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Embracing modernity pays: Cadastre modernization effects on local property tax collection

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This paper investigates the impact of the Mexican cadastre modernization program on local property tax revenue. We evaluate a comprehensive modernization initiative, which began in 2010 and included guidelines, technical assistance, and subsidies for local cadastres. Using panel data from 2000 to 2019 and a Difference-in-Differences approach, we find that municipalities adopting the program saw a 10% increase in property tax revenue within five years, rising to 30% after eight years. This effect varies significantly with local state capacity and the coordinating institution implementing the program. The program significantly enhances the state of local cadastres over the long term. Municipalities that adopt the program are more likely to invest in staff training, implement comprehensive cadastral management systems, and digitize their registries. Our results highlight the importance of local capacities and coordination in realizing the benefits of decentralization and modernization policies.

KEYWORDS
decentralization, property tax, state capacity, local governments, public finance

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La modernidad paga: Efectos de la modernización del catastro en la recaudación local del impuesto predial

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Este documento investiga el impacto del programa de modernización catastral mexicano en la recaudación local por impuesto predial. Evaluamos un programa de modernización integral, que comenzó en 2010 e incluyó directrices, asistencia técnica y subsidios para catastros locales. Utilizando datos de panel de 2000 a 2019 y un método de Diferencias en Diferencias, encontramos que los municipios que adoptaron el programa aumentaron en 10 % los ingresos por impuesto predial en los primeros cinco años, aumentando a 30 % después de ocho años. El efecto varía significativamente según las capacidades del gobierno local y la institución coordinadora que implementa el programa. Además, el programa mejora el estado de los catastros locales en el largo plazo. Los municipios que adoptan el programa son más propensos a invertir en capacitación de personal, implementar sistemas de gestión catastral integrales y digitalizar sus registros. Nuestros resultados destacan la importancia de las capacidades locales y la coordinación para concretar los beneficios de las políticas de descentralización y modernización.

KEYWORDS
decentralización, impuestos, capacidad estatal, gobierno local, finanzas públicas

1 | INTRODUCTION

Decentralization has the potential to enhance government efficiency by utilizing local knowledge and crafting policies that align more closely with local preferences and conditions. However, research indicates that decentralizing certain government functions, such as public service delivery, can lead to suboptimal outcomes due to limited state capacity and the risk of local elite capture (Mookherjee, 2015). Given these trade-offs, a critical question arises: how can governments design decentralization policies that achieve both efficiency and accountability?

We examine the case of property taxation, a responsibility frequently decentralized to local governments. Property tax can be a crucial revenue source (OECD et al., 2023) due to its low distortionary nature and the relatively easy observability of the tax base, given that it involves immovable property (Glaeser, 2013). Despite its potential, property tax remains significantly underutilized in developing countries. This underutilization is likely driven by local governments in the developing world facing incentives and constraints shaped by weakly institutionalized political environments (Besley and Persson, 2013).

Can the central government strengthen local property tax collection? We examine this issue by evaluating the determinants of adopting federal guidelines to modernize local cadastres in Mexican municipal governments —the smallest administrative units— and its effects on municipal property tax revenue.

Over the last two decades, the Mexican government has implemented initiatives to address inefficiencies in land administration systems, most notably *Programa de Modernización de los Registros Públicos de la Propiedad y Catastros* (*modernization program*). This paper examines the cadastre branch of this program, which aims to improve cadastral institutions nationwide. Officially starting in 2010 and managed by the *Secretaría de Desarrollo Agrario, Territorial y Urbano* (SEDATU) since 2013, the program includes three main components: the *Modelo Óptimo de Cadastro* (a set of detailed guidelines for cadastre improvement), technical assistance for state cadastral institutions, and a subsidy covering 60% of approved modernization project budgets for state governments.

We evaluate whether adopting modernization actions results in increased property tax collection at the local level. Municipalities can adopt program actions through three pathways: independently following the public national guidelines, following state-initiated modernization efforts, or through subsidies and assistance from SEDATU in coordination with their state government. This study seeks to identify the determinants and effects of municipalities adopting modernization actions suggested in the national guidelines at the municipality-level, and only consider state-level subsidies and technical assistance through their indirect effects on municipal adoption.

We use panel data from 2000 to 2019 for municipalities representing 76% of the country's total population, with detailed annual information on local revenues, specifically property tax collection. We identify if and when a municipality adopted the modernization program by utilizing retrospective data from the biannual Municipal Censuses from 2013 to 2019. Between 2011 and 2016, 359 municipalities adopted the program at various times. We exploit this variation and employ a Difference-in-Differences (DiD) design to estimate the program's effect on property tax revenue per capita.

There is significant heterogeneity in program adoption concerning timing, pre-treatment property tax revenue dynamics, and the municipalities' baseline socio-demographic and state capacity characteristics. Before estimating the program's effects on property tax revenues, we first examine the determinants of program adoption. We use baseline demographic data, local state capacity metrics, and cadastre characteristics to predict program adoption over time through a LASSO regression. The analysis reveals that municipalities with greater state capacity—indicated by the number of government functions performed and the education level of department heads—are more likely to adopt modernization actions. Furthermore, municipalities that have recently updated their cadastral values and those in states that received early subsidies from SEDATU for cadastre programs are also more likely to implement modernization efforts.

We then evaluate the program's effect on local property tax collection. Employing the Callaway and Sant'Anna (2021) time-group heterogeneity robust estimator and controlling for the best predictors of program adoption, we find that the cadastre modernization program significantly increases local property tax revenues per capita. The pre-treatment estimates are not statistically different from zero, supporting the assumption of conditional parallel trends based on not-yet-treated units and limited anticipation effects. Post-treatment, property tax revenue increases by approximately 10% in the first five years after adopting the program, rising to 30% eight years post-adoption. The Average Treatment Effect on the Treated (ATT) across different cohorts shows an average increase in property tax revenues of about 11%.

These results are robust to concerns related to anticipation effects, the choice of base period for computing pre-trend estimates, alternative control group definitions, sensitivity analysis to time-varying confounders, and the use of alternative DiD heterogeneity-robust estimators such as imputation estimators (Gardner, 2022; Borusyak et al., 2024) and Synthetic DiD (Arkhangelsky et al., 2021). Furthermore, consistent with the argument that the cadastre modernization program primarily affects local tax collection through property tax, we do not observe increases in other local tax or income sources.

The program effects exhibit significant heterogeneity across various dimensions. Earlier treated cohorts experience larger and more precisely estimated increases in property tax revenues. The impact of the program also varies significantly with local state capacity. Municipalities with high state capacity, characterized by more public administration functions and better-educated heads, see statistically significant increases in property tax revenue. Conversely, municipalities with low state capacity also experience increases, but these are more variable and not statistically significant. This heterogeneity underscores the crucial role of local institutional capacity in realizing the benefits of the cadastre modernization program.

The effectiveness of the cadastre modernization program also depends on the coordinating institution. Municipalities where the program was led by either the state government or local authorities saw significant increases in property tax revenue. In contrast, municipalities where the federal government coordinated the program did not experience statistically significant changes. This underscores the importance of local knowledge and the critical role of coordination between municipal and state institutions.

Our analysis reveals that the cadastre modernization program significantly enhances the state of local cadastres over the long term. Municipalities that adopt the program are more likely to invest in staff training, implement comprehensive cadastral management systems, and digitize their registries in 2022, over a decade after the initial adoption for some municipalities. Additionally, these municipalities tend to maintain up-to-date cadastral information and regularly update property and construction values, although they do not necessarily increase tax rates.

Finally, the program's impact on local expenditures is minimal. Our analysis of total municipal spending, public investment, personal services, and debt payments shows no significant changes. Although there is a non-significant trend toward increased debt payments in municipalities that have implemented the program for seven to eight years, overall expenditures remain largely unaffected. This suggests that while the program enhances property tax revenues, the absolute increase is insufficient to influence total municipal income and spending meaningfully. However, the limited increased revenue from property taxes may improve public finance health by enabling municipalities to manage debt obligations better, potentially leading to a more balanced and sustainable financial composition in the long term. Beyond property taxation, cadastres are used for land-use planning, property rights management, infrastructure development, and environmental monitoring. They provide essential data for urban planning, zoning regulations, and legal land ownership and usage disputes.

Our paper contributes to three main strands of economic literature. First, it extends the political decentralization literature, which explores the theoretical advantages of decentralization (Mookherjee, 2015) and the associated challenges such as corruption and limited state capacity (Besley and Persson, 2009). We add empirical evidence by examining a decentralization policy that combines central government guidelines and support with local government autonomy.

Second, our research is relevant to the literature on taxation in developing countries (Besley and Persson, 2013), particularly regarding interventions to improve tax collection. We build on studies demonstrating the positive effects of providing information to taxpayers (Del Carpio, 2014; Castro and Scartascini, 2015; Chirico et al., 2019; Eguino and Schächtele, 2020; Brockmeyer et al., 2021; Okunogbe, 2021; Cruces et al., 2022; Bergeron et al., 2023), incentivizing tax collectors (Khan et al., 2016, 2019), and increasing tax rates (Brockmeyer et al., 2021; Bradley, 2017). Our paper provides evidence on a policy aimed at enhancing local government capacities through improvements in municipal cadastres for property taxation.

Third, our study adds to the literature on technology adoption by local governments (Muralidharan et al., 2016). Dzansi et al. (2022) provide closely related insights by evaluating the impact of providing tablets with geospatial data to property tax collectors in Ghana, finding a 103% increase in bill issuance and revenue collection compared to a control group. In contrast, our research explores a broader context through a country-wide modernization initiative. We compare the effects of various modernization actions across municipalities rather than within them. Additionally, our study encompasses a more extensive set of interventions, including not only technological upgrades but also improvements in systems and processes within the cadastral institution.

The rest of the paper proceeds as follows. Section 2 presents the context. Section 3 presents the data. Section 4 outlines the empirical framework. Section 5 discusses the results and mechanisms. Section 6 concludes.

