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Empowering Local Governments: Evidence from Rural Land Tax Decentralization*

Pedro Henrique Cavalcanti   Renata Motta Café

Abstract

This paper examines the fiscal and extra-fiscal effects of decentralizing the collection of Brazil's rural land tax from the federal level to local governments. Using a difference-in-differences research design, we assess the impact of local tax enforcement on revenue, land use, and environmental outcomes. Decentralization led to sustained revenue gains, increased agricultural production, expanded reported environmental protection areas, and slightly decreased land concentration. Our findings highlight the role of property taxation as a policy instrument for environmental conservation and sustainable development.

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1 Introduction

Fiscal decentralization can lead to a more efficient allocation of public resources because local governments are better positioned to respond to community needs and preferences than central authorities (Oates, 1972). The geographic proximity between local tax authorities and taxpayers strengthens monitoring and enforcement, reducing tax evasion and improving compliance. In addition, fiscal decentralization may enhance public accountability (Faguet, 2014), as citizens perceive a more direct link between taxation and public service delivery, potentially increasing tax compliance.

On the one hand, decentralization of revenue collection can leverage local knowledge to improve compliance, increase responsiveness, and enhance accountability, consistent with the theoretical benefits of "bringing government closer to the people." On the other hand, decentralization can be limited by local government capacity, political constraints, and the potential for political capture (Smoke, 2014; Katovich and Moffette, 2024). Whether or not decentralization delivers on its promises is ultimately an empirical question, but direct empirical evidence on the limits of local taxation remains relatively scarce (Gadenne and Singhal, 2014; Mascagni, 2016). Identifying an appropriate counterfactual is challenging because decentralization typically affects entire countries and is often part of broader policy packages. Some empirical and anecdotal evidence comes from specific reforms that decentralized the provision of public services (Galiani et al., 2008; Kis-Katos and Sjahrir, 2017), but few studies provide rigorous evidence on the revenue side.

This study provides an empirical test of fiscal decentralization, considering the case of the rural land tax (ITR, for its acronym in Portuguese) in Brazil. This particular setting allows us to examine how decentralization affects both the efficiency of tax collection and the potential of taxes to achieve broader policy goals (extra-fiscal effects). Decentralization can increase enforcement and the perceived risk of punishment for landowners who do not declare their taxes correctly, which can encourage behavioral change toward accurate declarations.[1] Concerning the extra-fiscal impacts, we examined how bringing

[1]Economic theory suggests that a higher probability of detection and conviction increases the declared tax base. (Allingham and Sandmo, 1972).

tax control powers closer to the taxpayer affects the dynamics of land use and its environmental consequences. Specifically, we analyzed whether there was an increase in farm production, an improvement in environmental protection, and a decrease in land concentration.

The ITR has a long history of non-compliance and evasion in Brazil. Its primary purpose is not to raise revenue but to support the public policy of rural land deconcentration. The tax is levied on the ownership, possession, or use of a property located outside the urban area of the municipality and is calculated on the assessed value of the unbuilt land, the so-called Bare Land Value (*Valor da Terra Nua*, hereafter VTN). The ITR is levied progressively to discourage unproductive large estates. The rate increases with the size of the property and decreases non-linearly as the area devoted to production increases. In addition, areas declared to be of environmental interest are exempt.

The ITR can be an important instrument to support environmental policies through two main mechanisms (Lenti and Silva, 2016).[2] First, the government encourages increased productivity on existing rural land by imposing a higher tax on land speculators. This reduces the need to clear native vegetation to open up areas for agricultural production and contributes to the conservation of natural habitats and biodiversity. This line of action is relevant given the practices of land speculation in the Amazon, where individuals engage in deforestation and occupy public land with the expectation of future appreciation. Such speculation results in environmental, social, and economic losses, such as excessive deforestation, limited access to land by the poorest, and low productivity (Silva and Barreto, 2014). Effective ITR management could mitigate these losses.

Second, the ITR provides exemptions for areas of intact native vegetation and those undergoing regeneration, offering a direct financial incentive for landowners to comply with environmental regulations and conserve these areas. In Brazil, approximately 55% of natural vegetation is located on private land, highlighting the importance of engaging landowners in conservation efforts (Sparovek et al., 2015). The 2012 Forest Code establishes land use requirements for property holders to preserve native vegetation on

[2] Among the tax formats, taxation on real estates, such as land, is the least distortive (OECD, 2010).

private lands through two primary protection instruments: Permanent Preservation Areas (APPs) and Legal Forest Reserves (Chivari and Lopes, 2015).

Despite a promising tax design, the ITR has proven insufficient to achieve its objectives. Brazil's tax burden was equivalent to 32.44% of GDP in 2023, but the ITR collected only 0.03% of GDP, 20 times less than the urban property tax, which was 0.61% of GDP (STN, 2024b). The small amount collected contrasts with the country's vast land area and thriving agricultural and livestock sectors (Ahmad et al., 2019). The literature suggests that taxpayer self-declaration of the VTN and the degree of land use, combined with weak monitoring by the federal government, leads to fraudulent declarations, unrestricted tax evasion, and thus the fiscal and extra-fiscal irrelevance of the tax.

This historic challenge prompted a governance reform to transfer responsibility for ITR collection from the federal government to sufficiently capable municipalities through agreements with the federal government. To settle an agreement, the municipality must have adequate information technology capacity to access Brazil's Federal Revenue Service (RFB) systems and a staff of career civil servants capable of levying and collecting taxes. With the agreement in place, the municipal government receives 100% of the funds collected from the rural properties located within its borders, instead of the standard 50% when the RFB collects the tax. This change provided an opportunity to compare the effects of fiscal decentralization on an empirical basis.

We constructed a municipal-level panel dataset with data on ITR agreements and revenue, as well as indicators of land use, agricultural production, environmental impacts, and land concentration from 2003 to 2018. The methodology used to estimate the impact is a staggered difference-in-differences approach. The main hypothesis regarding the fiscal effect is that decentralization leads to an increase in tax revenue. This revenue growth can be attributed to two factors. First, there is a mechanical increase in municipal revenues, as convened municipalities now retain 100% of the amount collected from properties within their jurisdiction, compared to the previous 50%. Second, there is an improvement in the overall efficiency of tax collection within the partner municipalities, which are closer to taxpayers and can more effectively monitor compliance and enforce tax obligations.

We analyzed the fiscal impact in two ways: first, by assessing ITR transfers to municipalities, capturing both the mechanical and enforcement effects; and second, by evaluating total ITR collection per municipality, which reflects improved enforcement and compliance. Our findings indicate that transfers increased by 81.4%, while total ITR collection rose by 23%. Conversely, other municipal revenues, such as intergovernmental transfers unrelated to the ITR (e.g., the Municipal Participation Fund, FPM, or the urban property tax, IPTU), remained unaffected by the policy.

We found that municipal decentralization contributed to addressing the issue of unproductive large estates. Specifically, this led to an increase in agricultural area and production, as property owners adjusted their land use to meet the legal requirements for lower tax rates. Concurrently, pastureland usage decreased, particularly in regions where the productivity required to reduce tax payments is higher, signaling a substitution effect from pasture to agriculture. In addition, we observed a marginal increase in forest area in the initial years following the policy implementation, driven primarily by a rise in declarations that allowed these areas to qualify for tax exemptions. However, this conservation effect proved temporary, with the increase in forest cover disappearing by the third year. The policy did not lead to sustained reductions in deforestation or forest fires. Finally, we identified a 1–3% reduction in land concentration, as indicated by declines in the Gini index and the Herfindahl-Hirschman index, suggesting a more equitable distribution of land ownership.

This paper contributes to the literature in three main ways. First, it provides an empirical test of decentralization theory, which suffers from limited quantitative evidence. Our study distinguishes itself by comprehensively assessing the causal impact of ITR decentralization at the national level, using a research design to identify causal effects, and analyzing the underlying mechanisms. Previous studies using municipal-level data have conducted partial analyses of the impact of ITR decentralization (Caldeira et al., 2023; Heck et al., 2021; Quadros et al., 2024).

Heck et al. (2021) and Caldeira et al. (2023) focused exclusively on the fiscal effects of decentralization, reporting revenue increases of 8.8% and between 42% in the first year and 109% by the eighth year, respectively. These results suggest that more efficient tax enforcement under decentralization leads to higher ITR revenues. Meanwhile, Quadros et al. (2024) examined both the fiscal and extra-fiscal effects of ITR decentralization, but only within the state of Rio Grande do Sul. Their findings indicate that municipalities that entered into agreements experienced a 35% increase in revenue, a 12% increase in land use, and a 24% increase in the contribution of agricultural production to total GDP.

A notable contribution to the analysis of ITR decentralization was made by Bragança et al. (2024), who used restricted microdata from tax returns. Their results show significant fiscal effects, with ITR collection increasing by 20% five years after policy implementation and by 40% ten years after policy implementation. These effects are mainly due to an increase in the VTN declared by properties that already paid the tax. Regarding extra-fiscal effects, they show that the effective tax rate (based on declared size and land use) decreases by 5%, suggesting a moderate behavioral response. This is consistent with the findings on land use and environmental outcomes in this paper, although we compare different groups.[3]

Second, this paper contributes to the literature on property taxes and their untapped potential in developing countries (De Cesare, 2012; Bonet et al., 2014; Ahmad et al., 2019). While property taxes account for over 2% of GDP in OECD countries—reaching 3% in the United Kingdom, United States, and Canada—they typically represent less than 1% of GDP in developing and emerging economies.[4] This revenue gap not only constrains public resource generation but also undermines the effectiveness of land use and regulatory and environmental management policies that property taxation could otherwise support.

Property taxes constitute the most significant source of revenue for local governments worldwide (Bahl and Vazquez, 2008). Due to their immobile tax base, they are particularly well-suited for municipal decentralization (Bird, 1993; Weingast, 2009; Ahmad et al., 2019). Local governments, by virtue of their proximity to taxpayers, can collect more ac-

[3]The authors adopt a different strategy from ours and previous studies, comparing municipalities that signed the agreement in a given year and implemented the program with those that signed in the same year but did not fully implement it.

[4]Data available at https://data-explorer.oecd.org/.

curate information on properties, leading to improved assessments and enforcement. This closeness fosters a deeper understanding of local dynamics and enhances the efficiency of tax administration. Moreover, property taxes offer municipalities stable, predictable, and resilient revenue streams over time—an especially relevant feature within the framework of Brazilian federalism, where municipalities depend on intergovernmental transfers to meet their expenditure responsibilities.[5] By focusing on rural property tax, this study also fills a gap in the literature, which has predominantly focused on urban property tax.[6]

Third, this paper contributes to the emerging literature on tax policy and environmental management (Mottershead et al., 2021; Schaffer, 2021). Several countries have implemented tax policies to promote productive and sustainable land use, often combining penalties for unproductive land use and environmental degradation with incentives to enhance environmental sustainability (OECD, 2020). For instance, in the United States, the tax base for most farms is typically 40–70% below market value. In Canada, provinces administer property tax programs designed to support the agricultural sector. Similarly, in Australia, states offer tax exemptions for 'primary production land', and landowners may qualify for tax concessions if they participate in conservation agreement programs.

Ensuring environmental protection is a complex challenge that requires a combination of policy efforts. Understanding the potential and limitations of the extra-fiscal role of tax policy is crucial to maximizing the effectiveness of conservation efforts. By evaluating the impact of ITR decentralization on land use dynamics and environmental indicators, this study provides policymakers with insights into the potential of property taxes as a tool for environmental conservation and sustainable development.

Following this introduction, the article is organized as follows: Section 2 provides an overview of the institutional context of the ITR, focusing on Brazilian fiscal federalism and the policy of decentralizing its collection. Section 3 describes the data. Section 4 outlines the identification strategy, addressing potential selection bias and detailing the event

[5]In 2023, municipal governments collected 12% of public sector revenues but executed 16% of total expenditures, covering the gap through intergovernmental transfers (STN, 2024a).

[6]A search in the Brazilian Digital Library of Theses and Dissertations of the Brazilian Institute of Information in Science and Technology, conducted on December 29, 2024, yielded 20 results for the term 'ITR' (rural property tax) compared to 227 for 'IPTU' (urban property tax).

study and difference-in-differences methodologies. Section 5 presents the impact estimates and examines the mechanisms driving both fiscal and nonfiscal outcomes. Finally, Section 6 provides concluding remarks and suggests directions for future research.

2 Institutional Background

Brazil is a federation composed of three levels of government: federal (Union), state (26 states and the Federal District), and municipal (5,568 municipalities), all of which have administrative and financial autonomy and the competence to exercise their taxing powers and implement corresponding spending policies.

