Taxing Property in Developing Countries: Theory and Evidence from Mexico*

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Abstract

Property taxes in developing countries are plagued by high noncompliance and can exacerbate household liquidity constraints. We characterize the optimal trade-off between enforcement efforts and tax rates. Optimal policies depend on revenue elasticities from taxation and enforcement and on measures of taxpayer hardship—including the effect of taxes on consumption. We estimate these parameters using multiple sources of variation and administrative data from Mexico City. Empirically, both tax rate increases and enhanced enforcement raise tax revenue, but taxpayer behavior is also shaped by liquidity constraints. We combine our model and empirical results to evaluate the welfare effects of different policies. Despite the presence of liquidity constraints in our context, we find that raising taxes increases welfare. In contrast, private costs limit the desirability of enforcement as a policy tool. On the margin, a welfare-maximizing government would rather increase tax rates than enhance enforcement.

Keywords: property taxation, tax compliance, administrative capacity, liquidity constraints.
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We study the design and effectiveness of the most under-utilized tax in developing countries: the property tax. While lower-income countries generally raise less revenue as a share of GDP than higher-income countries, Figure 1 shows that this pattern is much more pronounced for the property tax than for any other tax. This paper studies whether cities around the developing world can tax property to provide local public goods and fund infrastructure investment. Do governments have the capacity to increase tax revenue? How should property tax systems account for welfare costs arising from liquidity constraints? Should welfare-maximizing governments raise tax rates on existing taxpayers or enforce taxes on delinquent households?

We answer these questions by combining administrative tax data, multiple sources of variation in different policy instruments, and a model of optimal property taxation. Our analyses pay particular attention to specific features of developing economies that may hamper tax collection: weak administrative capacity and household liquidity constraints. Weak administrative capacity would imply that property tax rate increases and enforcement actions would yield little or no additional tax revenue. We evaluate this hypothesis leveraging multiple quasi-experimental tax increases and a field experiment varying enforcement messages delivered to delinquent taxpayers. We show empirically that, despite significant under-compliance, it is possible to raise property tax revenue through both tax rate increases and additional enforcement.

Given the prevalence of liquidity constraints in developing countries, policymakers are concerned that property tax increases can inflict taxpayer hardship. Specifically, property taxes may exacerbate liquidity constraints as the tax is based on an illiquid stock rather than a flow of income or consumption. We validate these concerns empirically by showing that, following a tax increase, taxpayers are more likely to pay in installments and significantly reduce their consumption. Our model formalizes the government's trade-off between raising revenue to provide public goods and the welfare costs of raising tax rates. We conduct policy simulations by combining our model with our empirical estimates. While the presence of liquidity constraints increases the welfare cost of property taxation, we find that the government can raise welfare by increasing property tax rates.

An alternative approach to increase revenue is to more strictly enforce existing taxes on delinquent taxpayers. In contrast to other forms of taxation where taxpayers may hide income or assets, the property tax base is easily observable, which reduces the scope for evasion. Our model evaluates the welfare effects of enforcement by comparing the revenue gains from enforcement to the private costs incurred by taxpayers facing enforcement actions. While enforcement raises revenue, our estimates imply that private enforcement costs exceed the gains from the increase in tax revenue.

Our results provide a fundamental reassessment of the ways in which cities in developing countries can design property tax systems. Empirically, we show that, even in settings with significant under-compliance, governments may be able to use property tax revenue to provide public goods and invest in infrastructure. Our theoretical framework informs the design of property tax systems by considering both the revenue gains and the welfare costs of different policy instruments. Despite the presence of liquidity constraints, our empirical estimates imply that, on the margin, a welfare-maximizing government would prefer to raise property tax rates than rely on revenues from additional enforcement.

Our empirical analyses use administrative tax data on the universe of residential properties in Mexico City—the second-largest city in the Western Hemisphere. Mexico City exhibits important features that are common to many developing contexts: households face liquidity constraints and governments have limited enforcement capacity. In Mexico City, less than 20 percent of households have access to credit cards and over 40 percent of taxpayers are delinquent on their property taxes.

Our analysis proceeds in four steps. We first construct a model of optimal policy design, building on Keen and Slemrod (2017). The model characterizes the optimal design of three policy tools currently used by the government of Mexico City: tax rates, enforcement, and loans. In our setting, the government observes the tax liability, but taxpayers with low tax morale may not comply with the tax. When households are subject to liquidity constraints, they see a larger drop in consumption when they pay property taxes. The model characterizes optimal tax and compliance rates as functions of tax and enforcement elasticities as well as the consumption drop households experience when they pay property taxes.

We note two guiding insights for policy. First, liquidity constraints increase the welfare cost of taxation and yield lower optimal tax rates. Put differently, a government can set higher tax rates if it also provides liquidity to taxpayers. Second, while enhanced enforcement raises tax revenue, it also lowers welfare by increasing the private costs of tax delinquency. The model motivates our empirical analyses, which deliver the sufficient statistics needed to evaluate the welfare effects of different policies.

In our second step, we estimate tax rate and enforcement elasticities. Our analysis leverages large quasi-experimental tax hikes, which affect properties in specific cadastral value bands. Figure 2 shows that, depending on the year, tax rates increased between 18 to 47 percent. We use a regression discontinuity (RD) design to estimate short-term responses and a difference-in-differences (DiD) design to estimate medium-term responses. These research designs are bolstered by a number of checks, including that cadastral values are not manipulated, that property characteristics do not change discontinuously around band thresholds, and that treated and never-treated properties have similar pretrends. The two strategies yield similar estimates, implying revenue elasticities between 0.3 and 0.7. While these estimates directly show that governments can collect additional tax revenue, we also find that tax hikes significantly reduce compliance with the property tax.

A crucial feature of our setting is that 40 percent of taxpayers are delinquent on their property taxes. This is despite the fact that the government applies fines and interest to late payments and occasionally seizes the property of delinquent taxpayers. We study whether enforcement actions can succeed at raising revenue from delinquent taxpayers using a field experiment in which the tax authority sent enforcement letters to 80,000 delinquent taxpayers. Compared to a control group that received no letter, delinquent taxpayers who received a letter emphasizing sanctions and fines displayed triple the likelihood of making a payment. Variation in letter content allows us to identify enforcement messages that are more effective at encouraging compliance. Letters from female senders had slightly higher impacts than those signed by males, and letters from fiscal attorneys raised 50 percent more revenue than letters from compliance officers.

These empirical results demonstrate that the government is able to raise property tax revenue through either tax rate increases or enforcement. While these results reject the notion that tax capacity is at the heart of the under-reliance on property taxes, governments may worry that increased property taxation can exacerbate household liquidity constraints and cause hardship.

The third step of our analysis provides two pieces of evidence that liquidity constraints affect the ability of households to comply with the property tax. First, we show that tax hikes affect taxpayers' choice of payment modality. Descriptive patterns from properties across the property value distribution show that higher tax rates are associated with a higher likelihood that taxpayers pay in installments as opposed to paying their annual liability all at once. Using a DiD design, we find that tax hikes reduced taxpayers' propensity to pay their tax all at once and increased the take-up of paying in installments.[1]

To provide a second piece of evidence that property taxes interact with liquidity constraints, we combine administrative records with household survey data on consumption. We use a split-sample instrumental variables approach that leverages the quasi-experimental tax rate variation to estimate the impact of tax payments on consumption. The first stage—the effect of predicted tax changes on tax payments—is statistically very strong and has a similar magnitude to that of our estimates using administrative tax data. The exclusion restriction is that the predicted tax change only impacts consumption through the tax reforms. This restriction is likely to hold because the tax variation is very sharp and, as we show in our regression discontinuity and difference-in-differences analyses, tax increases are otherwise unrelated to other property characteristics and treated and untreated properties have similar trends prior to the tax increases. We find that tax increases affect the consumption of liquidity-constrained households. For instance, doubling property taxes would reduce the consumption of households without a credit card and at the 25th percentile of the income distribution by 7 percent.[2] The impacts of tax rate increases on consumption are key ingredients of optimal tax formulas, and heterogeneous effects by liquidity status allow us to quantify the effects of providing liquidity on optimal property taxes.

The fourth and final step of our analysis provides guidance to policymakers based on our empirical results. We first consider whether current tax rates are close to the revenue-maximizing tax

[1] Appendix H builds on the seminal work by Attanasio and Davis (1996) and Attanasio and Jappelli (2001), and its application to Mexico in Attanasio and Székely (2004), to show that households in Mexico City are imperfectly insured against income shocks, suggesting that liquidity constraints are pervasive. In Appendix I, we use daily payment data and variation in the deadlines for early-bird discounts to estimate a dynamic discrete choice model of payment timing. The model quantifies the welfare value of these early-bird discounts and shows that taxpayers have a very high value for liquidity.

[2] The reduction in consumption would not be surprising if taxpayers perceived the tax rate hikes as permanent. In our setting, however, the tax rate hikes do not affect consumption among the richer households, suggesting the tax rate changes are perceived as temporary and disproportionately affect households unable to smooth consumption.

rate. We find that current tax rates are far below the revenue-maximizing rate. Our results show that the government can further increase tax rates by 20-50 percent with very little risk of exceeding the revenue-maximizing tax rate. We then use our empirical estimates to implement our model of optimal tax administration. Even though compliance levels are low, the model shows that raising revenue through stricter enforcement has small or negative effects on welfare. This result follows from the fact that the model weighs the gains from additional revenue with the disutility delinquent taxpayers face from additional enforcement. While our enforcement intervention finds large effects on tax revenue, increasing enforcement is not welfare-improving.[3] By contrast, raising property tax rates to provide public goods can increase welfare. In addition, governments can improve the design of the tax by providing liquidity to taxpayers, lowering the welfare cost of taxation and allowing higher tax rates.

Our results are internally valid for Mexico City and should be interpreted as the effects of large interventions. The tax hikes we analyze were part of reforms that coincided with a 36 percent increase in property tax revenue for the city (see Figure B.1, Panel A). Our rigorous evaluations of these reforms show that a large part of this increase can be attributed to the causal impacts of tax increases. Similarly, by contacting 80,000 taxpayers, our field experiment reached close to 14 percent of delinquent taxpayers. Finally, because our enforcement intervention was part of regular enforcement campaigns, our results can be interpreted as in-equilibrium effects of existing policies.

Mexico City is a very useful laboratory for studying property taxation in a developing country context where administrative capacity and household liquidity constraints are present.[4] First, tax administrations in lower-income countries display weaker capacity in terms of human resources, skills, and technical equipment. For example, the number of tax audits per capita—a widely used proxy for tax administration capacity—is increasing in GDP per capita (see Panels A1 and A2 of Figure B.2). Mexico fits this pattern well by exhibiting a level of administrative capacity similar to other middle-income countries. Second, households in lower-income countries suffer from liquidity constraints. For instance, the share of households with a bank account, with a credit card, able to take a loan, or able to finance an unexpected expense is increasing in country per capita income.[5] As with tax capacity, measures of liquidity constraints in Mexico City are broadly representative of places with similar income levels, suggesting our results are likely externally valid for other developing countries.

This paper integrates two complementary approaches in the public finance and development

[3] This result mirrors Allcott and Kessler (2019), who show that it is possible for interventions such as ours to lower welfare even if they succeed at changing behavior.

[4] A challenge with studying property taxes is that tax systems vary across municipalities, restricting micro-studies of system features to one municipality. Data from Mexico City provides one of the largest possible samples of properties in a developing country municipality, allowing us to employ data-demanding estimation techniques.

[5] Households in developing countries experience more income volatility (Morduch 1995), have less access to insurance (Jack and Suri 2014; Townsend 1995), and less access to saving and borrowing in the formal financial system (Morduch and Karlan 2009; Demirguc-Kunt et al. 2017) than households in higher-income countries. Table B.1 describes consumer debt in Mexico City and Panels B1-B4 in Figure B.2 compare measures of liquidity constraints in Mexico with countries around the world.

economics literatures. The "economists as plumbers" framework of Duflo (2017) notes the crucial role of details in the implementation of policies. By working with local policymakers to evaluate specific details of actual policies, this approach uncovers margins for policy improvement that are absent from textbook models of property taxes. For example, our results inform the design of payment schedules to relax liquidity constraints and identify cost-effective enforcement messages. Similarly, the "tax systems" approach of Slemrod and Gillitzer (2013) notes that, in practice, issues related to remittance, compliance costs, and enforcement are key determinants of successful tax policies. We follow this approach by focusing on elements of the property tax system that are often overlooked—e.g., implicit loans in the form of discounts or alternative payment modalities—and by considering interactions between tax rates and enforcement policies.[6]

This paper contributes to the emerging literature on taxation in developing countries (Besley and Persson 2013, Pomeranz and Vila-Belda 2019). This literature has argued that the optimal mix of tax instruments can diverge from traditional public finance theory prescriptions in a context of limited enforcement capacity (Best et al. 2015). We introduce household liquidity constraints as an additional characteristic of developing economies, which is empirically important but often neglected by traditional optimal tax theory. We show that property taxes can generate larger distortions in the presence of liquidity constraints.[7]

Our paper is also related to the tax compliance literature (for a recent survey, see Slemrod 2018). This literature has traditionally been concerned with the accurate reporting of liabilities and the impact of detection, but has recently noted that payment enforcement is a separate and similarly important challenge, even in the US (Versprille, 2020). Recently, researchers have started evaluating novel tools for the enforcement of outstanding payments (Slemrod and Organ, 2020; Kessler, 2020; Perez-Truglia and Troiano, 2018; Dusek et al., 2020). Our study adds to these papers by showing how tax rates affect the level of delinquency and by evaluating the success of different enforcement messages in reducing delinquency. Our optimal tax model also considers the welfare gains from policies that target delinquency relative to other tax policies.

In addition, this study contributes to research that uses property taxes to study questions related to taxation and development (e.g., Khan et al., 2016, 2019; Okunogbe, 2019; Weigel, 2020; Balan et al., 2020). Best et al. (2020) study the implications of horizontal inequities for tax morale and compliance. Bergeron et al. (2020) study the effects of tax rates and enforcement on compliance and how these instruments jointly determine the revenue-maximizing rate. Consistent with our results, they find that responses to tax rate changes are likely driven by liquidity constraints. Our paper considers both revenue-maximizing and welfare-maximizing objectives to implement optimal

[6]This approach is also related to that of Meiselman (2018) and Brockmeyer et al. (2019), who build on Keen and Slemrod (2017) to examine the effectiveness of enforcement letters for taxpayers in Detroit and Costa Rica, respectively, and to that of Basri et al. (2019), who compare tax rate increases and tax administration investments in the context of corporate income taxation in Indonesia.

[7]Relative to a set of papers that focus on the role of information in enforcing taxes (Pomeranz, 2015; Naritomi, 2019), this papers studies compliance in a setting where the government has full information.

tax formulas and evaluates the relative desirability of enforcement and tax rate increases.

Finally, there is a large body of work on property taxes in the US, reviewed in Agrawal et al. (2020).[8] While this paper emphasizes aspects of property taxation that are more salient in developing countries, our results may be applicable to some developed country settings. For instance, liquidity constraints are also important in rich countries.[9] Similarly, several US cities have trouble collecting property taxes with noncompliance rates above 10% (Chirico et al., 2019).

The rest of the paper is structured as follows. Section 1 presents an optimal property taxation model that guides our empirical analysis. Sections 2 and 3 present the property tax system in Mexico City and the administrative data we use. We study the effect of tax rate changes on tax revenue in Section 4, the effect of enforcement on revenue in Section 5, and the role of liquidity constraints in Section 6. In Section 7, we use our empirical estimates to implement our optimal property tax model and discuss policy implications. Section 8 concludes.

1 Optimal Property Tax Administration with Liquidity Constraints

This section develops a model of optimal property taxation for developing countries building on work by Keen and Slemrod (2017). To match our empirical setting, we adjust their model by considering an observed and fixed tax liability and by focusing on compliance along the extensive margin.[10] We then show that liquidity constraints imply lower optimal property tax rates by raising the welfare cost of taxation. For this reason, governments can improve the administration of property taxes by providing liquidity to taxpayers. Finally, alleviating liquidity constraints also reduces the relative desirability of enforcement as a means of raising revenue.

1.1 Model Setup

Households i live two periods. They consume a private good c and a public good g and have uncertain income y in the first period. Households start owning a property of value H, pay a tax t in the first period, and use the liquidated value of the asset for consumption in the second period. These assumptions represent an initial state where households have committed to a level of housing consumption and a second period where households re-optimize housing and consumption.[11]

[8]A central concern in this literature is the impact of property taxes on the real estate market. We document that new construction is not strategically designed to target property tax thresholds and that tax increases are not likely to impact investment in existing housing units. Property taxes are unlikely to affect household location decisions, as funding for education services is not tied to neighborhood-level taxes, and as internal migration is lower in lower-income countries. This is especially true in our setting, as Mexico City offers unique amenities.

[9]Cabral and Hoxby (2012) show that property taxes are less popular when households lack escrow accounts to smooth tax payments. Similarly, Wong (2020) shows that small property tax increases in the US can lead to financial hardship including mortgage delinquency and declines in consumption.

[10]In contrast, Keen and Slemrod (2017) consider a model where taxpayers can take costly actions to "hide" income from the tax authority. Table C.1, Panel B, shows that most taxpayers either pay their tax in full or do not pay; very few pay partially.

[11]We present a simple model for clarity of exposition and discuss extensions in Section 1.5.

While the government observes the tax liability, households may decide not to pay the property tax. $\mathbb{I}[\text{Delinquent}_i]$ denotes the event of household i being delinquent. Households face two types of costs when they are delinquent. First, they incur a "tax morale shock" $M_i(\alpha)$, which is a function of the level of enforcement α. We assume $M_i(\alpha) = m(\alpha) + \varepsilon_i$. That is, households have a common private cost, $m(\alpha)$ with $\frac{\partial m(\alpha)}{\partial \alpha} > 0$, as well as idiosyncratic disutility from not paying taxes, $\varepsilon_i \sim F(\cdot)$.[12] Second, when households are delinquent, the value of their property depreciates by a factor z. This factor corresponds to back taxes collected by the government, including through the seizure of the property in lieu of property tax payments. Households solve the following problem:

$$
\begin{aligned}
\max_{s,\text{Delinquent}} \quad & u(c) + \beta u(c') + v(g) - M_i(\alpha) \times \mathbb{I}[\text{Delinquent}_i] \\
c \quad &= \quad y - tH(1 - \mathbb{I}[\text{Delinquent}_i]) - s \\
c' \quad &= \quad s(1+r) + H(1 - z \times \mathbb{I}[\text{Delinquent}_i]) \\
s \quad &\geq \quad 0,
\end{aligned}
$$

where savings receive an interest rate r and the level of public goods g is set by the government.

Conditional on the decision $j \in \{\text{Pay}, \text{Delinquent}\}$, optimal consumption is determined by the first order condition:

$$u'(c_s^j) \geq (1+r)\beta u'(c_s^{\prime,j}),$$

where we index consumption by savings, s. When $s > 0$, this equation holds with equality. When $s = 0$, the household is liquidity-constrained, and this equation holds with a strict inequality.

Households decide whether to comply with the property tax by comparing indirect utilities from paying and being delinquent. Denoting the mean indirect utility of payment decision j by V^j, the overall utility for household i is then $V_i = \max\{V^{\text{Pay}}, V^{\text{Delinquent}} + \varepsilon_i\}$. Finally, let V denote the population expectation over V_i.

Let $N^{\text{Pay}} = \mathbb{P}r(V^{\text{Pay}} > V^{\text{Delinquent}} + \varepsilon_i)$ be the fraction of households that pay their property tax. Following Busso et al. (2013), we note that:

$$\frac{dV}{dV^j} = N^j.$$

This expression shows that, because households have already optimized over being delinquent or paying, the overall effect on welfare from marginal changes to mean utilities does not depend on changes in delinquency status (i.e, $\frac{dN^{\text{Pay}}}{dV^{\text{Pay}}}$).

Consider now the effects of taxes on mean utilities:

$$\frac{\partial V^{\text{Delinquent}}}{\partial t} = 0 \quad \text{and} \quad \frac{\partial V^{\text{Pay}}}{\partial t} = -u'(c_s^{\text{Pay}})H.$$

[12] Glaeser (2006) argues that interventions such as ours may act as emotional taxes—a cost that needs to be taken into account in welfare evaluation. Other studies have also recognized the importance of private costs for welfare evaluations (e.g., Caplin, 2003; Loewenstein and O'Donoghue, 2006; Allcott and Kessler, 2019).

By the first expression, tax increases do not impact the mean utility of being delinquent. While the second equation applies both when $s = 0$ and $s > 0$, the interpretation differs across these cases. When $s > 0$, the envelope theorem holds and households readjust their savings, but the welfare effect of this readjustment cancels out. When $s = 0$, there is no such readjustment, as households are constrained. Because marginal utility is higher when $s = 0$, the welfare cost of raising taxes is also higher in this case.

Consider now the effects of increasing enforcement by raising α:

$$\frac{\partial V^{\text{Delinquent}}}{\partial \alpha} = -\frac{\partial m(\alpha)}{\partial \alpha} \quad \text{and} \quad \frac{\partial V^{\text{Pay}}}{\partial \alpha} = 0.$$

Enforcement lowers the mean utility of delinquency by increasing the private cost of not paying taxes, while tax-paying households are not directly affected by changes in enforcement.

Finally, the government uses tax revenue to provide public goods g and enforcement α at a cost $a(\alpha)$. Its budget constraint is:

$$g + a(\alpha) = tHN^{\text{Pay}} + zH(1 - N^{\text{Pay}}),$$

where z represents the back-taxes that the government will eventually collect from delinquent taxpayers. While the effects of policy changes on welfare do not depend on changes in the decision to pay or be delinquent, the effects of t and α on N^{Pay} are crucial drivers of tax revenue.

1.2 Optimal Property Tax

The government maximizes V subject to its budget constraint. To simplify exposition, we consider the case where income can take two values, one where households are liquidity-constrained, $s = 0$, and one with positive saving, $s > 0$. Substituting the government's constraint for g, a tax increase has the following impact on welfare:

$$-N^{\text{Pay}}H[\pi_s^{\text{Pay}}u'(c_s^{\text{Pay}}) + \pi_0^{\text{Pay}}u'(c_0^{\text{Pay}})] + v'(g) \times \left\{ HN^{\text{Pay}} + (t - z)H\frac{\partial N^{\text{Pay}}}{\partial t} \right\},$$

where π_s^{Pay} denotes the share of households who pay taxes with $s = 0$ and $s > 0$. We simplify this expression by rearranging, defining the tax elasticity of compliance $\varepsilon_t^{\text{Pay}} = \frac{\partial N^{\text{Pay}}}{\partial t}\frac{t}{N^{\text{Pay}}} < 0$, and approximating the marginal utility with a Taylor expansion (e.g., as in Chetty, 2006) to obtain:

$$MVPF_t = \underbrace{\frac{v'(g)}{u'(c)}}_{\text{Value of Public Goods}} - \underbrace{\frac{1 - \gamma(\pi_{0,c}^{\text{Pay}}\Delta c_0^{\text{Pay}} + \pi_{s,c}^{\text{Pay}}\Delta c_s^{\text{Pay}})}{1 + (1 - \tilde{z})\varepsilon_t^{\text{Pay}}}}_{\text{Welfare Cost Per Dollar of Revenue}}, \tag{1}$$

where $\gamma = \frac{-u''(c)c}{u'(c)}$ is the coefficient of relative risk aversion, $\tilde{z} \leq 1$ is the fraction of back-taxes collected in the future, and Δc measures the decrease in consumption in response to the property tax increase.[13]

Equation 1 shows that the marginal value of public funds (MVPF) (e.g., Atkinson and Stern, 1974; Slemrod and Yitzhaki, 2001; Hendren, 2016) from raising taxes depends on the value of public goods and the distortions associated with raising revenue. A positive $MVPF_t$ implies that welfare increases when property taxes are used to fund public goods. The costs of raising tax revenue are larger when taxpayers are less likely to comply with a tax increase (large ε_t in absolute value), when paying taxes leads to large drops in consumption, and when the government is not able to collect back taxes in future periods (low value of $\tilde{z}$). Funding public goods through property taxes will be less desirable in each of these cases.

We obtain an expression for the optimal property tax by setting $MVPF_t = 0$. Writing $\Delta c_s^{\text{Pay}} = -\eta_{t,s}^c t$, where $\eta_{t,s}^c > 0$ is the tax semi-elasticity of consumption, the optimal tax rate is:

$$t = \frac{(1 + (1 - \tilde{z})\varepsilon_t^{\text{Pay}})\frac{v'(g)}{u'(c)} - 1}{\gamma(\pi_{s,c}^{\text{Pay}}\eta_{t,s}^c + \pi_{0,s}^{\text{Pay}}\eta_{t,0}^c)}. \tag{2}$$

The optimal tax is larger when public goods are more valuable (larger value of $\frac{v'(g)}{u'(c)}$) and when taxes have a smaller effect on delinquency ($\varepsilon_t^{\text{Pay}}$ is close to zero). Similarly, because the consumption response is likely to be greater for liquidity-constrained households (i.e., $\eta_{t,0}^c > \eta_{t,s}^c$), the government can set higher property taxes when the fraction of liquidity-constrained households is smaller.

1.3 Optimal Enforcement

Consider now the government's choice to expend resources on enforcement. Increasing α has the following effect on welfare:

$$-(1 - N^{\text{Pay}})\frac{\partial m(\alpha)}{\partial \alpha} + v'(g) \times \left\{(t - z)H\frac{\partial N^{\text{Pay}}}{\partial \alpha} - \frac{\partial a(\alpha)}{\partial \alpha}\right\}.$$

In our setting, enforcement can be interpreted in terms of the money spent on mailing enforcement letters, so we assume that $a(\alpha) = \alpha$, where α is money spent on enforcement. Defining the enforcement elasticity of compliance $\varepsilon_\alpha^{\text{Pay}} = \frac{\partial N^{\text{Pay}}}{\partial \alpha}\frac{\alpha}{N^{\text{Pay}}} > 0$, the MVPF from enforcement is then:

$$MVPF_\alpha = \frac{v'(g)}{\frac{\partial m(\alpha)}{\partial \alpha}} - \frac{1 - N^{\text{Pay}}}{(1 - \tilde{z})N^{\text{Pay}}\frac{\varepsilon_\alpha^{\text{Pay}}Ht}{\alpha} - 1}. \tag{3}$$

The first expression is the value of public goods relative to the welfare cost of enforcement. The second is the welfare cost of raising revenue from a $1 - N^{\text{Pay}}$ fraction of households. The term $(1 - \tilde{z})\frac{\varepsilon_\alpha^{\text{Pay}}Ht}{\alpha}$ captures the revenue gains from enforcement net of the public cost of enforcement, α, and the reduction in future back taxes, $\tilde{z}$. We can use Equation 3 to evaluate whether an

[13] Note that Equation 1 depends on $\pi_{s,c}^{\text{Pay}}$, which represents the share of consumption by households that pay taxes with a given value of s. See Appendix A for details.

enforcement action improved welfare, i.e., whether $MVPF_\alpha > 0$.