2 | CONTEXT

2.1 | Property taxation in Mexico

In Mexico, property taxes account for only 1.8% of total tax revenues. This is low compared to other countries in Latin America and the Caribbean such as Colombia (8.7%), Uruguay (7.7%), Brasil (4.8%), Chile (4.8%) and Honduras (2.8%) (OECD et al., 2023). Moreover, according to the *Estadística de Finanzas Públicas Estatales y Municipales* dataset by the Mexican Statistics Office, in 2021, property taxes represent, on average, 2.8% of all revenues at the municipal level, and about 32% of their local self-generated revenues. These estimates are not much larger than in 2010 when property represented 2.3% of the local revenue of the average municipality.

Property taxation relies on well-functioning cadastres and property registries. Cadasters work as a comprehensive public record and map of all real estate and its characteristics, including the size, boundaries, and geographic location of each parcel and the property's value for tax purposes. Property registries establish ownership rights, document all the transactions involving property, and ensure the legality and validity of property titles.

In 2010, 85% of Mexican municipalities reported collecting property taxes. However, more than half of them, 56%, had not updated their cadastral registries and cadastral values in the last two years, resulting in municipalities collecting, on average, $114 MXN or around 5.24 2020 USD.

A substantial increase in municipal revenues could be achieved by improving and modernizing property taxation and cadastres. For instance, estimates indicate that property tax revenues could rise by 200 to 600% if the country collected taxes at levels comparable to other Latin American nations (IMCO, 2023). However, several obstacles must be addressed, including incomplete property registries and cadastral valuations, imprecise mapping systems, reliance on paper cartography and registries, and limited administrative staff and resources.

2.2 | The cadastre modernization program

In the last twenty years, the Mexican government has implemented initiatives to address the lag in the institutions in charge of the land administration system. This paper studies the main initiative, *Programa de Modernización de los Registros Públicos de la Propiedad y Catastros*, referred to as *modernization program* or *the program* in the following sections.

We will concentrate exclusively on the cadastre branch of this program due to the lack of available data on the implementation of registry modernization actions at the municipal level. Public property registries are primarily administered at the state level, with municipalities playing a smaller role in registry activities. Consequently, datasets on municipal public administrations do not include information related to property registries.

The cadastre modernization program is the largest policy aiming to improve cadastral institutions nationwide. The program started officially in 2010 and was first managed by *Secretaría de Desarrollo Social* and then was passed to *Secretaría de Desarrollo Agrario, Territorial y Urbano* (SEDATU) in 2013.[1]

The modernization program has three main components. First, the *Modelo Óptimo de Cadastro*, a homogeneous set of detailed guidelines for states and municipalities to overcome their existing inefficient cadastre systems, hereafter referred to as *the model*. These directives detail actions to foster improvements and technology adoption in seven dimensions: legal framework, cadastral processes, information technologies, public property registry-cadastre linkages, professionalization, quality management, and institutional policies.

Second, the program offers technical assistance to state governments to assess the condition of their cadastral institutions and develop a project to implement the most effective actions to meet the standards outlined in the *cadastre model*. An annual open call ensures that every state has the opportunity to participate. Throughout the process, states are provided with robust support if they take the initiative to engage. Third, the program provides a subsidy covering 60% of the budget for approved projects, while the beneficiaries are responsible for the remaining 40%. A committee evaluates submitted projects, prioritizing institutions that lag the most in their modernization efforts and projects that align closely with *modernization program*. Between 2011 and 2015, the program gave around 590 million pesos in subsidies to state governments to carry out cadastre modernization projects, and 80%

[1] There were some smaller programs aimed at modernizing cadastres before 2011, mostly managed by BANOBRAS. We exclude municipalities with modernization actions implemented before 2011, when the first subsidies to support *Programa de Modernización Catastral* started, from our analysis and present heterogeneity results by the institution in charge of supporting the municipality's modernization efforts.

There are three different pathways for municipalities to begin adopting actions from the modernization program. First, municipalities can independently implement the program by following the national cadastre guidelines. Second, similarly, states may initiate efforts to modernize their cadastral institutions from the cadastre model and coordinate these modernization actions within their municipalities. Third, states might receive subsidies and technical assistance from SEDATU or other federal government institutions. Consequently, states might either coordinate the modernization actions in their municipalities themselves or allow the federal institution to support the municipalities directly.

This paper aims to identify the determinants and effects of municipalities adopting the national guidelines for local cadastres, known as the *cadastre model*. Although we cannot directly assess the impact of subsidies and technical assistance provided to states on municipal taxation, we may observe their indirect effects if they influence municipalities' adoption of the cadastre guidelines.

3 | DATA

We combine multiple data sources and construct a municipality-year panel dataset covering 1,533 municipalities, which represent 76.5% of the country's population by 2020, to evaluate the determinants of adopting cadastre modernization actions at the local level and their effects on local revenues. We exclude all municipalities within Mexico City, which represents 7.3% of the country's population, since property taxes there are collected by the state government. Figure A.1 shows a map with the municipalities in the final sample.

| Modernization program take-up

To measure the local adoption of actions related to the cadastre modernization program, we utilize data from the National Census of Municipal Governments (*Censo Nacional de Gobiernos Municipales y Demarcaciones del Distrito Federal*). Collected biennially by the Mexican Statistics Office, *Instituto Nacional de Estadística, Geografía e Informática* (INEGI) since 2011, these censuses provide comprehensive data on municipal activities. Using data from the 2013-2019 censuses, we identify whether municipalities adopted actions from the cadastre modernization program during any year between 2010 and 2018, covering the program's first years.[2]

We exclude a group of 65 municipalities from the analysis that reported starting modernization actions before 2010, as we cannot determine the precise year they initiated these actions. Also, given that the census content has slightly changed over time and that these adoption measures are self-reported by municipal bureaucrats, we take a conservative approach and only consider that a municipality has implemented program actions if they are reported for at least two different years. Additionally, we collect information on the institutions that coordinated or provided support for the program in the municipalities (such as the state government or SEDATU) and the specific actions they reported implementing (e.g., updating the cadastral registry, improving cadastral processes). Between 2011 and 2016, 359 municipalities adopted the program at different points in time, representing around 23% of our sample. Figure A.2 shows the treatment history, namely, at which year each cohort

[2] We use responses to the question: "Has the municipality implemented actions of the Cadastre Modernization Program?", where respondents select the years when they implemented program actions. The list of years included varies across census years. For example, in 2013, the question pertains to 2010, 2011, 2012, and 2013, while in 2019, it only pertains to 2018. The program's adoption cannot be measured in subsequent censuses as the question is no longer asked.

adopted the program and the number of municipalities in each cohort.[3]

We also gather information on the adoption of the modernization program among state governments. Although we do not observe the direct implementation of specific modernization actions from the *cadastre model* at the state level, we can track whether a state has received subsidies and technical assistance from SEDATU for both cadastral and property registry branches. We create a state-year dataset indicating whether a given state received subsidies for each type of project from 2007 to 2020. For the years before 2015, the data is obtained from SEDATU's third quarterly report of 2015, which summarizes the subsidies granted since the program's inception. For 2016 and onwards, we compile the dataset from the list of projects reported annually on the program's webpage (Secretaría de Desarrollo Agrario, Territorial y Urbano, 2024).

Tax revenues

Data on municipal tax revenues and expenditures comes from the *Estadística de Finanzas Públicas Estatales y Municipales* (EFIPEM) dataset, collected by INEGI for the years 2000-2019. This dataset includes information on local revenues and their sources, including property tax and expenditures across different categories. INEGI compiles this information from local governments' financial registries and questionnaires to local fiscal authorities. While EFIPEM is the most comprehensive source available on local finances, it does not cover all municipalities consistently across all years.

To improve the coverage of this dataset, we impute missing values using a moving average method and cross-validate our imputation with another dataset that covers a shorter period (2013-2020) but includes more municipalities for that period than EFIPEM. We exclude municipalities with more than six observations missing, the median number of imputations, and apply an exponential weighting to a window of 3 observations, giving more weight to recent observations within the window. The dataset used for validation comes from Transparencia Presupuestaria, the expenditure observatory of the Mexican Ministry of Public Finance. Figure A.3 compares the EFIPEM dataset with imputed values and the Transparencia Presupuestaria validation data, demonstrating a correlation of 0.98. We convert all figures into 2020 constant Mexican pesos.

Figure 1 illustrates the evolution of property tax revenue per capita over the past two decades across different cohorts that adopted the program. By 2000, the cohort with the lowest revenue collected an average of barely 68 MXN. By 2019, this cohort had increased its average collection to 135 MXN, doubling its property tax revenue per capita.

The figure also highlights the variability in property tax revenue growth by adoption cohort. For instance, the earliest treated cohort collected an average of 93 MXN in 2000. However, by 2019, this cohort had increased its revenue to 300 MXN, effectively tripling its initial revenue. Other cohorts that adopted the program also experienced relatively high growth rates in property tax collection. Despite these growth rates, and as discussed in Section 2, property tax collection in Mexico remains very low in absolute terms across all cohorts.

[3]Cohort adoption is based on the year municipalities adopt the program for the first time.

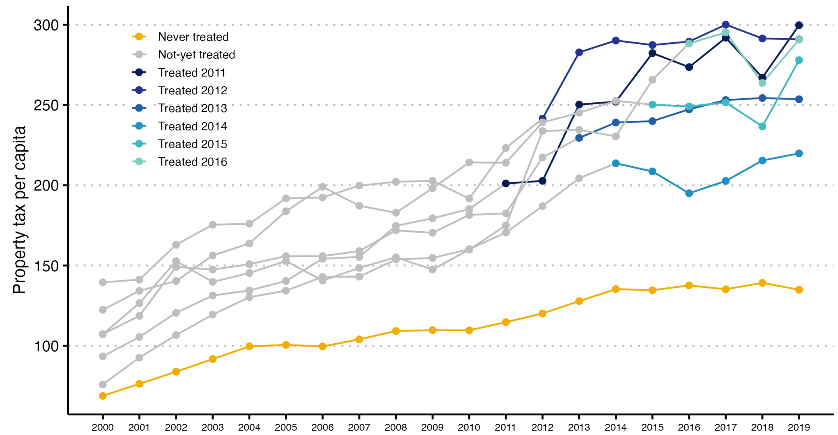

FIGURE 1 Property tax per capita by year of implementation of the modernization program in the municipality (treatment cohort). *Notes:* The y-axis shows the property tax per capita in 2020 constant Mexican pesos. The x-axis shows the year. The yellow dots and lines represent municipalities that have not yet been treated by 2018. The colored dots and lines represent post-treatment periods and a specific cohort of the program adoption, and the grey ones represent pre-treatment periods. Figure A.1 shows a map with the municipalities in the final sample and their year of program adoption. Figure A.2 shows the treatment history and number of municipalities per cohort. *Source:* Own elaboration based on multiple data sources detailed in 3.