Municipalities have the power to tax urban real estate (IPTU), the consumption of services (ISS), and the sale of real estate (ITBI). In 2023, Brazil had a tax burden equivalent to 32.4% of its gross domestic product (GDP). Of this total, municipalities collected the equivalent of 2.3% of GDP, states 8.1% and the Union 22% of GDP. Of the amount collected by municipalities, ISS accounts for 48% of the total, IPTU for 25%, and ITBI for 8% (STN, 2024b).[7]

The Rural Property Tax (ITR). The creation of the ITR has a long history, dating back to the first Constitution of the Republic of 1891. Since then, the ITR has undergone several changes in its structure and administration. Initially, it was part of the tax base of the states (1891 to 1961) and municipalities (1961 to 1964), until it became a federal tax administered by Brazil's Federal Revenue Service (RFB).

The current Federal Constitution of 1988 establishes that the ITR shall be progressive and its rates fixed in such a way as to discourage the maintenance of unproductive properties (Art. 153, § 4 of the Brazilian Constitution). The tax, which is assessed annually, is levied on the ownership, use, or possession of real estate located outside the urban area of the municipality, but is not levied on small rural properties if the owner has no other property. Although it is a federal tax, fifty percent of the revenue collected from properties within a municipality is returned to the local government.

[7]Municipal pension contributions and other municipal taxes account for the remainder.

The ITR is calculated and paid by the taxpayer based on the value of the bare land (VTN) and the degree of land use (GU), as shown in Equation 1. If the tax return is not submitted or contains incorrect information, the RFB may initiate tax collection procedures. The taxable area excludes areas of environmental interest[8] once the taxpayer has registered an Environmental Declaratory Act (ADA). The ADA allows a reduction of up to 100% in the amount of tax due. The VTN must reflect the market value of land, calculated on January 1 of each year, and is considered a self-assessment of bare land at market value. It is calculated from the value of the property, excluding the value of buildings, crops, pastures, and forests.

$$ITR = \frac{TaxableArea}{TotalArea} * VTN * Rate(GU, TotalArea) \quad (1)$$

The degree of land use is defined as the ratio of the area effectively used in the previous year - through planting, grazing, extractive exploitation, agriculture or aquaculture, or the implementation of a technical project - to the total area of the property, excluding areas designated for environmental preservation and necessary improvements.[9] The applicable tax rate varies between 0.03% and 20% depending on the property's total area and its land use degree, as detailed in Table 1. This results in a tax rate spectrum where the highest rate is 600 times greater than the lowest.

Table 1: ITR Rate According to Total Property Area and Degree of Use

Total Area (in hectares)	**Degree of Land Use (%)**				
	≤ 30	>30 and ≤ 50	>50 and ≤ 65	>65 and ≤ 80	>80
≤ 50	1.00	0.70	0.40	0.20	0.03
>50 and ≤ 200	2.00	1.40	0.80	0.40	0.07
>200 and ≤ 500	3.30	2.30	1.30	0.60	0.10
>500 and ≤ 1,000	4.70	3.30	1.90	0.85	0.15
>1,000 and ≤ 5,000	8.80	6.00	3.40	1.60	0.30
>5,000	20.00	12.00	6.40	3.00	0.45

Source: Law No. 9,393/1996.

Appy (2015) argues that from an economic point of view, the highest rate is excessively

[8] Areas of environmental interest include: Permanent Conservation Areas, Legal Reserves, Private Natural Heritage Reserves, Ecological Interests, Environmental Servitudes, Areas Covered by Native Forest and Areas Flooded for Hydroelectric Power Plants.

[9] Appendix Table A1 defines the concepts used to calculate the ITR Utilization Rate.

high, since in five years the amount of tax due is equal to the taxable VTN. On the other hand, the lowest rate is too low. This discrepancy encourages the manipulation of the indices, either by underestimating the VTN, by overestimating the size of the area of environmental interest (non-taxable) or by overestimating the land use degree and thereby reducing the applicable rate. The self-declaratory nature of the tax, combined with little federal oversight, contributes to poor collection performance.

A constitutional reform allowed the decentralization of tax supervision to local governments. According to the Proposed Constitutional Amendment (PEC) No. 41/2003[10], which has been transformed into Constitutional Amendment (EC) No. 42/2003, the measure aims to strengthen the fiscal and extra-fiscal performance of the ITR:

> 'This measure aims to allow the inspection, collection, and administration of this tax to be carried out by these federal entities, which, by virtue of constituting the geographical region where the property subject to the tax is located, are better able to guarantee its enforcement. In addition, it improves the use of the tax as an effective instrument for the implementation of public policies on land use, since the States and the Federal District have control and collection structures that are physically closer to rural properties.'

The regulation of EC No. 42/2003, through Law No. 11,250/2005 and Decree No. 6,433/2008, has allowed municipalities and the Federal District to sign agreements with the Federal Government to act in the inspection and collection of ITR. To enter these agreements, the municipalities must have adequate technological infrastructure to access the RFB's systems and have career civil servants trained in tax assessment (RFB Normative Instruction No. 884/2008 and its amendments and replacements). Once the agreement is in effect, the municipality takes over the ITR inspection and the issuance of tax notices, as well as bearing the costs of training employees and issuing tax documents, among other obligations. The tax power remains with the federal government, which continues to be responsible for its legislation. Decentralization cannot result in a tax reduction or exemption of any kind.

[10] The PEC initially proposed transferring ITR responsibilities to state governments.

In return, by signing the decentralization agreement, the municipality receives 100% of the ITR collected from rural properties within its jurisdiction through transfers from the federal government, beginning in the second month after the agreement is signed. There are no specific requirements as to how these funds should be used, and they are at the discretion of the municipality. Figure 1 illustrates the evolution of ITR revenue over time. After the agreements began in 2008, the total amount collected and net transfers to municipalities gradually increased. This behavior suggests a positive fiscal effect of the municipal decentralization policy, which will be evaluated in the following sections.

If the municipality decides to terminate the agreement or fails to meet the obligations agreed to with the RFB, such as inspection goals, the agreement may be terminated. This termination will be effective January 1 of the year following the date it is formalized. In total, 2,093 of the 5,568 municipalities signed agreements with the federal government between 2008 and 2016. In the first year, 62 municipalities signed an agreement. The year with the highest number of new municipalities signing agreements was 2009, with 1,222 municipalities, followed by 2013, with 247 municipalities.[11]

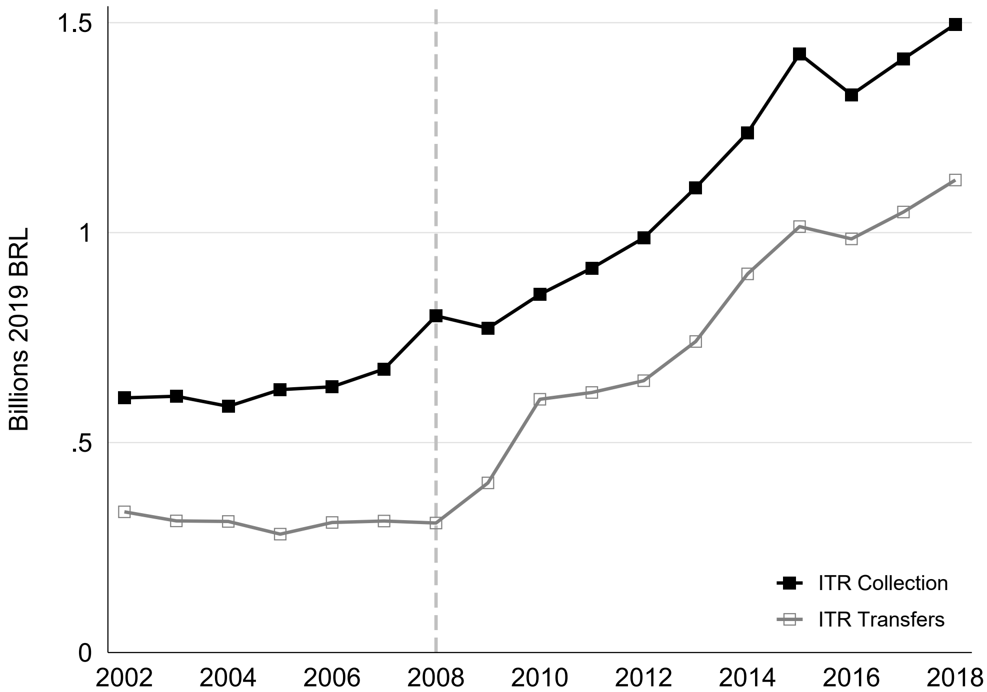
Nevertheless, Appy (2015) warns of the risk that municipalities' focus on using the ITR as a revenue source could eventually undermine the extra-fiscal objectives of the tax. He argues that any measures that reduce tax collection in favor of extra-fiscal objectives, including environmental objectives, could be met with resistance from municipalities.

Equation 1 shows that fiscal and extra-fiscal outcomes depend on different variables. The literature highlights that fiscal results are strongly influenced by enhanced control achieved through municipal decentralization, particularly in the verification of declared VTN. For example, Silva and Barreto (2014) estimate that in the state of Pará, the amount collected in 2011 (BRL 5.4 million) could have been nearly 10 times higher if the official VTN had been applied (BRL 51.2 million) and over 100 times higher if the market VTN had been used (BRL 271.4 million). Additionally, more effective government control can verify whether the declared land use degree aligns with reality.

On the other hand, the extra-fiscal results related to the dynamics of land use can

[11] Figure A1 illustrates the gradual adoption of agreements for the inspection and collection of ITR by municipal governments.

Figure 1: ITR Collection and Transfer by Year (2019 Prices)



Source: Brazil's Federal Revenue Service (tax collection) and National Treasury Secretariat (transfers).

be interpreted as a result of the change in the behavior of the rural landowner regarding the degree of land use and the taxable area of the property. With a higher probability of irregularities being detected by the municipal inspection body, rural landowners are encouraged to increase the productivity of the land to declare a higher land use and thus reduce the tax rate. Similarly, the landowner can choose to increase the declaration of areas of environmental interest, which also reduces the taxable area of the property.

This dual scenario, in which municipal decentralization can promote tax collection and extra-fiscal objectives or exacerbate possible tensions between the fiscal and extra-fiscal objectives of the ITR, motivates the empirical exercise in the following sections.

3 Data

This section presents the main data sources used in the study, as well as the selection criteria and processing procedure used to construct the data panel. All data is annualized and refers to the municipality level. Table 2 summarizes this information.

Table 2: Main Variables and Data Sources

Category	Variables	Source	Period
ITR Agreements	Start and end dates for the agreements.	Federal Revenue of Brazil (RFB)	2008–2018
ITR Revenue	Annual ITR collection and transfers.	RFB (collection), National Treasury (transfers)	2003–2018
Municipal Public Finances	Total current revenue, municipal taxes, and intergovernmental transfers.	National Treasury Secretariat (FINBRA)	1997–2018
Land Use	Land use classification (forest, pasture, crops, non-forest areas). Normalized variations following Assunção and Rocha (2019).	MapBiomas (satellite images)	1985–2018
Farm Production	Planted area, yield, and production volume of the main crops (rice, sugarcane, cassava, corn, soybeans). Yield is log-transformed following Jayachandran (2006).	IBGE (Municipal Agricultural Production - PAM)	2000–2018
Land Concentration	Number of properties and areas by property size. Calculation of the Land Gini Index following Hidalgo et al. (2010), and the Herfindahl-Hirschman Index (HHI).	IBGE (Agricultural Census)	2006, 2017
Deforestation	Annual deforested area, from August 1 to July 31. Normalized variations following Assunção and Rocha (2019).	National Institute for Space Research (INPE - PRODES)	1988–2018
Forest Fires	Annual fire outbreak count.	INPE (Queimadas program)	2000–2018
Environmental Declaratory Act (ADA)	Number of properties with ADA declarations; preserved area (permanent preservation, reforestation, native forest).	IBAMA	2008–2018
Municipal Characteristics	Total population, proportion of rural population, GDP, area and number of rural properties.	IBGE	2000–2018
Characteristics of Mayors	Level of education, rural profession, political party. Dummy variables to capture political alignment with the President of the Republic.	Superior Electoral Court (TSE)	Municipal elections: 2000, 2004, 2008, 2012, 2016

Notes: Own elaboration.

ITR Agreements. The RFB provides the dates of entry into force[12] and termination (whether compulsory or voluntary) of agreements between the municipalities and the federal government for the inspection and collection of ITR. The series spans from December 2008 to December 2018. After this period, a large-scale operation by the RFB excluded municipalities that were not in compliance with the terms of the agreement. We define the year in which the agreement came into effect as the start of the treatment.[13]

ITR Revenue. Data on annual ITR collections by municipality is provided by the RFB. For reasons of tax secrecy, the RFB omits the amounts if they are collected from a very small number of properties in order to protect the identity of the taxpayers. In addition, the data does not include amounts collected through tax forms that do not have a registered property number. As a result, the sum of the amounts reported per municipality is lower than the total ITR collected. The ITR collection remains part of

[12] Coinciding with the date published in the Federal Gazette (*Diário Oficial da União*).