Setting $MVPF_\alpha = 0$ yields the following condition for the optimal enforcement level α :

$$\varepsilon_\alpha^{\text{Pay}} = \frac{(1 - N^{\text{Pay}})\frac{\alpha\frac{\partial m(\alpha)}{\partial \alpha}}{v'(g)} + \alpha}{(1 - \tilde{z})N^{\text{Pay}}Ht}.$$

At the optimum α, the government equates the enforcement elasticity $\varepsilon_\alpha^{\text{Pay}}$ to the ratio of enforcement costs to tax revenue. Importantly, this ratio accounts for both public enforcement expenditures α and the private disutility from enforcement $m(\alpha)$ that is incurred by the $1 - N^{\text{Pay}}$ delinquent taxpayers.[14]

For a given enforcement level α, this expression defines the compliance rate that equates the marginal costs and benefits of enforcement:

$$N_\alpha^{\text{Pay}} = \frac{1 + \frac{\frac{\partial m(\alpha)}{\partial \alpha}}{v'(g)}}{(1 - \tilde{z})\frac{\varepsilon_\alpha^{\text{Pay}}Ht}{\alpha} + \frac{\frac{\partial m(\alpha)}{\partial \alpha}}{v'(g)}}. \tag{4}$$

This expression is useful from a policy perspective, as it tells the government whether the marginal benefit exceeds the marginal cost of enforcement, which happens when $N_\alpha^{\text{Pay}} < N^{\text{Pay}}$. The government can then raise welfare by increasing enforcement when N_α^{Pay}—which combines the administrative costs, the private costs, and the effectiveness of enforcement—is smaller than the observed compliance rate N^{Pay}.[15]

1.4 Relative Value of Enforcement and Liquidity Constraints

Equations 1 and 3 can also inform policy by showing whether it is preferable to raise tax revenue by increasing tax rates or by tightening up enforcement. Suppose the government increased taxes and reduced enforcement to keep spending g constant. Such a reform would improve welfare if:

$$MVPF_t \times u'(c) - MVPF_\alpha \times \frac{\partial m(\alpha)}{\partial \alpha} > 0. \tag{5}$$

Since this is a balanced-budget reform, this condition only compares the welfare costs of raising revenue and does not depend on the value of public goods. Importantly, because $MVPF_t$ depends on consumption changes but $MVPF_\alpha$ does not, the relative value of taxation over enforcement depends on the degree to which liquidity constraints increase the welfare costs of taxation. By providing liquidity, the government can reduce the fraction of liquidity-constrained taxpayers, which increases

[14] Keen and Slemrod (2017) call this term the "adjusted marginal cost-revenue ratio." The term $\alpha\frac{\partial m(\alpha)}{\partial \alpha}$ can be viewed as a first-order approximation of $m(\alpha)$. Private enforcement costs are discounted by the value of public goods $v'(g)$ since an increase in α requires lowering g.

[15] Figure A.1 provides graphical intuition for this result.

$MVPF_t$ as well as the relative value of taxation over enforcement.[16]

1.5 Limitations and Extensions

Our model simplifies the analysis to focus on the main forces in our empirical setting. We now discuss possible limitations and extensions to our conceptual framework.

1. Uncertainty. Our model assumes a discrete distribution for income shocks. Allowing for a range of possible incomes would not alter the main results. In this case, the average consumption drop across the range of possible incomes would measure the welfare costs from taxation.

2. Dynamics. Our model can also be extended to allow for multiple time periods and the importance of liquidity constraints carries over to dynamic models with uncertain income.[17] Moreover, as in other sufficient statistic models (e.g., Chetty and Finkelstein, 2013), consumption changes are robust welfare measures in the presence of dynamic considerations.

3. Consumption commitments and housing choice. Our analysis assumes that housing consumption is initially fixed. While the model could endogenize the decision to adjust housing, the ranges of property tax changes we consider are unlikely to trigger such decisions from homeowners, which constitute the vast majority of households in our data.

Nonetheless, consumption commitments can impact our analysis by amplifying the welfare cost of income shocks. Chetty (2004) shows that consumption commitments lead to larger drops in adjustable consumption and can further exacerbate welfare costs when housing and flexible consumption are complements. In our empirical implementation, we considering a range of values for γ, including larger values that account for these forces.

4. Housing market effects. Our model abstracts away from the effects of taxes on the supply of housing or on property values. While property taxes can impact the supply of housing, these effects are likely to be small in our setting. In Appendix F, we show that the complexity of the property tax system implies that increasing the property tax rate does not impact the supply of housing. Moreover, because property taxes are based on outdated cadastral values, the government's budget constraint is not affected by policy-driven changes in market values.

Nonetheless, a potential concern is that tax and spending policies can be capitalized into property values and that this will affect inter-temporal consumption decisions. Brueckner (1982) models the capitalization of local taxes and public goods into property values. At the efficient level of provision, increasing local public spending through property taxes leaves the value of housing unaffected. Our assumption of no capitalization effects is therefore correct when $\text{MVPF}_t = 0$, leaving Equation 2 unaffected by this assumption.[18] In the case of under-provision of public goods ($\text{MVPF}_t > 0$), in-

[16]Appendix A provides a detailed derivation of Equation 5 and the role of liquidity provision.

[17]For example, Deaton (1991) shows that even in periods when households are not constrained, precautionary savings produce behavior that is similar to that of liquidity constraints. This shows that interactions between property taxes and liquidity constraints continue to be important in dynamic settings.

[18]Because enforcement actions are directed at delinquent individuals, rather to the market as a whole, Equations 3–4 are unlikely to be affected by capitalization effects.

creasing public good provision by taxing property would increase property values.[19] Capitalization would increase the wealth of property owners. Unconstrained households would then reduce savings and constrained households would have larger consumption in the future. While the first channel would be reflected in the data through a smaller consumption drop, ignoring the second channel would lead us to overestimate the welfare cost of taxation. For this reason, assuming no capitalization effects implies that MVPF_t is a lower bound relative to the case with capitalization when public goods are under-provided. We return to this discussion in our empirical implementation.

5. Location decisions and tax competition. Unlike other models of property taxation (e.g., Agrawal et al., 2020), we do not consider migration or tax competition. These concerns are less important in developing countries where internal migration is generally lower (Bell et al. 2015) and in our specific setting because Mexico City offers unique amenities, which makes the possibility of tax-driven migration less relevant.

6. Redistribution and fairness. We assume the tax rate applies to properties of similar values. This assumption matches our setting, as the government relies on a partially progressive tax schedule with different tax rates for different value bands. If households responded to progressive property taxes by moving to properties of lesser value, our model could be extended by accounting for the resulting fiscal externality. However, as discussed above, we do not believe that this is the primary margin of adjustment in the context of developing countries.

Finally, our model does not allow for the rate of noncompliance to impact the utility of taxpayers. Besley et al. (2019) develop a model with fairness considerations to study the introduction of a poll tax in the UK, which increased evasion by 300–500%. While we show that tax hikes increase noncompliance, our effects are orders of magnitude smaller than those of the poll tax. Fairness motives are therefore unlikely to play a central role in the context of the policies we study.

Overall, the framework allows us to evaluate the welfare effects of tax and enforcement policies, as well as their relative desirability. Equations 1–4 motivate our empirical analysis to estimate key effects of different policies, including $\varepsilon_t^{\text{Pay}}$, Δc, and $\varepsilon_\alpha^{\text{Pay}}$. Section 7 implements these formulas using our empirical estimates and provides policy guidance for governments in developing economies.

[19] Bradbury et al. (2001) and Cellini et al. (2010) provide evidence that tax-financed increases in public good provision have positive effects on property values in the US. Gadenne (2017) finds that tax-financed public spending has significant impacts on the quality of public goods in Brazil. Gonzalez-Navarro and Quintana-Domeque (2016) show that randomly assigned street pavement increased property values in Mexico City. We safely ignore the case when public goods are over-provided, since $\text{MVPF}_t < 0$ implies that property taxes reduce welfare with or without capitalization effects.

2 Property Taxes in Mexico City

This section presents the property tax system in Mexico City.[20] We start by explaining the construction of the tax base and the tax rate schedule. We then discuss the main elements of the tax payment regulation and enforcement.[21]

2.1 Tax Base

The base for the property tax is the cadastral value V_{it} of property i in year t, which is determined by the following formula:

$$V_{it} = (A_{it}L_{it} + U_{it}M_{it})[1 - D_t \cdot (\mathbb{1}_{\{t-t_0 \leq 40\}}(t - t_0) + \mathbb{1}_{\{t-t_0>40\}}40)],$$

where A_{it} is the unit value of land in the neighborhood of property i, L_{it} is the total land area of the property in square meters, U_{it} is the unit value of construction in the neighborhood of property i, M_{it} is the total construction area of the property, D_t is a reduction applied per each year of antiquity, and t_0 is the year of construction of the property. That is, the tax base is the sum of the land and construction value, discounted for antiquity until the property is forty years old, whereupon the property value remains constant in age.[22] Assessed property values in the cadaster correlate strongly with commercial values (Figure B.1, Panel B).

The distribution of property values is quite stable during the period of our study. The unit values of land and construction, A_{it} and U_{it}, are based on commercial values and were updated only once during the period of our study (between 2008 and 2009). This change does not affect our estimations, which exploit variation between 2009-2012. In theory, taxpayers can appeal the cadastral valuation proposed by the government and propose their own valuation. In practice, less than 0.2 percent of appeals are approved.[23] Finally, the age discount makes it possible for

[20] We abstract away from political economy issues for a couple of reasons. First, Mexico City has had leftist governments since 1997. Because these governments have relied on political support from lower-income individuals, it is unlikely that pressure from wealthy individuals limits property taxation. Second, current government officials have expressed a desire to increase tax revenue specifically through property taxation. However, these officials are also sensitive to declining compliance rates and potential hardship for taxpayers. Given that political economy constraints are unlikely to explain the under-reliance on property taxes, we focus our analysis on the importance of compliance and liquidity constraints.

[21] While housing property is also taxed indirectly, these taxes do not interact with our variation. Property buyers pay a 2 percent transfer tax, income from property sales is subject to capital gains tax at a rate between 2 and 35 percent, and inheritances above 10,000,000 MXN (400,00 USD) are taxed at a rate between 10 and 30 percent. Note also that, in contrast to the US, property taxes do not determine neighborhood-level public goods.

[22] The registry of property transactions and the cadaster are held by two different levels of government (states and municipalities, respectively) and are not readily mergeable. For this reason, property transactions cannot be used to update cadastral values. While the tax base may depart from market values, note that this is also often the case in high-income countries. For instance, California's Proposition 13 generates large differences between assessed and market values. Similarly, Howard and Avenancio-Leon (2019) show that racial differences in assessment appeals drive large differences between assessments and market values across demographic groups.

[23] In 2010, 319,019 taxpayers filed appeals, but only 379 successfully obtained a reduction in their tax base. In 2011, 249 out of 177,681 taxpayer appeals were successful. In 2012, 162 out of 116,729 appeals were successful.

properties to change cadastral value bands over time. However, because the discount factor is so small ($D_t = 0.01$), very few properties drop to a lower cadastral value band during the five-year period we study. We exclude properties with a change in cadastral value band between 2009 and 2012 from our analyses.[24]

2.2 Tax Rates

Figure 2 shows that the property tax schedule is partly progressive. The schedule relies on 16 cadastral value bands: A to P.[25] For bands A–D, the tax is a band-specific lump-sum amount that increases over time with inflation. While the lump-sum amounts increase across bands A–D, they increase by less than the property value. For this reason, the average tax rate is decreasing in property values at the lower end of the value distribution. Properties in bands E–P face a progressive schedule, with marginal tax rates ranging from 7.5–16.9 basis points (a percent of a percent), which yield average tax rates that increase with property values. Using household survey data, we calculate that, on average, property tax payments correspond to between 0.5 and 1 percent of annual household income, with higher values for poorer households (see Figure B.1, Panel C).[26]

While marginal tax rates change little over the years, the average tax rates in bands E–J are also affected by abatements, which are applied to the gross tax liability. Abatements vary over time and have large impacts on average tax rates: abatements varied between 65 percent (in band E) to 10 percent (in band J). The original purpose of abatements was to ensure that the mean tax liability increased gradually from band E to J. Following the 2008 financial crisis, the government decided to remove the abatements, one cadastral value band at a time.[27]

The removal of abatements led to large and unexpected changes in mean tax rates over time and across value bands. Because our data cover the years 2008-2012, our analysis exploits three reform episodes: (1) the 2010 abatement removal for value band I, (2) the 2011 removal for band H, and (3) the 2012 removal for band G. Figure 2 shows that the largest rate changes between 2008 and 2012 were caused by removing these abatements. Among the three reform episodes, properties

[24] In total, we exclude 284,686 properties, 87% of which registered a cadastral value band change due to an increase in the construction area, for an average cadastral value change of 42%. Changes in land area, special amenities (e.g. lifts), and value depreciation over time account for the remaining 13% of value-band changes. Our results are robust to including these properties. In addition, exemptions of 30% or more of the annual tax liability are available to single mothers with children and seniors with incomes below a specified threshold. Our results are robust to dropping the approximately 7% of properties who ever received these exemption (Tables D.4 and E.3).

[25] The thresholds for these bands are constant over time, except between 2008 and 2009, when both the band thresholds and the tax rates were updated for inflation. In later years, only the tax rates are updated for inflation each year. Table B.2 shows the property tax schedule for 2009 as an example.

[26] Panel D in Figure B.1 shows the year-in-year growth rate of property tax payments. Given the small annual inflation adjustments to the liability, there is no anchoring of tax payments at the previous year's liability. Instead, the nominal payment amounts increase slightly each year.

[27] Table B.3 lists the abatement rates by value band and year. The government's intention was to remove all abatements, but to do so gradually to minimize potential backlash or unrest. Removing abatements was the administratively simplest way of raising tax rates. Figure B.1, Panel A, shows that property tax revenues dramatically increased after 2008 in Mexico City.

in band G saw the largest increase in taxes, and those in band I saw the smallest increase.

The government of Mexico City announced these rate increases every year when it published property tax rates for the following year. It is unlikely that the changes were anticipated by taxpayers, as they were not widely discussed in the media, and as each reform episode affected a small subset of properties. We show below that there is no evidence for any behavioral change prior to the reforms. Figure B.4 shows that properties treated with the quasi-exogenous tax rate increases are well distributed across the city. The average share of treated properties within a zipcode is only about 3%. The responses to these reforms therefore constitute individual taxpayer responses to tax rate changes rather than responses driven by public debate or general equilibrium changes in policy, attitudes, or perceptions.

2.3 Tax Payment and Enforcement

The legal liability for the property tax rests with the property owner. Property tax bills are delivered to the property and are addressed to the owner. At the beginning of the calendar year, taxpayers receive a bill for the yearly liability. To encourage early payment and increase compliance, the government offers early-bird and super-early-bird discounts if taxpayers pay their yearly liability in full before specific dates. The exact deadlines for the discounts and the discount rates vary over time (see Table B.4). While tax bills include the yearly tax liability, they can be paid in six bi-monthly installments. Additional bills are sent at the beginning of each bi-monthly period, and payments are due by the last day of the period. Property tax bills can be paid in person at government offices, banks, and convenience stores.[28]

When taxpayers miss a payment, the government automatically updates the unpaid liabilities for monthly inflation and applies a surcharge for every month of late payment. Taxpayers who have not paid their yearly liability by April 30th of the following year are catalogued as delinquent taxpayers and face additional penalties and surcharges.[29]

The Ministry of Finance of Mexico City regularly conducts enforcement campaigns to encourage the payment of outstanding property tax debt and to sustain voluntary compliance. Enforcement interventions have varied over time. For instance, enforcement letters have varied in message content over the years (e.g., emphasizing sanctions or public goods provision or simply conveying a reminder). The delivery method for these messages (e.g., letter, phone call, or email) has also varied

[28]Figure B.3 shows a typical property tax bill. While the owner may not receive the tax bill if renters do not notify owners or if the cadaster is out of date, this is a minor concern for enforcement in Mexico City, where only 15 percent of households are renters. Table B.5 shows descriptive statistics on property owners and renters. While is is possible (though not observable to us) that property tax compliance is lower for renter properties, this can explain only part of the delinquency rate, which is much higher (40%) than the rental rate.

[29]While the monthly surcharge varies over time, it is on average 1 percent of the outstanding liability for each month of delay. That is, if a taxpayer makes an overdue payment after 6 months, the government adds a 6 percent surcharge to the inflation-updated liability. Table C.1, Panel C, shows the additional fees paid by delinquent taxpayers who made outstanding tax payments in 2008 and 2009. The table shows that late payment fines are applied to almost all late-payers, and that they represent a substantial fraction—between 15 and 30 percent—of the tax liability.

over time, as has the target group. In some years, all delinquent taxpayers were contacted, while in other years, enforcement has focused on smaller subsets of taxpayers with large debts. We use one of these enforcement interventions to estimate the effects of enforcement in Section 5.

While taxpayers who are unresponsive to administrative enforcement can be prosecuted, the government does not have the capacity to do this in a systematic way. In extreme cases, the government can seize a delinquent taxpayer's property. While this is rare, it does happen (see Table C.1, Panel C). The government can even pursue a jail sentence of up to ten years for tax delinquency.

3 Administrative Tax Data

Our empirical analyses exploit three datasets on the universe of the 1.9 million tax-liable residential properties in Mexico City from 2008 to 2012. First, the cadaster—or tax register—lists all properties with their unique property tax ID, post code, and property characteristics such as land area, construction area, land and construction value, and total property value. We exclude properties that change characteristics over time, leaving properties with fixed cadastral values. Our main dataset consists of a balanced panel of over 95 percent of all properties.

Second, we use data from annual and bi-monthly property tax bills for all properties. These bills include the property value, tax liability, bill issue date, and due date. Third, we use data from the universe of property tax payments. For each payment, we have data on the relevant tax bill and period, amount, date, and additional variables including inflation adjustments, surcharges, and penalties for late payment. We link the billing and payment data to the cadaster via the unique ID.

The majority of our analyses study outcomes at the property-year level. The main outcome variables are the annual payment amount in current Mexican pesos (MXN, thousand) and the compliance share, defined as the ratio of tax payment to gross liability. Additional outcomes include dummies for zero, partial, and full payment of the net tax liability (net of any early-bird and super-early-bird discounts). Finally, we characterize payment timing with dummies indicating early (all-at-once), bi-monthly (payment in installments), and late payment.

A salient feature of the data is that the distribution of properties is skewed toward low value bands. While the majority of properties fall into bands A–E, the distribution of cadastral values is slightly less skewed. Because of the progressive tax schedule, tax liabilities are more evenly distributed across value bands. However, because compliance is higher for low value bands, the distribution of tax payments is less evenly distributed (see Figure C.1 for details).

The data reveal interesting trends. While the gradual eliminations of abatements led to a rise in the mean tax liability, average tax payments—in absolute terms and as a share of the yearly liability—have decreased over time. The decrease in tax payments is partly driven by a rise in the share of properties making zero payments and a decline in the share of properties paying in full. These patterns showcase the importance of understanding how households respond to tax rate increases and whether enforcement efforts can influence the decaying compliance rate.[30]

4 The Elasticity of Tax Revenues to the Tax Rate

This section estimates the effects of tax rate changes on tax payment and compliance. We study three quasi-experimental reforms: mean tax increases for properties in value bands I, H, and G in 2010, 2011, and 2012, respectively. We first present results from an RD estimation that exploits the sharp discontinuities in tax rate changes at thresholds between the treated value bands and bands below. These estimations yield estimates of short-term local average treatment effects for properties close to each threshold. We then estimate medium-term effects using a DiD design that uses properties in never-treated value bands as controls. In Appendix F, we show that tax rate increases do not impact new property construction.

4.1 Short-Term Effects: Regression Discontinuity Estimation

Our RD estimation relies on discontinuous tax rate *changes* at the lower thresholds of cadastral value bands that experienced large tax rate increases. We focus on rate changes—rather than levels—since tax rate levels differ between value bands and because there are small yearly inflation adjustments to rates in all bands. Finally, we use the band below as the counterfactual since properties in the band above the treated band were treated in the previous year.

Consider the properties in a treated band in year t as well as the properties in the band immediately below it. Let $\hat{V}_i = V_i - V_-$ denote the distance between the value of property i, V_i, and the lower limit of the treated band, V_-. Let $Y_{i,t}$ denote the outcome of interest for property i in period t. We estimate the effect of the tax rate increase on the year-on-year change in the outcome of interest as follows:

$$\Delta Y_{i,t} = \alpha + \beta T_i + f(\hat{V}_i) + g(\hat{V}_i)T_i + \epsilon_{i,t},$$

where T_i is an indicator for properties in the treated band, i.e., $T_i = \mathbb{1}_{\{V_i \geq V_-\}}$; f and g are continuous functions; and $\epsilon_{i,t}$ is an error term.

The validity of this approach relies on the assumption that taxpayers cannot manipulate their property valuation in response to a change in the tax rate. To validate this assumption, we test for a discontinuity in the distribution of the running variable around the treatment cut-off. We are unable to reject the null hypothesis of no manipulation of property values around the treatment cut-off for all three reforms using both the McCrary (2008) test (see Figure D.1, Column A) and the

[30] Table C.1 describes additional property characteristics. For instance, the average property was built in 1985 and had a land area of 123 square meters and a construction area of 126 square meters.

Bugni and Canay (2020) test (see Table D.1).[31] In addition, we test for discontinuities in property characteristics around the treatment thresholds and find no significant differences in the year of construction, land area, or construction area (see Figure D.1, Columns B-D). Finally, we note that, in the unlikely case that taxpayers had anticipated the tax rate increase and responded already before the change went into in effect, our estimates of the tax payment increase would be biased towards zero. We show below that there is no evidence for an anticipatory response.

Estimates

Figures 3 and 4 show the results for the three different reform episodes (rows) and four different outcomes (columns). Each panel plots the year-on-year (pre- vs post-reform) change for a given outcome in 20 equally spaced cadastral value bins around the lower threshold of the treated band. Each graph reports a third-order polynomial fit along with 95 percent confidence intervals.

Column A of Figure 3 shows that the legislated tax rate increases were indeed applied as intended and generated a 9.1 basis point increase in the mean tax rate at the band threshold in 2010 and even larger increases of 12.1 and 18.0 basis points in 2011 and 2012. Column B shows that tax payments jumped substantially—between 450 and 600 MXN—in all reforms episodes. However, payments increased by less than the mechanically expected increase, as compliance fell.[32] Figure 4 shows that the share of taxpayers paying their liability in full fell by 5.5 ppt in 2010, by 6.4 ppt in 2011, and by over 10 ppt in 2012. The compliance share also decreased in all reform episodes by 3.2–6.2 ppt.[33]

Table 1 presents the implied tax rate elasticities for the outcomes considered in Figures 3–4.[34] Column (2) lists the elasticities of tax revenue to the tax rate. When the change in the mean tax rate is 9.1 basis points, the elasticity of tax revenues is 0.55, whereas the estimate is 0.31 when the tax rate increases by 18.0 basis points. While these estimates are consistent with the notion that larger tax rate changes also generate larger compliance responses, we cannot reject the null that these elasticities are equal to each other at conventional significance levels. Table 1 also reports semi-elasticities and tax compliance elasticities, which we use in our policy analysis in Section 7.

To demonstrate the robustness of our results, we compare our main estimates from the cubic polynomial regression with the results from local polynomial regressions with varying bandwidths and degrees of polynomial in Figure D.2. Table D.2 shows the results from specifying an optimal

[31] The Bugni and Canay (2020) test provides an alternative approach to testing for manipulation of cadastral values. This test examines the balance in the number of observations around the cut-off. Unlike the McCrary (2008) test, it does not rely on local density estimates.

[32] The tax liability for a property at the value band threshold of 2.3 million MXN increased by 2100 MXN in 2010. Liabilities increased by close to 2350 MXN in 2011 and 2900 MXN in 2012.

[33] Note that these compliance drops are not due to changes in the tax base, as the latter is not updated during the study period and appeals against the tax liability are overwhelmingly unsuccessful, as mentioned in Section 2.1. Because administrative tax data do not record whether properties are occupied by renters or owners, we cannot explore heterogeneity along this margin.

[34] We compute the elasticity $\epsilon_{y,t} = \frac{\partial y}{\partial t}\frac{t}{y}$ using $\frac{\partial y}{\partial t}$ from the RD estimates and $\frac{t}{y}$ from outcome means at baseline.

bandwidth in local linear regressions as in Calonico, Cattaneo and Titiunik (2014). The estimates are statistically indistinguishable from those in Table 1.

As an additional robustness test, we consider an alternative specification for our RD estimates. Because we study the effects of discontinuous tax changes around thresholds, we follow Lalive (2008), Lemieux and Milligan (2008), and Grembi, Nannicini and Troiano (2016) by estimating a differences-in-discontinuities model on our panel data:

$$\begin{aligned}\Delta Y_{i,t} =&\alpha_0 + \beta_0 T_i + f_0(\hat{V}_i) + g_0(\hat{V}_i)T_i +, \\ &[\alpha_1 + \beta_1 T_i + f_1(\hat{V}_i) + g_1(\hat{V}_i)T_i]D_t + \epsilon_{i,t},\end{aligned}$$

where D_t is an indicator for the time period when the abatement is removed. The effect of the abatement removal, in excess of the effect of the smaller year-on-year tax rate changes, is given by β_1. The results displayed in Table D.3 show that the β_1 estimate from this equation is very similar to our main estimates, and we can generally reject the null hypothesis that $\beta_1 = \beta_0$.

These results show that while sharp increases in average tax rates have sizable effects on tax payments, taxpayers also respond by decreasing their compliance with the property tax. While the RD approach yields precise and highly credible estimates of short-term responses to tax increases, compliance in future years may depend on broader responses by taxpayers.[35]

4.2 Medium-Term Dynamics: Differences-in-Differences

An important question for policymakers is whether the effects of tax rate increases persist over time or are temporary. For instance, while liquidity-constrained taxpayers may temporarily decrease compliance after a tax rate increase, they may also make up for missed payments in later years. In this example, RD estimates would under-estimate medium-term revenue elasticities.

We estimate medium-term effects using a DiD design that captures the evolution of compliance outcomes over time. This approach compares properties in the treated value band to properties in other high-value bands that never experienced a tax increase. Specifically, for a tax rate increase occurring in year t_0, we estimate

$$Y_{it} = \alpha + DD_{it}\beta + \gamma_i + \delta_t + \epsilon_{it}, \tag{6}$$

where Y_{it} denotes the compliance outcome of property i in year t, α is a constant, DD_{it} is a dummy taking the value of 1 when property i belongs to the treated value band and $t \geq t_0$, δ_t and γ_i denote year and property fixed effects, and ϵ_{it} is the error term. For all years, we use properties in bands K and L as controls.[36] The identifying assumption is that, absent the tax hikes, the

[35] Because the control bands are treated in $t+1$, we cannot use the RD approach to estimate dynamic responses.