Other variables

To analyze the determinants of program take-up and make the case for parallel trends in our estimation of the program effects, we gather various data at the municipal level for the year 2010, our baseline year. We also include various sociodemographic variables from the 2010 Population Census by INEGI, municipal poverty estimates from López-Calva et al. (2022), geographic characteristics from INEGI's National Geostatistical framework, and electoral variables from the Recent Mexican Election Vote Returns dataset (Magar, 2018).

To describe the municipal public administration, we incorporate a comprehensive set of variables from the 2011 Census of Municipal Governments, which covers data for the year 2010. We collect detailed measures to characterize the state of property taxation and cadastres before the program's beginning, including the time elapsed since the last cadastral registry update or value adjustment and the institution responsible for property taxation. To assess state capacity, we gather data on the functions performed by the public administration and the characteristics of municipal public institution leaders, such as gender, education level, and tenure. We also examine the presence of key local government entities, including municipal planning committees, development plans, internal control institutions for managing and accounting for municipal resources, inter-governmental associations, and the extent of public service coverage within the municipality.

We include data on the long-term characteristics of cadastres and property taxation from the 2023 Census of Municipal Governments to provide evidence of the mechanisms underlying the program's effects. This census offers detailed information on the functioning of cadastres and includes measures closely related to the *cadastre model*. We examine various aspects such as staff training, management system and cadastral register characteristics, cadastral registers and mapping updates, and changes to the property tax base, rates, and values during 2022. Unfortunately, most of these variables are not available for previous years.

4 | EMPIRICAL FRAMEWORK

We aim to evaluate whether the cadastre modernization program increases local property tax revenue. We employ a Difference-in-Difference (DiD) research design with the following econometric specification:

$$y_{mt} = \alpha_m + \gamma_t + \beta \cdot D_{mt} + \varepsilon_{mt} \tag{1}$$

where m represents a municipality and t a year. The term y denotes the (log) property tax revenue per capita. The treatment is defined by $D_{mt} = \mathbb{1}[t \geqslant G_m]$, which is an indicator variable that equals one if, by year t, municipality m adopted the program or belongs to the group or cohort G_m. The terms α_m and γ_t represent municipal and year fixed effects, respectively. We cluster standard errors at the municipal level, which is the level adopting the treatment.

Recent econometric literature indicates that if there is a staggered treatment adoption and treatment effects are heterogeneous across multiple periods, the canonical two-way fixed effects (TWFE) estimation procedure will be biased by comparing newly treated units with already treated units (de Chaisemartin and D'Haultfœuille, 2020; Goodman-Bacon, 2021; Sun and Abraham, 2021; Borusyak et al., 2024). Consistent with Figure 1, this is likely the case in our study, where i) we have data spanning fifteen years, ii) municipalities decide to adopt the program in different years, and iii) there is potential treatment heterogeneity.

Among the various proposed heterogeneity robust estimation methods to address this issue, we use Callaway and Sant'Anna (2021) given the identification assumptions it can accommodate. Thus, the parameter of interest is the group-time Average Treatment Effect on the Treated (ATT):

$$ATT(g, t) = E[Y_t(g) - Y_t(0) \mid G = g] \tag{2}$$

which represents the average effect of the program for municipalities in group g at time t. Intuitively, the Callaway and Sant'Anna (2021) estimator estimates treatment effects by comparing the change in outcomes over two periods and two groups, then aggregates these estimates across all treated groups to compute the event-study average treatment effect.

4.1 | Identification Strategy

The main assumption in the DiD setting is the parallel trends assumption (PTA). In our context, the trajectory of property tax revenue per capita over time for municipalities that adopted the program, had they not adopted the treatment, would be identical to the trajectory of property tax revenue per capita for municipalities that did not adopt the program.

In staggered treatment DiD designs, one way to adapt the PTA is to assume that units that received treatment at some point would have had the same trends as those that never received the treatment, namely, the "clean" controls. However, in our setting, that assumption would most likely not hold. Figure 1 shows that the municipalities with higher property tax revenue per capita are adopting the program. Moreover, these same municipalities also adopt the program at earlier stages. As such, it would be difficult to assume that there is no anticipation in adopting the program.

Thus, we follow Callaway and Sant'Anna (2021) and modify the PTA based on not-yet-treated units for the group-time ATT:

$$ATT(g,t) = E[Y_t - Y_{g-1} \mid G = g] - E[Y_t - Y_{g-1} \mid D_t = 0, G \neq g]. \tag{3}$$

This assumption implies that municipalities that have not yet adopted the program by time s ($s \geqslant t$) can serve as valid comparison groups when estimating the ATT for the group that adopted the program at time g. The authors show that a weaker version of the PTA in Equation 3 can hold conditional on covariates. Finally, besides the conditional PTA on not-yet-treated units, we also assume that the adoption of the program is not reversible. We test the robustness of our assumptions and respective results using different estimation methods, robustness checks, and placebo exercises in Section 5.2.1.

5 | RESULTS

5.1 | Determinants of the take-up of the modernization program

The adoption of the modernization program is not random. Understanding its determinants is essential for causally identifying the parameters of interest and informing policy recommendations by understanding the necessary conditions for the program's success.

We predict the program's take-up at the municipal level:

$$D_m = \alpha + X_m + \varepsilon_m \tag{4}$$

where D_m represents a dummy variable equal to one if municipality m adopts the program at any point between 2011 and 2016. As predictors, X_m, we use a set of baseline variables measured around 2010 as detailed in Section 3, including various sociodemographic variables, local revenue data, measures of municipal state capacity, characteristics of local cadastres and reception of SEDATU subsidies for modernization programs. We use LASSO regression to identify the most relevant predictors and then apply the sharpened False Discovery Rate (FDR) q-values as proposed by Anderson (2008) to select statistically significant predictors.

Figure 2 illustrates the predictors identified. Our analysis reveals that several measures of municipal state capacity are significant for program adoption. Specifically, municipalities that perform more government functions and have more educated department heads are more likely to implement cadastre modernization actions. Additionally, the condition of cadastres is a key predictor; municipalities that updated their cadastral values approximately two years prior are more likely to pursue modernization efforts. The timing of SEDATU subsidies to states to carry out modernization projects also matters. Municipalities in states that received subsidies for cadastre programs early and for public property registries later are more likely to adopt modernization actions. This observation suggests a potential tradeoff between efforts to modernize property registries and those aimed at cadastre modernization.

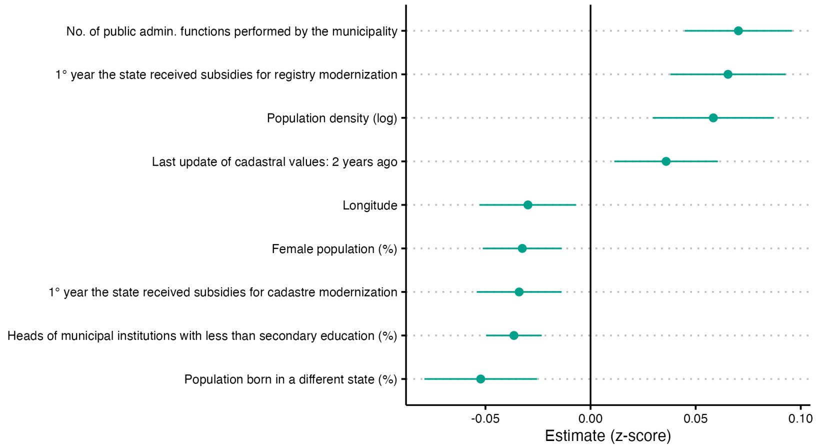

FIGURE 2 Program take-up' best predictors. *Notes:* The y-axis shows the best predictors of a municipality adopting the program at any point between 2011 and 2016, as specified in Equation 4, using LASSO selection and sharpened FDR q-values (Anderson, 2008). The x-axis shows the standardized coefficient. Confidence intervals are at 95 percent. *Source:* Own elaboration based on multiple data sources detailed in 3.

Table B.1 presents the balance of baseline covariates before and after residualizing for the nine most relevant predictors. The results demonstrate that accounting for these predictors effectively balances differences between treated and non-treated municipalities at baseline.

5.2 | Effects of modernization on local revenues

The cadastre modernization program increases local property tax revenues. Figure 3 shows our main results using Callaway and Sant'Anna (2021) event-study-like estimation method using not-yet-treated units. Note that we use a universal base period, allow for one period of anticipation, and include the best baseline predictors of program take-up as covariates using Doubly Robust estimators (Sant'Anna and Zhao, 2020).

Figure 3 shows the pre-treatment estimates before the reference period in orange. The pre-trends are not statistically different from zero. The estimate for one period before the program adoption shows an increase in property tax revenue, aligned with our priors of anticipation. These results suggest that the conditional PTA on not-yet-treated units might hold.

The post-treatment adoption estimates show that property tax revenue per capita increases by around 10% for municipalities with exposure between one and five years to the program. Finally, municipalities that adopted the program earlier, the 2011 cohort, see gains in property tax revenue up to almost 30%.

The weighted average ATT across groups, or the overall effect of adopting the program across all groups that have ever adopted it, shows that municipalities adopting the program increase property tax revenue per capita by an average of 11%. We test the robustness of our results using a battery of robustness and falsification checks.