[13] ITR decentralization agreements become effective in the second month following the signing of the agreement.

the federal tax revenue and reaches the municipality as a current transfer. The National Treasury Secretariat Constitutional Transfers Database provides ITR transfer amounts per municipality, net of applicable deductions.[14] For this paper, we have constructed a balanced panel with positive values for tax collection and transfers per municipality from 2003 to 2018.[15]

Land Use. Land use information was obtained from MapBiomas, a dataset that uses satellite imagery to classify the use of each 30 square meter pixel into different categories each year. There are broad categories, such as anthropogenic or natural areas, and more detailed categories, such as crops, pastures, forests, and others. To smooth the cross-sectional differences due to the heterogeneity in the size of municipalities, the data is normalized as in Assunção and Rocha (2019).[16] This procedure standardizes the variable by adjusting the mean and standard deviation within each municipality. A few municipalities where no land use change was detected during the analysis period were excluded from the regression analysis.[17]

Farm Production. The Municipal Agricultural Production Survey (PAM) of the Brazilian Institute of Geography and Statistics (IBGE) provides information on planted area, volume, yield, and agricultural production. The planted area is an indicator that allows measurement of the variation of production in extensive terms. Yield, on the other hand, captures the variation in intensive terms, reflecting the productivity of land use. Given the heterogeneity of agricultural production in the country, we calculated the log variable[18] of crop yield for the five most important crops in terms of revenue, soybean, sugarcane, maize, rice, and cassava, similar to Jayachandran (2006). The yield of each crop was normalized to have a mean of zero and allow for comparisons across crops. Weights are given by the share of crop revenue at the county level.

[14]There is a deduction of 20% for the FUNDEB (education) and a deduction of 1% for the PASEB (labor policy).

[15]There are 4,821 municipalities with data available in the balanced panel, of which 2,001 entered into agreements at some point, while 2,820 are in the control group.

[16]The normalization is done with the formula: Norm.$Y_{it} = \frac{Y_{it}-\bar{Y}_{it}}{\text{sd}(Y_{it})}$, where y_{it} is the independent variable for municipality i in year t, $\bar{y_{it}}$ is the mean of y_{it} and $\text{sd}(y_{it})$ is the standard deviation of y_{it}.

[17]Municipalities with no land use change are excluded because their lack of variation over time makes normalization undefined. This affects less than 4% of the sample, ensuring the robustness of the results.

[18]Weighted average of the logarithm of the volume of the crop produced or area cultivated.

Land Concentration. The Agricultural Census, collected by the IBGE, provides information at the municipal level on the number of properties and the areas covered by rural properties, divided into groups of areas ranging from zero to more than 2,500 hectares. We used the 2006 and 2017 agricultural censuses to calculate the land Gini index, similar to Hidalgo et al. (2010).[19] To ensure the robustness of the results, we also calculated the Herfindahl-Hirschman Index (HHI).

Deforestation. The National Space Research Institute (INPE) provides deforestation data using satellite imagery through the Project for Monitoring Deforestation in the Legal Amazon (PRODES). PRODES provides annual estimates that do not correspond to the calendar year. For a year t, the system records the cumulative deforested area between August 1 (year t - 1) and July 31 (year t). Thus, we define deforestation as the area of forest in the municipality, in square kilometers, cleared in the 12 months before August of a given year. We then normalized the deforestation measure using the same system for variations in land use.

Forest Fires. INPE's Queimadas program provides daily data on fire outbreaks, collected through satellite imagery, registered in areas as small as 30 square meters. This data is then aggregated to calculate the annual fire outbreaks per municipality.

Environmental Declaratory Act. IBAMA provides information on areas of environmental interest on rural properties registered on the ADA form. This information makes it possible to create an annual database of the number of properties with ADA declarations per municipality and the total area declared as permanent protection and native forest per municipality. ADA declarations have been required annually since 2007, so the number of declarations spikes in the years when farmers self-regularize. To avoid bias, we use this dataset from 2008 onwards.

Other Data Sources. The panel includes basic municipal information provided by the IBGE, such as total population and share of rural population, GDP, area, and number of rural properties. It also includes characteristics of the mayors provided by the Superior Electoral Tribunal (TSE), such as level of education, occupation[20], and political

[19] Appendix Section B.2 the construction of the land concentration indicators.

[20] The mayor is considered to have a rural occupation if he is a farmer, agronomist, agriculturalist,

party, which allows for an analysis of political alignment with the party of the President of the Republic or with the presidential coalition.

4 Identification Strategy

This section outlines the strategy employed to identify the causal impact of the agreements on fiscal and extra-fiscal variables. Initially, we present descriptive statistics and discuss the approaches used to address potential selection bias and limitations to causal identification. Next, we detail the methodology, incorporating event study and difference-in-differences techniques. Lastly, we explain how confounding factors are addressed and provide an assessment of covariate balance.

4.1 Descriptive Statistics and Potential Selection Bias

This section describes the characteristics of the municipalities that participated in the program and examines the timing of their entry. The results indicate that, although there are systematic differences between municipalities that joined the program and those that did not, the year of entry is random and cannot be predicted based on the observable characteristics of the municipalities.

Table 3 presents descriptive statistics comparing municipalities that have signed the agreement (at any time) with those that have not. Panel A shows that municipalities with an agreement have, on average, a smaller population and a larger area than those without an agreement. In addition, GDP per capita is significantly higher in municipalities with an agreement, with a higher share of agriculture in GDP.

Panel B of Table 3 shows that the municipalities with agreements have, on average, fewer rural properties, but the area covered by these properties is three times larger. Family farms, which are usually exempt from paying ITR, are similar in number and area, although there are fewer family farms and their area is slightly larger in the municipalities

rancher, livestock farmer, agricultural producer, owner of an agricultural, livestock and forestry establishment, operator of agricultural, livestock and forestry implements, agricultural technician, surveying technician, agronomy and surveying technician, agricultural worker, livestock worker, rural worker, or cowboy, as defined in Bragança and Dahis (2022).

Table 3: Descriptive Statistics for Convened and Nonconvened Municipalities

	Has an Agreement?		**Difference (1) - (2)**	
	Yes	**No**	**Diff.**	**SE**
	(1)	(2)	(3)	(4)
Panel A. Socioeconomic characteristics (in 2007)				
Population (in 10,000)	2.84	3.81	-0.97	(0.22)
Area (in km^2)	1811.91	1035.85	776.06	(59.08)
GDP (BRL per capita)	9264.28	6321.37	2942.91	(109.33)
Share agriculture in GDP (%)	0.26	0.20	0.06	(0.00)
Rural population (%) (2000)	33.37	44.18	-10.81	(0.26)
Panel B. Rural properties (in 2006)				
No. of properties (in 1,000)	0.87	1.05	-0.17	(0.01)
Covered area (in km^2)	1000.14	375.61	624.52	(17.99)
No. of Family Agriculture properties	0.68	0.91	-0.23	(0.01)
Covered area of Family Agriculture (in km^2)	157.79	145.88	11.91	(2.42)
Panel C. Mayor characteristics (in 2004)				
Same Party as President	0.09	0.07	0.02	(0.00)
Same Coalition as President	0.20	0.19	0.01	(0.00)
Mayor w/ Agricultural Occupation	0.49	0.49	0.00	(0.01)
Mayor w/ University Degree	0.22	0.20	0.02	(0.00)

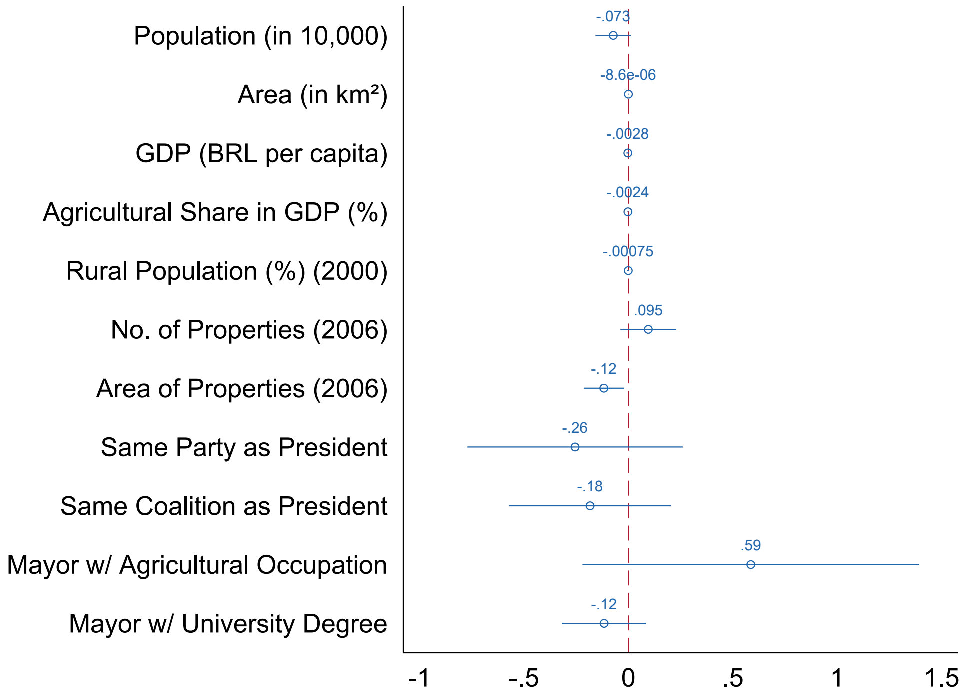
Notes: The table presents descriptive statistics for municipalities with and without agreements prior to policy implementation. Panel A shows socioeconomic characteristics in 2007, except where indicated. Panel B describes the characteristics of rural property in 2006. Panel C describes the characteristics of mayors elected in 2004. Means are reported for municipalities with and without agreements (columns 1 and 2), the difference between the means (column 3, Diff.), and the standard errors (column 4, SE) of the differences.

with agreements. Finally, Panel C of Table 3 shows little difference in the political variables of mayors elected prior to the ITR decentralization policy agreements. In terms of political alignment, municipalities with an agreement were slightly more aligned with the federal government than municipalities without an agreement, both in terms of affiliation with the same party and belonging to the same coalition as the President of the Republic. Mayors with a university degree are slightly more common in agreement municipalities. There is no difference in occupation, with the category 'agricultural occupation' referring to those who perform some rural activity.

In short, there are structural differences between the municipalities that have signed agreements and those that have not, in terms of socioeconomic characteristics, size, and structure of rural property, but they are relatively similar in their political characteristics. To systematically examine the timing of entry, we classified the 2,001[21] municipalities with

[21] Of the 2,093 municipalities, 92 were excluded from the construction of a balanced panel with positive values for tax collection and transfers from 2003 to 2018, as data for at least one year was missing.

Figure 2: Characteristics of Convened Municipalities and Entry Time



Notes: The figure presents the point estimates and standard errors for the cross-section of municipalities with agreements, showing the coefficients of an ordered logit model that uses the year of entry as the dependent variable and the socioeconomic, rural property, and political characteristics from Table 3 as explanatory variables.

agreements in the database by the date the agreement was signed. We then estimated an ordered logit model using this classification as the dependent variable and the first-difference transformations of the characteristics in Table 3 as explanatory variables.[22] The goal is to see if trends in certain characteristics are associated with the time at which municipalities sign agreements.

Figure 2 shows the results of these relationships. The coefficients associated with the variables of the socioeconomic profile of the municipalities and the characteristics of rural properties are close to zero and insignificant, suggesting that they have no discernible effect on the probability of a municipality joining the program later. We used these results to examine the timing of entry as an exogenous variation.

The political variables, on the other hand, have higher, albeit imprecise, point estimates. It appears that greater political alignment with the president's party and a

[22]The first difference of a variable is defined as the change from one period to the next, helping to capture variations over time while removing potential trends.

higher level of education are associated with earlier entry into the agreement. On the other hand, municipalities with mayors involved in rural activities tend to join it later.

4.2 Difference-in-Differences and Event Study Methodology

The main results are estimated using difference-in-differences over multiple periods. The central assumption of this methodology is that in the absence of the treatment (tax decentralization agreement), the treatment and control units would have followed parallel trends over time. To assess the validity of this assumption, we estimated an event study specification. In this analysis, we used the year in which the agreement was signed as the initial treatment period. The specification is estimated using the following equation[23]:

$$y_{igt} = \sum_{k=-6}^{9} \beta_k D_{lkit} + \mu_i + \theta_t + \lambda_{mt} + X_{it}\beta + Z_i t + \epsilon_{igt} \quad (2)$$

Where g indexes the new agreement events. In the case of fiscal outcomes, the dependent variable y_{igt} is the value of the ITR collection or ITR transfers per capita of a given municipality i in year t. Our interest lies in the coefficients β_k on the binary variables $D_{igt}^k = 1\{t = e_{ig} + k\}$ which indicate whether a year t is exactly k years after the event time e_{ig} for event g in municipality i.