[36] Among the bands that are never treated with one of the large quasi-experimental tax rate increases, properties in bands K and L are the closest in property value to the treated bands. Figures E.2-E.4 show that properties in other untreated bands also exhibit similar pre-reform trends and yield similar results.

outcomes for properties in the treatment and control groups would have trended in parallel. Under this assumption, the point estimate for β captures the causal effect of the tax rate change on compliance. Given the large share of zeros in our outcome variables, we estimate Equation 6 in levels. To obtain a relative effect, we scale point estimates and standard errors by the mean outcome in the treatment group in the last pre-reform year.[37]

Estimates

Figures 5 and 6 capture dynamic responses to tax rate changes. The figures are structured like Figures 3 and 4: The rows pertain to the three different reform episodes, while the columns reflect the different outcome variables. In each graph, the vertical black line indicates the timing of treatment, the red solid line represents the average outcome in the treated band, and the blue dotted line represents the average outcome in control bands K and L. In all panels, outcomes are scaled by the pre-reform group-specific mean.

The timing of the reforms and the length of our dataset mean that we can observe three post-reform periods for the 2010 reform, two post-periods for the 2011 reform, and one post-period for the 2012 reform. On the other hand, we observe the longest pre-reform period (four years) for the 2012 reform, and the shortest (two years) for the 2010 reform. We do not detect any significant difference in pre-trends between the treatment and control groups for any reform episode, and no evidence of an anticipated response to the reform. In contrast, we observe a precise and sharp deviation in trends in each of the reform years.

Consistent with the legislative changes, mean tax rates increased significantly after every reform event (Figure 5, column A). As with the RD estimates, we find large increases in tax payments (column B). However, decreases in the share of taxpayers paying in full and in the compliance share (Figure 6) show that compliance also fell significantly. The results are qualitatively similar across the three reform episodes, though the magnitude of the compliance drop is largest for the 2012 reform, which triggered the largest tax rate change. Following the 2012 reform, the full payment share fell by 30 percent, and the compliance share fell by 18 percent. For the 2010 reform, a 17 percent increase in the mean tax rate triggered a 11.6 percent increase in tax payment amounts. The payment response was moderated by a 4 percent reduction in the compliance share. In turn, the drop in the compliance share was partly driven by a 10 percent drop in the share of on-time payments-in-full.[38]

One possible explanation for the smaller estimates for the 2010 and 2011 reforms is that these estimates capture effects over longer post-reform periods (two and three years, respectively), while the estimate of the 2012 tax change only captures the effect for a single post-reform period. However,

[37] The results are very similar when estimating Equation 6 via pseudo-Poisson maximum likelihood (Santos Silva and Tenreyro 2006), which is suitable when outcome variables are highly skewed or have a large share of zeros (Brockmeyer and Hernandez 2019).

[38] We also find that the tax rate hikes increased taxpayers' likelihood of making an appeal against their tax liability (Figure E.1), even though hardly any appeals lead to a change in the tax liability (see footnote 23).

we obtain similar compliance drops for the 2010 and 2011 tax changes when we estimate DiD effects using a single post-reform period (see Table E.1). These results raise the possibility that larger tax changes can trigger more-than-proportional compliance responses.

Table 2 summarizes the treatment effect estimates and the implied elasticities. The elasticity of tax revenues with respect to the tax rate is presented in column (2). This elasticity ranges from 0.697 in response to the 17 percent increase in the tax rate affecting band I in 2010 to 0.489 in response to the 40 percent increase in the tax rate affecting band G in 2012.[39] While these numbers are very similar to the RD estimates, the DiD estimates are more precisely estimated and reject the null hypothesis that the elasticities from 2010 and 2012 are equal to each other.[40]

The results of our DiD analysis show that tax rate increases lead to persistent changes in both tax payment and compliance behaviors. By using a different set of control properties than in the RD analysis, the DiD also bolsters the likelihood that we are measuring the causal effects of changes in tax rates. As in the RD analysis, we find smaller payment elasticities when tax rates increase by a larger amount. In Section 7, we explore the implications of these effects for the revenue-maximizing rate.[41]

5 The Elasticity of Tax Revenues to Enforcement

Governments around the world face a trade-off when raising tax revenue: increase tax rates on taxpayers who are not delinquent, or broaden the number of taxpayers by enforcing existing taxes on delinquent taxpayers. In the context of Mexico City, this trade-off is stark since 40 percent of taxpayers are delinquent. We characterize this trade-off by estimating the elasticity of tax payment to enforcement using a field experiment we designed and evaluated in collaboration with the Ministry of Finance of Mexico City.

5.1 Field Experiment

The Ministry of Finance sent out enforcement letters to 80,000 delinquent taxpayers between July 28 and August 11, 2014, requesting that they pay their outstanding tax debt accumulated from bimester 4 of 2009 to bimester 3 of 2014. A control group of 10,000 delinquent taxpayers received no letter. The mode of delivery, sample selection, and information provided in the letters corresponds to the Ministry's typical practices. Therefore, our estimates can be viewed roughly as

[39] Note that, while the elasticities are comparable in the RD and the DiD estimation, the point estimates for the treatment effect are not comparable, as the RD estimates a level change and the DiD estimates a relative change.

[40] In Appendix E, we perform robustness tests of our DiD estimations. We confirm that the results are very similar when using other value bands as control group (Table E.2 and Figures E.2-E.4), dropping taxpayers benefiting from exemptions (Table E.3) and clustering the standard errors at different levels or bootstrapping them (Table E.4). We also obtain similar results when exploiting variation in tax rates across all value bands in panel regressions (Table E.5).

[41] A potential concern is that tax rate increases might reduce investment in real estate. We discuss this possibility and test for it empirically in Appendix F. We find no evidence of impacts on real estate investment.

in-equilibrium effects. Our estimates also have general validity, as the cadastral value distribution among delinquent taxpayers is similar to that of the population (Table G.1). Each personalized letter lists the bimester(s) for which tax payment is overdue, requests payment within 15 working days after receipt of the letter, and lists the institutions accepting payment (tax administration offices, bank branches, convenience stores).

The treatment group in our intervention was divided into eight groups of 10,000 taxpayers, each receiving a slightly different variant of the letter. Figure G.1 illustrates the experimental design, and Figure G.3 shows the text of the letters. Half of the letters put additional emphasis on sanctions used to enforce the tax (referred to below as the sanctions treatment), while the other half emphasized the fact that property tax revenue is used to fund health services, education, and community infrastructure (referred to as the public goods treatment). Within these two main groups, half of the letters were signed by a compliance officer and the other half by a (more senior) fiscal attorney. In addition, the gender of the signatory was varied arbitrarily. Fiscal attorney signatures were either male or gender neutral (the first name was signed only as an initial), while compliance officer signatures were either female or gender neutral.

5.2 Empirical Results

Figure 7 displays the effects of the enforcement intervention. The plots show trends in payment outcomes around the time of the intervention and distinguish among the control group, the sanctions treatment, and the public goods treatment. As expected, the three groups exhibit linear trends in all outcomes prior to the intervention. The treatment groups start diverging in early August when the first letters are delivered.[42] The divergence accelerates sharply by mid-August. This timing coincides with the end of the 15-day deadline to respond to the letter starting after all letters are delivered. In contrast, we do not see any trend changes for the control group.

The graphs display point estimates for β_1 and β_2 from the regression

$$Y_i = \alpha + \beta_1 T1_i + \beta_2 T2_i + \epsilon_i,$$

where Y_i is the outcome for property i evaluated 40 days after all letters were sent, α is a constant, $T1_i$ and $T2_i$ are dummies indicating the two mutually exclusive treatments (the sanctions treatment and the public goods treatment), and ϵ_i is the error term.

The results in Figure 7 show that the sanctions treatment generated a 9.4 percentage point increase in the likelihood of making any payment toward outstanding tax debt and a 54 peso increase in the amount of payment. Relative to the control group, the intervention close to tripled the payment likelihood and doubled overall payments. The public goods treatment had smaller but statistically significant effects. Comparing Panels B (any payment) and C (payment amount) suggests that the public goods treatment is relatively more regressive, generating payment by taxpayers

[42] It takes three to five days for letters to be delivered.

with disproportionately smaller liabilities.[43] We find similar results when we control for property characteristics X_i (e.g., cadastral value and age of the property) or when we estimate treatment effects using a DiD framework (Table G.2).

Table 3 reports estimates of the treatment effects for all treatments in pair-wise comparisons. Panel A lists the effects on the likelihood of making any payments toward outstanding tax debt, and Panel B shows the effects on payment amount. In addition to confirming the significant difference between the sanctions and public goods treatments (column 1), the table shows that the seniority of the enforcement officer matters: a fiscal attorney signature achieves a larger impact than a compliance officer signature (column 2). Furthermore, although one might expect a gender bias in taxpayers' response to male/female signatures, our evidence rejects this idea. In fact, male signatures have a smaller impact than gender-neutral signatures, and female signatures have a slightly larger impact than gender-neutral signatures (columns 3 and 4). While we consistently reject the null hypothesis that male signatures have larger effects, we can reject the null hypothesis that female signatures have smaller effects only when we control for property characteristics (Table G.2).

The size of the enforcement effects in Mexico City compares favorably to those of other compliance interventions. In a meta-analysis of tax compliance experiments, Atinyan and Asatryan (2019) find that deterrence nudges increase extensive margin compliance on average by only 1.5-2.5%. When focusing on comparable property tax compliance interventions, we find that our effects are slightly smaller than those in Weigel (2020), who shows that a door-to-door campaign in the Congo increased compliance (likelihood of payment) from 0.05% to 11%; similar to those in Okunogbe (2019), who finds that a detection and penalty intervention in Liberia increased compliance from 3% to 9%; and larger than those in Del Carpio (2014), who finds that a social norms intervention in Peru increased compliance from 29% to 34.5%.

The results of our field experiment show that enforcement actions are a cost-effective means for the government to raise revenue. However, while stricter enforcement may raise tax revenue, the welfare costs of doing so may not always exceed the increase in private costs to delinquent taxpayers. Section 7 uses these estimates to implement our model and provides policy guidance on whether it is preferable to raise tax revenue through increased tax rates or through stricter enforcement.

6 Property Taxes and Liquidity Constraints

The model in Section 1 shows that the welfare costs of taxing property may be exacerbated by the presence of liquidity constraints. We now implement two empirical strategies that show that household liquidity constraints shape taxpayer behavior. We first show that property tax rates

[43] We interpret the public goods treatment effect as being due to enforcement, since we compare the public goods letter to a non-letter control and since any type of letter from the Ministry of Finance is likely to given the impression of increased enforcement. Studies comparing public goods messages to neutral baseline messages from the tax administration mostly find no effect (Atinyan and Asatryan 2019).

affect taxpayers' choice to pay late or in installments. We then show that tax increases lead to consumption drops for households without access to credit.[44]

6.1 Evidence from the Choice of Payment Modality

As a first test of liquidity constraints, we examine how taxpayers' choice of payment modality responds to the tax rate. Taxpayers can pay their annual liability in installments or can pay in full at the beginning of the year, taking advantage of the early-bird discount. Liquidity constraints may lead households to pay in installments rather than all at once. Conditional on attempting to pay in installments, liquidity-constrained taxpayers may also be less likely to remain compliant.

We provide two pieces of evidence that taxes impact payment modality. First, we exploit variation generated by the non-monotonous shape of the tax rate schedule in a regression-kink-style analysis. As discussed above, the mean tax rate as a share of the property value is first decreasing and then increasing with property values. The lines with blue square markers in Panels A-C of Figure 8 plot the schedule of mean tax rates, which features an inflection point in value band D.

Panel A in Figure 8 also shows that the likelihood of making any tax payment (including partial payments) is negatively correlated with the mean tax rate. Payment compliance is first increasing and then decreasing in property values, with a peak in band D, where the tax rate is minimized. Panel B shows that conditional on making any payment, the likelihood of paying all at once (as opposed to attempting to pay in installments) is also negatively correlated with the mean tax rate, again with an inflection point in band D. Panel C shows that conditional on attempting to pay in installments, the likelihood of paying all six installments on time (as opposed to paying partially or late) is also negatively correlated with the mean tax rate, again with an inflection point in band D. This evidence is highly consistent with liquidity constraints shaping taxpayer behavior, as the inflection points in these three data series are otherwise hard to explain.

To provide a second piece of evidence that taxes impact payment modality, we now show that the quasi-experimental tax rate increases we analyzed in Section 4.2 are also associated with changes in payment modality. In Panels D–F of Figure 8, we implement the DiD design in Equation 6 using the sample of taxpayers that make at least a partial payment in each year. Consistent with the view that tax rate increases activate liquidity constraints, we find that treated taxpayers become more likely to attempt paying their liability in installments as opposed to paying all at once. These taxpayers hence forgo the early bird discounts. One interpretation of the discounts is that taxpayers that do not pay in full before the deadline take out a loan from the government. The results suggest that taxpayers are more likely to avail themselves of these loans when tax rates increase.

[44]In addition, in Appendix I we use data on the timing of payments to show that households have a high value for liquidity.

6.2 Evidence from Consumption Data

As a third test of the presence of liquidity constraints, we now study whether property tax increases impact consumption. As we discuss in Section 1, liquidity constraints can increase the welfare cost of taxing property, and the effect of taxes on consumption is a key input for our optimal tax formulas.[45]

Because our administrative tax data do not measure consumption, we use additional data from the Mexican Household Income and Expenditure Survey (*Encuesta Nacional de Ingresos y Gastos de los Hogares*, ENIGH). To study the impact of taxes on consumption, we aim to estimate the following specification:

$$\ln C_{it} = \alpha + \beta_1 \ln P_{it} + \delta_1 \ln I_{it} + \gamma_1 X_{it} + \varepsilon_{it}, \tag{7}$$

where P_{it} is the property tax payment of household i in year t, C_{it} is household per capita consumption, I_{it} is household per capita income, and the control vector X_{it} contains year dummies and *delegación* (i.e., city district) fixed effects. In this equation, β_1 measures the consumption elasticity with respect to property tax payments. If paying property taxes leads households to decrease consumption, we would expect to find that $\beta_1 < 0$.

Previous work has estimated regressions similar to Equation 7 to study the impacts of unexpected income shocks (e.g., Attanasio, 1999; Blundell et al., 2008) and unemployment insurance payments (e.g., Gruber, 1997; Kroft and Notowidigdo, 2016) on consumption. An important concern with Equation 7 is that property tax payments are likely correlated with other factors that influence consumption. For instance, households facing unmeasured income shocks may decide to skip a property tax payment and may also decrease everyday consumption. These kind of shocks would lead to upwardly biased estimates of β_1.[46]

To provide unbiased estimates of β_1, we use the tax increases we analyze in Section 4 to isolate variation in property tax payments that is unrelated to other drivers of consumption. Consider the following first-stage equation:

$$\ln P_{it} = \pi_1 + \pi_2 Z_{it} + \delta_2 \ln I_{it} + \gamma_2 X_{it} + \epsilon_{it}, \tag{8}$$

where the instrument Z_{it} measures the percentage increase in mean property tax rates driven by the removal of abatements. As our RD and DiD estimations show, tax increases have significant effects on tax payments, suggesting that Z_{it} would be a relevant and statistically strong instrument. The exclusion restriction is that tax rate changes only impact consumption through property tax payments. Our results in Section 4 show that tax changes lead to sharp variation between treated and untreated households and that these households have parallel trends on a number of outcomes prior to the tax increases. These results suggest that the tax-change-driven variation in Z_{it} is likely

[45] Appendix H shows that household consumption in Mexico City is not fully insured against income shocks, and that property tax payments also responds to income shocks.

[46] Indeed, OLS estimations of Equation 7 yield positive estimates of β_1.

unrelated to other determinants of household consumption.[47]

Our instrumental variables strategy requires three key variables: consumption, C_{it}; tax payments, P_{it}; and tax rate changes, Z_{it}. Unfortunately, while the ENIGH data measure consumption and property tax payments, they do not record tax liabilities. We overcome this issue by using a split-sample instrumental variables strategy (e.g., Angrist and Krueger, 1992; Card and McCall, 1996) that combines information from our administrative tax data and our household survey data. Specifically, we use property characteristics that are common in both datasets to construct a proxy for the change in tax liability. As we discuss in Section 2.1, a property's cadastral value—and hence the tax liability—is based on land and construction area, unit values of land and construction that vary across districts (*delegaciones*), and property age. We therefore use the administrative tax data to calculate Z_{it} as the average year-to-year change in tax liability for fine bins of land area×construction area×property age×district×year. We then assign values of Z_{it} to the ENIGH data based on household characteristics.[48] Finally, to account for the uncertainty in our measures of Z_{it}, we bootstrap this procedure to calculate standard errors.

We obtain an estimate of $\pi_2 = 0.473(SE = 0.069)$ when we estimate Equation 8 (see Table J.1). The first-stage regression shows that Z_{it} is highly predictive of tax payments and yields an F-statistic over 40. π_2 has a natural economic interpretation: it is the elasticity of tax payments to changes in mean property tax rates. It is therefore reassuring that our estimate of π_2 has a similar magnitude to our estimated elasticities in Tables 1 and 2.

Table 4 reports the IV estimates of Equation 7. Column (1) shows that while tax payments have a negative effect on consumption, this relationship is not statistically significant. Because we expect tax payments to have larger impacts for lower income households and for households without access to credit, we augment Equation 7 by including interactions with income and credit access.[49] Column (2) shows the estimates produced when we interact tax payment with household income, where we normalize log income relative to the cross-sectional mean. This column reveals a statistically significant difference in the effects of tax payments on consumption across different households. Column (3) shows the results from interacting tax payment with credit constraints, as measured by access to a credit card. The interaction of tax payment with credit constraints is statistically significant and is negatively related to consumption. This interaction is particularly important since 80 percent of households do not have access to credit cards. Finally, Column (4) shows that the interactions with income and credit constraints have the same sign and are

[47] In contrast to the US, property tax revenue is not used to fund neighborhood schools or other amenities. Any benefits from additional tax revenue would be spread among the more than 20 million residents of Mexico City.

[48] Because we compute Z_{it} using the universe of property tax records, this procedure measures precise changes in tax liability. Appendix J provides additional details.

[49] We also include interactions between the instrument and relevant variables in the first stage.

statistically significant when we include both interactions in the estimation.[50]

The last specification of Table 4 helps us understand the magnitude and heterogeneity in the effects of property taxes on consumption. According to these parameters, doubling property taxes leads to a decline in consumption of 3.5 percent + 1.2 percent for households without access to credit.[51] The decline is even larger for low-income households. For a family with income in the 25th percentile of the distribution, doubling property taxes leads to a 3.8 decrease in consumption. Additionally, if that family does not have access to credit, doubling property taxes would lead to a consumption decline of 7.3 percent.[52]

While doubling property taxes might seem extreme, recall that the sanctions treatment in our field experiment in Section 5 led to a doubling of tax payments relative to the control group. To put these estimates in the perspective of our tax changes, recall that property taxes increased by 20 percent in 2010, by 27 percent in 2011, and by 47 percent in 2012. According to our estimates, these tax changes led to consumption drops of 1.9–3.4 percent for the most affected households.

The following section discusses how governments can use the evidence that liquidity constraints impact tax compliance to improve the design of property taxes.

7 Policy Analysis

We now use our results to provide policy guidance for the design of the property tax. We consider two potential objectives for the government. First, we assume the government's single aim is to maximize tax revenue, and we use the different tax changes analyzed in Section 4 to estimate the revenue-maximizing tax rate. Second, we assume that the government aims to set tax and enforcement policies to maximize the well-being of its residents. We provide policy guidance by combining the effects of tax increases on tax payments and consumption as well as the effects of enforcement actions on compliance to implement the model from Section 1.

7.1 Revenue-Maximizing Tax Rate

Our empirical results from Section 4 show that larger tax increases imply smaller revenue elasticities and that tax increases have a significant effect on the fraction of delinquent taxpayers. These results

[50] These estimates are robust to using an alternative definition for Z_{it}. Namely, we define $\tilde{Z}_{it}$ as the predicted probability that a household's property is part of the treated cadastral value band in 2010 (band I). As with our previous formulation, this instrument isolates reform-driven variation in the tax liability. Tables J.2 and J.3 show that we find similar estimates when we use this instrument or when we use both instruments.

[51] This magnitude is reasonable since, as mentioned above, household survey data report that average property tax payments can be close to 1 percent of annual income. Moreover, Chetty (2004) notes that income shocks can lead to larger changes in consumption when households face consumption commitments, such as with housing.

[52] Table J.4 reports the details of these marginal effects. To gauge the magnitude of these effects, note that Gruber (1997); Kroft and Notowidigdo (2016) estimate that losing a job without unemployment insurance (UI) would lead to a 23 percent drop in consumption in the US, and that increasing the UI replacement rate by 10 ppt would reduce this drop by 2.7 percent.

raise the possibility that further tax increases may have small or even null effects on revenue. To evaluate this possibility, we use our empirical estimates to characterize the degree to which current tax rates are close to the revenue-maximizing tax rate.

Building on the corporate tax literature (Clausing, 2007; Devereux, 2007; Kawano and Slemrod, 2015; Suárez Serrato and Zidar, 2018), we estimate a quadratic relation between taxes and revenue:

$$\ln Rev_t = \beta_1 \tau_t + \beta_2 (\tau_t)^2.$$

Revenue is a concave parabola of taxes when $\beta_1 > 0$ and $\beta_2 < 0$. Intuitively, $\beta_1 > 0$ implies that introducing a small tax raises revenue, and $\beta_2 < 0$ implies that the marginal impact on revenue $(\beta_1 + 2\beta_2\tau_t)$ is smaller for higher tax rates. At the revenue-maximizing rate, the marginal impact of a tax increase is zero, which implies that revenue is maximized by $\tau^* = \frac{-\beta_1}{2\beta_2}$. Key empirical questions are then whether $\beta_2 < 0$ and whether large values of β_2 imply small values of τ^*.

To connect this framework to our results, write the effect of a tax change on revenue as:

$$\underbrace{\frac{\Delta \ln Rev_t}{\Delta \tau_t}}_{\text{Semi-Elasticity: } \eta_t} = \beta_1 + 2\beta_2\tau_t.$$

This expression implies that we can estimate β_1 and β_2 from multiple estimates of the revenue semi-elasticity at different values of τ_t.[53] Let $\hat{\boldsymbol{\eta}} = [\hat{\eta}_{2010}, \hat{\eta}_{2011}, \hat{\eta}_{2012}]'$ be the vector of semi-elasticities from the three tax changes and define the matrix $\boldsymbol{W} = [\mathbf{1}_t, 2\boldsymbol{\tau_t}]$. Using a simple application of classical minimum distance (CMD), we estimate β_1 and β_2 as a linear combination of the semi-elasticities: $[\hat{\beta}_1, \hat{\beta}_2]' = (\boldsymbol{W}'\boldsymbol{W})^{-1}(\boldsymbol{W}'\hat{\boldsymbol{\eta}})$.[54] We then use these estimates to test whether $\beta_2 < 0$ and to study the implied revenue-maximizing rates τ^*.

Applying this method to our estimates from Section 4, we obtain estimates of $\beta_2 = 1.64(SE = 2.34)$ when using the regression discontinuity estimates of $\hat{\boldsymbol{\eta}}$ and $\beta_2 = 3.29(SE = 0.74)$ when using the difference-in-difference estimates.[55] The result that both estimates of β_2 are positive implies that current property tax rates are significantly below the revenue-maximizing rate. This result is driven by the fact that our semi-elasticity estimates are not decreasing in τ_t. As Tables 1 and 2 show, we estimate larger semi-elasticities for larger values of τ_t.

While the point estimates for β_2 are positive, we also consider how uncertainty in these estimates

[53] One potential concern is that the three tax changes estimate effects from households in different parts of the home value distribution, leading to different elasticities. This is not the case. The thresholds for the three reforms were approximately 2.275, 1.95, and 1.625 million pesos. The three elasticities are based on comparable properties that are 325 thousand pesos—about 16 thousand dollars—apart.

[54] See Chamberlain (1984) for a guide to CMD and Suárez Serrato and Zidar (2016) for a recent application.

[55] While we can reject the null hypothesis that $\beta_2 < 0$ with a p-value < 0.001 when we use the DiD estimates, we cannot reject this hypothesis when we use the RD estimates. See Table J.5 for details. Importantly, this result is not driven by a lack of statistical precision. Estimates of β_1 and β_2 yield precisely estimated revenue semi-elasticities at the average tax rate of $0.010(SE = 0.002, t - stat = 5.29)$ for the regression discontinuity case and $0.012(SE = 0.001, t - stat = 19.78)$ for the difference-in-difference case.

affects our policy analysis. To explore the role of uncertainty, we simulate 10,000 values of β_1 and β_2 based on their joint distribution and characterize the resulting distribution of τ^*. This exercise shows that 80 percent of the time, the revenue-maximizing rate is greater than 159 basis points. We also find that 90 percent of the simulated values yield estimates of τ^* above 73 basis points and that only 5 percent of the estimates are below 61 basis points.[56] Given that the highest tax rate in the three reforms was 50 basis points, these results show that the government can raise the property tax rate by 20-50 percent with very limited risk of going beyond the revenue-maximizing rate.

The policy takeaway from this analysis is that rigorous empirical evidence from recent tax increases shows that current tax rates are significantly below the revenue-maximizing tax rate.[57]

7.2 Optimal Tax Rates and Enforcement

While the government may be able to collect additional tax revenue by taxing property at rates below τ^*, the welfare costs from increasing tax rates or tightening enforcement may exceed the value taxpayers obtain from using the additional revenue to provide public goods. For this reason, it is possible that the optimal tax rate may fall significantly below the revenue-maximizing rate. In addition, the revenue-maximizing analysis does not provide any guidance as to whether the government should rely on tax rate increases or enforcement actions to collect revenue. We now implement the welfare-maximizing model from Section 1 that incorporates these important insights.

Consider first the MVPF of tax increases and the optimal tax rate from Equations 1 and 2. We implement these formulas using our empirical estimates along with different values for the calibrated parameters, as summarized in Table A.1. Using the effects of tax changes on consumption, we set the consumption drop to $\Delta c_0 = -0.07$ for liquidity-constrained households and to $\Delta c_s = -0.01$ for unconstrained households. We then vary the fraction of liquidity-constrained households between 80%—the fraction of households without access to credit cards—and zero.[58] In the model, the tax elasticity captures the decrease in compliance following a tax increase. This concept is best approximated by the compliance share elasticity, which weighs drops in compliance by revenue. We use two DiD estimates of this elasticity: $\varepsilon_t^{\text{Pay}} \in \{-0.24, -0.46\}$. We calibrate three parameters. First, we let $\gamma \in \{1, 3\}$.[59] Second, we consider values of $\frac{v'(g)}{u'(c)} \in [1, 3]$.[60] Finally, we use data on the fraction of back-taxes that the government collects in future years to set $\tilde{z} = 10\%$.[61]

[56] These simulations are based on our regression discontinuity results. The difference-in-difference estimates imply larger revenue-maximizing rates in all cases.

[57] Our findings contrast Haughwout et al. (2004), who find that in three of four major US cities property tax rates are close to the peak of the Laffer curve.