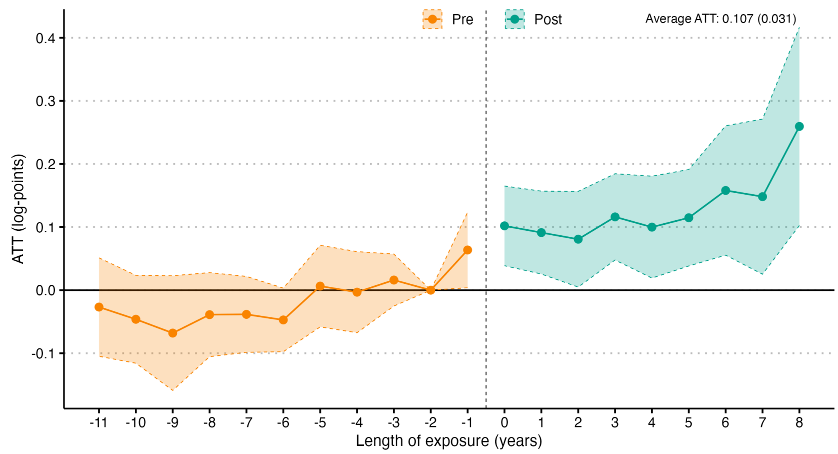

FIGURE 3 Event study: Program adoption and property tax revenue per capita. *Notes:* Event study using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. The y-axis shows the dynamic DiD estimate in log-points. The x-axis shows the lenght of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists in not-yet treated municipalities. Estimation using a universal based period with one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.

5.2.1 | Robustness and falsification checks

Anticipation. In our main specification, we allow for a limited anticipation effect of the modernization program, where municipalities may alter their taxation behavior one period before the adoption of modernization actions begins. Do municipalities anticipate the program take-up further in advance? Figure B.1 shows the event-study graph allowing for three periods of anticipation. Consistent with our previous results, there is anticipation for one year before treatment; however, the other two pre-treatment anticipation estimates are not statistically different from zero. These results suggest municipalities do not anticipate the treatment much further in advance, and our ATT estimates are robust to anticipation considerations.[4]

Base period. We present our dynamic estimates using a universal base period, set two periods before treatment, to calculate the treatment effects. This approach results in a standard event-study design (Roth, 2024). However, our pre-treatment estimates might vary if we employ the varying base period approach proposed by Callaway and Sant'Anna (2021), which alters the visual test for pre-trends. This method involves computing a pseudo-ATT for each treatment period by comparing the change in outcomes for a specific group relative to its comparison group in the pre-treatment periods. Figure B.2 displays the results using a varying base period. While the post-treatment estimates remain identical to those in our main specification, the pre-treatment estimates differ but are not statistically significant from zero. This indicates that the results of the pre-trends test are not sensitive to the choice of the base period, providing further evidence in favor of the conditional parallel trends

[4]Our estimates without anticipation follow almost the same pattern as those with one period of anticipation. However, without anticipation, all estimates are shifted by a constant. The pre-trend estimates are flat but negative, and the post-treatment estimates are increasing starting from zero, making such an event-study graph misleading. One can rescale the estimates without anticipation by normalizing them to the period before treatment and achieve the same results as we do when accounting for one period of anticipation.

assumption (PTA) using not-yet-treated units as controls.

Alternative control group. We test whether our results are robust to an alternative control group definition. As explained in Section 3, we define a municipality as treated if they have implemented actions of the modernization program for more than one year. Thus, our control group is composed of municipalities who have never implemented the program, *never-treated*, and municipalities who have implemented it for at most one year. In this exercise, we remove never-treated municipalities from the estimation sample and only keep municipalities that implemented actions for exactly one year between 2011-2018. We hypothesize that this control group is likely more similar to the treatment group and should reduce the threat of a PTA violation compared to the baseline specification. Figure B.3 shows that our results are unchanged under this exercise.

Sensitivity analysis to time-varying confounders. Our baseline results show that pre-trends are not statistically different from zero. However, insignificant pre-trends do not imply parallel trends (Kahn-Lang and Lang, 2020; Roth, 2022). We conduct a relative magnitude sensitivity analysis following Rambachan and Roth (2023). Intuitively, this exercise measures how strong the post-treatment estimates are relative to the largest deviation in the pre-treatment period.

Figure B.4 shows that our dynamic estimate just after receiving the treatment, or in period zero, is robust to post-treatment time-varying unobserved heterogeneity as large as the largest deviation of the pre-treatment period. Thus, only relatively large time-varying confounding factors after treatment during our study period could rule out our estimates.

One way to gauge whether these relative magnitudes are low or high is by comparing the dynamics of property tax revenues as shown in Figure 1. During our study period, property tax revenues exhibit little volatility, even including the 2008 Great Recession, suggesting that large shocks are unlikely to affect our estimates.

Alternative estimators. We also test the robustness of our results using alternative heterogeneity-robust DiD estimators with different identification assumptions. First, we employ the imputation estimators proposed by Borusyak et al. (2024) and Gardner (2022). These estimators fit a two-way fixed effects (TWFE) model using only observations from units and periods that are not yet treated. They then infer the never-treated potential outcome for each treated unit based on their predicted values from this regression. Regarding comparisons, Borusyak et al. (2024) treatment effects are calculated relative to the average of the pre-treatment periods, while Callaway and Sant'Anna (2021) compare all periods relative to the last pre-treatment period. For comparisons, Borusyak et al. (2024) calculate treatment effects relative to the average of the pre-treatment periods, while Callaway and Sant'Anna (2021) compare all periods relative to the last pre-treatment period. We apply the imputation estimators using the alternative control group previously described and account for one period of anticipation. As shown in Figure B.5, our results remain robust when using these imputation estimators.

While we use best predictors of program adoption to address concerns about selection into the program, we also use the synthetic difference-in-differences (SDiD) methodology proposed by Arkhangelsky et al. (2021). Bridging conventional DiD and Synthetic Control (SC) methods (Abadie and Gardeazabal, 2003; Abadie et al., 2010, 2015; Abadie, 2021), the SDiD uses time and unit weights to match pre-exposure outcome trends and relax the parallel trends assumption. In our setting, SDiD could be more suitable since it puts more weight on control units that are, on average, similar in terms of their past outcome to the target treated units, and it emphasizes periods that are, on average, similar to the target treated periods. Moreover, SDiD can accommodate the staggered roll-out setting of the program (Arkhangelsky et al., 2021; Porreca, 2022). Figure B.6 shows SDiD results by cohort. While the estimation procedures and identification assumptions are different and only use never-treated units for the control group, the average SDiD ATT estimate across cohorts is 0.104 log points, identical to our baseline results.

Falsification: Effect on other revenue sources. To accurately identify the impact of adopting the modernization program, we should observe no effects on other local revenue sources unrelated to cadastres. Potential threats to identification include the possibility that municipalities more inclined to enforce general taxation might also be those adopting the cadastre modernization program, or that changes in federal transfers could drive municipalities to seek alternative revenue sources, such as property taxation.

Our analysis in Figure B.7 shows no significant effect on the revenue collected from municipal licenses, permits, and water rights fees, which would be sensitive to general taxation enforcement. Additionally, Figure B.8 indicates no impact of the program on total local revenue, federal transfers (*participaciones federales*), earmarks (*aportaciones federales*), or municipal debt. This is not surprising, as while the program implied a high increase in property tax revenue in relative terms (Figure 3), the absolute levels are quite low (Figure 1).

5.3 | Potential mechanisms

This section discusses potential mechanisms to explain why the modernization program increased property tax revenue per capita. We first present results on heterogeneous effects by cohort adoption, local state capacity, and the institution coordinating the program. Finally, we present suggestive evidence on how the program improved the state of local cadastres.

Heterogeneity by adoption cohort. Earlier cohorts implementing the program observed significant increases in local property tax collection. Figure B.9 shows the Average Treatment Effect on the Treated (ATT) by cohort using the aggregation schemes from Callaway and Sant'Anna (2021). The 2011-2013 cohorts experienced increases between 12% and 16% in their local property tax revenue.

While later cohorts also saw increases in their collections, these were not statistically significant. The last cohort, for instance, shows considerable variability due to the small number of treated units at that time. These results follow a similar pattern when using the SDiD method by cohort, as shown in Figure B.6.

These findings suggest that although all treated units experienced increases in property tax collection, the effects become significant only after sufficient time has passed for the program to be fully adopted and effectively implemented.

Local state capacity. Another potential explanation for some municipalities' statistically significant property tax collection increases is their higher local state capacity. We test this hypothesis by examining the heterogeneous effects of municipal state capacity at baseline.

Specifically, we divide the sample into *high* and *low* local state capacity based on two dimensions in 2010: i) the number of public administration functions performed by the municipality, and ii) the share of municipal institution heads with less than secondary education. We classify a municipality as having *high* local state capacity if the number of public administration functions in 2010 was above the sample mean (thirteen), and *low* otherwise. Under this classification, 59% of the municipalities in our sample are classified as having *high* local state capacity, and 41% as *low*, resulting in relatively equal group sizes.

Similarly, we classify municipalities as having *high* local state capacity if the share of municipal institution heads with less than secondary education is below the sample mean (15%), and *low* otherwise. Under this classification, 79% of the municipalities in our sample are classified as having *high* local state capacity, and 21% as *low*.

For each dimension, we estimate a different ATT for *high* and *low* local state capacity using the treated and control units in each group. Figure 4 shows our results by local state capacity. Regardless of whether we look at the number of functions performed by the municipality or the human capital of their heads, municipalities with *high* local state capacity at baseline see statistically significant increases in property tax revenue, equal to the average ATT across all groups. Municipalities classified as having *low* local state capacity also see increases in their property tax collection; however, the estimates are very noisy and not statistically significant. Given the sample size between the local state capacity classifications, this result is likely driven by high heterogeneity in the program's effects rather than sample size.

Altogether, these results imply that the positive effects of the cadastre modernization program on property tax collection do not occur in a vacuum but rather rely heavily on municipalities' local institutional capacity when they adopt the program.