We normalize $\beta_{k=-1} = 0$, so we interpret all coefficients β_k as the effect of the tax decentralization agreement on the dependent variable exactly k years after the entry event, and we consider a window of six years before and nine years after entry. The control group comprises municipalities that have not yet received treatment, but will do so within the observed time frame, as well as those that will not receive treatment at any point during the study period.

The vector X_{it} includes variables such as population, municipal GDP per capita, and controls for environmental policies implemented within the study period, as described in Section 4.3. The vector Z_i includes variables that interact with the year to establish linear time trends, as well as a variable that identifies the state. The inclusion of a linear time trend allows for the control of certain temporal and regional variations that affect

[23] We provide a robustness check using an alternative estimation method in Section B1.

fiscal results.

The specification includes year fixed effects (θ_t), to control for common time trends, such as macroeconomic conditions and rural policies, as well as municipal fixed effects (μ_i) which absorb time-invariant municipality characteristics, such as institutional features. Standard errors are clustered at the municipality level.

Thus, the first step is to assess whether the pretreatment trends are parallel between the treated and control groups.[24] If we cannot reject the parallel trends assumption, we can proceed with difference-in-differences modeling using the canonical two-way fixed effects approach. This allows us to estimate the causal effect of the agreement on tax revenue while controlling for possible confounding factors. The model is given by:

$$y_{it} = \mu_i + \theta_t + \lambda D_{it} + X_{it}\beta + Z_i t + \epsilon_{it} \tag{3}$$

Where, in the case of fiscal effects, y_{it} represents tax revenue or ITR transfers to municipality i in period t. The coefficient λ measures the average causal effect of the agreement on the dependent variable. To control for differences between units that do not vary over time, we included municipal fixed effects, represented by μ_i. We also included year-fixed effects, represented by θ_t, to capture common shocks or trends that affect all units in a given period. The sets X_{it} and Z_i contain the same variables used in Equation 2.

4.3 Addressing Confounding Factors and Balancing Covariates

One of the main challenges for our identification strategy is the potential presence of contemporaneous effects. This occurs when other policies or interventions affect the treatment and control groups differently during the period in which the treatment is implemented. If events affect only one of the groups, the impact estimate may be biased. The period from 2003 to 2018 was characterized by the implementation of new policies aimed at strengthening environmental regulations. These policies coincided with the implementation of the agreement and, if not properly accounted for, could confound the

[24] The pretreatment trend test is equivalent to estimating Equation 3 with $\beta_{k=0}$ for $k < 0$.

causal impact analysis.

In 2008, the Ministry of the Environment selected 36 priority municipalities[25] in the legal Amazon for a stricter system of monitoring deforestation and enforcing environmental laws. This group was responsible for 45% of the region's deforestation in the previous year. Assunção and Rocha (2019) show that the policy led to a significant reduction in deforestation in these municipalities. At the same time, the Central Bank enacted Resolution 3,545/2008, which required proof of legal land titles and compliance with environmental regulations to approve subsidized rural credit in the Amazon region. Assunção et al. (2020) showed that this resolution led to a 60% reduction in deforestation, especially in municipalities where cattle ranching was the main economic activity. In 2012, the Ministry of Environment introduced a list of priority municipalities for the Cerrado biome, including 53 priority municipalities in an action plan to prevent and control deforestation and fires.

To reduce potential confounding effects, the main specification included: (i) a dummy variable for priority municipalities in the legal Amazon; (ii) a dummy for priority municipalities in the Cerrado; and (iii) the log of the annual number of environmental fines imposed at the municipal level in the previous year.

Another concern is the imbalance of covariates in the treated and control groups. Table 3 shows that in 2007, municipalities that complied with the agreement were generally wealthier and larger with larger rural areas, but with fewer properties. Figure A2 shows that compliance was strongest in the Midwest region, particularly in the states of Mato Grosso and Mato Grosso do Sul.

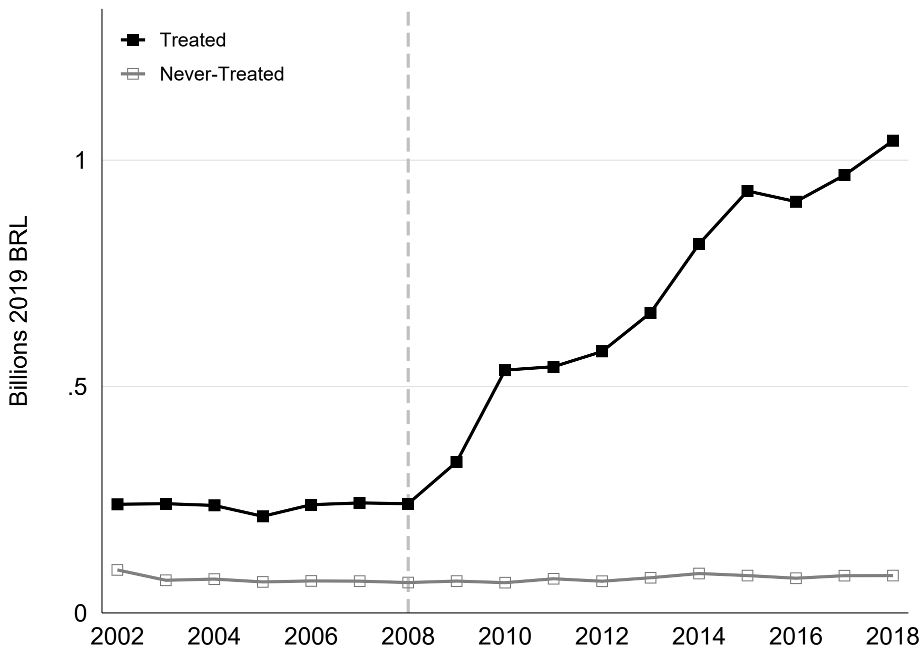
To address this imbalance, we included a set of controls and linear trends that captured pre-existing differences between the groups. This allowed the isolation of the causal effect of the agreement on ITR collection, controlling for variables that could have influenced the results independently of the intervention.

[25]Seven municipalities were added to the priority list in 2009 and another seven in 2011.

5 Fiscal Results

Figure 3 illustrates the evolution of total ITR transfers, expressed in billions of Brazilian Reais (BRL, 2018 values), for two groups of municipalities — treated (in each period) and control — over the period from 2003 to 2018. The data show that treated municipalities began to experience accelerated growth in ITR transfers starting in 2009, coinciding with the implementation of the decentralization policy.

Figure 3: Evolution of ITR Transfers in Convened and Nonconvened Municipalities



Notes: Each point on the black solid line represents the sum of ITR transfers for municipalities that joined the agreement at some point between 2008 and 2016, while the points on the gray solid line represent the transfers for municipalities that did not join the agreement during the same period.

A comparison between 2008 and 2018 reveals a 4.32-fold increase in ITR transfers for the sample of municipalities treated at any point, reaching BRL 1.043 billion. In contrast, municipalities in the control group maintained remarkably stable ITR transfers throughout the period. Both groups exhibited similar trends in ITR transfers before treatment, further emphasizing the significant impact of the policy.

Figure 4 presents the event study with ITR transfers and ITR collection as the dependent variables. Both reveal a sharp increase in ITR revenue following the implementation of the decentralization program. The estimated coefficients for the periods prior to municipalities joining the agreement indicate no statistically significant difference between the trends of the treated and control groups. This finding supports the hypothesis that the observed increase in ITR revenue is attributable to the program rather than external factors or preexisting trends.

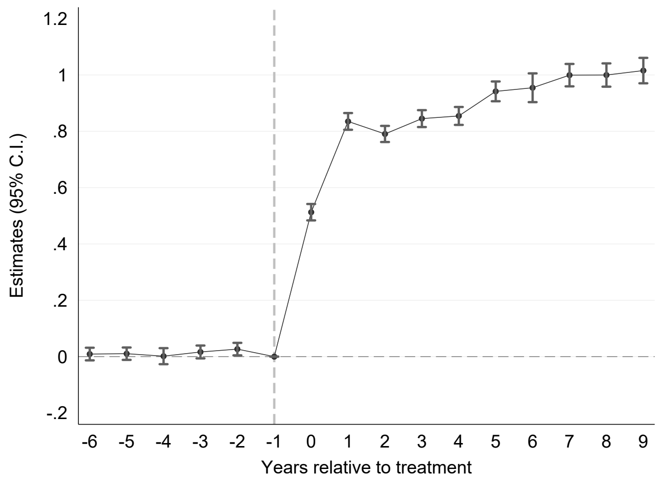
The impact of ITR decentralization on fiscal transfers comprises two distinct components. The first is the enforcement component, which reflects the expansion of the ITR tax base due to enhanced inspection and enforcement measures introduced through decentralization. The second is the mechanical component, which represents the automatic increase of 50 percentage points (pp.) in the share of ITR transfers allocated to municipalities following the formalization of a decentralization agreement[26]. In contrast, the enforcement component drives the impact on tax collection. We demonstrate in the Appendix that the effect captured for ITR transfers surpasses the effect of the ITR collection.

Table 4 presents the results of Equation 3 for ITR transfers, ITR collection, and other variables related to the public finances of municipalities used as placebos. Column (1) shows an increase of 81.4% in ITR transfers in municipalities that joined the agreement. This corresponds to the mean increase of BRL 48,840 based on the pretreatment average (in 2007). This extra money is suitable for small-scale initiatives, depending on local priorities and the specific context, such as purchasing school supplies, installing or repairing basic infrastructure, funding small medical equipment or supplies for local health clinics, and supporting local community events or cultural activities. Similarly, column (2) shows a significant increase of 23% (BRL 25,300) in ITR collection, confirming the positive impact of the program on overall efficiency gains due to better enforcement.

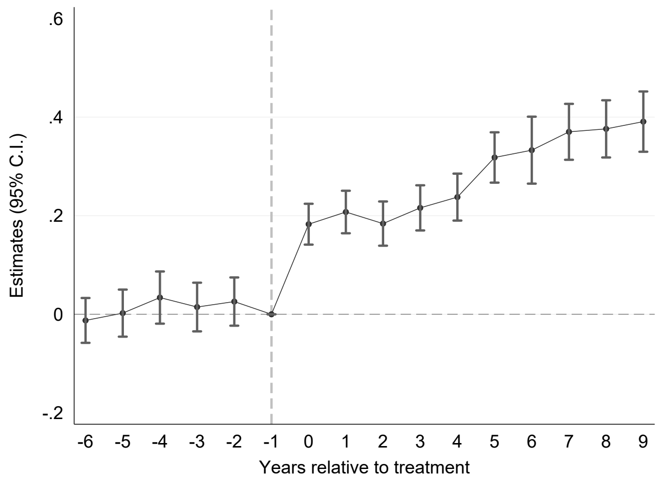
[26] Appendix Section B1 discusses the relative contributions of the enforcement and mechanical components to the observed impact on transfers.

Figure 4: Event Study of Decentralization Agreement on ITR Transfers and Collection

(a) ITR Transfers



(b) ITR Collection



Notes: Each point on the solid line represents the estimates β_k defined in Equation 2, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

Table 4: Impact of ITR Decentralization Agreements on Revenue

Outcome	ITR Transfers (1)	ITR Collection (2)	FPM (3)	IPTU (4)
Agreement	0.814***	0.230***	0.009	0.003
	(0.012)	(0.022)	(0.009)	(0.020)
Observations	78,768	78,768	76,717	75,878
Mean Dep. Var.(2007)	BRL 0.06M	BRL 0.11M	BRL 7.15M	BRL 1.12M
Munic and Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: The table reports the impact of the agreements on ITR collection and transfers, as well as on the placebo variables FPM and IPTU. The coefficients represent the average effect of the agreements during the post-treatment period, estimated by Equation 3 using a difference-in-differences model. Each specification includes municipal and year-fixed effects, control variables, and state-year dummies. Dependent variables are log-transformed. The table includes the average of the dependent variable in 2007 (pretreatment), in millions of BRL (2018). Standard errors in parentheses are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.

Although we cannot test directly with aggregated data, the literature identifies VTN as the key variable driving improved revenue. Specifically, using microdata from tax declarations, Bragança et al. (2024) finds that the increase in VTN for properties that were already paying land taxes (intensive margin) is the main driver, accounting for a 25% increase in tax revenue. The effect of the extensive margin, that is, the entry of new properties, is smaller, contributing to about 1% increase in tax revenue.