[58] That is, $\pi_{0,c}^{\text{Pay}} = 1 - \pi_{s,c}^{\text{Pay}} = 80\%$ or zero. Based on these estimates, $\eta_{t,s}^c = \frac{\Delta c_s}{\tau}$, where τ is the average tax rate.

[59] Chetty and Looney (2006) offer a similar calibration in a developing country context. The larger value captures the possibility that consumption commitments amplify welfare costs (Chetty, 2004).

[60] While estimates of the value of public goods from the United States imply $\frac{v'(g)}{u'(c)} \approx 1.5$ (Cellini et al., 2010; Suárez Serrato and Wingender, 2014), this value may be larger in countries with a lower provision of public goods.

[61] Figure C.2 shows that the government recovered 10 percent of outstanding debt between 2008 and 2012.

Panel A1 of Figure 9 implements Equation 1. As expected, the MVPF is increasing in the marginal value of public goods. The blue line plots an initial parametrization that assumes there are no liquidity-constrained households, that $\gamma = 1$, and a low value of the tax elasticity $\varepsilon_t^{\text{Pay}}$. In this case, raising property tax rates increases welfare as long as the value of public goods is greater than 1.25. Additional lines show the effect of progressively assuming that 80% of households are liquidity constrained, that $\gamma = 3$, and that compliance is more elastic to tax rate increases. The green line shows that—in the most conservative case—increasing taxes only raises welfare if the value of public goods is greater than 1.75.

Panel A2 of Figure 9 implements the optimal property tax from Equation 2.[62] For ease of interpretation, we only plot positive tax rates and we top-code optimal tax rates at 250 basis points. The relaxed assumptions behind the blue line imply that as long as the value of public goods exceeds 1.5, the optimal tax rate is greater than 250 basis points. Liquidity constraints (red line), higher welfare costs of consumption declines (yellow), and larger compliance drops (green) all work to reduce the optimal tax rate. While these lines illustrate how different forces influence optimal tax rates, the red line is a reasonable case for practical purposes. This line shows optimal tax rates greater than 70 basis points whenever the value of public goods is greater than or equal to 1.5. This suggests that while liquidity constraints generally work to lower optimal tax rates, current property tax rates may still be below the optimal rates.[63]

While the ingredients above suffice to implement the tax formulas, the enforcement formulas in Equations 3 and 4 depend on the welfare costs of enforcement: $\frac{\partial m(\alpha)}{\partial \alpha}$. In contrast to the marginal value of public goods, we know relatively little about the tax morale costs of enforcement (Singhal and Luttmer, 2014). To implement these equations, we show in Appendix A that $\frac{\partial m(\alpha)}{\partial \alpha}$ can be expressed as the welfare cost of a tax that, combined with a change in α, leaves N^{Pay} unaffected. Using this result, we have $\frac{\partial m(\alpha)}{\partial \alpha} = u'(c)\left(\frac{Ht}{\alpha}\right)\left(\frac{\varepsilon_\alpha^{\text{Pay}}}{-\varepsilon_t^{\text{Pay}}}\right)$ and the $MVPF_\alpha$ is now:

$$MVPF_\alpha = \frac{v'(g)}{u'(c)} \frac{-\varepsilon_t^{\text{Pay}}}{\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)} - \frac{1 - N^{\text{Pay}}}{(1-\tilde{z})N^{\text{Pay}}\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha) - 1}. \tag{9}$$

Similarly, the compliance rate that equates the marginal cost and benefit of enforcement is now:

$$N_\alpha^{\text{Pay}} = \frac{1 - \frac{\varepsilon_t^{\text{Pay}}}{\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)} \frac{v'(g)}{u'(c)}}{1 - (1-\tilde{z})\varepsilon_t^{\text{Pay}} \frac{v'(g)}{u'(c)}}.$$

One benefit of these equations is that we can implement them using estimates of $\varepsilon_\alpha^{\text{Pay}}$, in addition to the values used to implement Equation 1. Interestingly, while a larger value of $\varepsilon_\alpha^{\text{Pay}}$ implies that enforcement is more effective at collecting tax revenue, it also discounts the value of public

[62] As with all sufficient statistic formulas (Chetty, 2009), we assume constant elasticities to implement Equations 2 and 4. Equations 1 and 3 do not rely on this assumption as they measure marginal effects of policy changes.

[63] As we note in Section 1, allowing for the capitalization of taxes and spending on property values would result in higher optimal tax rates.

goods. The intuition for this result is that more effective enforcement actions have larger welfare costs (through $m(\alpha)$).[64] We implement this equation using estimates from Section 5. To do so, note that $\varepsilon_{\alpha}^{\text{Pay}} \times \left(\frac{Ht}{\alpha}\right)$ is the effect of receiving a letter on tax payments. We therefore use the values $\varepsilon_{\alpha}^{\text{Pay}} \times \left(\frac{Ht}{\alpha}\right) \in \{54, 16\}$, where the larger value corresponds to the sanctions treatment and the lower value corresponds to the public goods motivation. In addition, we use the observed share of compliers $N^{\text{Pay}} = 60\%$ as well as a hypothetical value of greater compliance of $N^{\text{Pay}} = 90\%$.

Panel B of Figure 9 implements Equation 9 and the compliance rate at the optimal enforcement level. The blue line in Panel B1 plots the MVPF under an initial parametrization that assumes low values of the compliance elasticity $\varepsilon_{\alpha}^{\text{Pay}}$ (from the public goods treatment), the tax elasticity $\varepsilon_{t}^{\text{Pay}}$, and the compliance rate N^{Pay}. In this case, stricter enforcement does not increase welfare within the range of the graph. More effective enforcement (from the sanctions treatment), larger values of $\varepsilon_{t}^{\text{Pay}}$, and greater compliance all work to make enforcement more effective at raising welfare. Assuming the yellow line is a practical scenario implies that additional enforcement may only have small or negative welfare effects.

Panel B2 plots the compliance rate that equates the marginal cost and benefit of enforcement. As we discuss in Section 1, the government can increase welfare by increasing enforcement when $N_{\alpha}^{\text{Pay}} < N^{\text{Pay}}$. Conversely, it would be preferable to reduce enforcement when $N_{\alpha}^{\text{Pay}} > N^{\text{Pay}}$. Regardless of the value of public goods, the observed compliance rate of $N^{\text{Pay}} = 60\%$ lies below N_{α}^{Pay} in both our baseline parameterization and for the case with higher $\varepsilon_{\alpha}^{\text{Pay}}$. While the optimal compliance rate is not very sensitive to the enforcement elasticity, a larger tax elasticity implies a lower value for $\frac{\partial m(\alpha)}{\partial \alpha}$, which shifts down the curve N_{α}^{Pay}. In this case, the green line shows that when the value of public goods is close to 1.75, current compliance rates are close to optimal.

Finally, we use the model to evaluate whether it is preferable to increase tax rates or tighten enforcement. We use Equation 5 to compute the welfare effect of a balanced-budget policy that increases taxes and reduces enforcement. Panel C shows how the welfare effect of this policy varies with the tax elasticity $\varepsilon_{t}^{\text{Pay}}$. Since taxes are less distortionary when $\varepsilon_{t}^{\text{Pay}}$ is closer to zero, the welfare effect of this policy increases with $\varepsilon_{t}^{\text{Pay}}$. The dashed lines report our RD and DiD estimates of $\varepsilon_{t}^{\text{Pay}}$. The blue line shows that increasing tax rates and reducing the reliance on enforcement raises welfare as long as $\varepsilon_{t}^{\text{Pay}}$ is greater than our smallest estimate of -0.46. The relative desirability of taxes over enforcement diminishes slightly when we allow for larger utility costs of consumption changes (red dotted line) and when we additionally allow for the more effective enforcement intervention (dashed yellow line). Nonetheless, most of our estimates of $\varepsilon_{t}^{\text{Pay}}$ imply that taxation is more desirable than enforcement as a means of raising tax revenue. Finally, the green line shows a hypothetical case where we additionally assume a higher level of compliance. The welfare cost of enforcement is smaller in this case since fewer taxpayers incur the private cost $m(\alpha)$, which increases the relative desirability of enforcement.

[64] As in Keen and Slemrod (2017), this is a feature and not a bug. That is, maximizing welfare will necessarily discount the benefits of policies that harm the well-being of delinquent taxpayers.

8 Conclusion

This paper brings together the "economists as plumbers" framework of Duflo (2017) and the "tax systems" approach of Slemrod and Gillitzer (2013) to study the design of property taxes in a holistic and detailed manner. Our work draws on administrative tax data from the universe of residential properties in Mexico City and various quasi-experimental and experimental identification strategies. We examine traditional policy tools featured in optimal tax theory—i.e., the tax rate—in addition to tax system features such as enforcement, payment schedules, and payment modality, as well as interactions between these different tools.

We show that it is possible to raise property tax revenue through higher tax rates or through enforcement. Collectively, the variation we study contributed to a 36 percent increase in total property tax revenue. However, we also find that taxpayer behavior is sensitive to liquidity constraints. Tax rate increases lead to drops in compliance, an increased likelihood of paying in installments, and reductions in consumption. Liquidity constraints thus need to be taken into account when designing property tax systems in developing countries. Because our study is based in Mexico City, a setting that is similar to other developing countries in terms of the prevalence of household liquidity constraints and the level of administrative capacity, our findings carry broad relevance.

Our optimal tax model combines our empirical estimates of tax, enforcement, and consumption elasticities to quantify the optimal tax rate and compliance level. The model illuminates when a welfare-maximizing government would rather increase tax rates or enhance enforcement. Since we calculate that our field experiment generated welfare losses, we conclude that it is not desirable to increase enforcement. In contrast, while liquidity constraints increase the welfare cost of raising tax rates, we find that current tax rates are still below their optimal level. Because optimal tax rates depend on the share of liquidity-constrained taxpayers, we identify the provision of liquidity as an important policy tool that can lessen the welfare costs of property taxation.

Overall, our results reveal that details of property tax systems can have important impacts on taxpayer welfare and revenue collection. In particular, the optimal design and administration of loans for liquidity-constrained taxpayers—including terms of eligibility, interest rates, and payment schedules—is an important avenue for future research. Future work continuing to build on the "economists as plumbers" and "tax systems" paradigms are likely to yield important insights in other settings (e.g., Okunogbe, 2019; Bergeron et al., 2020) and to illuminate the roles of tax fairness and equity (e.g., Best et al., 2020).

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Tables

Table 1: The Effect of Tax Rates on Tax Payment – Regression Discontinuity Estimates

	Mean tax rate (basis points)	Payment amount (MXN thousands)	Payment in full (percentage points)	Compliance share × 100
	(1)	(2)	(3)	(4)
		I. Estimates for the 2009-2010 treatment		
T	9.127 ***	.584 **	-5.483 ***	-3.208
	(.059)	(.24)	(2.122)	(2.043)
Properties	17864	17864	17864	17864
Adjusted R-squared	.981	.01	.004	.001
Mean at baseline (treated band)	50.112	5.836	36.626	47.881
Implied elasticity		.55	-.822	-.368
		(.226)	(.318)	(.234)
Implied Semi-elasticity		.011	-.016	-.007
		(.005)	(.006)	(.005)
		II. Estimates for the 2010-2011 treatment		
T	12.147 ***	.575 ***	-6.433 ***	-4.939 ***
	(.031)	(.131)	(1.523)	(1.296)
Properties	28094	28094	28094	28094
Adjusted R-squared	.994	.015	.003	.001
Mean at baseline (treated band)	47.461	4.734	35.072	47.478
Implied elasticity		.475	-.717	-.407
		(.108)	(.17)	(.107)
Implied Semi-elasticity		.01	-.015	-.009
		(.002)	(.004)	(.002)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.765	.77	.881
		III. Estimates for the 2011-2012 treatment		
T	18.002 ***	.452 ***	-10.949 ***	-6.228 ***
	(.024)	(.085)	(1.387)	(1.185)
Properties	48838	48838	48838	48838
Adjusted R-squared	.996	.017	.009	.006
Mean at baseline (treated band)	41.06	3.287	37.969	44.885
Implied elasticity		.314	-.658	-.316
		(.059)	(.083)	(.06)
Implied Semi-elasticity		.008	-.016	-.008
		(.001)	(.002)	(.001)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.191	.755	.462
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.313	.617	.832

Notes: This table reports results from the RD estimation discussed in Section 4.1. Each year, properties in a specific value band are treated with a large tax rate increase. The treated value bands are I, H and G in the years 2010, 2011 and 2012, respectively. We compare these properties to properties just below the lower threshold of the treated value band. The estimation equation is $\Delta Y_{i,t} = \alpha + \beta T_i + f(\hat{V}_i) + g(\hat{V}_i)T_i + \epsilon_{i,t}$, where $\hat{V}_i$ denotes the distance between the value of property i and the lower limit of the treated band, T_i indicates properties in the treated band, and f and g are third-order polynomial functions. Standard errors are robust to heteroskedasticity and clustered at the post code level. The elasticity $\epsilon_{y,t} = \frac{\partial y}{\partial t}\frac{t}{y}$ is calculated using $\frac{\partial y}{\partial t}$ from the RD estimates and $\frac{t}{y}$ from outcome means at baseline. The compliance share (the outcome in column 4) is defined as the tax payment divided by the tax liability. Figures 3 and 4 present the RD estimation graphically. Table D.2 shows the robustness to local linear regressions with optimal bandwidth. Figure D.2 shows the robustness to varying bandwidths and degrees of polynomial.

Table 2: The Effect of Tax Rates on Tax Payment – Differences-in-Differences Estimates

	Mean tax rate	Payment amount	Payment in full	Compliance share
	(1)	(2)	(3)	(4)
		I. Estimates for the 2009-2010 treatment		
DD	.166 ***	.116 ***	-.103 ***	-.041 ***
	(.000)	(.017)	(.017)	(.011)
Adjusted R-squared	.998	.007	.003	.012
Properties (treatment)	5747	5747	5747	5747
Properties (control)	6510	6510	6510	6510
Implied elasticity		.697	-.617	-.244
		(.101)	(.104)	(.067)
Implied Semi-elasticity		.014	-.012	-.005
		(.002)	(.002)	(.001)
		II. Estimates for the 2010-2011 treatment		
DD	.232 ***	.169 ***	-.149 ***	-.070 ***
	(.000)	(.02)	(.015)	(.01)
Adjusted R-squared	.996	.007	.005	.017
Properties (treatment)	9661	9661	9661	9661
Properties (control)	6511	6511	6511	6511
Implied elasticity		.728	-.642	-.3
		(.085)	(.064)	(.043)
Implied Semi-elasticity		.015	-.014	-.006
		(.002)	(.001)	(.001)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.639	.485	.293
		III. Estimates for the 2011-2012 treatment		
DD	.401 ***	.196 ***	-.300 ***	-.182 ***
	(.000)	(.029)	(.014)	(.01)
Adjusted R-squared	.994	.003	.016	.038
Properties (treatment)	15227	15227	15227	15227
Properties (control)	6508	6508	6508	6508
Implied elasticity		.489	-.747	-.455
		(.073)	(.035)	(.025)
Implied Semi-elasticity		.012	-.018	-.011
		(.002)	(.001)	(.001)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.004	.000	.000
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.005	.000	.000

Notes: This table reports results from the DiD estimation discussed in Section 4.2, using the same tax rate changes leveraged in Table 1. The estimating equation is $Y_{it} = \alpha + DD_{it}\beta + \gamma_i + \delta_t + \epsilon_{it}$, where DD_{it} indicates treated properties in post-reform years and δ_t and γ_i denote year and property fixed effects. We estimate this equation in levels, and transform the point estimates into relative effects, scaling them by the treatment group mean in the last pre-reform year. Standard errors are similarly scaled, applying the delta method. Standard errors are robust to heteroscedasticity and clustered at the property level. The treated value bands are I, H and G in the years 2010, 2011 and 2012, respectively. The control group is composed of properties in bands K and L. The elasticity $\epsilon_{y,t} = \frac{dy}{dt}\frac{t}{y}$ is calculated using $\frac{dy}{y}$ and $\frac{t}{dt}$ from the DiD estimates. Note that, while the elasticity estimates in this table are comparable to those in Table 1, the point estimates of the treatment effect are not directly comparable, as the RD estimates a level change. Figures 5 and 6 present the results graphically. Appendix E presents various robustness tests.

Table 3: The Effect of Enforcement Letters on Tax Payment – Experimental Estimates

1: Letter Content		2: Sender Position		3: Male Sender		4: Female Sender	
Sanctions	Public Good	Fiscal Attorney	Compliance Officer	Male	Neutral	Female	Neutral
Outcome A: Any Payment							
9.364***	4.858***	7.598***	6.624***	7.038***	8.157***	6.772***	6.477***
(.29)	(.274)	(.284)	(.281)	(.332)	(.337)	(.329)	(.329)
.000		.390		.000		.002	
Outcome B: Payment Amount (MX Pesos)							
54.226***	16.051***	42.416***	27.861***	39.707***	45.124***	29.025***	26.698***
(2.593)	(2.297)	(2.496)	(2.407)	(2.979)	(2.942)	(2.807)	(2.811)
.000		.422		.000		.089	

Notes: This table evaluates the effect of enforcement letters, as discussed in Section 5, on payment of outstanding tax debt, contrasting the different treatments summarized in Figure G.1. Each column 1-4 and panel corresponds to one regression. We estimate $Y_i = \alpha + \beta_1 T1_i + \beta_2 T2_i + \epsilon_i$, where Y_i is the outcome for property i evaluated 40 days after all letters were sent, α is a constant, $T1_i$ and $T2_i$ are dummies indicating the two mutually exclusive treatments (e.g., the sanctions treatment and the public goods treatment), and ϵ_i is the error term. The outcome is any payment in panel A and the payment amount in Panel B. The outcomes are cumulative over time for each property. The bottom line of each panel reports the p-values from a Wald test of significant differences between each pair of treatment estimates. Figure 7 presents accompanying non-parametric evidence for the effect of the sanctions treatment and public goods treatment. Since the treatment and control groups exhibit slightly different trends prior to the intervention, as shown in Figure G.2, we display the data and run our estimations on detrended data. To do that, we estimate the following regression on the pre-intervention data: $Y_{igt} = \mu_g \cdot t + \alpha_i + \lambda_t + \epsilon_{igt}$, where t indicates days and g treatment groups. We then subtract the trend $\mu_g \cdot t$ from each treatment group. In all estimations, weekends are excluded from the sample. Payment amounts are winzorized at the 99th percentile. Standard errors in parentheses are robust to heteroscedasticity and are clustered at the property level. Table G.2 shows that the results are robust to including property characteristics as controls and estimating the treatment effects via difference-in-differences.

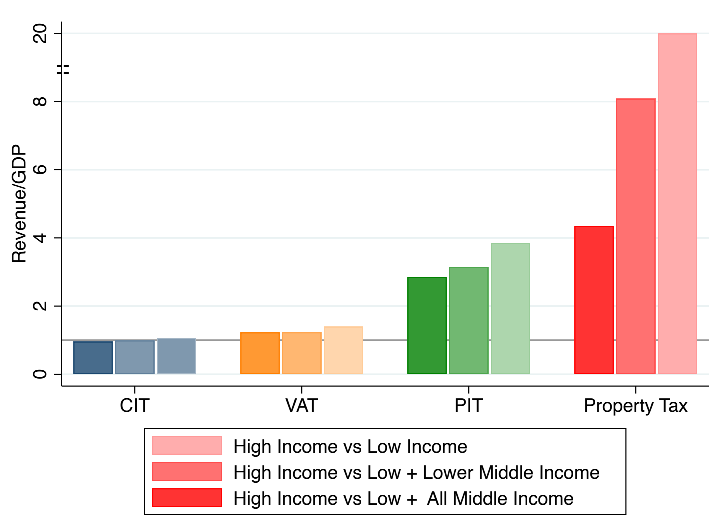
Table 4: The Effect of Property Taxes on Consumption – Instrumental Variable Estimates

	(1)	(2)	(3)	(4)
log(Pay)	-.006	-.024	.002	-.012
	(.052)	(.055)	(.051)	(.053)
log(Pay) × log(pc income)		.066 ***		.046 **
		(.024)		(.023)
log(Pay) × Lack of credit			-.041 ***	-.035 ***
			(.007)	(.006)
log(pc income)	.815 ***	.435 ***	.782 ***	.52 ***
	(.035)	(.13)	(.032)	(.129)

Notes: This table reports the second-stage results from the IV estimation discussed in Section 6.2. N=2,649. All regressions include *delegación* fixed effects and year dummies. Bootstrapped standard errors based on 1,000 replications are in parentheses. The outcome is log(pc consumption). Log(pc income) is centered at the mean. The first-stage results are shown in Table J.1. Robustness tests using alternative instruments are shown in Tables J.2 and J.3.

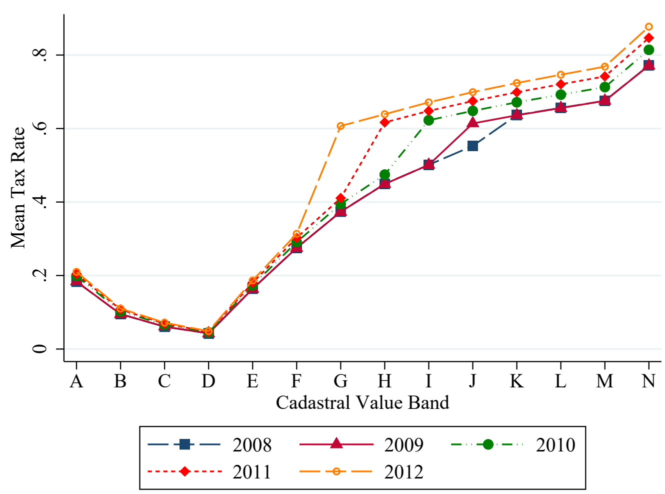
Figures

Figure 1: Ratio of Tax Revenue to GDP in High-Income vs Lower-Income Countries



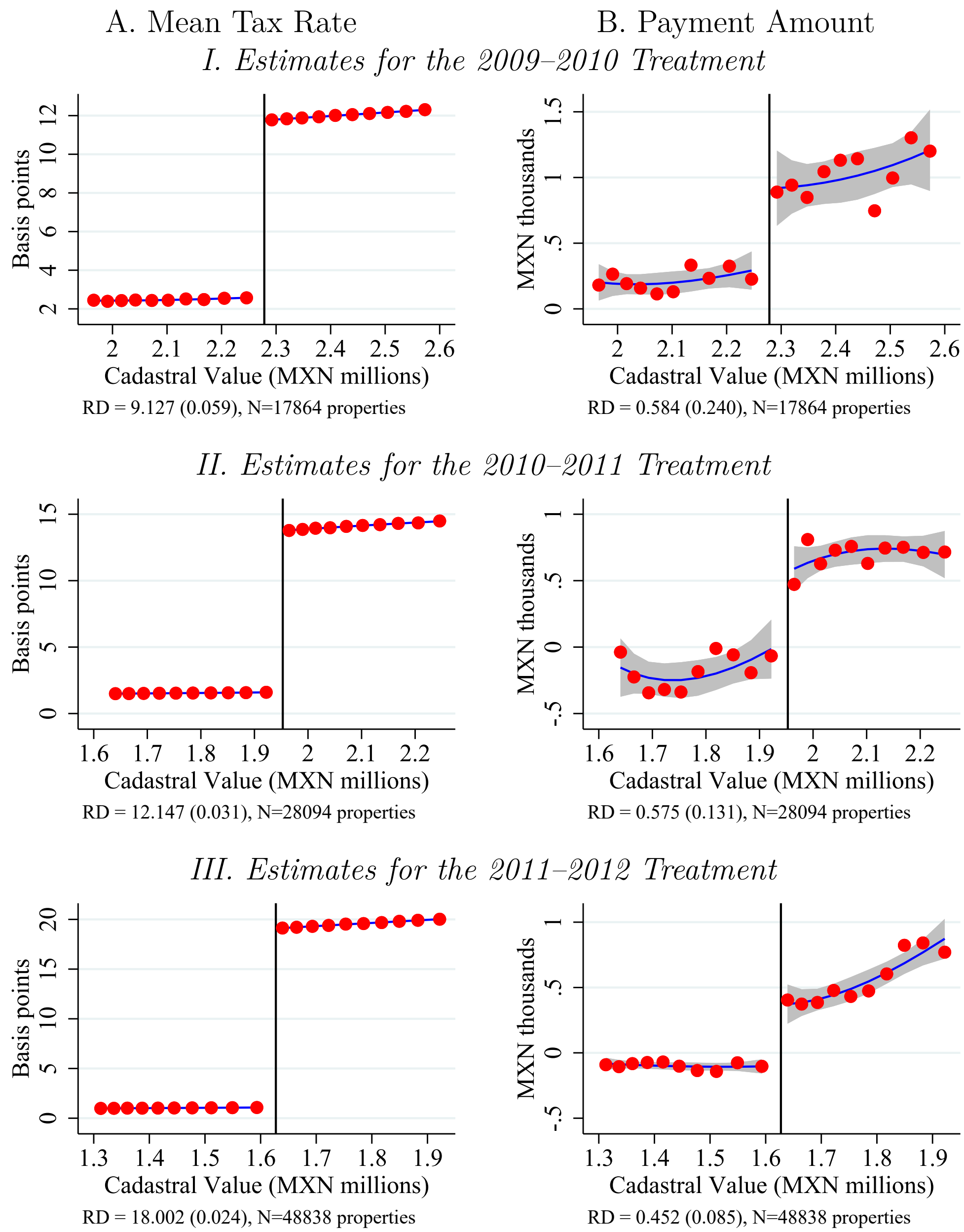
Notes: This figure shows the ratio of tax revenue as a share of GDP in high-income versus lower income countries, as discussed in the introduction, for corporate income taxes (CIT), value-added taxes (VAT), personal income taxes (PIT), and property taxes in 2017. This is based on data from the IMF World Revenue Longitudinal Dataset and the WB World Development Indicators. Country income classifications follow the World Bank Atlas methodology.

