacts on new state and municipal PAs, as the percentage of total municipal area.

	State		Municipal	
	(1)	(2)	(3)	(4)
	PAs (no APAs)	Only APAs	PAs (no APAs)	Only APAs
Marginal gain × ICMS-E law	0.2115**	1.7498***	0.0366*	0.8758***
	(0.0834)	(0.5122)	(0.0220)	(0.3348)
ICMS-E law	−0.0055	−0.0335	0.0083	0.1353**
	(0.0135)	(0.0845)	(0.0073)	(0.0536)
Lack space for PAs (no APAs)	−0.0302***	0.0109	4e−04	−0.0175
	(0.0056)	(0.0137)	(0.0012)	(0.0135)
Lack space for APAs	–	−0.0968***	–	−0.0073***
		(0.0064)		(0.0019)
Agricultural production	0***	−4e−06***	0*	2e−06***
	(0)	(1e−06)	(0)	(1e−06)
Livestock	0.0001	−0.0006	−0.0001	−0.0007
	(1e−04)	(9e−04)	(1e−04)	(5e−04)

Notes: All regressions include time and municipal fixed effects, as well as controls according to 3.2. Columns 1 and 3 consider all PAs, except APAs for state and municipal PAs, respectively. Columns 2 and 4 estimates consider exclusively APAs for state and municipal APAs, respectively. Coefficients for ICMS-E law are conditional on revenue share equal to 0. Standard errors are clustered at the municipal level.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 2
ICMS-E impacts on new state and municipal PAs, as the percentage of total municipal area weighted by area.

	State		Municipal	
	(1)	(2)	(3)	(4)
	PAs (no APAs)	Only APAs	PAs (no APAs)	Only APAs
Marginal gain × ICMS-E law	0.1692**	2.8401***	0.0431*	0.5340*
	(0.0839)	(0.3311)	(0.0260)	(0.2799)
ICMS-E law	0.0199	0.0069	0.0062	0.1563**
	(0.0216)	(0.0851)	(0.0063)	(0.0676)
Lack space for PAs (no APAs)	−0.0324***	0.0084	2e−04	−0.0122***
	(0.0015)	(0.0059)	(4e−04)	(0.0045)
Lack space for APAs		−0.0949***		−0.0090***
		(0.0017)		(0.0013)
Agricultural production	−1e−06***	−3e−06***	0**	1e−06*
	(0)	(1e−06)	(0)	(1e−06)
Livestock	3e−04	6e−04	−1e−04	−0.0012
	(3e−04)	(0.0013)	(1e−04)	(0.0010)

Notes: All regressions include time and municipal fixed effects, as well as controls according to 3.2. Columns 1 and 3 consider all PAs, except APAs for state and municipal PAs, respectively. Columns 2 and 4 estimates consider exclusively APAs for state and municipal APAs, respectively. Coefficients for ICMS-E law are conditional on revenue share equal to 0. In this case, standard errors were not clustered.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

mayor with a four-year term running on an ability to secure additional revenue streams and thereby committing to more APAs to secure some ICMS-E revenue before the next election.

States also proposed unrestricted PAs (APAs) as a response to ICMS-E, though as they do not receive revenue they have no particular reason to use PAs with less impact. State environmental institutions may prefer to use ICMS-E to support the implementation of strictly protected and sustainable use that tend to have more conservation impact (Pfaff et al., 2014; Nolte et al., 2013). However, there may exist local resistance to stricter PAs, leading states to propose some APAs too. Related, while we generally find that a lack of physical space to locate new PAs reduces the impact of ICMS-E on PAs taken as a whole, it has a non-significant positive trend on the creation of new state APAs. This is logical from the state perspective since if there are fewer opportunities to create new restrictive PAs, new APAs can still be created, even overlaying other PA categories. Viewed as part of the multiple conservation options that can be deployed at the state level, APAs supported by the ICMS-E may be useful as buffer areas around other PAs in broader strategy.

One limitation of our study is that it was not possible to observe the polygons for the municipal PAs' geographic limits. We would have liked to do that, in order to test whether the PAs were sited upon relatively less economically valuable lands. Lacking that information, we might assume that lower-cost PAs are created first; then, the marginal cost of new PAs rises as space falls, predicting effects of space.

Some have suggested that using lowest-opportunity-cost areas is a good strategy as a cost-effective path to conservation (Droste et al., 2018). However, as has long been shown, it is also a way to achieve less effective conservation (Joppa and Pfaff, 2011), since the resulting protected area state contributes little additionality. Globally, protecting the lowest opportunity-cost areas terrestrial areas will only increase the number of threatened vertebrate species covered by legal protection by 6%, from 2014 to 2020, even if the Aichi targets are met for bringing approximately 17% of the world's terrestrial surface under protection (Venter et al., 2014). In any case, the ICMS-E program's formula did not use differences in lands' values in any way. What it does do is shift the yardstick as more PAs are created: others' actions and even one's own past actions do not promote continuous PA growth (Droste et al., 2018) but instead cause a drop in the incentive to keep responding to the ICMS-E with new PAs.

Overall, we found that ICMS-E does positively contribute to the expansion of the protected area estate in the Brazilian Atlantic Forest. Since it is a program that offers benefits to municipalities, it does not *per se* generate conflict. On the contrary, it supports state government institutions in the implementation of biodiversity conservation, possibly lowering local resistance to new PAs. The only caveat we demonstrate is that its formula essentially closes down its own impacts when the program is successful, i.e., ICMS-E is a self-limiting incentive. If the agencies currently feel that more PAs would be positive on net, perhaps a redesign of the formula would be needed to boost the incentives actors have for creating PAs.

6. Conclusion

Generally, our results corroborate the idea that a conditional-funds-transfers program (or performance-oriented fiscal transfer as posed by Droste et al. (2018)) such as the ICMS-E promotes new PAs (May et al., 2002; Droste et al., 2017). Yet we also shed new light on both the longevity and quality of the program's influence. Following one of our core hypotheses, the ICMS-E instrument limits its own impact over time because the marginal financial gain from creating new PAs declines as the stock of existing PAs increases. In terms of the quality of those impacts, we see that ICMS-E contributes strongly to the creation of new unrestricted PAs, proposed at both the state and municipal levels, but is less effective at incentivizing the creation of protected areas with greater conservation value, at the municipal level. This is an understandable consequence of municipalities' interests in generating revenue and reducing costs. Overall, we find that the environmental incentives generated by the ICMS-E instrument vary in their influence on proposals for new PAs by state versus by municipal governments. In contexts

where the ICMS-E marginal incentive is still significant, our results indicates that it can be a useful tool.

Data availability

The data that support the findings of this study are available from the corresponding author upon request. The full R-code used to conduct this analysis is available at a personal GitHub repository (https://github.com/pruggiero2/ICMS-E_self_limiting).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107219.

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