Columns (3) and (4) of Table 4 present a set of placebo tests designed to assess whether the observed changes in ITR collection and transfers can be attributed to other tax policies or unrelated increases. Column (3) reports the results of Equation 3 using FPM, the primary municipal transfer, as the dependent variable. The distribution of FPM is based on the municipal population, which is orthogonal to participation in the decentralization agreement. In column (4), the dependent variable is IPTU, the municipal tax on urban property, which was not affected by the ITR decentralization policy. The results of these placebo tests show no significant impact on FPM or IPTU revenues, further supporting the validity of the findings.

6 Extra-Fiscal Results

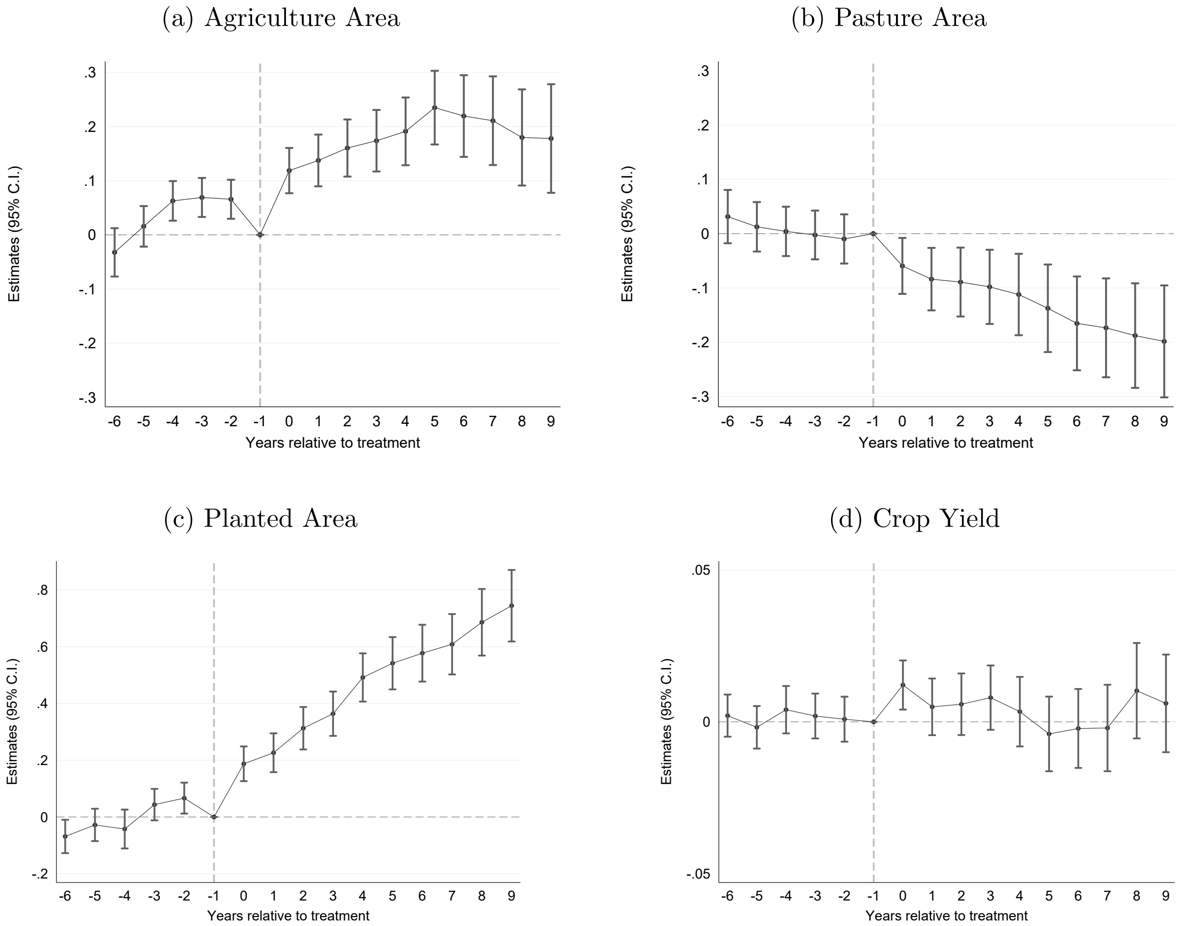
To estimate the extra-fiscal effects, we replaced y_{ig} in the Equations 2 and 3 with variables at the municipal level representing: (i) agriculture and pasture production, (ii) forest area, deforestation, and forest fire occurrence, as well as the number of ADA declarations, and (iii) land concentration indicators.

6.1 Land Use and Farm Production

Figure 5 presents the results of the event study for agricultural and pasture areas at the municipal level, based on satellite data. The mechanism behind these results is the incentive to increase the degree of land use, enabling properties to legally qualify for a lower tax rate.

Panel (a) illustrates a sustained increase in the area dedicated to agriculture, while Panel (b) depicts a decrease in pasture area immediately after the municipalities entered the agreements. These patterns appear to intensify over time. Although there is no evident pre-treatment trend for pasture, a mild upward trend is observed for agriculture. Panels (c) and (d) show the results for the log of the total planted area and crop yield, respectively, based on data from the municipal agricultural production survey. While the results indicate a sustained increase in agricultural area, no significant effect is observed for crop yield (kg/ha).

Figure 5: Event Study of Decentralization Agreement on Land Use and Farm Production



Notes: Each point on the solid line represents the estimates β_k defined in Equation 2, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

Table 5 summarizes the impact of the agreements on land use and farm production. Panel (a) presents the results for the main outcomes. The treatment led to an increase in land use for agriculture as a strategy to avoid higher taxation. Column (1) shows that the agreements are associated with a precise increase of 0.139 standard deviations in the area devoted to agriculture, which corresponds to 5,660 square kilometers, or about 32% of the average area of the municipalities that signed the agreements. For pasture, column (2) shows an average reduction of 0.059 standard deviations, which, although less precise, corresponds to 5,150 square kilometers, or about 11% of the average area. Column (3) reinforces the agricultural result, showing an increase of 0.381 standard deviations in planted area, corresponding to 16,765 square kilometers, or about an 82% increase[27]. The effects on crop yield in column (4) are not significant, which is to be expected since the mechanism for reducing tax payments is based on land use rather than land productivity.

Table 5: Impact of ITR Decentralization Agreements on Land Use and Farm Production

Panel A: Land Use	Agriculture (km^2) (1)	Pasture (km^2) (2)	Planted Area (km^2) (3)	Crop Yield (kg/ha) (4)
Agreement	0.139***	-0.059*	0.381***	0.005
	(0.024)	(0.028)	(0.031)	(0.004)
Observations	75,600	78,768	78,768	77,010
Mean Dep. Var. (2007)	17,554	45,657	20,382	1.02
Munic and Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Panel B:	Agriculture (km^2) - Med. Yield		Pasture (km^2) - Prod. Zone	
Heterogeneity	Above	Below	High	Low
	(1)	(2)	(3)	(4)
Agreement	0.107***	0.114***	-0.202***	0.034
	(0.038)	(0.030)	(0.054)	(0.026)
Observations	37,520	38,064	38,656	40,112
Mean Dep. Var. (2007)	24,430	1,877	86,942	41,330
Munic and Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: The table reports the estimated impact of agreements on land-use outcomes, including agricultural and pasture areas, planted area, and crop yield in Panel (a), as well as heterogeneity by baseline productivity in Panel (b). The coefficients represent the average effect of the agreements during the post-treatment period, estimated by Equation 3 using a difference-in-differences model. Each specification includes municipal and year-fixed effects, control variables, and state-year dummies. Variables in Panel (a), columns (1), (2), and (3), and Panel (b) are normalized to have a mean of zero and a standard deviation of one. Crop yield is calculated for the five most important crops in terms of revenue and measured in log. Standard errors, reported in parentheses, are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.

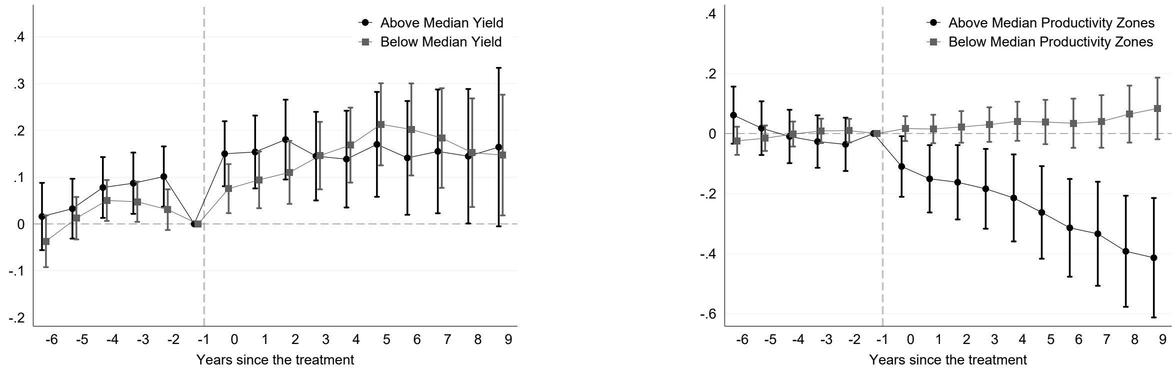
Figure 6 and Panel (b) of Table 5 explore the results from Panel (a) regarding agricultural area (column 1) and pasture area (column 2) by baseline productivity. For agriculture, the sample is divided into two groups based on the median yield prior to treatment. The impact is similar across both groups, though slightly higher for areas with crop yield below the median. In areas above the median yield, the effect of the ITR agreements, which is 0.107 standard deviations, represents an increase of 20% relative to the pretreatment values for this group. In areas below the median yield, the effect of

[27]The planted area refers to the total area cultivated with agricultural crops throughout the year. This means that the same piece of land can be counted more than once if it was used for multiple plantings during the year.

0.114 standard deviations corresponds to an increase of 28% relative to the pretreatment mean of this group.

Figure 6: Event Study of Decentralization Agreement on Land Use by Productivity Zones

(a) Agriculture Area (b) Pasture Area



Notes: Each point on the solid lines represent the estimates β_k defined in Equation 2, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

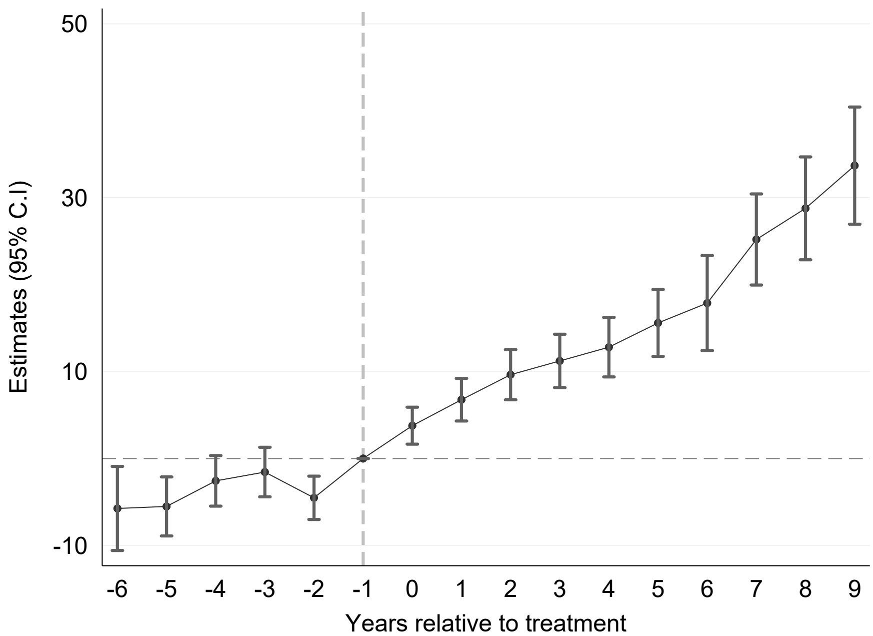
For pasture, we consider the productivity zones defined by the National Institute for Colonization and Agrarian Reform (INCRA). These zones impose minimum productivity requirements that vary according to regional characteristics such as climate, soil type, vegetation cover, and topography. The effect of decentralized monitoring on pasture area is not significant in zones with lower minimum productivity requirements (column 4), where the cost of compliance is relatively low. This suggests that landowners in these areas may face less pressure to change land use because their existing practices already meet or exceed the minimum thresholds to reduce tax payments.

However, in zones requiring higher minimum productivity, the estimated effect is a reduction in pasture area of 0.202 standard deviations, or nearly a 28% reduction relative to pretreatment values (column 3). This substantial reduction suggests that the cost of maintaining minimum productivity requirements is a key driver of land use change. The increased monitoring associated with the decentralization agreements likely increased the cost of maintaining extensive pasture in these regions with the tax payment, prompting landowners to convert land to higher value or more productive uses, such as crop production or other income-generating activities.