Figure 2: Variation in Tax Rates over Time and across Cadastral Value Bands, 2008–2012



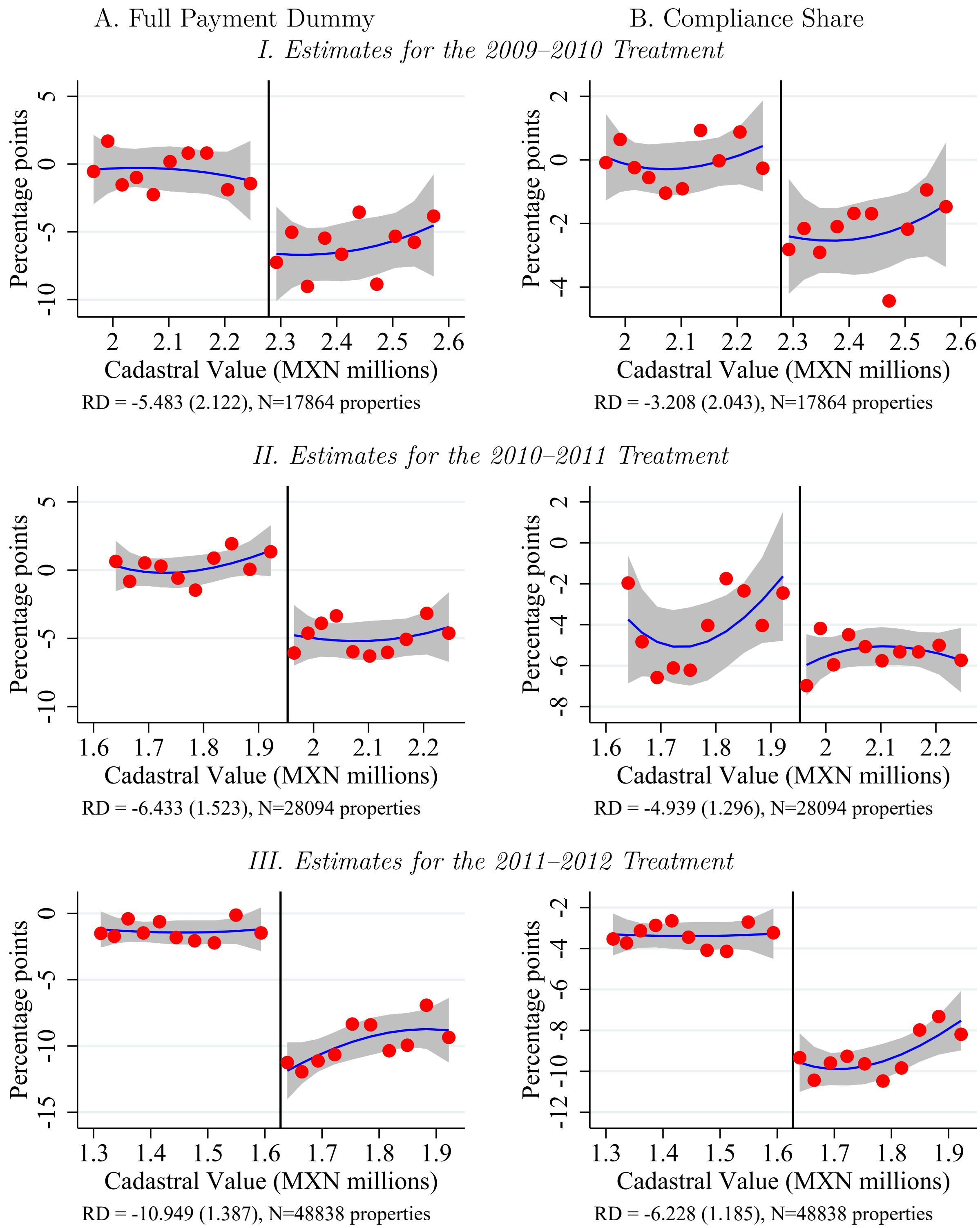
Notes: As discussed in the introduction, this figure shows the mean tax rate in percentage points by cadastral value band and year. We construct this figure using administrative tax bills.

Figure 3: The Effect of Tax Rates on Tax Payment – Regression Discontinuity Estimates



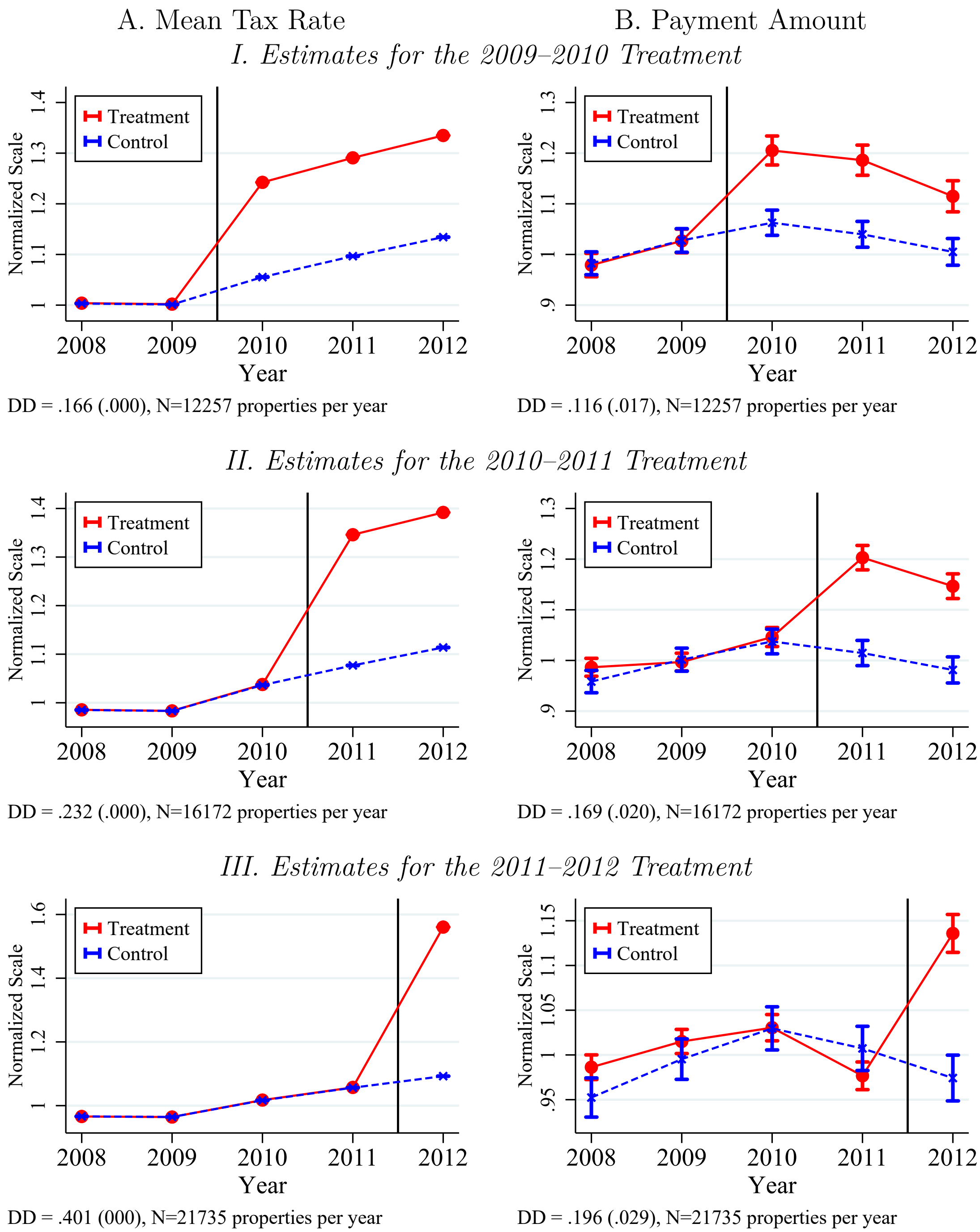
Notes: These graphs implement the RD estimation from Section 4.1. The red dots represent the mean outcome in equally spaced cadastral value bins. The solid blue lines (grey areas) depict a fitted third-order polynomial (the corresponding 95% confidence intervals). The vertical black lines mark the thresholds between the control and treatment bands. Properties to the right of the threshold are treated with a tax rate increase. We use the band below as the counterfactual since properties in the band above the treated band were treated in the previous year. The treated value bands are I, H and G in the years 2010, 2011 and 2012, respectively. The notes display the estimate for β from $\Delta Y_{i,t} = \alpha + \beta T_i + f(\hat{V}_i) + g(\hat{V}_i)T_i + \epsilon_{i,t}$, where $\hat{V}_i$ denotes the distance between the value of property i and the lower limit of the treated band, T_i indicates properties in the treated band, and f and g are third-order polynomial functions. Standard errors are robust to heteroscedasticity and clustered at the postcode level. Table 1 summarizes the estimates and implied elasticities. Table D.2 shows the robustness to local linear regressions with optimal bandwidth. Figure D.2 shows the robustness to varying bandwidths and degrees of polynomial.

Figure 4: The Effect of Tax Rates on Compliance – Regression Discontinuity Estimates



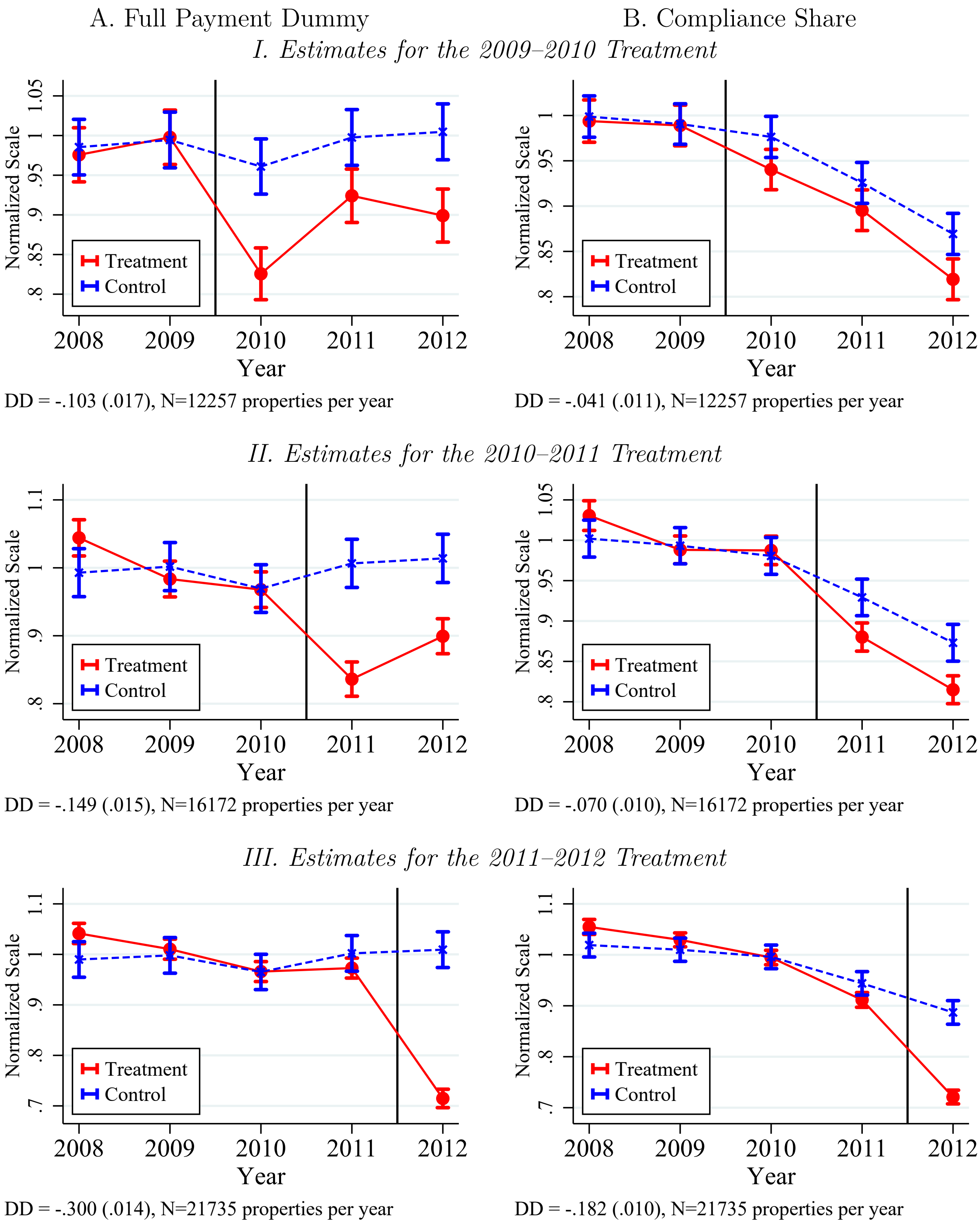
Notes: This figure is identical to Figure 3 but displays the results for different outcomes: a dummy indicating that taxpayers paid their liability fully and on time and the compliance share, defined as the tax payment divided by the liability.

Figure 5: The Effect of Tax Rates on Tax Payment – Difference-in-Difference Estimates



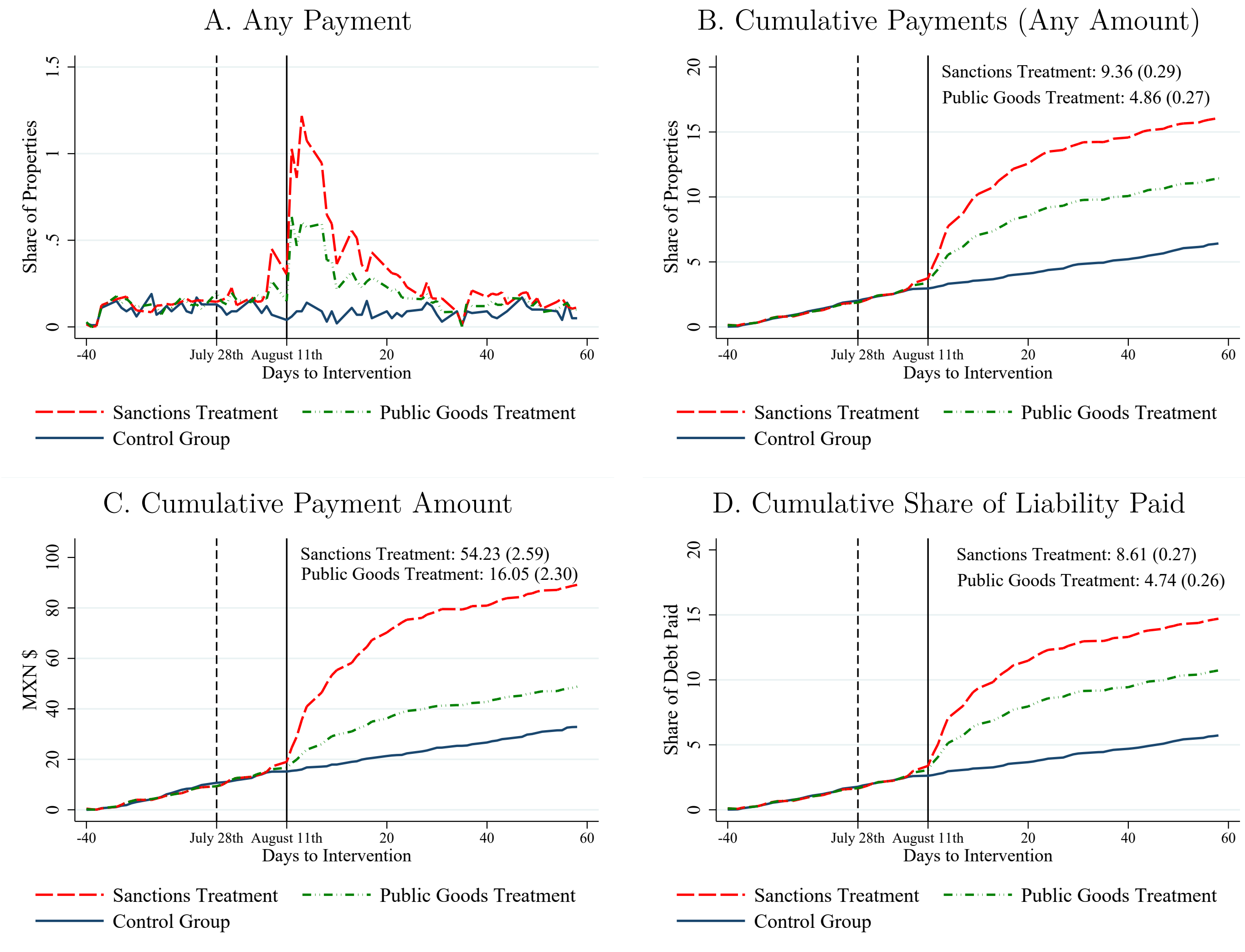
Notes: These graphs implement the DiD estimation from Section 4.2. Treatment and control group outcomes are normalized by their pre-reform mean. The vertical black lines mark the treatment timing. The notes display the estimate for β from $Y_{it} = \alpha + DD_{it}\beta + \gamma_i + \delta_t + \epsilon_{it}$, where DD_{it} indicates treated properties in post-reform years and δ_t and γ_i denote year and property fixed effects. We estimate this equation in levels, and transform the point estimates into relative effects, scaling them by the treatment group mean in the last pre-reform year. Standard errors are similarly scaled, applying the delta method. Standard errors are robust to heteroscedasticity and clustered at the property level. The treated value bands are I, H and G in the years 2010, 2011 and 2012, respectively. The control group is composed of properties in bands K and L. Table 2 summarizes the estimates and implied elasticities. Appendix E presents various robustness tests.

Figure 6: The Effect of Tax Rates on Compliance – Difference-in-Difference Estimates



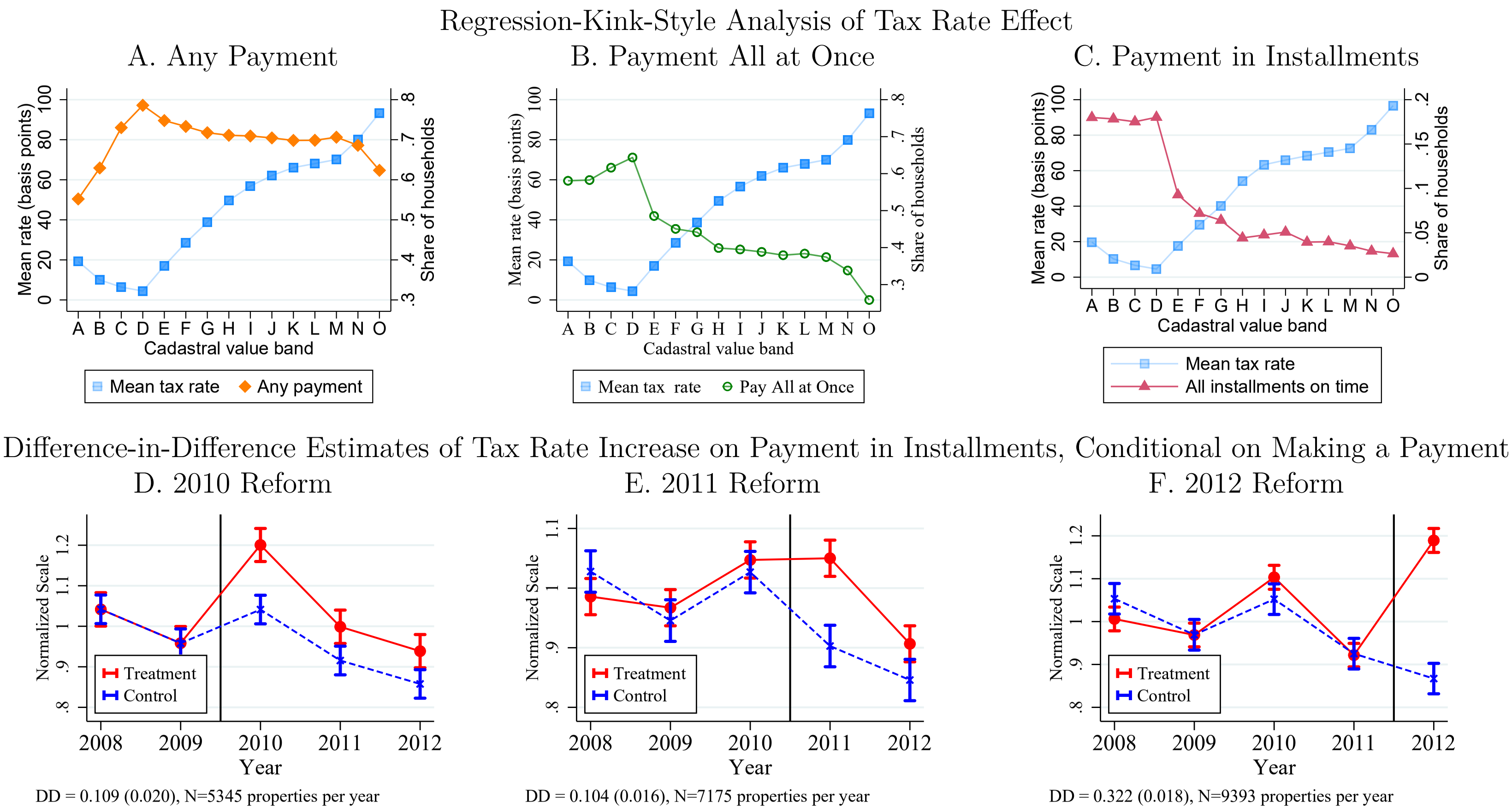
Notes: This figure is identical to Figure 5 but displays the results for different outcomes: a dummy indicating that taxpayers paid their liability fully and on time and the compliance share, defined as the tax payment divided by the liability.

Figure 7: The Effect of Enforcement Letters on Tax Payment



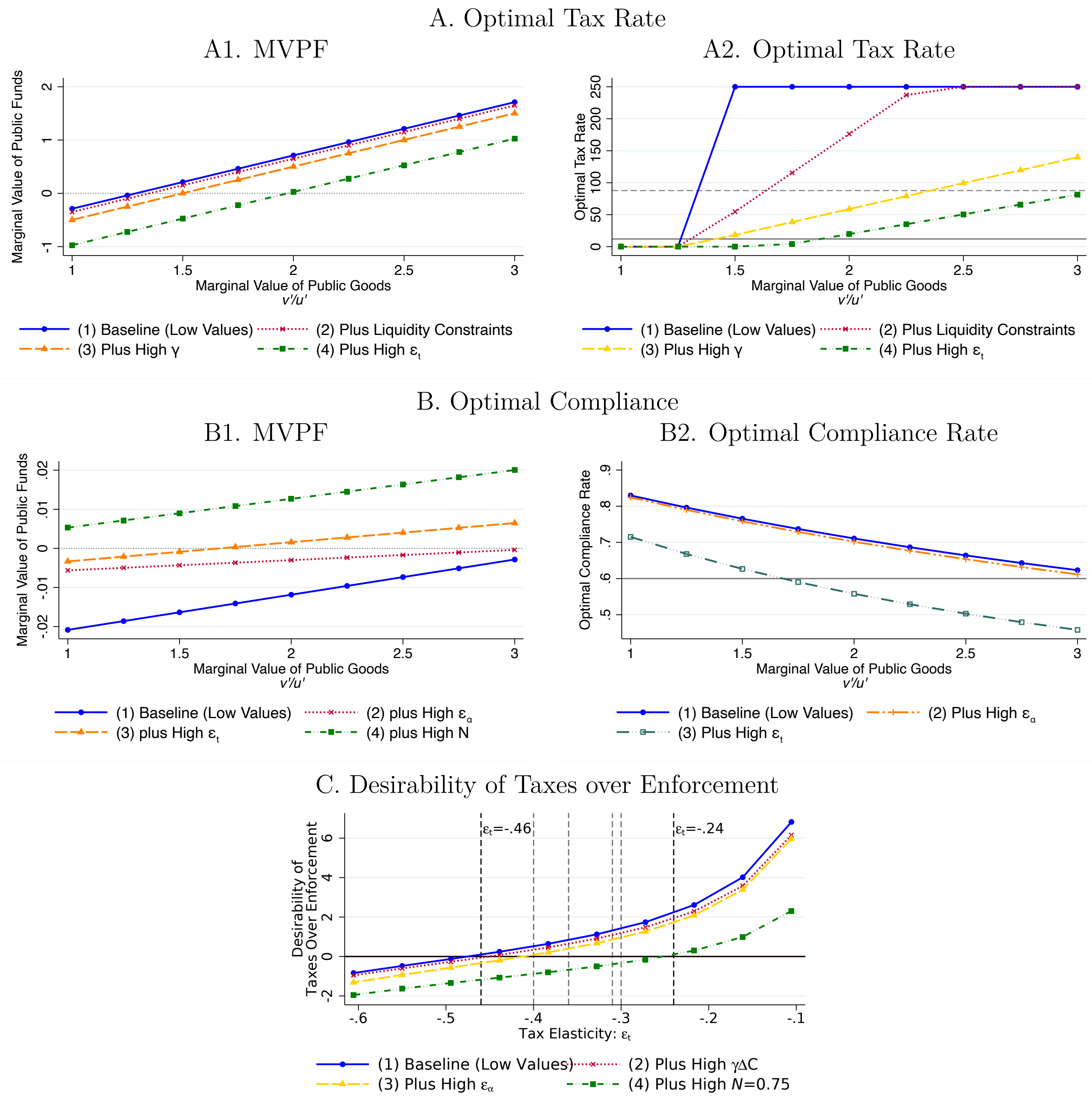
Notes: This figure displays taxpayers' response to enforcement letters, as discussed in Section 5. Panel A shows the share of properties that made a payment on any given day around the time of the enforcement intervention. Panel B shows the cumulative share of properties that made a payment, panel C shows the average cumulative payment amount, and panel D displays the share of the outstanding liability paid. We consider payments made between July and November 2014 against outstanding debt for the period from bimester 4, 2009, to bimester 3, 2014. The period during which the letters were sent—July 28 and August 11, 2014—is represented by the vertical lines. Panels B–D display the point estimates β_1 and β_2 from the OLS regression $Y_i = \alpha + \beta_1 T1_i + \beta_2 T2_i + \epsilon_i$, where where Y_i is the outcome for property i evaluated 40 days after all letters were sent and $T1_i$ and $T2_i$ are dummies for the sanctions treatment and the public goods treatment, respectively. Since the treatment and control groups exhibit slightly different trends prior to the intervention, as shown in Figure G.2, we display here and run our estimations on detrended data. To do that, we run the following regression on the pre-intervention data: $Y_{igt} = \mu_g \cdot t + \alpha_i + \lambda_t + \epsilon_{igt}$, where t indicates days and g treatment groups. We then subtract the trend $\mu_g \cdot t$ from each treatment group. This is reasonable as the pre-intervention trend is indeed almost perfectly linear and the control group trend continues linearly after the intervention. In all estimations, weekends are excluded from the sample. Payment amounts are winzorized at the 99th percentile. Standard errors are robust to heteroscedasticity and are clustered at the property level. Table 3 presents regression estimates evaluating all treatment arms of the intervention, Table G.2 shows the robustness of these results to controlling for property characteristics in the estimation, and to estimation via difference-in-difference.

Figure 8: The Effect of Tax Rates on Tax Payment Modality



Notes: These graphs examine the effect of tax rates on payment modality, as discussed in Section 6.1. Panels A-C display the mean tax rate and households' payment modality choice by cadastral value bands. In all panels, the blue squares indicate the mean tax rate. In addition, panel A shows the share of households that made any payment towards their tax liability, regardless of the payment modality. For households that made a payment, panel B shows the share that paid their liability in full all at once (as opposed to attempting to pay in installments). For households that attempted to pay in installments, panel C displays the share that made all six installment payments on time, hence remaining compliant (as opposed to households that paid only partially or late). Panels D-F are identical to Figures 5 and 6, with the sample restricted to taxpayers that register a payment (including partial payments) every year. The outcome is a dummy indicating whether the taxpayer paid her tax liability in installments or attempted to do so (including paying late or partially) as opposed to paying her full liability all at once.