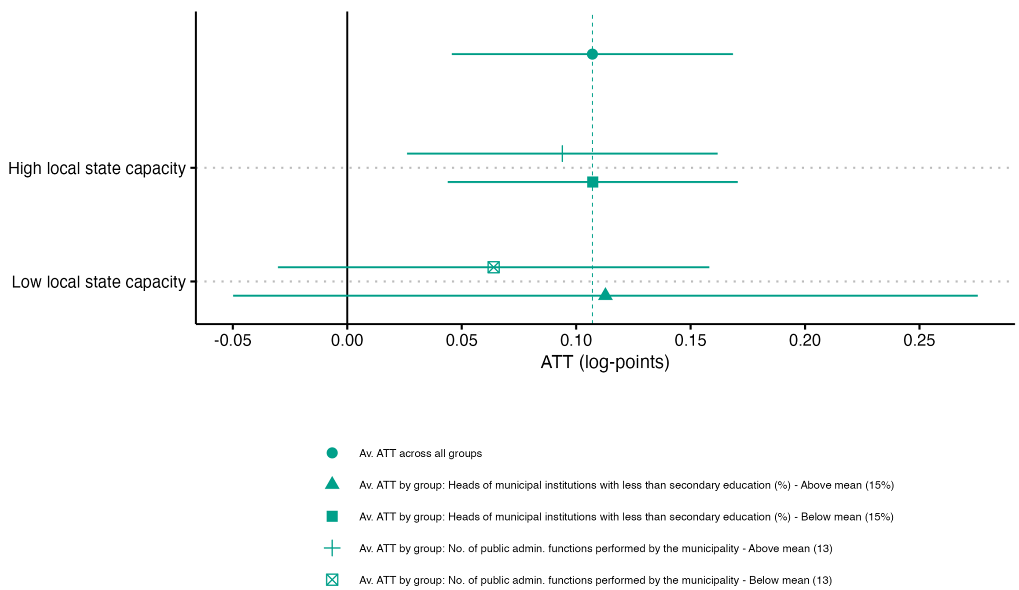

FIGURE 4 Heterogeneous effects by baseline state capacity. *Notes:* The figure shows five different treatment estimates. All treatment effects are calculated using Callaway and Sant'Anna (2021) ATT(g,t) estimation method using not-yet treated units as controls and controlling for the best predictors of program adoption at baseline depicted in Figure 2. The circle represents the average ATT across all groups, which corresponds to the estimation in Figure 3. For the other estimates, the y-axis represents the estimation sample. We divide the sample according to the mean of two different measures of municipal state capacity at baseline: the share of municipal administration heads with less than secondary education, and the number of functions performed by the municipality. *Source:* Own elaboration based on multiple data sources detailed in section 3.

Institution coordinating the program. The last heterogeneity dimension we explore concerns which institution coordinated the first implementation of the program. We divide our sample into three groups based on the administrative level responsible for implementing the program: i) the federal government (*SEDESOL*, *SEDATU*, *BANOBRAS*); ii) the state government; or iii) the municipality.

In our sample, 62% of the municipalities did not implement the program. Only 4% were coordinated by the federal government, 26% by the state government, and 8% by the municipality.

We estimate the ATT for each group, comparing treated and control municipalities. Figure 5 shows the heterogeneous results by the institution coordinating the program.

Municipalities where the federal government coordinated the first implementation of the cadastre modernization program saw increases in property tax collection, though these increases were not statistically significant.

In contrast, municipalities where the program implementation was coordinated by the state government or the municipality itself saw statistically significant increases in their local property tax collection. These estimates are not statistically different from the average ATT across all groups. Given the small share of municipalities implementing the program independently, these results suggest that beyond time and local state capacity, the program's effects are influenced by the level of decentralization and local knowledge regarding the relationship between cadastre modernization and property tax collection.

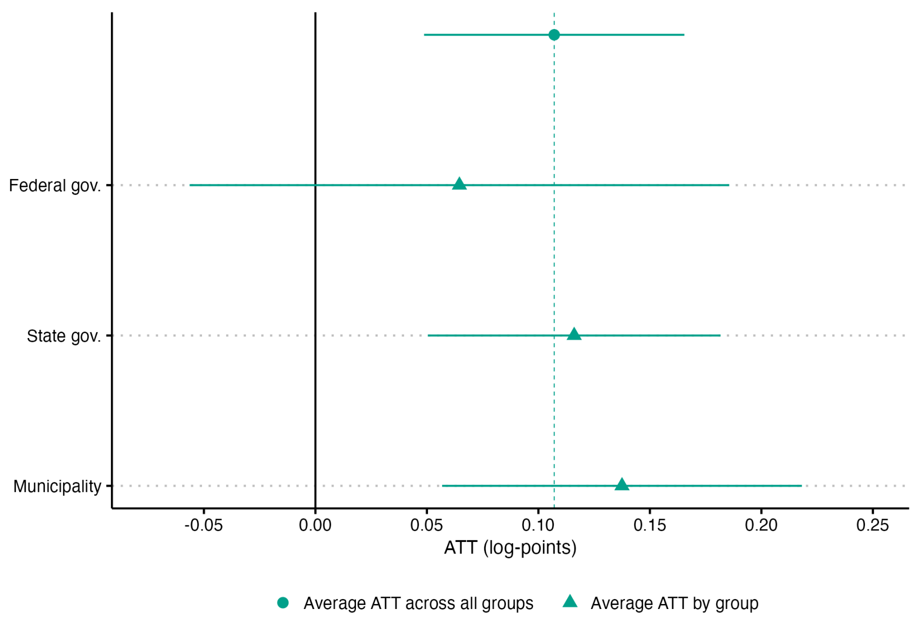

FIGURE 5 Heterogeneous effects by institution coordinating the program. *Notes:* The figure shows 4 different treatment estimates. All treatment effects are calculated using Callaway and Sant'Anna (2021) ATT(g,t) estimation method using not-yet treated units as controls and controlling for the best predictors of program adoption at baseline depicted in Figure 2. The circle represents the average ATT across all groups, which corresponds to the estimation in Figure 3. For the other estimates, the y-axis represents a different group of treated municipalities. Then, the x-axis shows the ATT of an estimation where the only treated units included in the estimation are the ones whose modernization program is coordinated by that institution. Therefore, each estimate shows the effect of adopting a modernization program coordinated by a given institution compared to a control group of not-yet-treated municipalities who eventually get a modernization program from the same institution or municipalities that have not adopted any cadastre modernization actions by 2018. *Source:* Own elaboration based on multiple data sources detailed in section 3.

Effects on the state of municipal cadastres. To conclude our mechanisms analysis, we aim to identify which aspects of municipal cadastres were enhanced through adopting the modernization program. However, comprehensive data on the state of municipal cadastres is only available in the 2023 Census of Municipal Governments. Table 1 presents the results of various OLS regressions, examining various cadastre variables measured in 2022 in relation to the adoption of the modernization program between 2010 and 2016. All models include state fixed effects and control for the most relevant baseline predictors of program adoption.

We find evidence indicating a long-term improvement in the state of local cadastres among municipalities that adopt modernization actions. The program is associated with a higher likelihood of cadastre staff receiving training and establishing a cadastral management system. Additionally, cadastre registries are more likely to be digitized, include information on property tax values, and be updated during the year. Cadastral mapping is also more likely to be updated and stored digitally. In terms of property tax values, municipalities that undertake cadastral modernization are more likely to adjust the tax base and update property and construction values. However, the likelihood of raising the tax rate does not increase. It is important to note that, after adjusting for multiple hypothesis testing, only the effects on staff training, registry format and updating, as well as mapping format and updating, remain statistically significant.

TABLE 1 Program adoption and cadastre characteristics in 2022

	Staff received training (1)	Has cadastral management system (2)	Registry is digital (3)	Registry incl. prop. tax. values (4)	Updated registry in 2022 (5)	Updated mapping in 2022 (6)	Sh. of maps in digital format (7)	Changed prop. tax base (8)	Changed prop. tax rate (9)	Changed property values (10)
Program adoption	0.068	0.039	0.050	0.037	0.099	0.063	0.054	0.053	-0.015	0.050
	(0.028)	(0.020)	(0.022)	(0.030)	(0.027)	(0.029)	(0.024)	(0.032)	(0.032)	(0.029)
Dep. var. mean	0.471	0.652	0.634	0.486	0.503	0.302	0.268	0.272	0.269	0.403
Observations	1,458	1,458	1,458	1,458	1,458	1,458	1,458	1,458	1,458	1,458
R^2	0.472	0.658	0.622	0.435	0.550	0.469	0.448	0.199	0.145	0.398
Sharp. FDR q-val	0.056	0.109	0.071	0.245	0.003	0.081	0.071	0.156	0.488	0.148

Notes: Clustered standard errors at the municipal levels in parenthesis. All specifications include state fixed effects and control for the best baseline predictors of program adoption. *Source:* Own elaboration based on multiple data sources detailed in 3.

5.4 | Effects on local expenditures

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Finally, we study whether the program has any effect on local expenditures. We replicate our baseline specification and use the Callaway and Sant'Anna (2021) estimator to analyze the program's potential effects on municipal total spending, expenditure on public investment, personal services, and debt payments. Figure B.10 shows our event-study results.

Consistent with our null results on overall total revenue, the program has no effect on total expenditure. Moreover, we do not find statistically significant effects on public investment or personal services. Although the effects on debt payments are not statistically significant, municipalities implementing the program for around seven to eight years seem to increase their debt payments. However, this increase is not statistically significant.

These results are consistent with the argument that while the program does indeed increase local property tax revenue, the increase in absolute levels is too low to affect total income and, consequently, total expenditure.

6 | CONCLUSION

Our study reveals that the Mexican cadastre modernization program significantly boosts local property tax revenues, demonstrating the potential of well-designed decentralization policies to enhance fiscal outcomes. The program's success is contingent on the capacity of local governments and the effectiveness of coordination between federal and local authorities. Municipalities with higher state capacity and those where local or state governments led the implementation experienced more pronounced revenue increases, emphasizing the crucial role of local context and leadership.