6.2 Environmental Protection

The primary mechanism driving conservation is that inspection and control encourage an increase in ADA declarations, which allow a portion of the property to be exempt from ITR taxation. Figure 7 shows a significant increase in the number of properties filing ADA declarations after the agreement. However, it remains unclear whether this increase has translated into measurable improvements in environmental indicators. This section presents the results of estimating the impact of ITR decentralization on satellite imagery data for forest cover and environmental protection indicators. It also examines the characteristics of ADA declarations at the municipal level.

Figure 7: Number of Properties Reporting ADA Declarations



Notes: Each point on the solid line represents the estimates β_k defined in Equation 2, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

Table 6 presents the difference-in-difference estimates. In Panel (a), column (1) shows an average increase in forest cover of 0.056 standard deviations, which corresponds to an increase of 25,115 square kilometers, or 42%, relative to pretreatment values for the treated group. Columns (2) to (4) analyze the impact of the agreements on other environmental protection measures: deforestation, the transition from natural to anthropogenic areas[28], and the occurrence of forest fires. The estimated coefficients for these variables are not statistically significant, indicating that the agreements did not have a significant impact on them. Although useful in promoting the creation and registration of forest areas, the treatment does not seem to have been strong enough to encourage more concrete actions in environmental protection.

Table 6: Impact of ITR Decentralization Agreements on Environmental Protection

Panel A: Environmental Indicators	Forest (km^2) (1)	Deforestation (2)	Natural to Anthropogenic (3)	Forest Fires (4)
Agreement	0.056*	0.004	-0.007	-0.011
	(0.032)	(0.007)	(0.020)	(0.015)
Observations	78,768	75,616	78,768	78,768
Mean Dep. Var. (2007)	59,886	-	-	-
Munic and Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Panel B: ADA Reports	# Properties (1)	Mean Area (km^2) (2)	APP (km^2) (3)	Forest (km^2) (4)
Agreement	12.690***	-134.967**	-5.589	8.581***
	(1.378)	(59.170)	(5.195)	(2.313)
Observations	52,935	52,935	52,935	43,138
Mean Dep. Var. (2007)	71.9	55,516	3,451	679
Munic and Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: The table reports the estimated impact of agreements on environmental protection outcomes in Panel (a) and ADA-related variables in Panel (b). The coefficients represent the average effect of the agreements during the post-treatment period, estimated by Equation 3 using a difference-in-differences model. Each specification includes municipal and year-fixed effects, control variables, and state-year dummies. Variables in Panel (a) are normalized to have a mean of zero and a standard deviation of one. Standard errors, reported in parentheses, are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.

Panel (b) examines the mechanism behind the induction of environmental protection by analyzing the impact of the agreements on ADA declarations, including the number of properties declaring areas of environmental interest, the average area declared per property, and the areas associated with different categories such as Permanent Protection Areas (APP) and native forests. The results show that the agreements led to an average increase of 12.69 properties declaring ADA per municipality (column 1), an increase of 18% compared to the 2008 average for the treated group.

[28]This indicator from MapBiomas measures the number of hectares converted from natural categories (e.g., forests and rivers) to anthropogenic categories (e.g., urban and agricultural areas).

The average area per property declaring ADA decreased slightly by about 134.96 square kilometers (column 2), or 0.2% of the pretreatment value. This suggests that the treatment encouraged reporting of smaller protected areas that were previously considered insignificant for reporting.

No increase was observed in APP (column 3), consistent with the fact that these areas are defined by the Federal Government, which limits the ability of landowners to influence them. However, consistent with the results in Panel (a), column (1), the area reported as native forest increased by 8.58 square kilometers in treated municipalities (column 4). This represents an increase of 1.3% over the pretreatment average for the treated group.

6.3 Land Concentration

A core objective of the ITR is to reduce land concentration. Table 7 presents the impact of decentralization agreements on this metric. We estimate a difference-in-differences model with two periods: 2006 (pre-treatment) and 2017 (post-treatment). The analysis reveals that post-treatment land concentration, measured by both the land Gini index (column 1) and the HHI (column 2), decreases significantly in municipalities that joined the ITR agreement compared to municipalities that did not. Specifically, the reduction of 0.008 points in the Gini index corresponds to a decrease of approximately 1% relative to the pretreatment average. The effect on the HHI index is even more pronounced, indicating a reduction of 2.89% compared to the pretreatment average.

The difference in results between the Gini and the HHI can be attributed to the fact that the Gini measures general inequality and is less sensitive to large concentrations, whereas the HHI is more affected by changes in concentration and shows a greater reduction when there is a large dispersion of land.

We also assess the heterogeneous effects of the agreements, accounting for the year in which municipalities joined. The interaction between the treatment indicator and the difference between 2017 and the year of treatment quantifies the number of years each municipality has been under the agreement. The hypothesis tested is that the effects of the treatment on land concentration follow a monotonic linear relationship. The results

Table 7: Impact of ITR Agreements on Land Concentration

	Land Concentration		Share of Properties (by hectare group)				
	Gini	HHI	0 to 50	50 to 200	200 to 500	500 to 1000	More than 1000
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	-0.008***	-0.006***	-0.055***	0.026***	0.015***	0.007***	0.007***
	(0.002)	(0.002)	(0.004)	(0.003)	(0.001)	(0.001)	(0.001)
Treatment x (2017 - Year of Treatment)	-0.001**	-0.000	-0.007***	0.003***	0.002***	0.001***	0.001***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	9642	9642	9642	9642	9642	9642	9642
Mean (2006)	.760	.207	.782	.142	.043	.016	.015

Notes: The table shows the impact of the decentralization agreements on the outcomes related to land concentration. The coefficients represent the average effect of the agreements during the post-treatment period, estimated using a difference-in-differences model. Includes control variables. Standard errors, shown in parentheses, are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.

suggest that for each additional treatment year, the Gini indices decrease by 0.001 points.

Columns (3) to (7) investigate the effects according to property size groups to understand the source of the land concentration changes. There is a decrease in the smallest property group (up to 50 hectares), which is largely compensated by a significant increase in the medium-sized property groups (50 to 200 hectares and 200 to 500 hectares), while the largest property groups (above 500 hectares) experience only a marginal increase.

7 Conclusion

This paper examines the fiscal and extra-fiscal effects of decentralizing the Rural Land Tax (ITR) administration to Brazilian municipalities, considering a short to medium-term time frame (up to nine years after the policy is implemented). Historically, the ITR has been characterized by high levels of evasion and poor monitoring. According to the theory of decentralization, greater geographic proximity between the tax authority and the taxpayer allows for greater control and monitoring in the case of taxes on visible and immovable bases, such as land. Decentralization can increase enforcement and the perceived risk of punishment for landowners who do not declare the tax correctly, which may encourage them to make more accurate tax declarations.

Using a difference-in-differences research design and a balanced panel from 2003 to 2018, we find that real and perceived increases in control and oversight led to an 81.4% increase in transfers and a 23% increase in ITR collection. Other municipal revenues, such as intergovernmental transfers unrelated to ITR, remain unaffected by the policy. This finding provides empirical support for decentralization theory and addresses the limited worldwide quantitative evidence on its impact.

The policy is estimated to have increased tax collection by BRL 387 million (in 2018 prices) over the period from 2008 to 2018.[29] Despite these positive effects, the total amount collected remains low, representing only 0.03% of GDP in 2023. Furthermore, the literature highlights that the current level of collection is still well below its potential

[29] Details of the calculation are provided in Annex Table B1.

(Silva and Barreto, 2014; Fendrich et al., 2022).[30]

Regarding the extra-fiscal effects, the results point to an increase in agricultural production, forestation and the declaration of environmental protection areas in the ADAs, along with a decrease in land concentration, demonstrating the compatibility between fiscal and extra-fiscal objectives. With regard to livestock, there is evidence of a reduction in pasture area, especially in less productive regions. However, the patterns in environmental indicators are weaker, as there is no change in deforestation or forest fires.

Ensuring environmental protection is a multifaceted challenge that requires a combination of efforts and effective policies on several fronts. Understanding the potential and limitations of the extra-fiscal use of tax policy is critical to maximizing the effectiveness of conservation initiatives and promoting sustainable development. There is also great potential to expand tax collection and improve fiscal and extra-fiscal outcomes through more effective monitoring.

[30]The total ITR collection in 2017, if the rules were properly followed, was calculated by Fendrich et al. (2022) to be BRL 5.75 billion, almost four times the actual amount collected, BRL 1.5 billion.

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Appendix A. Additional Tables and Figures

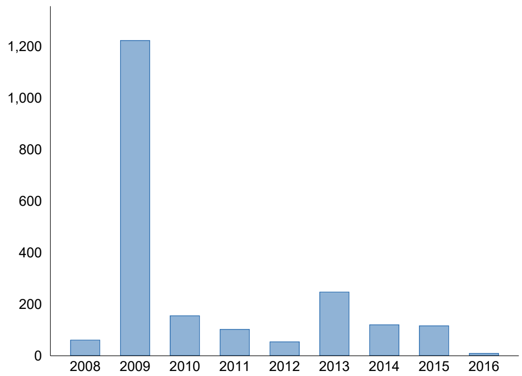
Table A1: Concepts Used to Calculate the ITR Utilization Rate

Concept	Definition
Taxable Area	Total area of the property, excluding areas of permanent preservation, legal reserve, private natural heritage reserve, forest easement, areas of ecological interest for the protection of ecosystems declared by the competent body, and areas proven to be unfit for rural activity that are also declared to be of ecological interest by a federal or state authority.
Area Actually Used	The portion of the rural property's usable area that, in the year prior to the ITR taxable event, was planted with crops, served as pasture (native or planted), was used for extractive exploitation, farming, aquaculture, or for the implementation of a technical project, in accordance with the relevant legislation.
Usable Area	The usable area that can be employed for agriculture, livestock, farming, aquaculture, or forestry is the total area of the property, excluding non-taxable areas and areas occupied by useful and necessary improvements.
Degree of Use	Percentage ratio between the area actually used for rural activities and the usable area of the property.

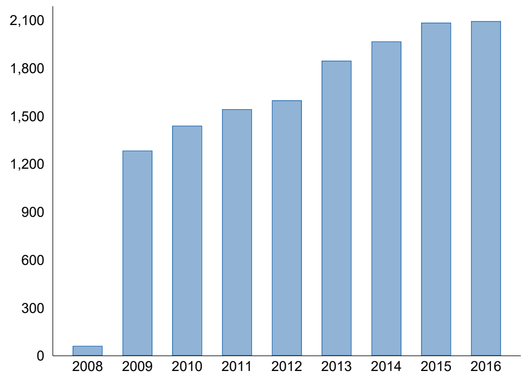
Source: Law No. 9.393, of December 19, 1996.

Figure A1: Municipal ITR Agreements per Year

(a) New Agreements

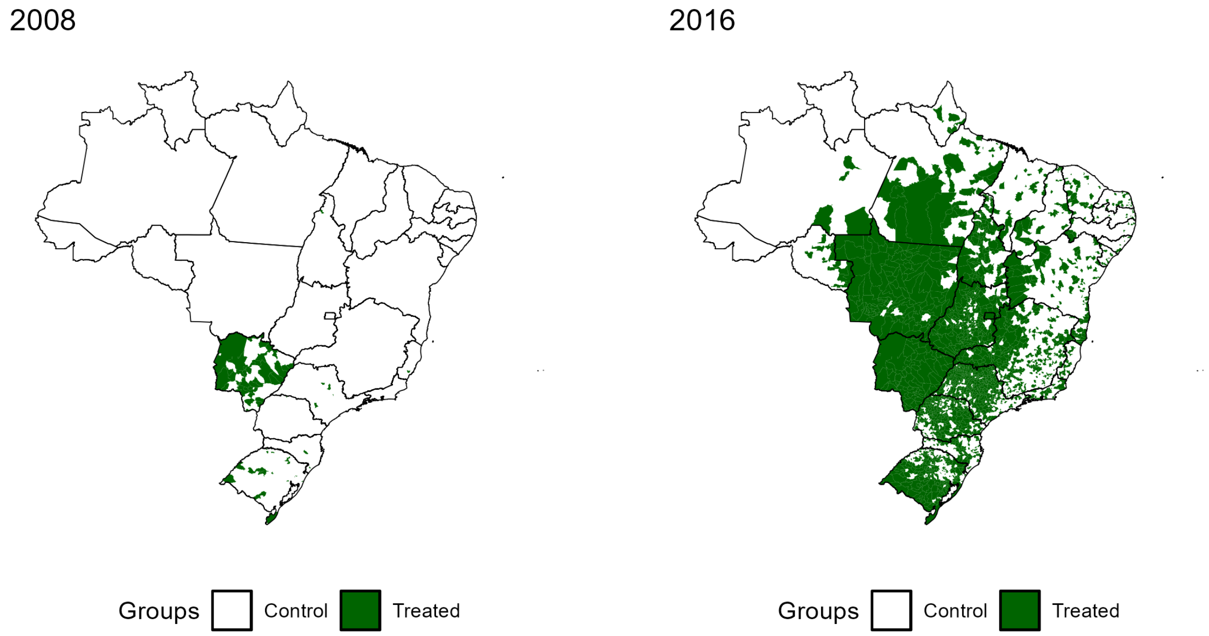


(b) Cumulative Agreements



Source: Brazil's Federal Revenue Service (RFB).