Figure 9: Policy Analysis



Notes: This figure displays results from the optimal policy analysis discussed in Section 7.2. Panel A plots the $MVPF_t$ and the welfare-maximizing tax rate. The optimal tax rate is top-coded at 250 basis points. Panel B plots the $MVPF_\alpha$ and the optimal compliance rate. The horizontal solid line in panel A2 represents the observed average tax rate between 2008 and 2012, while the dashed line represents the max tax rate in the same period. In panel B2, the horizontal line represents the observed average compliance rate between 2008 and 2012. Panel C plots the welfare impact of a balanced-budget policy that increases taxes and reduces enforcement, as in Equation 5. The dashed lines represent estimates of $\varepsilon_t^{\text{Pay}}$ from Tables 1 and 2.

Online Appendix: Not For Publication

This appendix contains additional information and analyses. Appendix A provides additional model results. Appendix B includes additional contextual information on property taxes in Mexico City. Appendix C presents summary statistics on the data we use. We present additional details for regression discontinuity analysis in Appendix D, for the difference-in-difference analysis in Appendix E, for real response estimations in Appendix F, for the field experiment in Appendix G, for the analysis of liquidity constraints in Appendix H, for the analysis of payment modality and timing in Appendix I, and for the instrumental variable estimation in Appendix J.

A Model Appendix

This section expands on Section 1 by presenting additional derivations and results.

A.1 Approximating Marginal Utility

For a given individual, we approximate marginal utility with a first-order Taylor expansion:

$$u'(c) \approx u'(\bar{c}) + u''(\bar{c}) \times (c - \bar{c}) = u'(\bar{c})[1 - \gamma \times \Delta c],$$

where Δc is the percentage change in consumption (i.e., $\Delta c \leq 0$) and $\gamma = -\frac{u''(\bar{c})\bar{c}}{u'(\bar{c})}$ is the coefficient of relative risk aversion and captures the curvature of utility.

We now approximate the average marginal utility. Letting $\bar{c} = \bar{c}_0^{\text{Pay}}\pi_0^{\text{Pay}} + \bar{c}_s^{\text{Pay}}\pi_s^{\text{Pay}}$ be the average consumption across the two types of households, we express the average marginal utility as:

$$\begin{aligned}
\pi_s^{\text{Pay}} u'(c_s^{\text{Pay}}) + \pi_0^{\text{Pay}} u'(c_0^{\text{Pay}}) &\approx \pi_0^{\text{Pay}}[u'(\bar{c}) + u''(\bar{c})(c_0^{\text{Pay}} - \bar{c})] + \pi_s^{\text{Pay}}[u'(\bar{c}) + u''(\bar{c})(c_s^{\text{Pay}} - \bar{c})] \\
&= u'(\bar{c}) + u''(\bar{c})(\pi_0^{\text{Pay}} c_0^{\text{Pay}} + \pi_s^{\text{Pay}} c_s^{\text{Pay}} - \bar{c}) \\
&= u'(\bar{c})[1 - \gamma(\pi_{0,c}^{\text{Pay}} \Delta c_0^{\text{Pay}} + \pi_{s,c}^{\text{Pay}} \Delta c_s^{\text{Pay}})],
\end{aligned}$$

where $\pi_{0,c}^{\text{Pay}} = \frac{\bar{c}_0 \pi_0^{\text{Pay}}}{\bar{c}_0 \pi_0^{\text{Pay}} + \bar{c}_s \pi_s^{\text{Pay}}}$ is the consumption share of liquidity-constrained households. Assuming $c_0^{\text{Pay}} = c_s^{\text{Pay}}$, then $\pi_{0,c}^{\text{Pay}} = \pi_0^{\text{Pay}}$.

A.2 Measuring $\frac{\partial m(\alpha)}{\partial \alpha}$

One drawback of Equation 3 is that we do not directly observe the welfare cost of additional enforcement, $\frac{\partial m(\alpha)}{\partial \alpha}$. We now show that we can measure this quantity using the relative responses to taxes and enforcement. First, note that because $N^{\text{Pay}} = \mathbb{P}r(V^{\text{Pay}} > V^{\text{Delinquent}} + \varepsilon_i)$, it follows that

$$\frac{\partial N^{\text{Pay}}}{\partial V^{\text{Pay}}} = -\frac{\partial N^{\text{Pay}}}{\partial V^{\text{Delinquent}}}.$$

Let Δt be a tax increase such that the combined effect of the tax and the marginal enforcement action leaves N^{Pay} unaffected. We then have:

$$\begin{aligned} 0 &= dN^{\text{Pay}} = \frac{\partial N^{\text{Pay}}}{\partial V^{\text{Pay}}}\frac{\partial V^{\text{Pay}}}{\partial t}\Delta t + \frac{\partial N^{\text{Pay}}}{\partial V^{\text{Delinquent}}}\frac{\partial V^{\text{Delinquent}}}{\partial \alpha} \\ &= \underbrace{\frac{\partial N^{\text{Pay}}}{\partial V^{\text{Pay}}}}_{>0}\underbrace{\left(\frac{\partial V^{\text{Pay}}}{\partial t}\Delta t - \frac{\partial V^{\text{Delinquent}}}{\partial \alpha}\right)}_{=0}. \end{aligned}$$

Because the first term is non-zero, the second term being equal to zero implies that:

$$\Delta t = \frac{\frac{\partial V^{\text{Delinquent}}}{\partial \alpha}}{\frac{\partial V^{\text{Pay}}}{\partial t}} = \frac{-\frac{\partial m(\alpha)}{\partial \alpha}}{-u'(c)H} = \frac{\frac{\partial m(\alpha)}{\partial \alpha}}{u'(c)H}.$$

Because this joint tax and enforcement change is such that N^{Pay} is unaffected, we can write:

$$\begin{aligned} 0 &= \Delta t\frac{\partial N^{\text{Pay}}}{\partial t} + \frac{\partial N^{\text{Pay}}}{\partial \alpha} \\ 0 &= \frac{\frac{\partial m(\alpha)}{\partial \alpha}}{u'(c)H}\frac{\varepsilon_t^{\text{Pay}}}{t} + \frac{\varepsilon_\alpha^{\text{Pay}}}{\alpha} \\ \frac{\partial m(\alpha)}{\partial \alpha} &= u'(c)\left(\frac{Ht}{\alpha}\right)\left(\frac{\varepsilon_\alpha^{\text{Pay}}}{-\varepsilon_t^{\text{Pay}}}\right), \end{aligned}$$

where the second line substitutes for Δt and transforms the expression into terms of elasticities and the third line solves for $\frac{\partial m(\alpha)}{\partial \alpha}$. This expression shows that we can measure $\frac{\partial m(\alpha)}{\partial \alpha}$ as a multiple of marginal utility that depends on the tax payment per household relative to the money spent on enforcement, $\left(\frac{Ht}{\alpha}\right)$, and the relative effects of taxes and enforcement on compliance, $\left(\frac{\varepsilon_\alpha^{\text{Pay}}}{-\varepsilon_t^{\text{Pay}}}\right)$.

This expression also shows that the welfare cost of enforcement is increasing in $\varepsilon_\alpha^{\text{Pay}}$. This makes sense. If a given enforcement action has a large effect on payment, the equivalent tax increase would have to be greater to result in the same effect on compliance. However, while a larger value of $\varepsilon_\alpha^{\text{Pay}}$ implies that enforcement raises more revenue, it also implies that enforcement is relatively less attractive from a welfare perspective.

We can then re-express $MVPF_\alpha$ as:

$$MVPF_\alpha = \frac{v'(g)}{u'(c)}\frac{-\varepsilon_t^{\text{Pay}}}{\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)} - \frac{1-N^{\text{Pay}}}{(1-\tilde{z})N^{\text{Pay}}\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)-1}.$$

Similarly, the optimal rate of compliance is:

$$N_\alpha^{\text{Pay}} = \frac{1-\frac{\varepsilon_t^{\text{Pay}}}{\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)}\frac{v'(g)}{u'(c)}}{1-(1-\tilde{z})\varepsilon_t^{\text{Pay}}\frac{v'(g)}{u'(c)}}.$$

A.3 Implementing the Model

To implement our model in Section 7.2, we use empirically estimated parameters (in blue in the table below) and calibrated or calculated parameters (in red). For all estimated parameters, we use the lower bound and upper bound of our estimates across different specifications. For the consumption drop in response to the tax rate change, the lower bound is for households at the 75th percentile of the income distribution who have access to credit. The upper bound is for households at the 25th percentile of the income distribution who do not have access to credit. The coefficient of relative risk aversion is calibrated based on the literature. The share of compliant taxpayers is 60% in our data. As an upper bound, we use 90%, which is closer to the compliance levels observed in high-income countries. The share of back taxes eventually collected is 10% in our data.

Table A.1: Parameters For Policy Simulation

A. Welfare Effects of Enforcement

$MVPF_\alpha$	$\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)$	$\varepsilon_t^{\text{Pay}}$	N^{Pay}
$\frac{v'(g)}{u'(c)}\frac{-\varepsilon_t^{\text{Pay}}}{\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)} - \frac{1-N^{\text{Pay}}}{(1-\tilde{z})N^{\text{Pay}}\varepsilon_\alpha^{\text{Pay}}(Ht/\alpha)-1}$	$\{16, 54\}$	$\{-0.24, -0.46\}$	$\{0.60, 0.90\}$

B. Welfare Effects of Tax Increases

$MVPF_t$	Δc	γ	$\varepsilon_t^{\text{Pay}}$
$\frac{v'(g)}{u'(c)} - \frac{1-\gamma\Delta c^{\text{Pay}}}{1+(1-\tilde{z})\varepsilon_t^{\text{Pay}}}$	$\{-0.01, -0.07\}$	$\{1, 3\}$	$\{-0.24, -0.46\}$

A.4 Comparing $MVPF_\alpha$ and $MVPF_t$

We now consider the welfare effect of increasing taxes and reducing enforcement while keeping government expenditure constant. The welfare impact of this policy experiment is given by:

$$dW = W_t + W_\alpha \cdot \left.\frac{d\alpha}{dt}\right|_{g=0}.$$

From the government budget constraint, we have that

$$\left.\frac{d\alpha}{dt}\right|_{g=0} = -\frac{HN(1+(1-\tilde{z})\varepsilon_t^{\text{Pay}})}{\frac{tHN}{\alpha}(1-\tilde{z})\varepsilon_\alpha^{\text{Pay}} - 1}.$$

From Equations 1 and 3, we can write:

$$\begin{aligned} W_t &= MVPF_t \times u'(c)\left(HN(1+(1-\tilde{z})\varepsilon_t^{\text{Pay}})\right) \quad \text{and} \\ W_\alpha &= MVPF_\alpha \times \frac{\partial m(\alpha)}{\partial \alpha}\left(\frac{tHN}{\alpha}(1-\tilde{z})\varepsilon_\alpha^{\text{Pay}} - 1\right). \end{aligned}$$

Combining these four expressions we then have that:

$$dW = u'(c)\left(HN(1+(1-\tilde{z})\varepsilon_t^{\text{Pay}})\right) \times \left[MVPF_t - MVPF_\alpha \times \frac{\frac{\partial m(\alpha)}{\partial \alpha}}{u'(c)}\right].$$

Recalling from above that $\frac{\frac{\partial m(\alpha)}{\partial \alpha}}{u'(c)} = \left(\frac{Ht}{\alpha}\right)\left(\frac{\varepsilon_{\alpha}^{\text{Pay}}}{-\varepsilon_{t}^{\text{Pay}}}\right)$, we have:

$$dW \propto MVPF_t - MVPF_{\alpha} \times \left(\frac{Ht}{\alpha}\right)\left(\frac{\varepsilon_{\alpha}^{\text{Pay}}}{-\varepsilon_{t}^{\text{Pay}}}\right).$$

We use this expression to plot Panel C of Figure 9.

A.5 Government Provision of Liquidity

Assume now that the government allows households that pay property taxes to borrow up to the amount of the property taxes at interest rate r.[65] We can interpret this rate of return as incorporating a risk adjustment for the possibility that households do not pay back the loan. Because the government can eventually seize the asset, this collateral implies this adjustment is low.

The provision of liquidity to constrained taxpayers lowers the welfare cost of taxation since consumption would be less affected. Specifically, the change in consumption for constrained households is now $\eta_{t,l}^{c} \times t$, where it is plausible to assume that $\eta_{t,l}^{c} \approx \eta_{t,s}^{c} < \eta_{t,0}^{c}$. Therefore, when the government provides liquidity, $MVPF_t$ is greater, since the effect on consumption is smaller. The provision of liquidity to constrained taxpayers also means that enforcement becomes relatively less desirable since liquidity increases the value of $MVPF_t$.

The assumption that the government charges a risk-adjusted interest rate implies that the government's budget constraint is not affected by providing liquidity. Departing from this assumption, it is also possible to study the optimal provision of liquidity. As in Andreoni (1992), the government may have incentives to act as a "loan shark." The government's budget constraint is now:

$$g + a(\alpha) = tHN^{\text{pay}} + zH(1 - N^{\text{pay}}) + (\rho - r) \times \pi_{l}^{\text{Pay}} N^{\text{pay}} tH,$$

where the last term is the revenue from charging interest ρ on the taxes of the share of taxpayers π_{l}^{Pay} who obtain a loan from the government.

This implies $\frac{dV^{\text{Pay}}}{d\rho} = -u'(c^{\text{Pay}})H\pi_{l}^{\text{Pay}}$ and $\frac{dV_{l}^{\text{Delinquent}}}{d\rho}$. The effect of increasing ρ on welfare is then:

$$-N^{\text{Pay}}\pi_{l}^{\text{Pay}}u'(c_{l}^{\text{Pay}})H + v'(g) \times \left\{(t - z)H\frac{\partial N^{\text{Pay}}}{\partial \rho} + \pi_{l}^{\text{Pay}}N^{\text{pay}}tH + (\rho - r) \times tH\left[\pi_{l}^{\text{Pay}}\frac{\partial N^{\text{Pay}}}{\partial \rho} + \frac{\partial \pi_{l}^{\text{Pay}}}{\partial \rho}N^{\text{pay}}\right]\right\}.$$

The MVPF for ρ is then:

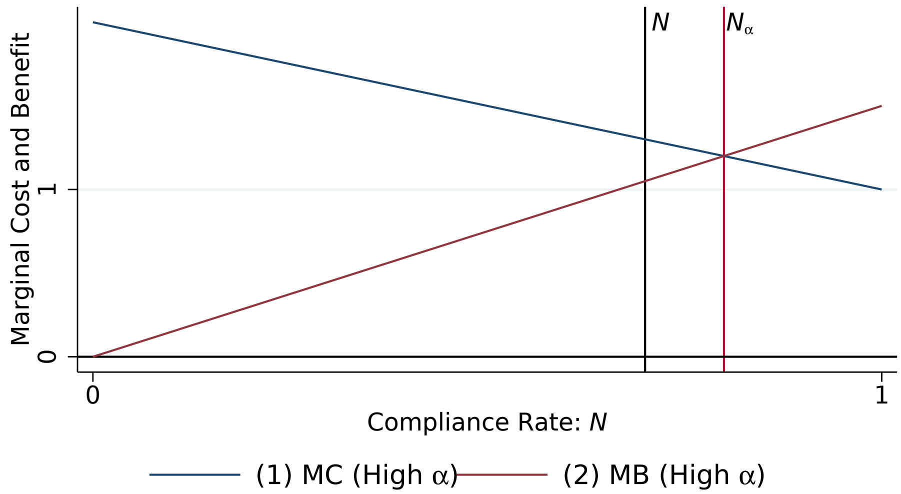
$$MVPF_{\rho} = \frac{v'(g)}{u'(\bar{c})} - \frac{\rho(1 - \gamma\pi_{l,\rho}^{\text{Pay}}\Delta c_{l,\rho}^{\text{Pay}})}{\frac{t-z}{\pi_{l}^{\text{Pay}}}\varepsilon_{\rho}^{\text{Pay}} + t\rho + (\rho - r) \times t[\varepsilon_{\rho}^{\text{Pay}} + \varepsilon_{\rho}^{\pi_l}]}.$$

The optimal value of ρ solves this expression when set equal to zero. From this expression, it follows that the government might set $\rho > r$ and therefore act as a "loan shark" if the value of providing public goods through loans exceeds the welfare cost of raising revenue in this way.

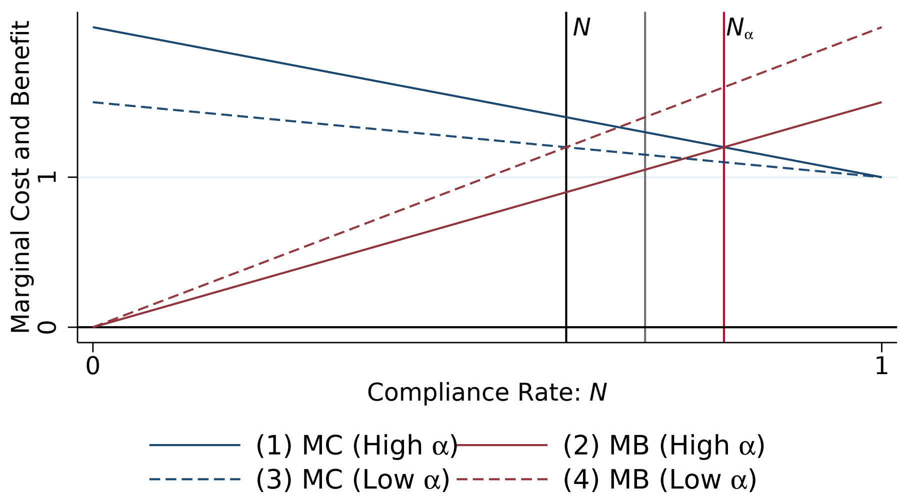
[65] We assume that only households that pay property taxes and have no savings may decide to take out a loan.

Figure A.1: N_α Equates the Marginal Cost and Benefit From Enforcement

A: $N_\alpha > N$: MC of Enforcement Exceeds MB



B: Effect of Lowering α



Notes: This figure plots the marginal cost and benefit of enforcement as well as the implied N_α. The marginal cost of enforcement (plotted in blue) is given by $(1-N)\frac{\frac{\partial m(\alpha)}{\partial \alpha}}{v'(g)}+1$, which includes the private and public costs of enforcement. The MC of enforcement is a decreasing function of N and equals 1 when $N = 1$ (this is because we assume $a(\alpha) = \alpha$, so that $\frac{\partial a(\alpha)}{\partial \alpha} = 1$). The marginal benefit of enforcement (plotted in red) is given by $(1-\tilde{z})\frac{Ht}{\alpha}\varepsilon_\alpha^{\text{Pay}}N$, which starts at the origin and increases with N. In Panel A, the MC equals the MB at N_α. This figure assumes that the observed compliance rate $N < N_\alpha$. At the observed compliance rate N, the MC of enforcement exceeds the MB, such that welfare would be increased by lowering α. Panel B shows the effect of lowering α. For lower values of α, the term $\frac{\partial m(\alpha)}{\partial \alpha}$ is smaller, resulting in a flatter MC curve (shown in the dashed line). For lower values of α, the elasticity $\varepsilon_\alpha^{\text{Pay}}$ is higher (i.e., initial enforcement efforts are more effective), resulting in a steeper MB curve (shown in the dashed line). In Panel B, MB equals MC at the new N, which is lower than N in Panel A.

B Context Appendix

Table B.1: Consumer debt in Mexico City

Variable	Mean (1)
Credit take-up	
Informal	.345
Formal	.302
Both	.084
None	.437
Informal borrower shares by type of lender (not exclusive)	
Pawnshop	.135
Friends	.32
Family	.729
Other	.013
Reasons for informality	
Voluntary	.578
Non-eligibility (lack of access)	.288
Initial costs	.125
Other	.009
Formal borrower shares by credit source (not exclusive)	
Credit card	.834
Bank loan	.113
Mortgage	.189
Car/Other	.079
Number of mortgages (liquidity constraints)	
One	1
Two or more	0
Use of formal credit	
Paying a bill	.161
Other	.839
Observations	877

Notes: The table examines consumer debt in Mexico City in 2018, using data from the national financial inclusion survey (*Encuesta Nacional de Inclusión Financiera*, ENIF). This is discussed in the Introduction.

Table B.2: Tax Schedule, 2009

Band	Cadastral Value Lower Limit (MXN)	Cadastral Value Upper Limit (MXN)	Lump-Sum Liability (MXN)	Tax Rate on Excess from Lower Limit (percent)	Percent Abatement on Liability
	(1)	(2)	(3)	(4)	(5)
A	0.11	162,740.82	32	0	0
B	162,740.83	325,481.16	37	0	0
C	325,481.17	650,963.56	45	0	0
D	650,963.57	976,444.70	55	0	0
E	976,444.71	1,301,927.10	737.28	0.09542	65
F	1,301,927.11	1,627,408.26	1,047.86	0.11091	45
G	1,627,408.27	1,952,889.39	1,408.85	0.11461	30
H	1,952,889.40	2,278,371.81	1,781.88	0.12522	20
I	2,278,371.82	2,603,852.96	2,189.45	0.13097	15
J	2,603,852.97	2,929,335.38	2,615.73	0.13478	10
K	2,929,335.39	3,254,816.51	3,054.42	0.13892	0
L	3,254,816.52	3,580,297.67	3,506.58	0.1427	0
M	3,580,297.68	3,906,090.04	3,971.04	0.15075	0
N	3,906,090.05	11,718,268.85	4,462.17	0.16278	0
O	11,718,268.86	24,663,843.29	17,178.84	0.16286	0
P	24,663,843.30		38,262.00	0.16902	0

Notes: This table presents an example of the annual tax schedule discussed in Section 2.2, focusing on the year 2009.

Table B.3: Abatements on Gross Tax Liability

Band	2008	2009	2010	2011	2012	2013
	(1)	(2)	(3)	(4)	(5)	(6)
G	30	30	30	30	20	20
H	20	20	20	0	0	0
I	15	15	0	0	0	0
J	10	0	0	0	0	0

Notes: This table displays the abatement rates discussed in Section 2.2.

Table B.4: Early-Bird Discounts and Payment Deadlines

Year	Super Early Bird		Early Bird		Reference Rates		
	Deadline	Discount	Deadline	Discount	Central Bank	Treasury Bonds	Mortgages
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2008	Jan 31	7%	Feb 28	4%	7.5%	7.42%	12.22%
2009	Jan 31	8%	Feb 28	4%	8.25%	7.59%	12.78%
2010	Jan 31	5%	Feb 28	0%	4.5%	4.49%	12.79%
2011	Jan 10	7%	Jan 31	3%	4.5%	4.14%	12.22%
2012	Jan 17	7%	Jan 31	4%	4.5%	4.27%	12.53%
2013	Jan 31	7%	Feb 28	6%	4.5%	4.15%	12.13%

Notes: This table displays the early-bird discount schedules discussed in Sections 2.3 and Appendix I. Discounts are applied to the annual tax liability. All interest rates are annualized.

Table B.5: Home Ownership in Mexico

Panel A: Renting vs Owning

	Homeowners	Renters	Others	P value
	(1)	(2)	(3)	(4)
Share of the population	62.1	14.2	23.6	
Average Monthly Labor Income (MXN)	3966.1	5394.7	3785.7	0.017
	(263.893)	(473.894)	(363.832)	
Number of Rooms	2.2	1.7	1.8	0.000
	(.048)	(.075)	(.064)	
Number of Household Members	4	3.5	3.7	0.127
	(.092)	(.166)	(.141)	
Age Head of Household	55.5	37	44.8	0.000
	(.748)	(1.466)	(1.348)	

Panel B: Homeowners Characteristics

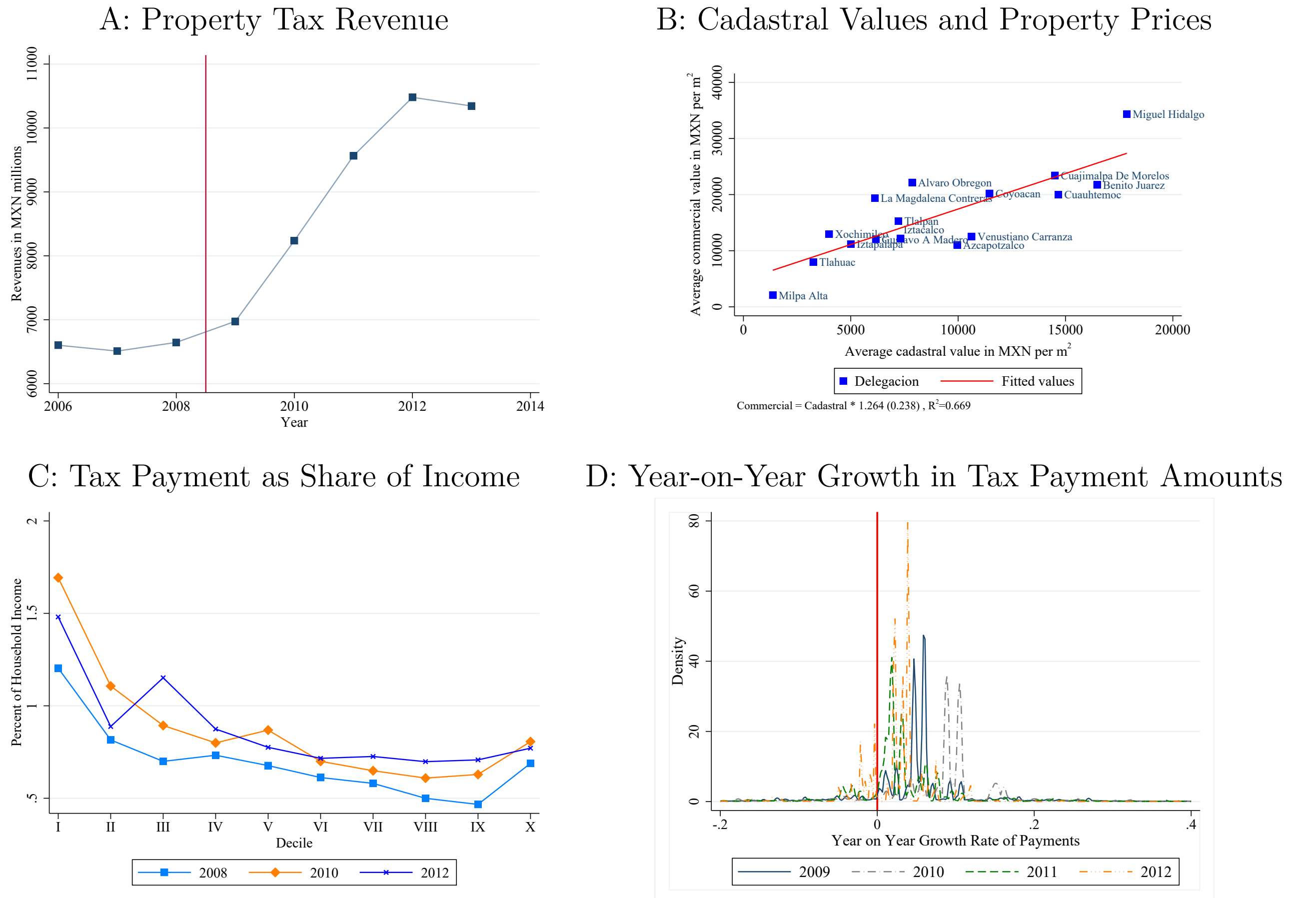
Home Financing	Current Mortgage	Pays Property Tax	Property Tax Payment Amount	Own a Second Home
(1)	(2)	(3)	(4)	(5)
14.3	9.9	56.6	300.3	5.4
(1.627)	(1.392)	(2.306)	(20.009)	(1.051)

Panel C: Home Financing

	Gender		Income Quintiles				
Total	Male	Female	Poorest	2nd	3rd	4th	Richest
(1)	(2)	(3)	(1)	(2)	(3)	(4)	(5)
4.3	4.8	3.9	0.0	2.3	8.0	5.0	6.1
(0.643)	(1.080)	(0.785)	(0.00)	(1.171)	(1.877)	(1.558)	(1.510)

Notes: The table examines home ownership in Mexico, as discussed in Section 2.3. Panel A and B displays summary statistics of Mexican households by ownership status, based on the 2014 ENVI (Encuesta Nacional de Vivienda) from the nationalinstitute of statistics. In panel A, the home status "Others" includes lent properties and properties under litigation. The P-values in panel A evaluate the differences between homeowners and renters. In Panel B, "Home Financing" indicates the share of owners that have received any kind of loan to finance their home purchase. Panel C displays the share of households with a mortgage in the country, and its demographic correlates, based on data from the 2017 World Bank Findex database. Standard errors are in parentheses. The difference in the share of observations with a mortgage in Panels B and C is driven by differences in the sample. Panels A and B are for Mexico City, while Panel C is for the whole country.