However, while the program improves property tax collection, it does not substantially alter overall municipal expenditures, suggesting that the additional revenue may not drastically impact total spending or public finance health. Nonetheless, the enhanced property tax revenues could contribute to more sustainable municipal finances in the long term. This study contributes to the broader literature on decentralization and tax policy, offering insights into how central government support can effectively complement local autonomy to achieve better fiscal outcomes.

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A | DATA

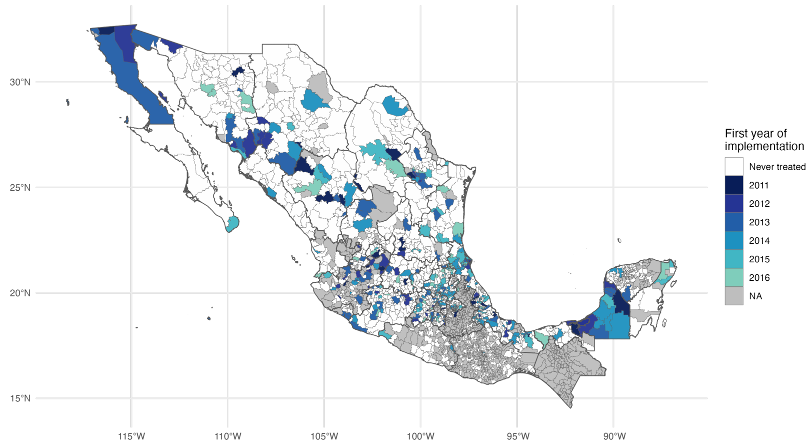


FIGURE A.1 First year of implementation of the program by municipality. *Notes:* The colored municipalities are units that adopted the program between 2011 and 2016. The municipalities in white are units in the control group. The grey-colored municipalities are those for which we do not have systematic data on property tax throughout the period of study. Figure 1 shows the evolution of property tax revenue per capita per cohort through time. Figure A.2 shows the treatment history and number of municipalities per cohort. *Source:* Own elaboration based on INEGI's Census of Municipal Governments 2013-2019 and municipal public finance data sources detailed in 3.

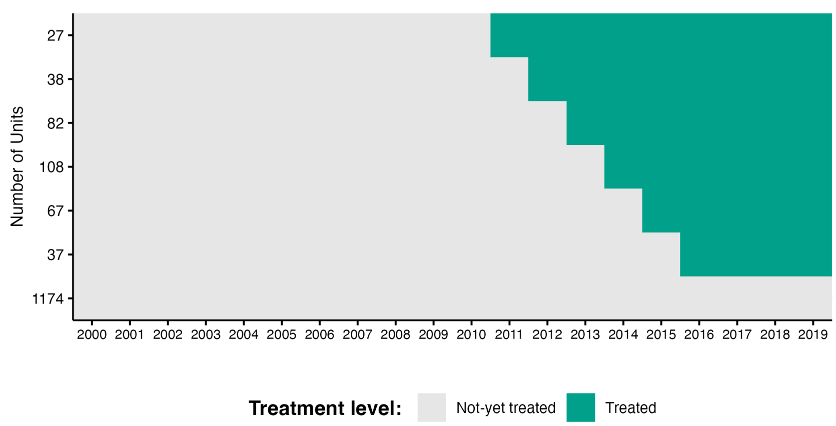


FIGURE A.2 Modernization program take-up: Treatment history. *Notes:* Grey-colored tiles indicate not yeat treated cohorts. Green tiles indicate treated cohorts. The-x axis shows the year. The y-axis shows the number of municiaplities adopting the modernization progaram in each cohort. Figure 1 shows the evolution of property tax revenue per capita per cohort through time. Figure A.1 shows a map with the municipalities in the final sample and their year of program adoption. *Source:* Own elaboration based on multiple data sources detailed in 3.

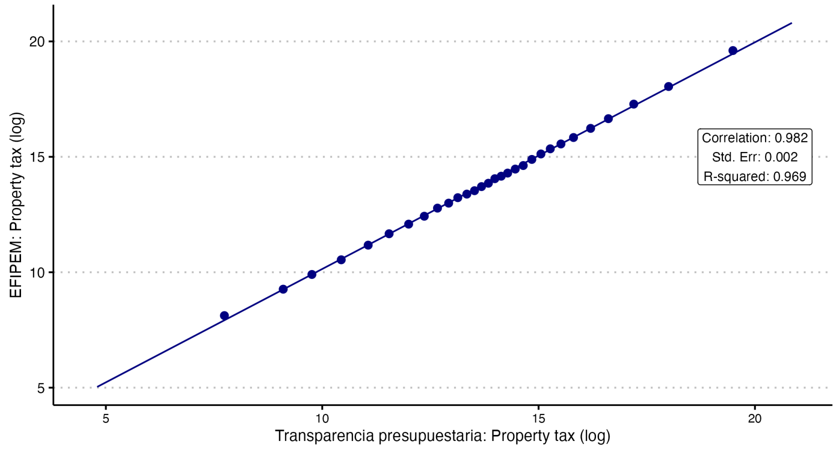


FIGURE A.3 Property tax imputation validation. *Notes:* Binscatter regression using Cattaneo et al. (2024). The x-axis shows the (log) property tax according to Transparencia Presupuestaria. The y-axis shows the imputed (log) property tax using EFIPEM. *Source:* Own elaboration using Transparencia Presupuestaria and EFIPEM datasets on local property tax revenues as detailed in 3.

B | RESULTS

TABLE B.1 Balance on baseline characteristics before and after residualizing

	Raw		Residualized	
Variable	Estimate	q-value	Estimate	q-value
Average years of schooling	-0.018	0.683	-0.048	1.000
Households with female head	-0.006	0.866	-0.016	1.000
Mean inhabitants per dwelling	0.054	0.046	0.140	0.268
Indigenous population	0.007	0.845	0.017	1.000
Innactive population	0.068	0.066	0.177	0.268
Economically active population	0.099	0.266	0.256	1.000
Population born in a different state	-0.074	0.001	-0.055	1.000
Female population	-0.026	0.189	0.016	1.000
Employed population	-0.010	0.999	-0.026	1.000
Poverty measured by capabilities	0.034	0.709	0.089	1.000
Per capita income	0.019	0.866	0.048	1.000
Gini index	-0.012	0.472	-0.030	1.000
Federal transfers (*participaciones federales*)	0.011	0.779	0.028	1.000
Earmarks (*aportaciones federales*)	0.009	0.779	0.023	1.000
Debt	-0.008	0.767	-0.022	1.000
Longitude	-0.043	0.142	-0.035	1.000
Latitude	-0.003	0.999	-0.007	1.000
Population density (log)	0.050	0.088	-0.021	1.000
Number of municipal functions	0.062	0.014	-0.020	1.000
Num. of autonomous institutions	0.010	0.767	0.026	1.000
Num. of department heads	-0.010	0.866	-0.025	1.000
Department heads (%)				
Male	0.009	0.866	0.025	1.000
Female	-0.020	0.443	-0.053	1.000
Education: no information	0.079	0.001	0.082	1.000
Education: secondary or less	0.029	0.046	-0.002	1.000
Education: upper secondary	0.021	0.142	-0.017	1.000
Education: tertiary	0.061	0.001	0.027	1.000
Tenure: no information	-0.020	0.293	-0.033	1.000
Tenure: < 3 years	0.014	0.276	0.061	0.268
Tenure: 3-5 years	-0.024	0.113	-0.040	1.000
Tenure: 6-10 years	0.004	0.962	0.017	1.000
Tenure: > 10 years	-0.014	0.472	-0.033	1.000
Mun. has internal control institutions	0.004	0.879	0.010	1.000
Mun. has development plan	-0.018	0.276	-0.046	1.000
Mun. has planning committee	0.007	0.845	0.017	1.000
Coverage of water services	0.007	0.866	0.017	1.000
Coverage of trash collection services	-0.009	0.767	-0.023	1.000
Coverage of street maintenance services	-0.003	0.965	-0.009	1.000
Coverage of public security service	0.007	0.866	0.019	1.000
Num. of intergovernmental associations	0.036	0.189	0.094	1.000
Intergovernmental assoc.: state gov.	-0.023	0.379	-0.058	1.000
Intergovernmental assoc.: other mun.	0.006	0.866	0.017	1.000
Intergovernmental assoc.: federal gov.	-0.012	0.683	-0.030	1.000
Last cadastre update: less than 1 y. ago	0.029	0.472	0.075	1.000
Last cadastre update: 2 y. ago	-0.004	0.999	-0.009	1.000
Last cadastre update: 3 y. ago or more	-0.011	0.845	-0.028	1.000
Last cadastre update: never	-0.012	0.570	-0.032	1.000
Last values update: less than 1 y. ago	-0.010	0.866	-0.027	1.000
Last values update: 2 y. ago	0.034	0.116	-0.004	1.000
Last values update: 3 y. ago or more	0.015	0.709	0.039	1.000
Last values update: never	-0.015	0.488	-0.038	1.000
Municipality was responsible for the last update	0.000	1.000	0.001	1.000
State was responsible for the last update	-0.016	0.779	-0.041	1.000
Private firm was responsible for last update	-0.006	0.866	-0.016	1.000
Municipality collects property tax	0.035	0.102	0.091	0.461
State collects property tax	0.017	0.472	0.045	1.000
First year of SEDATU subsidies for property registries	0.072	0.001	0.016	1.000
First year of SEDATU subsidies for cadastre	-0.045	0.004	-0.029	1.000
First year of SEDATU subsidies for integral project	0.004	0.965	0.011	1.000

Notes: Standardized coefficients of regressions following specification in Equation 4. The first two columns show the correlation and sharpened FDR q-values of regressing a dummy equal to one if a municipality adopted at any point in time the cadastre modernization program. The second two columns show the coefficients and q-values after residualazing the program take-up by

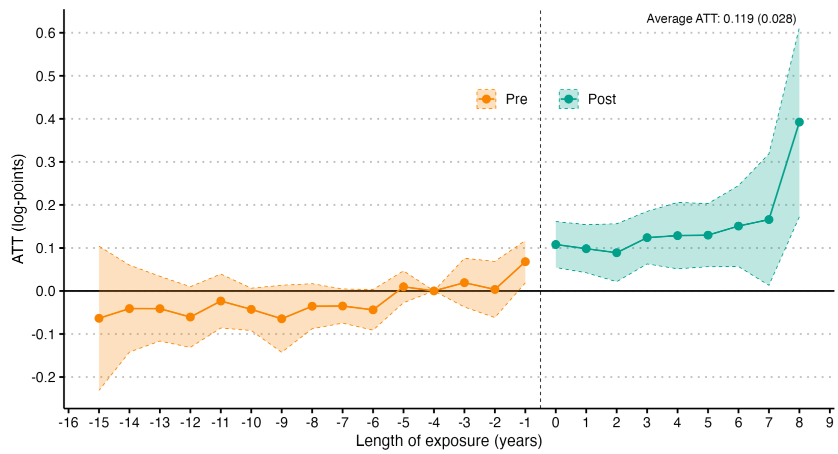


FIGURE B.1 Robustness: Anticipation. *Notes:* Event study using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. The y-axis shows the dynamic DiD estimate in log-points. The x-axis shows the lenght of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists in not-yet treated municipalities. Estimation using a universal based period with three period of anticipation, thus the reference is period minus four. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.