Figure A2: Spatial Distribution of Treated and Non-Treated Municipalities - 2008/2016



Notes: The figure shows the spatial distribution of municipalities with and without ITR decentralization agreements between 2008 and 2016.

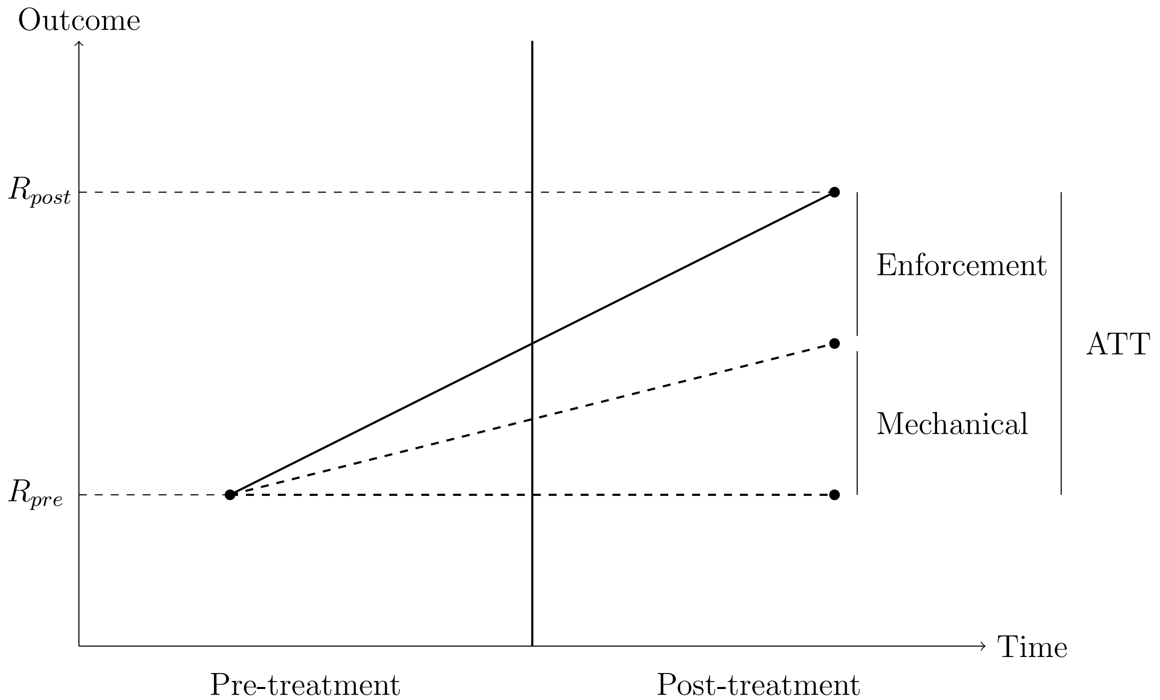
Appendix B. Data Construction and Analysis

B.1 Enforcement and mechanical components of the fiscal effect

The impact of ITR decentralization on fiscal transfers can be decomposed into two distinct components. The first is the *enforcement component*, which captures the expansion of the ITR tax base attributable to enhanced inspection and enforcement measures implemented as a result of decentralization. The second is the *mechanical component*, which reflects the automatic 50 percentage-point (pp.) increase in the share of ITR transfers allocated to municipalities upon formalizing a decentralization agreement.

This section formalizes the econometric definitions of these components. Figure B1 illustrates the decomposition of the Average Treatment Effect on the Treated (ATT) on ITR transfers before (R_{pre}) and after (R_{post}) decentralization.

Figure B1: Enforcement and Mechanical Components of the ATT



Notes: The figure illustrates the decomposition of municipal ITR transfer revenues before (R_{pre}) and after (R_{post}) the decentralization agreement. The observed ATT comprises two parts: a mechanical component due to the increase in the share from 50% to 100%, and an enforcement component resulting from improved tax collection.

Assume that ITR revenues (transfers and collection) for the control group remains constant over time. Let $\tau(D, T)$ denote the ITR total collection and $\tilde{\tau}$ denote ITR transfers, where $D \in \{0,1\}$ denotes the control ($D = 0$) or treatment ($D = 1$) group, and $T \in \{0,1\}$ denotes the pretreatment ($T = 0$) or post-treatment ($T = 1$) period. Under the assumption of a flat trend for the control group:

$$\tau(0,0) = \tau(0,1)$$

For the treatment group, post-treatment ITR collection grows proportionally due to enforcement improvements, characterized by a factor $\beta > 1$:

$$\tau(1,1) = \beta \cdot \tau(1,0)$$

Before decentralization, treated municipalities received half the ITR collection as transfers:

$$\tilde{\tau}(1,0) = 0.5 \cdot \tau(1,0) \tag{4}$$

After decentralization, the ATT on transfers can be expressed as:

$$\tilde{\tau}(1,1) - \tilde{\tau}(1,0) = \beta \cdot \tau(1,0) - 0.5 \cdot \tau(1,0) = (\beta - 0.5) \cdot \tau(1,0) \tag{5}$$

Isolating Components

To isolate the mechanical component, assume a counterfactual scenario where the enforcement factor (β) is present since the pretreatment period. Adapting from Equation 5, the difference in transfers can be attributed to the mechanical increase only:

$$\beta \cdot \tau(1,0) - 0.5 \cdot \beta \cdot \tau(1,0) = 0.5 \cdot \beta \cdot \tau(1,0)$$

To isolate the enforcement component, assume a counterfactual scenario for Equation 5 without the 50 pp. increase in the post-treatment period. The difference in transfers due to enforcement is:

$$0.5 \cdot \beta \cdot \tau(1,0) - 0.5 \cdot \tau(1,0) = 0.5 \cdot (\beta - 1) \cdot \tau(1,0)$$

Thus, the total ATT on transfers can be expressed as:

$$\tilde{\tau}(1,1) - \tilde{\tau}(1,0) = \underbrace{0.5 \cdot (\beta - 1) \cdot \tau(1,0)}_{\text{enforcement}} + \underbrace{0.5 \cdot \beta \cdot \tau(1,0)}_{\text{mechanical}} \tag{6}$$

Using Equation 4 in Equation 6, we have:

$$\tilde{\tau}(1,1) - \tilde{\tau}(1,0) = \underbrace{(\beta - 1) \cdot \tilde{\tau}(1,0)}_{\text{enforcement}} + \underbrace{\beta \cdot \tilde{\tau}(1,0)}_{\text{mechanical}} = \underbrace{(2\beta - 1) \cdot \tilde{\tau}(1,0)}_{\text{total effect}} \tag{7}$$

We can conclude that the majority of the increase in transfers is explained by the mechanical component (β) without requiring any changes in enforcement or tax collection efficiency. The enforcement component explains $(\beta - 1)$ of the total effect.

B.2 Constructing Land Inequality Indicators

We used the Gini index to measure inequality in land distribution, based on data from the 2006 and 2017 agricultural censuses. The census data, which refer to the number of properties and the area they occupy, are organized into area size groups, with categories in ascending order, ranging from 'producers with no area' to 'more than 2,500 hectares' in 2006 and 'more than 10,000 hectares' in 2017. We denote each area group by the subscript g. Thus, for each municipality m, there are $N_{g,m}$ properties in each group g, covering a total area of $A_{g,m}$ hectares. Similarly to the ITR data, the IBGE omits the information on the total area of a g-group when it concerns a small number of properties in order to protect the identity of the owners. In these cases, the value of $A_{g,m}$ is replaced by the lower limit of the area of the group multiplied by the number of properties $N_{g,m}$. In other words, if for a municipality m the group 'between 500 and 1,000 hectares' has the value of $A_{g,m}$ suppressed for reasons of confidentiality, we multiply 500 by $N_{g,m}$ to obtain a reference estimate of the area occupied by this group. With these adjustments, we calculate the land Gini index for each municipality m using the cumulative sum of areas and properties, allowing us to capture the inequality in land distribution across different property size groups. The Gini index is computed as:

$$G_m = 1 - \sum_{k=0}^{n-1} (X_{k+1,m} - X_{k,m})(Y_{k+1,m} + Y_{k,m}) \tag{8}$$

where $X_{k,m}$ and $Y_{k,m}$ represent the cumulative proportion of properties and cumulative proportion of land area, respectively, for municipality m, ordered by ascending property size. In addition, we calculated the Herfindahl-Hirschman Index (HHI) to quantify the degree of land concentration. For each municipality m, we calculated the area share of each group g, which is given by A_g/A_{total}, where A_{total} is the total area occupied by properties in the municipality. The HHI is obtained by summing the squares of these shares:

$$HHI_m = \sum_g \left(\frac{A_{gm}}{A_{total}, m}\right)^2 \tag{9}$$

B.3 Cumulative Increase in ITR Collection

In this section, we calculate the cumulative effect on rural property tax (ITR) collection from 2008 to 2018 as a result of municipalities signing agreements to decentralize tax inspection and collection. Table B1 shows the number of municipalities that signed agreements each year, the estimated average impact on the collection, and the total cumulative value.

The calculation is made by multiplying the number of municipalities that joined the agreement in a given year by the average treatment effect of BRL 25,300 in revenue per municipality. This increase is then accumulated over the years in which the municipality remains under the effect of the agreement, taking into account the annual impact of each municipality in all subsequent years until 2018.

For example, in 2008, 62 municipalities joined the agreements and the estimated average impact generated an increase of BRL 1,568,600 that year. Since these municipalities remain in the agreement for 10 years, until 2018, the cumulative impact from 2008 to 2018 is BRL 15,686,000. This process is repeated for each year that the municipalities enter into the agreements, with the impact added up according to the years covered.

At the end of the period from 2008 to 2018, the total cumulative impact of the agreements will be BRL 387,975,500, at 2018 prices.

Table B1: Cumulative Increase in Collection

Year of entry	# Municipalities Treated	Average Treatment Effect	Annual Total	Years Treated	Total Value
2008	62	BRL 25,300	BRL 1,568,600	10	BRL 15,686,000
2009	1,172	BRL 25,300	BRL 29,651,600	9	BRL 266,864,400
2010	150	BRL 25,300	BRL 3,795,000	8	BRL 30,360,000
2011	98	BRL 25,300	BRL 2,479,400	7	BRL 17,355,800
2012	53	BRL 25,300	BRL 1,340,900	6	BRL 8,045,400
2013	230	BRL 25,300	BRL 5,819,000	5	BRL 29,095,000
2014	115	BRL 25,300	BRL 2,909,500	4	BRL 11,638,000
2015	111	BRL 25,300	BRL 2,808,300	3	BRL 8,424,900
2016	10	BRL 25,300	BRL 253,000	2	BRL 506,000
			Total Accumulated in 2018 (at 2018 prices)		BRL 387,975,500

Appendix C. Robustness Check

C.1 Staggered Difference-in-Differences

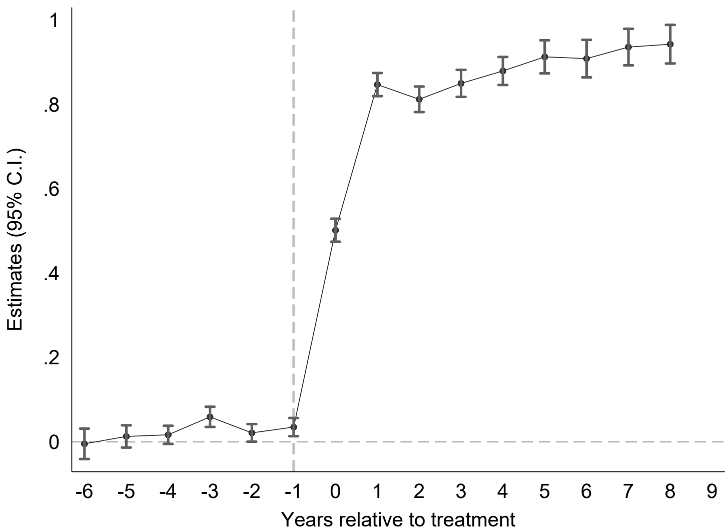
Section 4.2 outlines the empirical strategy employed to assess the impact of decentralization agreements on fiscal and extra-fiscal outcomes. Given the staggered implementation of the program across municipalities, we adopt a difference-in-differences (DiD) approach combined with event study estimation. While our baseline estimates yield robust and economically meaningful results, recent advances in the econometrics of panel data with staggered treatment adoption have highlighted potential biases in two-way fixed effects (TWFE) estimators. Specifically, Callaway and Sant'Anna (2021), Sun and Abraham (2021), and De Chaisemartin and D'haultfœuille (2023) show that TWFE estimation can introduce negative weighting problems when treatment effects are heterogeneous across cohorts or over time, potentially leading to inconsistent estimates of the true effect.