Figure B.1: Property Taxes in Mexico City

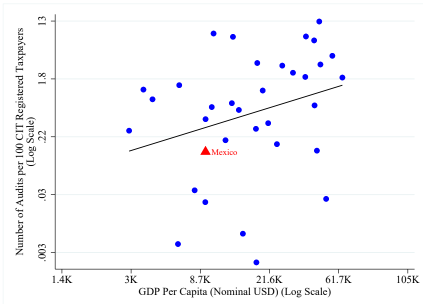


Notes: These figures show key facts about property taxes in Mexico City, and are discussed in Sections 2.1 and 2.2. Panel A shows the total property tax revenue by year for Mexico City in nominal terms from government records. Panel B shows the correlation between average cadastral and commercial property values at the *delegación*-level. Average commercial prices were obtained from propiedades.com, one of the largest real estate websites in Mexico. Prices were retrieved on the 4th of June of 2020, and they were discounted for inflation using INEGI's inflation calculator. Cadastral values are from the administrative data. Panel C plots the property tax payment reported in the ENIGH household survey (*Encuesta Nacional de Ingresos y Gastos de los Hogares*) as a share of total household income, conditional on property tax payment being non-zero. Each line corresponds to a different survey round. Panel D displays the year-on-year growth rate of property tax payments, $\frac{Pay_t - Pay_{t-1}}{Pay_{t-1}}$. The sample is restricted to taxpayers who made a payment in both year t and $t-1$. The figure shows that there is no anchoring of tax payments at the previous year's liability or tax payment amount, as liabilities are inflation-adjusted each year.

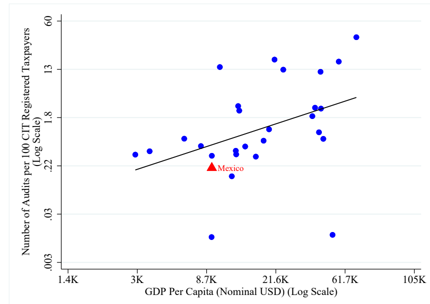
Figure B.2: Relevance and External Validity of the Mexico (City) Context

A: Tax Administration Capacity Around the World

A1: Comprehensive Audit Rate

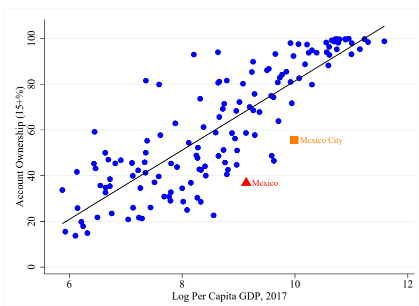


A2: CIT Audit Rate

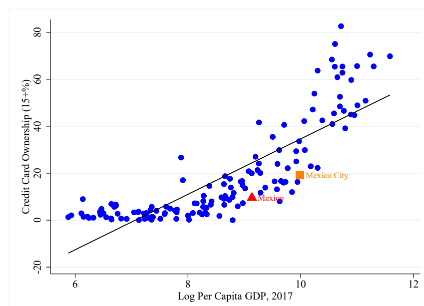


B: Household Liquidity Constraints Around the World

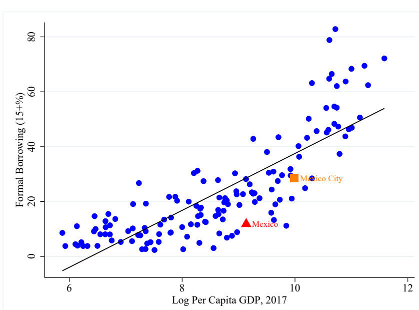
B1: Share of Adults with a Bank Account



B2: Share of Adults with a Credit Card



B3: Share of Adults with a Formal Loan



B4: Share of Adults Able to Cover an Emergency Expense from Savings

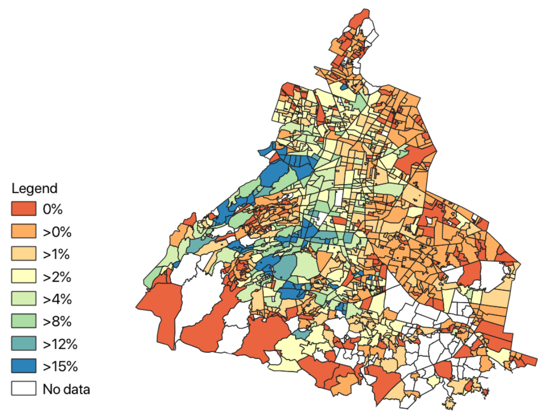
Notes: As discussed in the Introduction, this figure shows the correlation between measures of government tax administration capacity and household liquidity constraints with GDP per capita and the levels of these indicators for Mexico, as well as for Mexico City where available. The data for panels A1 and A2 are from the 2016 Revenue Administration Fiscal Information Tool (RA-FIT). The audit rate consists of the number of audits by each type conducted by the tax authority divided by the number of CIT-registered taxpayers. The data for panels B1–B4 are from the 2017 World Bank Findex database for all countries and from the 2018 National Financial Inclusion Survey for Mexico City. Panel B4 displays the share of adults who can cover an emergency (unexpected expense approximately equivalent to 500 USD) from personal savings (formal or informal). This statistic is not available for Mexico City only.

Figure B.3: Property Tax Bill

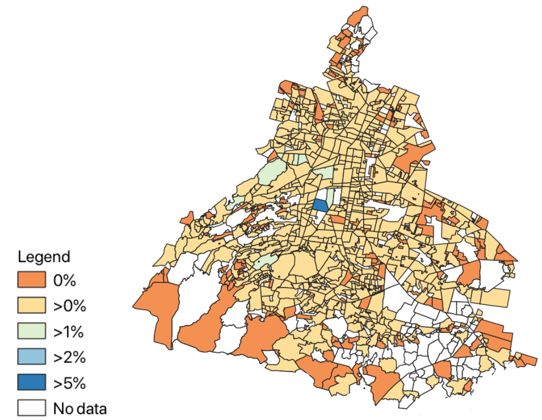
Notes: This figure displays a typical property tax bill sent to home owners, as discussed in Section 2.3.

Figure B.4: Distribution of Treated Properties Across Neighborhoods in Mexico City

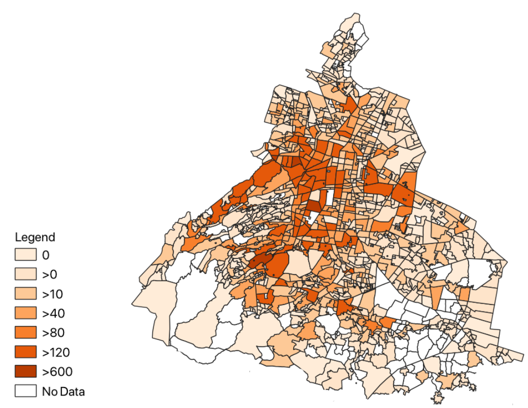
A: Neighborhood Density of Treated Properties



B: Distribution of Treated Properties



C: Count of Treated Properties



Notes: Panel A shows the density of treated properties within neighborhoods in Mexico City. The density is the number of treated properties in a given neighborhood divided by the total number of properties in the neighborhood. Panel B shows the distribution of treated properties across neighborhoods. For each neighborhood, we show the ratio between the number of treated properties in this neighborhood and the total number of treated properties in the City. Panel C shows the number of treated properties in each neighborhood. These maps are discussed in Section 2.2.

C Data Appendix

Table C.1: Summary Statistics
Panel A: Property Characteristics

	2008 (1)	2009 (2)	2010 (3)	2011 (4)	2012 (5)
Property Value (MXN)	585,320	617,487	613,493	609,478	605,346
	(1,121,680)	(1,185,320)	(1,180,471)	(1,174,999)	(1,169,283)
Yearly Liability (MXN)	1,457	1,540	1,630	1,704	1,788
	(10,097)	(10,671)	(11,214)	(11,607)	(11,985)
Mean Tax Rate × 100	.1112	.1114	.1198	.1259	.1323
	(.1243)	(.1245)	(.1349)	(.1427)	(.1532)

Panel B: Payment Characteristics

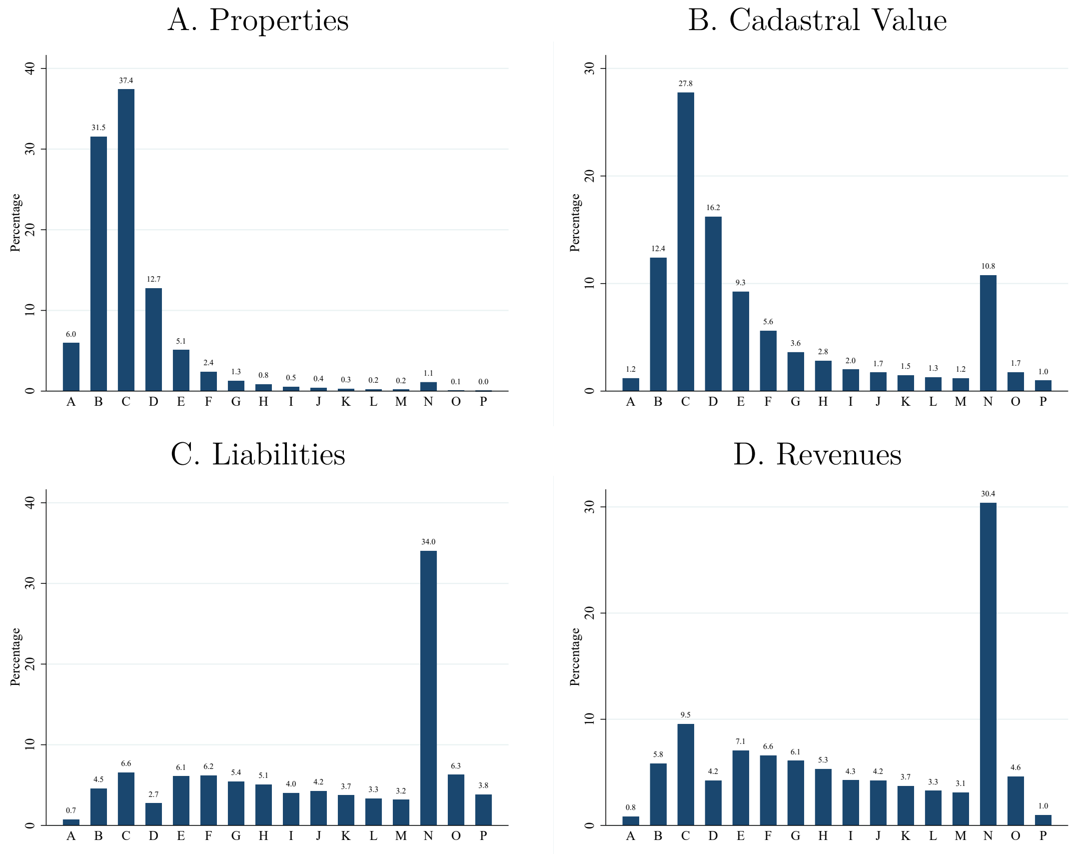
	2008	2009	2010	2011	2012
Payment (current MXN)	680	698	729	709	686
	(4078)	(4126)	(4439)	(4703)	(4563)
Compliance share	.628	.61	.591	.538	.488
	(.931)	(.711)	(.776)	(.62)	(1.149)
Payment type					
Zero payment	.275	.276	.307	.366	.432
	(.446)	(.447)	(.461)	(.482)	(.495)
Partial payment	.172	.174	.174	.136	.097
	(.377)	(.379)	(.379)	(.343)	(.296)
Early Full Payment	.413	.432	.416	.455	.461
	(.492)	(.495)	(.493)	(.498)	(.498)
Non-Early Full Payment	.141	.118	.103	.043	.01
	(.348)	(.323)	(.304)	(.204)	(.1)

Panel C: Penalties and Fees

	2008		2009	
	Mean (1)	Median (2)	Mean (3)	Median (4)
Late Payment Dummy (before due date 2)	.086		.085	
Inflation-Adjusted Liability (dummy)	.065		.053	
Inflation-Adjusted/Original Liability	1.299	1.222	1.164	1.193
Late Payment (after due date 2, within 2 years)	.065		.053	
Penalty Dummy	.005		0	
Surcharge Dummy	.065		.053	
Seizure Dummy	.001		0	
Penalty/Liability	.838	1	.226	.101
Surcharge/Liability	.183	.145	.154	.147
Seizure/Liability	.019	0	0	0
Total/Liability	1.299	1.222	1.164	1.193
Delinquent Taxpayer Dummy	.247		.252	

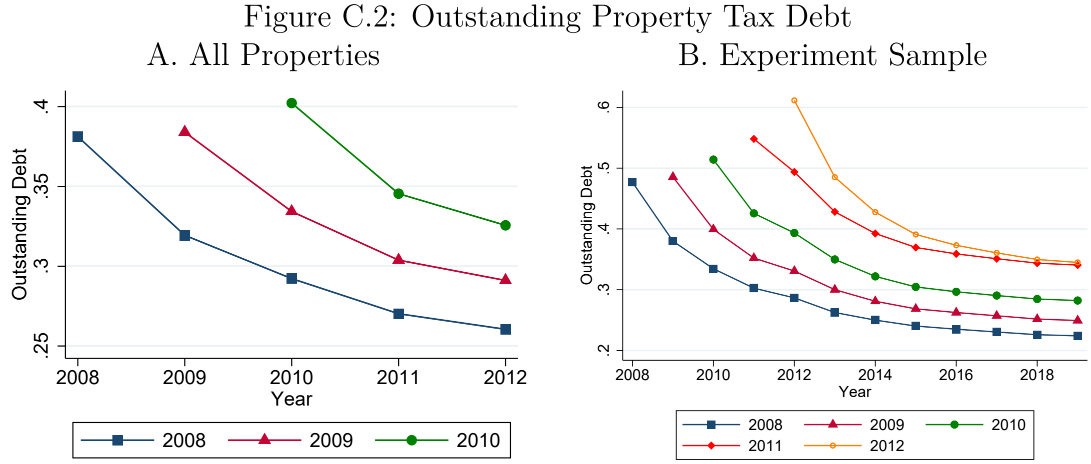
Notes: Panel A reports summary statistics for 1420,259 properties with an average land area of 126 (SE 381) square meters and an average construction area of 126 (SE 161) square meters. Panel B reports summary statistics on payments. Panel C reports summary statistics on penalties and fees from the administrative tax data discussed in Section 3.

Figure C.1: Distribution of Property Characteristics by Value Band



Notes: This figure shows the distribution of property characteristics by cadastral value band, as discussed in Section 3, for the balanced panel of residential properties in Mexico City whose cadastral value did not change between 2009 and 2012.

Figure C.2: Outstanding Property Tax Debt



Notes: This figure shows how the share of each year's unpaid tax liability evolves over time. This is referenced in Section 7.2. Panel A includes all taxpayers with outstanding tax debt. Panel B restricts the sample to taxpayers targeted in the enforcement intervention.

D RD Appendix

Table D.1: Identification Check for Regression Discontinuity Estimation

	Band I (2010)	Band H (2011)	Band G (2012)
	(1)	(2)	(3)
P-value ($H_0 : f^+_{\text{Value}} = f^-_{\text{Value}}$)	.444	.828	.752
q	138	190	250
N (left)	1647	2237	3076
N (right)	1059	2109	3501
Total N	2706	4346	6577
Effective N (left)	74	97	122
Effective N (right)	64	93	128

Notes: This table reports results from the RD validity test proposed by Bugni and Canay (2020), as discussed in Section 4.1. This test examines the continuity of the running variable at the cut-off, an implication of the assumption of no manipulation. In particular, the fraction of units under treatment and control should be similar at both sides. The test statistic exploits the fact that, under the null, the number of treated units out of the q observations closest to the cut-off is approximately distributed as a binomial with sample size q and probability $\frac{1}{2}$. The paper proposes a data-dependent rule for q, the number of "effective" observations near the cut-off.

Table D.2: Robustness of Regression Discontinuity Estimation – Using Local Linear Regressions with Optimal Bandwidth

	Mean Tax Rate (basis points)	Payment Amount (MXN thousands)	Payment in Full (percentage points)	Compliance Share × 100
	(1)	(2)	(3)	(4)
	I. Estimates for the 2009-2010 treatment			
T	8.923 ***	.61 *	-8.426 **	-2.471
	(.105)	(.323)	(3.606)	(2.641)
Properties	17864	17864	17864	17864
Mean at Baseline (treated band)	50.112	5.836	36.626	47.881
Implied Elasticity		.587	-1.292	-.29
		(.311)	(.553)	(.31)
	II. Estimates for the 2012-2011 treatment			
T	12.109 ***	.667 ***	-5.8 **	-3.019
	(.033)	(.16)	(2.573)	(2.032)
Properties	28094	28094	28094	28094
Mean at Baseline (treated band)	47.461	4.734	35.072	47.478
Implied Elasticity		.552	-.648	-.249
		(.133)	(.288)	(.168)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.918	.302	.908
	III. Estimates for the 2011-2012 treatment			
T	17.958 ***	.644 ***	-9.615 ***	-3.833 *
	(.018)	(.134)	(1.567)	(2.051)
Properties	48838	48838	48838	48838
Mean at Baseline (treated band)	41.06	3.287	37.969	44.885
Implied Elasticity		.448	-.579	-.195
		(.093)	(.094)	(.104)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.52	.819	.785
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.668	.204	.772

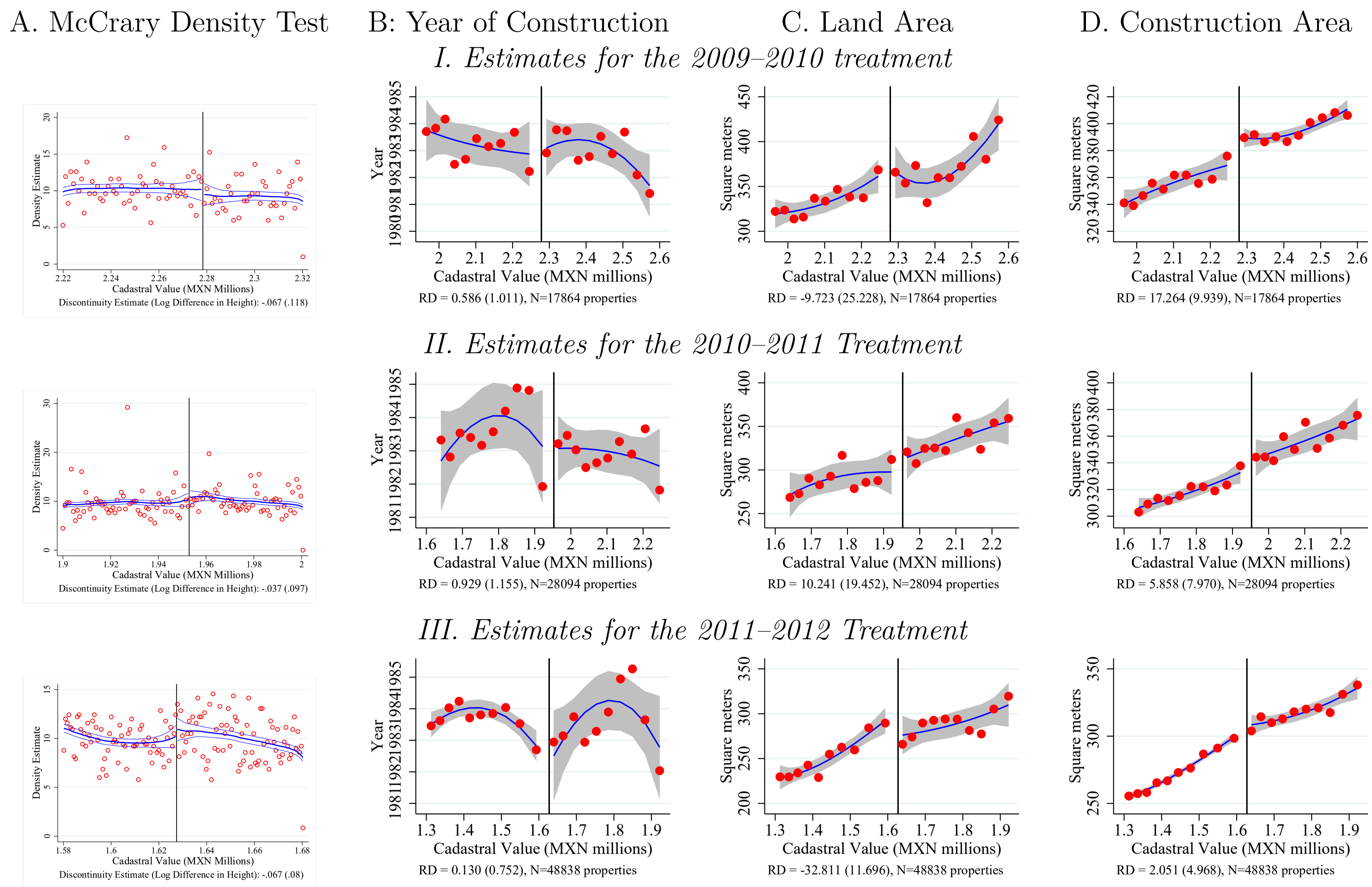
Notes: This table is identical to Table 1, but uses local linear regressions with optimal bandwidth as in Calonico et al. 2014. The estimates are statistically indistinguishable from the preferred specification.

Table D.3: Robustness of Regression Discontinuity Estimation – Differences-in-Discontinuities Estimates

	Mean Tax Rate (basis points)	Payment Amount (MXN thousands)	Payment in Full (percentage points)	Compliance Share × 100
	(1)	(2)	(3)	(4)
	I. Estimates for the 2009-2010 treatment			
β_1	8.23 ***	1.019 ***	-5.377 ***	1.521
	(.05)	(.183)	(1.695)	(1.399)
Properties	17864	17864	17864	17864
Years of Data	4	4	4	4
Adjusted R-Squared	.318	.005	.002	.001
Mean at Baseline (treated band)	50.112	5.836	36.626	47.881
Implied Elasticity		1.063	-.894	.193
		(.191)	(.282)	(.178)
P-value ($H_0 : \beta_0 = \beta_1$)	.000	.000	.000	.915
	II. Estimates for the 2010-2011 treatment			
β_1	9.71 ***	.445 ***	-2.568 **	-3.584 ***
	(.066)	(.12)	(1.248)	(1.081)
Properties	28094	28094	28094	28094
Years of Data	4	4	4	4
Adjusted R-Squared	.31	.005	.003	.002
Mean at Baseline (treated band)	47.461	4.734	35.072	47.478
Implied Elasticity		.459	-.358	-.369
		(.124)	(.174)	(.111)
P-value ($H_0 : \beta_0 = \beta_1$)	.000	.000	.009	.013
	III. Estimates for the 2011-2012 treatment			
β_1	20.017 ***	.503 ***	-11.621 ***	-7.285 ***
	(.038)	(.071)	(1)	(.932)
Properties	48838	48838	48838	48838
Years of Data	4	4	4	4
Adjusted R-Squared	.934	.006	.003	.002
Mean at Baseline (treated band)	41.06	3.287	37.969	44.885
Implied Elasticity		.314	-.628	-.333
		(.045)	(.054)	(.043)
P-value ($H_0 : \beta_0 = \beta_1$)	.000	.000	.000	.000

Notes: This table shows, as discussed in section 4.1, the effect of the tax rate changes driven by the abatement removal, in excess of the effect of the smaller year-on-year tax rate changes, given by β_1 in the estimating equation $\Delta Y_{i,t} = \alpha_0 + \beta_0 T_i + f_0(\hat{V}_i) + g_0(\hat{V}_i)T_i + [\alpha_1 + \beta_1 T_i + f_1(\hat{V}_i) + g_1(\hat{V}_i)T_i]D_t + \epsilon_{i,t}$, where D_t is an indicator for the time period when the abatement is removed. This equation is very similar to our main estimates in Table 1.

Figure D.1: Identification Tests for Regression Discontinuity Estimation

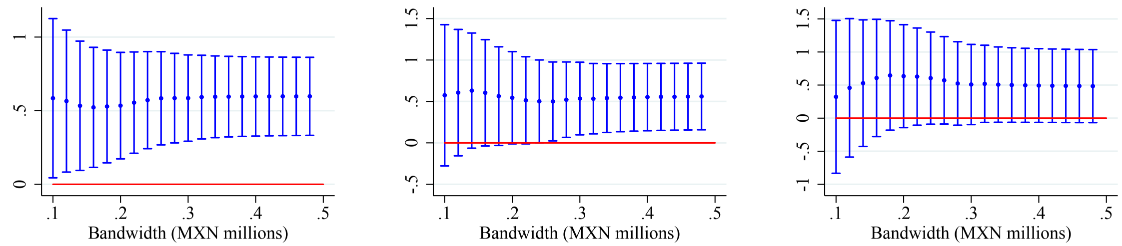


Notes: The panels in column A display the density of properties by cadastral value around the lower threshold of bands I, H and G, which were treated with large tax rate increases. We test for a discontinuity in the density at the threshold, as proposed by McCrary 2008. In columns B-D, we test for discontinuities in property characteristics around the treatment thresholds and find no significant differences. The graphs are constructed as in Figures 3 and 4. These results are discussed in Section 4.1.