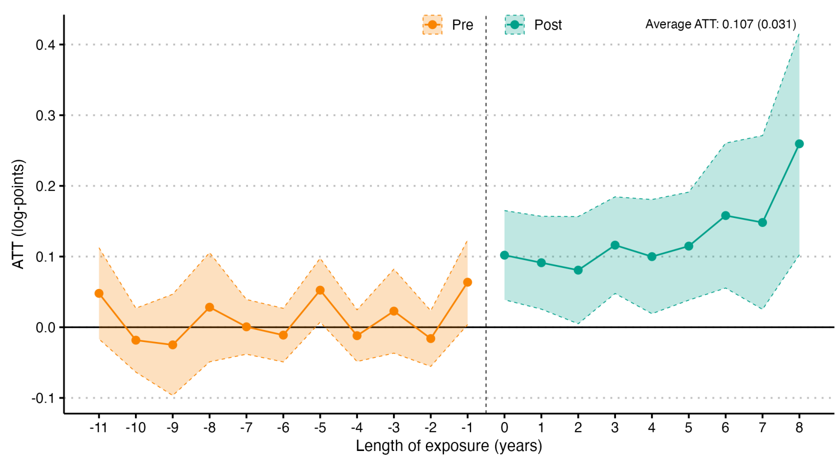


FIGURE B.2 Robustness: Varying base period. *Notes:* ATT(g,t) using Callaway and Sant'Anna (2021) estimation method. The y-axis shows the dynamic DiD estimate in log-points. The x-axis shows the lenght of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists in not-yet treated municipalities. Estimation using a varying base with one period of anticipation, thus the reference is period minus two. The varying base pre-trends estimates compare the change in outcomes for a particular group relative to its comparison group in the pre-treatment periods. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.

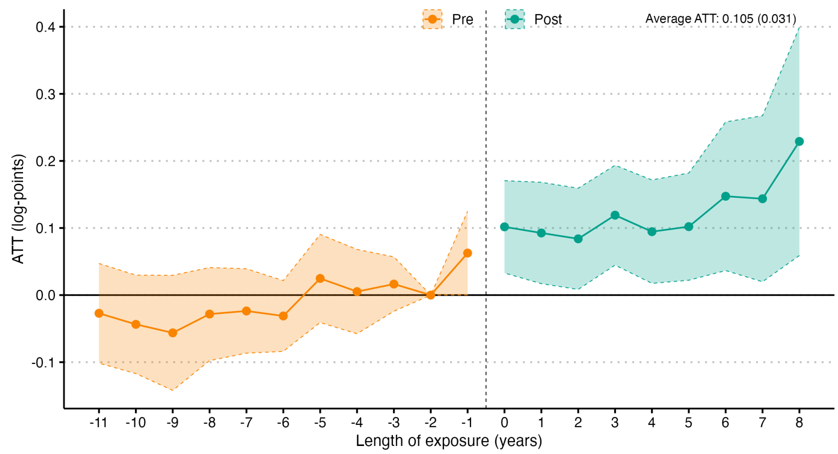
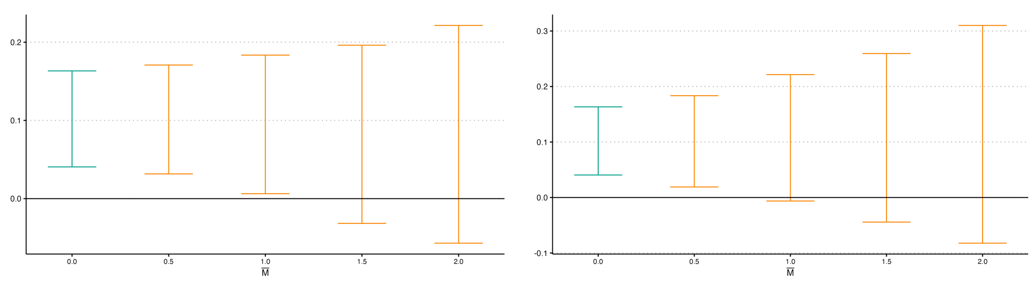
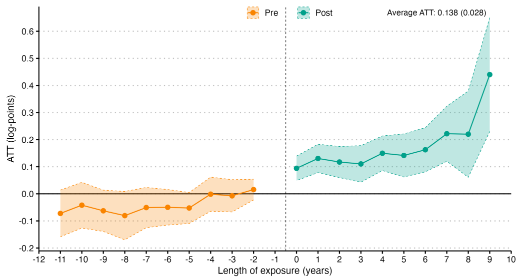


FIGURE B.3 Robustness: Alternative control group. *Notes:* Event study using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. The y-axis shows the dynamic DiD estimate in log-points. The x-axis shows the lenght of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists in municipalities implemented actions for exactly one year between 2011-2018, removing the never-treated municipalities. Estimation using a universal based period with one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.

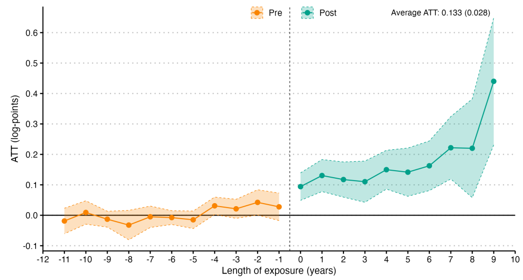


(a) Honest DiD using short-run pre-trends (b) Honest DiD using medium-run pre-trends

FIGURE B.4 Robustness: Sensitivity analysis. *Notes:* Relative magnitude sensitivity analysis for our estimate at relative time zero in Figure 3 using Rambachan and Roth (2023) Honest DiD. Panel (a) uses five pre-treatment periods. Panel (b) uses eleven pre-treatment periods. *Source:* Own elaboration based on multiple data sources detailed in 3.

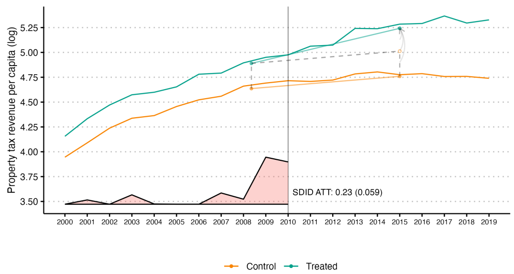


(a) Borusyak et al. (2024)

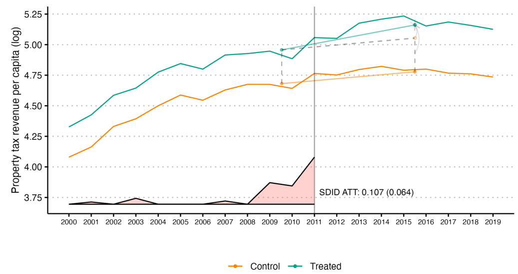


(b) Gardner (2022)

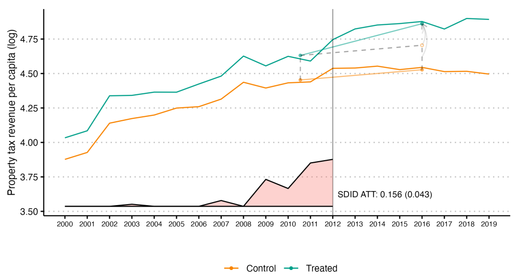
FIGURE B.5 Robustness: Imputation estimators. *Notes:* Event-study like graphs using Borusyak et al. (2024) and Gardner (2022) imputation estimators. The y-axis shows the dynamic DiD estimate in log-points. The x-axis shows the lenght of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists in not-yet and never treated municipalities. Estimation using one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. Note that these are not standard event-study designs Roth (2024). *Source:* Own elaboration based on multiple data sources detailed in 3.



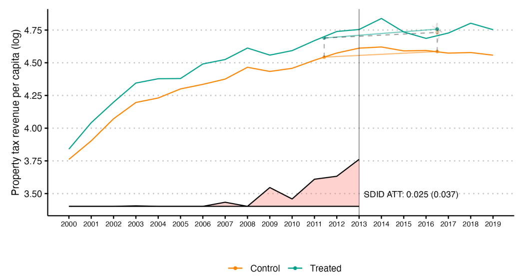
(a) Cohort: 2011



(b) Cohort: 2012

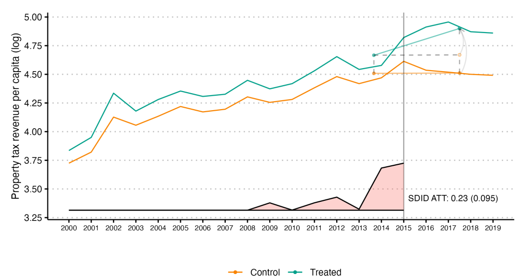


(c) Cohort: 2013



(d) Cohort: 2014

(e) Cohort: 2015



(f) Cohort: 2016

FIGURE B.6 Robustness: Synthetic DiD. *Notes:* Event-study graphs using Arkhangelsky et al. (2021) Synthetic DiD. Each panel shows a treatment cohort. The x-axis shows the year. The y-axis shows the (log) property tax per capita. The green line represents the observed (log) property tax revenue per cohort. The orange line represents the synthetic control using optimal weights on units and time. Each panel includes the cohort specific ATT estimate and standard error using jackknife method. The average ATT across groups is 0.104 log-points, with a standard error of 0.023. *Source:* Own elaboration based on multiple data sources detailed in 3.