To address these methodological concerns and ensure that our results are not driven by model-specific choices, we complement the primary analysis with an alternative estimator robust to treatment effect heterogeneity: the group-time average treatment effect (GATT) estimator (Callaway and Sant'Anna, 2021). This estimator explicitly constructs counterfactuals using never-treated or not-yet-treated units, thereby mitigating biases that arise when comparing early and late adopters. This robustness test confirms that our identification strategy remains valid in the presence of dynamic treatment effects and suggests that negative weighting biases do not meaningfully affect our main findings.

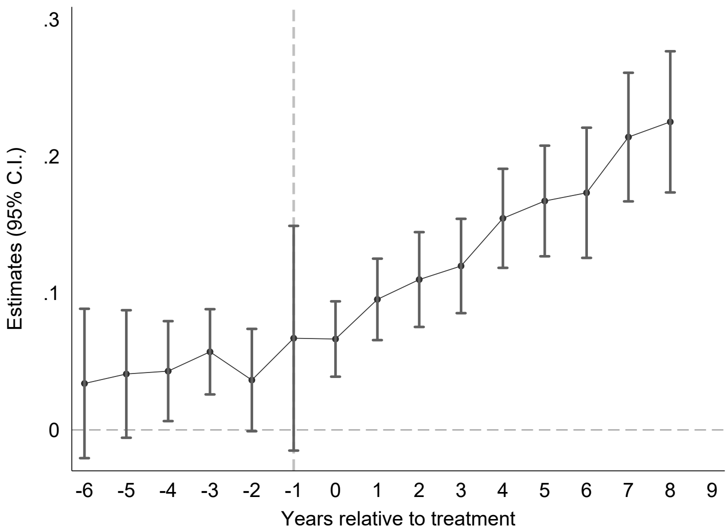
Figure C1 presents the event study estimates for ITR transfers and collection using the staggered DiD framework of Callaway and Sant'Anna (2021), hereafter CS. The results closely resemble those reported in Figure 4, which employs the TWFE specification. Both estimations reveal a pronounced increase in ITR revenue following decentralization, reinforcing the internal validity of our estimates. Moreover, the dynamic treatment effects captured by the Callaway and Sant'Anna (2021) estimator confirm the persistence of the fiscal impact over time, strengthening the interpretation that the observed revenue gains are attributable to the decentralization reform.

Figure C1: Event Study of Decentralization Agreement on ITR Transfers and Collection (CS)

(a) ITR Transfers



(b) ITR Collection



Notes: Each point on the solid line represents the estimates β_k using Callaway and Sant'Anna (2021) method, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

Table C1 presents the estimated effects of the decentralization program on ITR collection and transfers using the TWFE and CS approaches. Columns (1) and (4) presents the TWFE estimates without state-year fixed effects, columns (2) and (5) the TWFE estimates with state-year fixed effects (our preferred specification), and columns (3) and (6) the estimates from the CS specification. The results are consistent across specifications, with both methods indicating a significant increase in ITR revenues following decentralization. In particular, while the magnitude of the coefficients varies slightly depending on the inclusion of state-by-year fixed effects, the overall pattern remains unchanged.

Table C1: Impact of ITR Decentralization Agreements on Revenue (TWFE and CS)

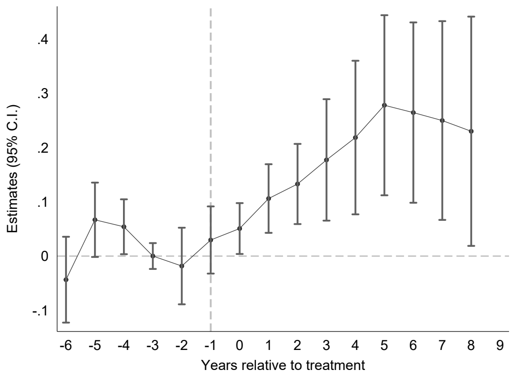
Outcome	ITR Collection			ITR Transfers		
	(1)	(2)	(3)	(4)	(5)	(6)
Agreement	0.458***	0.230***	0.268***	1.011***	0.814***	0.947***
	(0.022)	(0.022)	(0.014)	(0.011)	(0.012)	(0.017)
Observations	78,768	78,768	78,768	78,768	78,768	78,768
Estimation Method	TWFE	TWFE	CS	TWFE	TWFE	CS
State x Year FE	No	Yes	-	No	Yes	-
Munic and Year FE	Yes	Yes	-	Yes	Yes	-
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table reports the impact of the agreements on ITR collection and transfers using the Two-way Fixed Effects (TWFE) and the Callaway and Sant'Anna (2021) methods. The coefficients from columns (1)-(2) and (4)-(5) represent the average effect of the agreements during the post-treatment period, estimated by Equation 3 using a difference-in-differences model. Each specification includes municipal and year-fixed effects, control variables, and state-year dummies. Dependent variables are log-transformed. Standard errors in parentheses are clustered at the municipality level. ***p $<$ 1%; **p $<$ 5%; *p $<$ 10%.

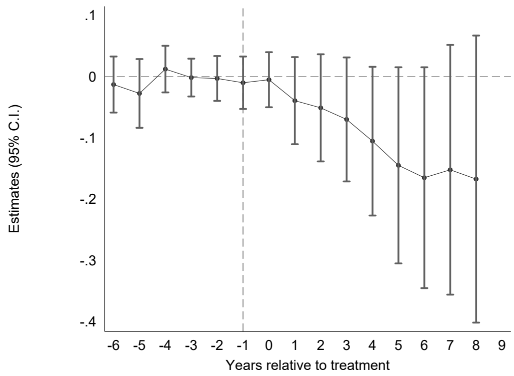
Figure C2 presents the results of the event study for agricultural and pasture areas at the municipal level using the CS methodology. The findings remain consistent with those obtained using the TWFE approach, albeit slightly noisier. Panel (a) continues to show a sustained increase in the agricultural area, while panel (b) depicts an immediate decline in pasture area following the agreements, with both trends intensifying over time. As before, no clear pretreatment trend is observed for pasture, whereas a mild upward trend appears for agriculture. Similarly, panels (c) and (d) present the results for the log of total planted area and crop yield, respectively, using municipal agricultural production survey data. While the increase in agricultural area remains evident, no significant effect is detected for crop yield (kg/ha).

Figure C2: Event Study of Decentralization Agreement on Land Use and Farm Production

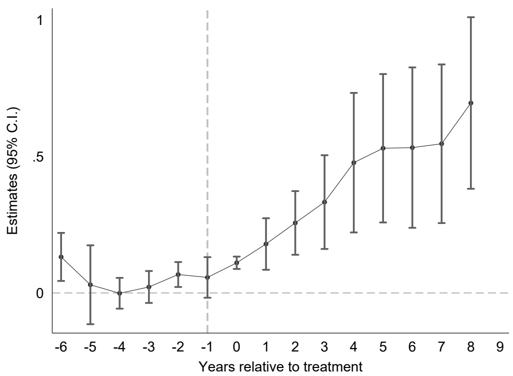
(a) Agriculture Area



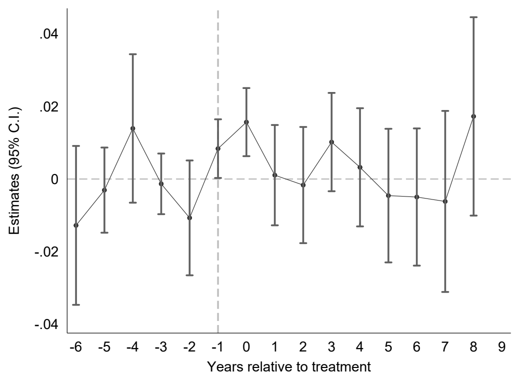
(b) Pasture Area



(c) Planted Area



(d) Crop Yield



Notes: Each point on the solid line represents the estimates β_k using Callaway and Sant'Anna (2021) method, where k is the number of years relative to the year of entry into the agreement. The β_k coefficients reflect the difference-in-differences estimates of the dependent variables relative to the year before joining the agreement. SE are clustered at the municipality level and 95% confidence intervals are reported for each regression.

Table C2 shows the impact of ITR decentralization agreements on land use and agricultural production. Odd columns show the results for our preferred specification (TWFE) and even columns show the results estimated by CS. In both cases, the estimates indicate that the policy led to a significant expansion of agricultural land at the expense of pasture, while the impact on crop productivity is negligible. The increase in agricultural area is statistically significant in both specifications, suggesting that the agreements provided incentives for landowners to intensify land use. This expansion appears to be driven, at least in part, by a reallocation of land away from pasture, as evidenced by the negative and significant coefficients on pasture area. The estimates for planted area are even more pronounced, reinforcing the interpretation that the agreements contributed to land intensification rather than mere land reallocation. However, the absence of significant effects on crop yield (coefficients close to zero in both models) suggests that while agricultural land expanded, productivity per hectare remained largely unchanged. This could imply that the newly cultivated land was either less productive or that adjustments in input use were insufficient to increase yields in the short run.

Table C2: Impact of ITR Decentralization Agreements on Land Use and Farm Production (TWFE and CS)

Outcome	Agriculture		Pasture		Planted Area		Crop Yield	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Agreement	0.139***	0.193***	-0.059*	-0.100***	0.381***	0.424***	0.005	0.004
	(0.024)	(0.031)	(0.028)	(0.037)	(0.031)	(0.045)	(0.004)	(0.005)
Observations	75,600	73,376	78,768	73,376	78,768	73,376	77,010	71,604
Estimation Method	TWFE	CS	TWFE	CS	TWFE	CS	TWFE	CS
State x Year FE	Yes	-	Yes	-	Yes	-	Yes	-
Munic and Year FE	Yes	-	Yes	-	Yes	-	Yes	-
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table reports the estimated impact of agreements on land use outcomes, including agricultural and pasture areas, planted areas, and crop yield, using the Two-way Fixed Effects (TWFE) method and the Callaway and Sant'Anna (2021) method. TWFE specification includes municipal and year-fixed effects, control variables, and state-year dummies. Variables are normalized to have a mean of zero and a standard deviation of one. Crop yield is calculated for the five most important crops in terms of revenue and measured in log. Standard errors, reported in parentheses, are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.

Finally, Table C3 examines the environmental impact of the ITR decentralization agreements, focusing on forest cover, deforestation, conversion of land from natural to anthropogenic use, and forest fires. Odd columns show the results for our preferred specification (TWFE) and even columns show the results estimated by CS. The results suggest that the agreements had a positive and significant impact on forest cover, as indicated by the positive coefficients in both the TWFE and CS specifications, with the impact estimated by CS being even more pronounced. In contrast, the estimates for deforestation, land conversion, and forest fires are small and not statistically significant, indicating that the agreements did not lead to systematic changes in these indicators.

Table C3: Impact of ITR Decentralization Agreements on Environmental Protection (TWFE and CS)

Outcome	Forest		Deforestation		Natural to Anthropogenic		Forest Fires	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Agreement	0.056*	0.139***	0.004	-0.001	-0.007	0.047	-0.011	-0.019
	(0.024)	(0.028)	(0.007)	(0.012)	(0.020)	(0.025)	(0.015)	(0.018)
Observations	78,768	75,616	78,768	75,616	78,768	75,616	78,768	75,616
Estimation Method	TWFE	CS	TWFE	CS	TWFE	CS	TWFE	CS
State x Year FE	Yes	-	Yes	-	Yes	-	Yes	-
Munic and Year FE	Yes	-	Yes	-	Yes	-	Yes	-
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table reports the estimated impact of agreements on environmental protection outcomes, focusing on forest cover, deforestation, land conversion from natural to anthropogenic uses, and forest fires, using the Two-way Fixed Effects (TWFE) method and the Callaway and Sant'Anna (2021) method. TWFE specification includes municipal and year-fixed effects, control variables, and state-year dummies. Variables are normalized to have a mean of zero and a standard deviation of one. Standard errors, reported in parentheses, are clustered at the municipality level. ***p < 1%; **p < 5%; *p < 10%.