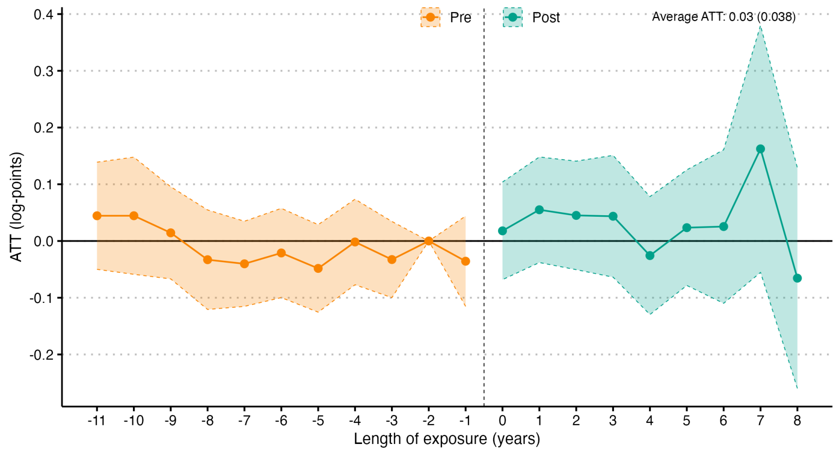
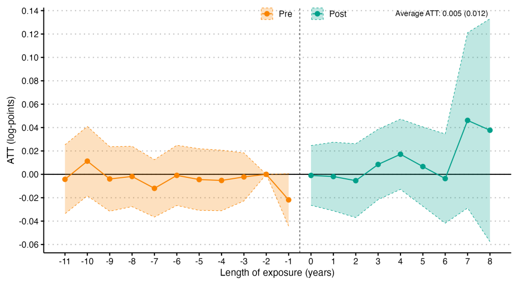
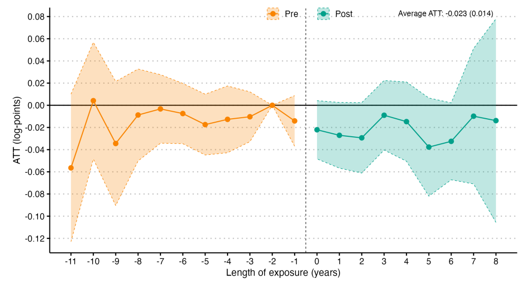


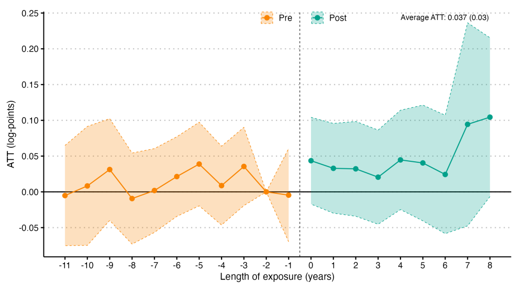
FIGURE B.7 Falsification: Program adoption and municipal revenue by licenses and permits and water rights fees. *Notes:* Event study using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. The y-axis shows the dynamic DiD estimate of the effect of the adoption of cadastre modernization program actions on the per capita water right fee revenue in log-points. The x-axis shows the length of exposure to the treatment. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists of not-yet treated municipalities. Estimation using a universal based period with one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.



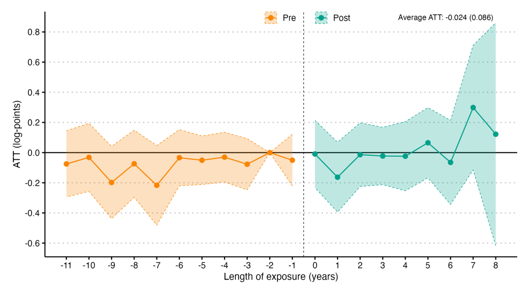
(a) Total municipal revenue



(b) Federal transfers (*participaciones*)



(c) Earmarks (*aportaciones*)



(d) Debt

FIGURE B.8 Program adoption and other sources of municipal revenues. *Notes:* Event studies using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. Each y-axis shows the dynamic DiD estimate on the outcome in each plot title in log-points. The x-axis shows the length of exposure to the treatment, the adoption of the cadastre modernization program in the municipality. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists of not-yet treated municipalities. Estimation using a universal base period with one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.

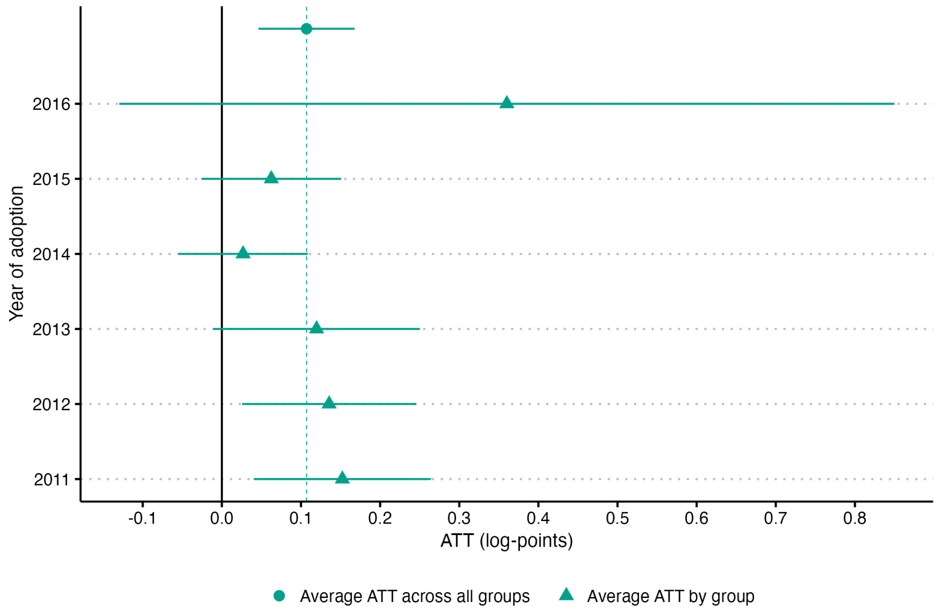
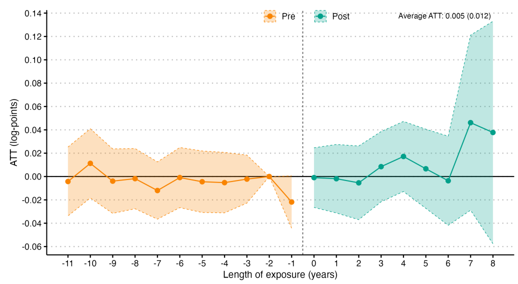
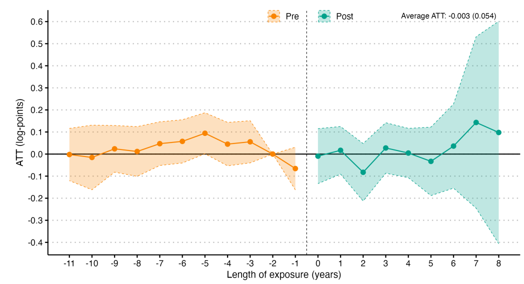


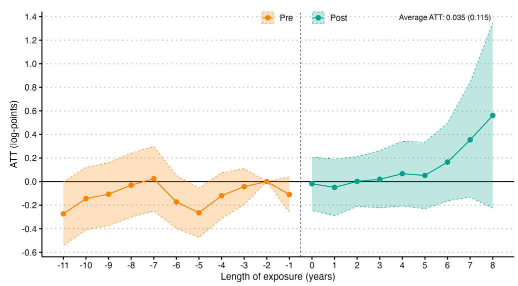
FIGURE B.9 Heterogeneous effects by year of program adoption. *Notes:* The y-axis indicates the adoption cohort, the first years when a municipality implements caddastre modernization actions. The x-axis provides estimates of the average effect of participating in the treatment for municipalities on property tax revenue in log-points for each adoption cohort averaged across all years after treatment. Treatment effects are calculated using Callaway and Sant'Anna (2021) ATT(g,t) estimation method using not-yet treated units as controls and controlling for the best predictors of program adoption at baseline depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in section 3.



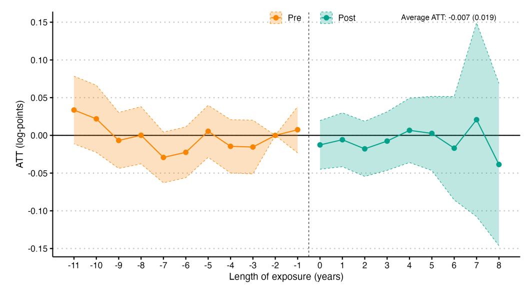
(a) Total municipal expenditures



(b) Public investment



(c) Debt payments



(d) Personal services

FIGURE B.10 Event studies: program adoption and municipal expenditures. *Notes:* Event studies using Callaway and Sant'Anna (2021) ATT(g,t) estimation method. Each y-axis shows the dynamic DiD estimate on the outcome in each plot title in log-points. The x-axis shows the length of exposure to the treatment, the adoption of the cadastre modernization program in the municipality. The orange dots and grids represent pre-treatment estimates. The green dots and grids represent post-treatment estimates. Confidence intervals are at 95 percent using standard errors clustered at the municipal level. The control group consists of not-yet treated municipalities. Estimation using a universal base period with one period of anticipation, thus the reference is period minus two. Baseline controls include the program's best predictors depicted in Figure 2. *Source:* Own elaboration based on multiple data sources detailed in 3.