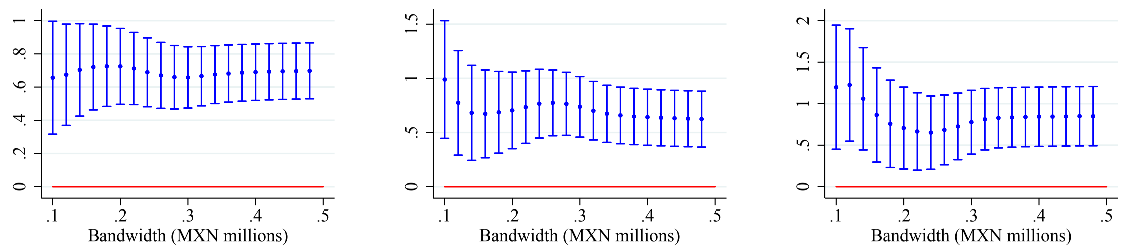
Figure D.2: Robustness of Regression Discontinuity Estimates by Bandwidth and Degree of Polynomial

A. Polynomial of Degree 1   B. Polynomial of Degree 2   C. Polynomial of Degree 3

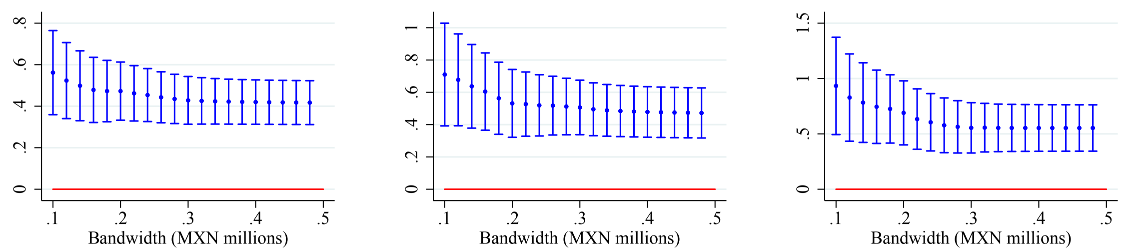
I. Estimates for the 2009–2010 Treatment



II. Estimates for the 2010–2011 Treatment



III. Estimates for the 2011–2012 Treatment



Notes: This figure documents the robustness of our RD estimations, as discussed in Section 4.1 and displayed in Figures 3. We focus on the payment amount as outcome. Each panel plots the point estimates and 95% confidence intervals of the treatment effect for different bandwidth values between 0.1 and 0.5 MXN millions in 0.02 increments (horizontal axis). Each row reports results for the different treatments, and each column presents the estimates for a different polynomial in cadastral value.

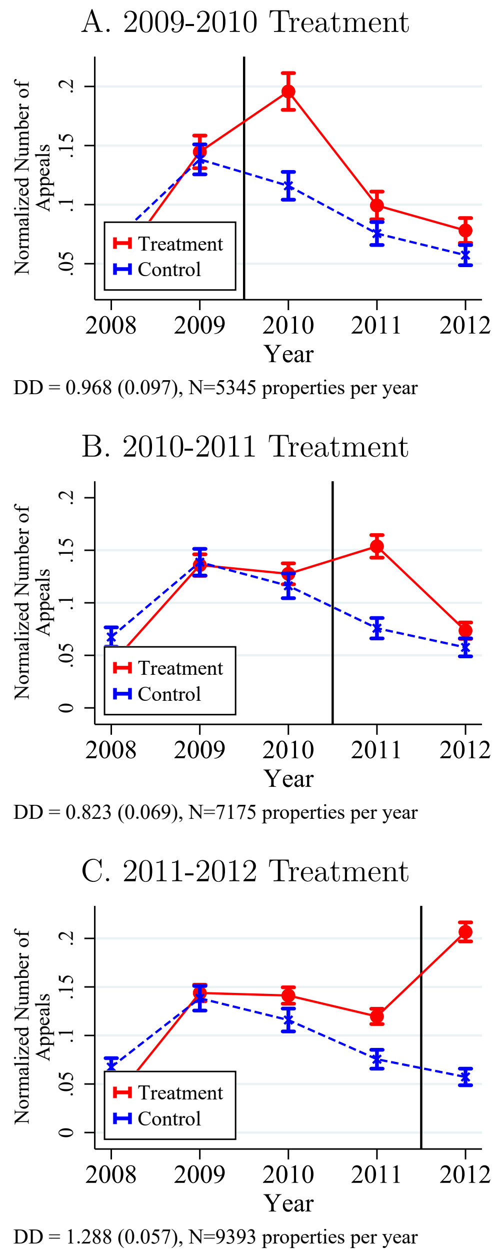
Table D.4: The Effect of Tax Rates on Tax Payment – Regression Discontinuity Estimates Robustness to Dropping Taxpayers with Exemptions

	Mean tax rate (basis points)	Payment amount (MXN thousands)	Payment in full (percentage points)	Compliance share × 100
	(1)	(2)	(3)	(4)
		I. Estimates for the 2010 treatment		
T	9.115 ***	.592 **	-4.916 **	-2.836
	(.066)	(.259)	(2.33)	(2.184)
Properties	15190	15190	15190	15190
Adjusted R-squared	.98	.008	.003	.001
Mean at baseline (treated band)	50.109	5.635	39.227	46.239
Implied elasticity		.577	-.689	-.337
		(.252)	(.327)	(.26)
Implied Semi-elasticity		.012	-.014	-.007
		(.005)	(.007)	(.005)
		II. Estimates for the 2011 treatment		
T	12.141 ***	.679 ***	-6.18 ***	-3.268 **
	(.035)	(.133)	(1.717)	(1.298)
Properties	23882	23882	23882	23882
Adjusted R-squared	.993	.017	.003	.001
Mean at baseline (treated band)	47.473	4.546	37.465	45.552
Implied elasticity		.584	-.645	-.281
		(.114)	(.179)	(.111)
Implied Semi-elasticity		.012	-.014	-.006
		(.002)	(.004)	(.002)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.981	.906	.841
		III. Estimates for the 2012 treatment		
T	17.998 ***	.571 ***	-10.469 ***	-6.001 ***
	(.028)	(.092)	(1.535)	(1.295)
Properties	41040	41040	41040	41040
Adjusted R-squared	.996	.027	.008	.003
Mean at baseline (treated band)	41.073	3.367	40.627	46.04
Implied elasticity		.387	-.588	-.297
		(.062)	(.086)	(.064)
Implied Semi-elasticity		.009	-.014	-.007
		(.002)	(.002)	(.002)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.131	.775	.895
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.465	.765	.882

Notes: This Table is identical to Table 1 but excludes taxpayers who ever got a subsidy or exemption. It demonstrates the robustness of the RD results to dropping these taxpayers.

E DiD Appendix

Figure E.1: The Effect of Tax Rates on Appeals



Notes: This figure is identical to Figure 5, but the outcome variable is a dummy capturing whether or not the property owner appealed against the property tax liability. We restrict the sample to taxpayers making a payment every year, as we observe the appeals only for these taxpayers. Hardly any of the appeals result in a change in the tax liability (footnote 23). When calculating the DiD estimates displayed under the graphs, we take into account only the first post-reform year, as the graphical evidence suggests that the increase in appeals is primarily limited to the first post-reform year. Among taxpayers in the treatment group (in the restricted sample of taxpayers making a payment each year), the share filing an appeal is 14.46% in 2009, 12.76% in 2010 and 11.96% in 2011. These results are discussed in Section 4.2.

Table E.1: The Effect of Tax Rates on Tax Payment – Differences-in-Differences Estimates
Robustness to Using Only One Post-Reform Period

	Mean tax rate	Payment amount	Payment in full	Compliance share
	(1)	(2)	(3)	(4)
		I. Estimates for the 2010 treatment		
DD	.171 ***	.110 ***	-.136 ***	-.034 ***
	(.000)	(.018)	(.019)	(.012)
Adjusted R-squared	.996	.014	.006	.002
Properties (treatment)	5747	5747	5747	5747
Properties (control)	6510	6510	6510	6510
Implied elasticity		.643	-.794	-.200
		(.106)	(.113)	(.07)
		II. Estimates for the 2011 treatment		
DD	.236 ***	.163 ***	-.178 ***	-.063 ***
	(.000)	(.022)	(.017)	(.011)
Adjusted R-squared	.993	.008	.006	.009
Properties (treatment)	9661	9661	9661	9661
Properties (control)	6511	6511	6511	6511
Implied elasticity		.690	-.753	-.267
		(.092)	(.071)	(.047)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.777	.812	.279
		III. Estimates for the 2012 treatment		
DD	.401 ***	.196 ***	-.300 ***	-.182 ***
	(.000)	(.029)	(.014)	(.010)
Adjusted R-squared	.994	.003	.016	.038
Properties (treatment)	15227	15227	15227	15227
Properties (control)	6508	6508	6508	6508
Implied elasticity		.489	-.747	-.455
		(.073)	(.035)	(.025)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.016	.021	.000
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.023	.048	.000

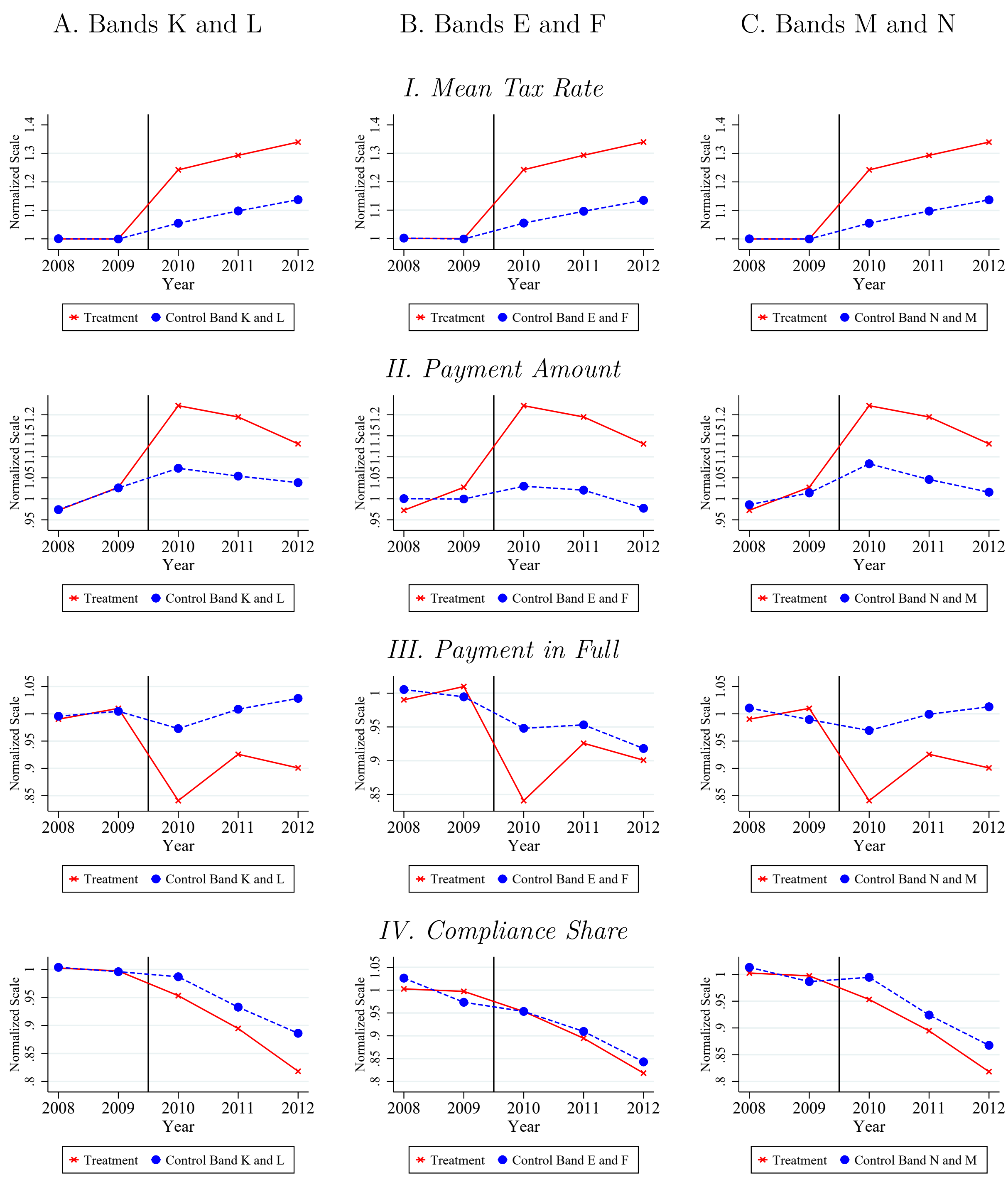
Notes: This table is identical to Table 2 but uses only one post-reform period for each reform episode. This confirms the robustness of our main DiD estimates, in which we use between one and three post-reform years, depending on the reform. These results are discussed in Section 4.2.

Table E.2: The Effect of Tax Rates on Tax Payment – Differences-in-Differences Estimates Robustness to Different Control Bands

	Mean Tax Rate (basis points)	Payment amount (MXN thousands)	Payment in full	Compliance share
	(1)	(2)	(3)	(4)
		I. Estimates for the 2009-2010 treatment		
K and L	.166	.116	-.103	-.041
	(.000)	(.017)	(.017)	(.011)
E and F	.255	.169	-.029	-.001
	(.000)	(.010)	(.013)	(.009)
M and N	.275	.163	.001	.024
	(.000)	(.010)	(.013)	(.009)
K,L,E,F,M and N	.268	.165	-.018	.01
	(.000)	(.010)	(.013)	(.009)
		II. Estimates for the 2010-2011 treatment		
K and L	.232	.169	-.149	-.07
	(.000)	(.02)	(.015)	(.010)
E and F	.331	.175	-.073	-.038
	(.000)	(.008)	(.010)	(.007)
M and N	.355	.166	-.021	.018
	(.000)	(.008)	(.010)	(.007)
K,L,E,F,M and N	.347	.17	-.049	-.008
	(.000)	(.008)	(.010)	(.007)
		III. Estimates for the 2011-2012 treatment		
K and L	.401	.196	-.3	-.182
	(.000)	(.029)	(.014)	(.010)
E and F	.517	.16	-.216	-.145
	(.000)	(.009)	(.009)	(.007)
M and N	.545	.138	-.161	-.087
	(.000)	(.009)	(.009)	(.007)
K,L,E,F,M and N	.536	.151	-.189	-.114
	(.000)	(.009)	(.009)	(.006)

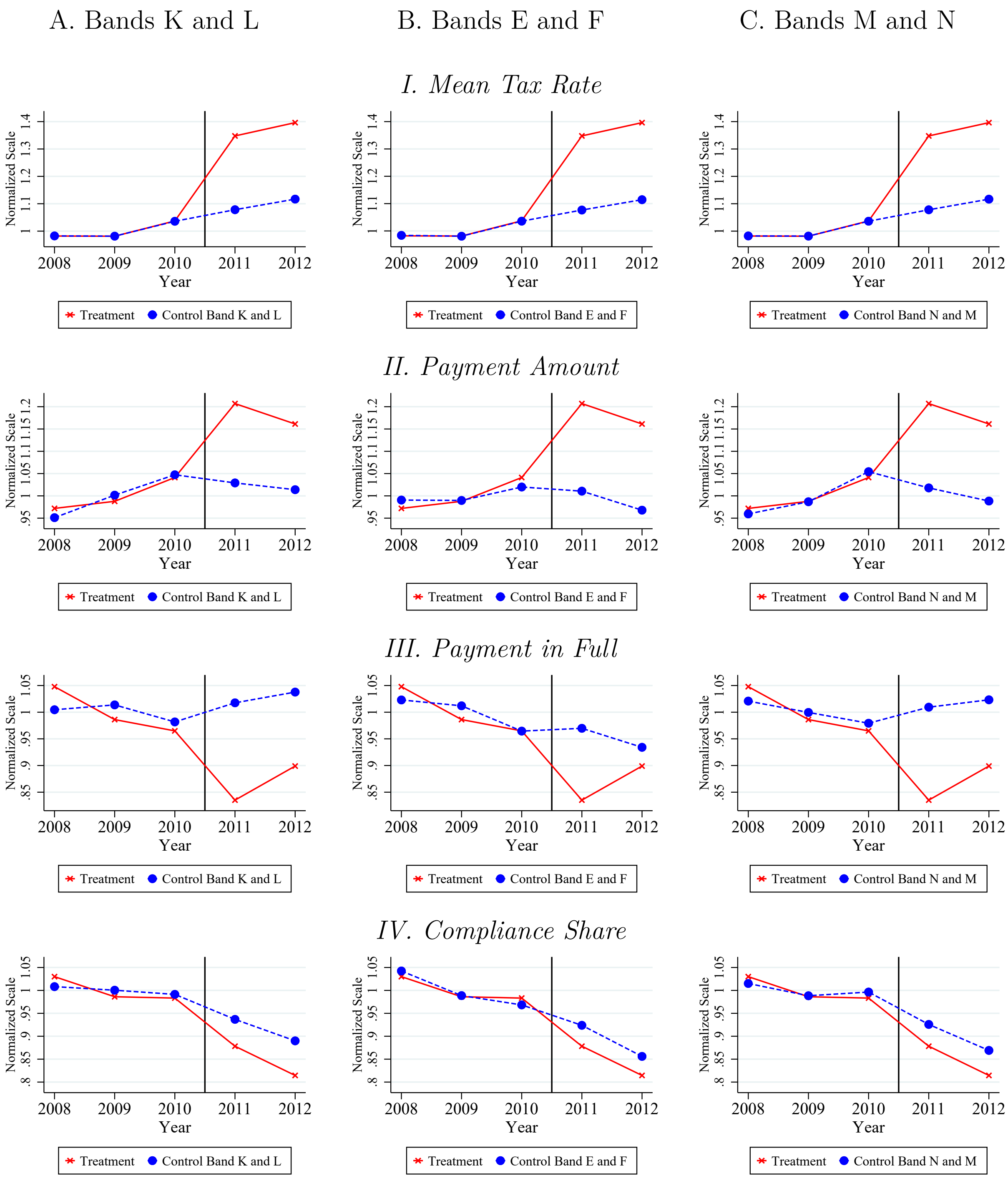
Notes: This table is similar to Table 2, but displays the point estimates from the DiD estimation using alternative value bands as control groups. In each panel, the first line reproduces our preferred estimates from Table 2, using properties in bands K and L as control group. The remaining lines display estimates using alternative control groups. Using band J as a control group is not an option, as properties in this band were treated in 2008-2009. The table shows that our preferred specification yields results that are similar to the alternative specifications, but slightly less optimistic about the tax rate increases. In our preferred specification, tax payments increase a bit less and compliance falls a bit more than in alternative specifications. Yet we still conclude that tax rate increases are welfare improving. Choosing a different specification would only strengthen this conclusion. These results are discussed in Section 4.2.

Figure E.2: Parallel Trends with Different Control Groups - 2009-2010 Treatment



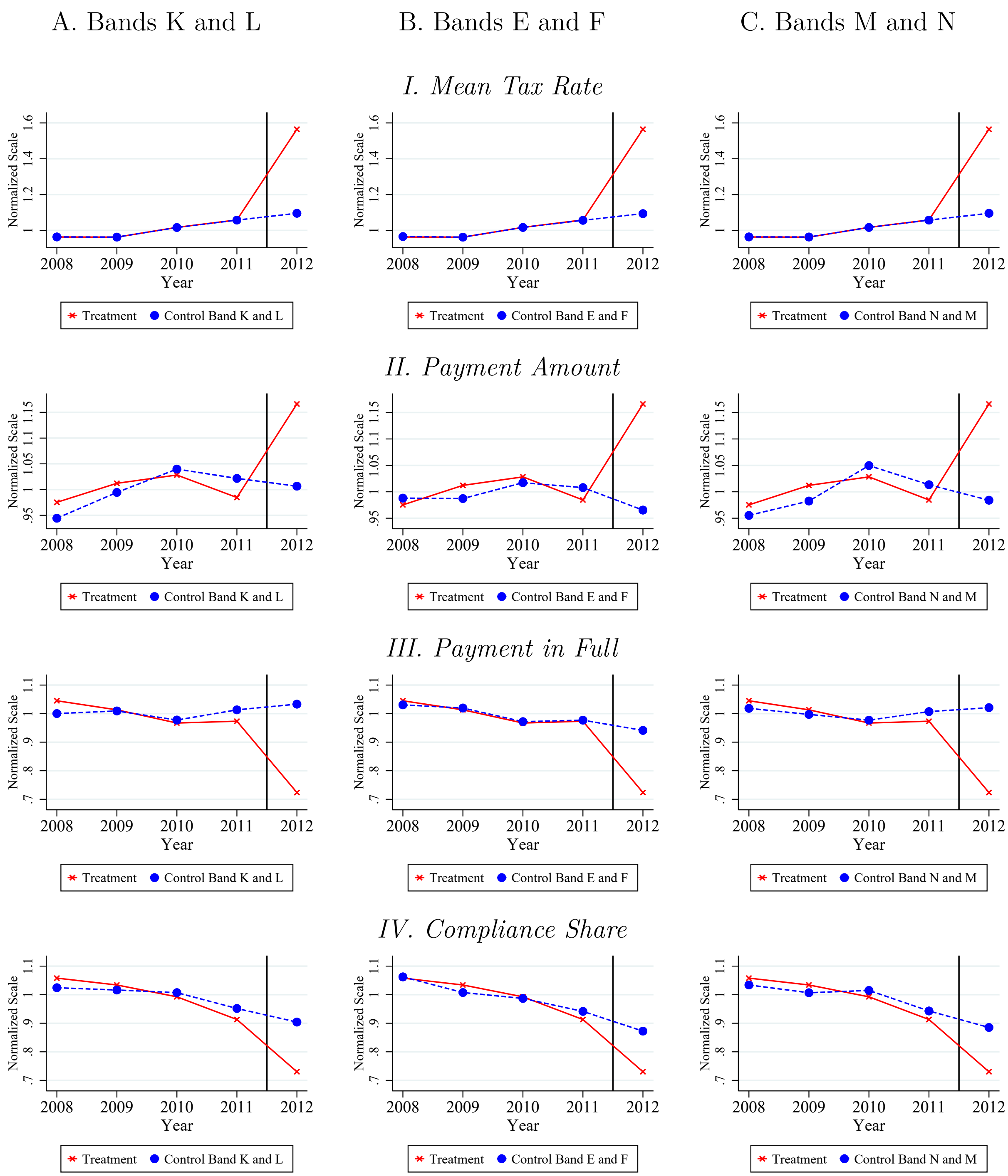
Notes: This figure is similar to Figures 5 and 6, but considers two alternative control groups: bands E and F (column B), and bands M and N (column C). Using band J as a control group is not an option, as properties in this band were treated in 2008-2009. Column A reproduces the preferred specification in which bands K and L are the control group. The treated band in this figure contains properties in band I, as the figure focuses on the 2009-2010 reform, in which properties in band I were treated with a quasi-exogenous tax rate increases. Figures E.3 and E.4 show similar graphs, focusing on the 2010-2011 and the 2011-2012 reforms respectively. The corresponding DiD estimates for all reform episodes are displayed in Table E.2. These results are discussed in Section 4.2.

Figure E.3: Parallel Trends with Different Control Groups - 2010-2011 Treatment



Notes: This figure is identical to Figure E.2 but focuses on the 2010-2011 reform, in which properties in band H were treated with a quasi-exogenous tax rate increase. The treatment group in this figure thus contains properties in band H. The corresponding DiD estimates are displayed in Table E.2.

Figure E.4: Parallel Trends with Different Control Groups - 2011-2012 Treatment



Notes: This figure is identical to Figure E.2 but focuses on the 2011-2012 reform, in which properties in band G were treated with a quasi-exogenous tax rate increase. The treatment group in this figure thus contains properties in band G. The corresponding DiD estimates are displayed in Table E.2.

Table E.3: The Effect of Tax Rates on Tax Payment – Differences-in-Differences Estimates Robustness to Dropping Taxpayers with Exemptions

	Mean tax rate	Payment amount	Payment in full	Compliance share
	(1)	(2)	(3)	(4)
		I. Estimates for the 2010 treatment		
DD	.167 ***	.084 ***	-.093 ***	-.048 ***
	(.000)	(.019)	(.018)	(.012)
Adjusted R-squared	.998	.011	.005	.004
Properties (treatment)	4854	4854	4854	4854
Properties (control)	5530	5530	5530	5530
Implied elasticity		.502	-.558	-.289
		(.112)	(.107)	(.074)
Implied Semi-elasticity		.01	-.011	-.006
		(.002)	(.002)	(.001)
		II. Estimates for the 2011 treatment		
DD	.232 ***	.107 ***	-.142 ***	-.077 ***
	(.000)	(.021)	(.015)	(.011)
Adjusted R-squared	.995	.012	.004	.008
Properties (treatment)	8194	8194	8194	8194
Properties (control)	5531	5531	5531	5531
Implied elasticity		.463	-.611	-.332
		(.092)	(.066)	(.047)
Implied Semi-elasticity		.01	-.013	-.007
		(.002)	(.001)	(.001)
P-value ($H_0 : \epsilon_{2011} = \epsilon_{2010}$)		.489	.331	.393
		III. Estimates for the 2012 treatment		
DD	.401 ***	.14 ***	-.282 ***	-.16 ***
	(.000)	(.031)	(.015)	(.011)
Adjusted R-squared	.993	.009	.013	.019
Properties (treatment)	12928	12928	12928	12928
Properties (control)	5528	5528	5528	5528
Implied elasticity		.35	-.705	-.399
		(.077)	(.037)	(.027)
Implied Semi-elasticity		.009	-.017	-.01
		(.002)	(.001)	(.001)
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2011}$)		.182	.000	.006
P-value ($H_0 : \epsilon_{2012} = \epsilon_{2010}$)		.071	.000	.002

Notes: This Table is identical to Table 2 but excludes taxpayers who ever got a subsidy or exemption. It demonstrates the robustness of the DiD results to dropping these taxpayers. These results are discussed in Section 4.2.

Table E.4: The Effect of Tax Rates on Tax Payment – Differences-in-Differences Estimates
Robustness to Different Clustering Levels

		Standard Error Cluster Level:		
	Point Estimate	Taxpayer	Postal Code	Bootstrap Delegacion
	(1)	(2)	(3)	(4)
	I. Estimates for the 2009-2010 treatment			
Mean Tax Rate (basis points)	.166	.007	.007	.015
Payment amount (MXN thousands)	.116	.017	.017	.016
Payment in full (percentage points)	-.103	.006	.006	.005
Compliance share × 100	-.041	.536	.536	.387
	II. Estimates for the 2010-2011 treatment			
Mean Tax Rate (basis points)	.232	.006	.006	.026
Payment amount (MXN thousands)	.169	.020	.020	.031
Payment in full (percentage points)	-.149	.005	.005	.004
Compliance share × 100	-.07	.482	.482	.406
	III. Estimates for the 2011-2012 treatment			
Mean Tax Rate (basis points)	.401	.006	.006	.037
Payment amount (MXN thousands)	.196	.029	.029	.038
Payment in full (percentage points)	-.300	.006	.006	.005
Compliance share × 100	-.182	.498	.498	.562

Notes: This table is similar to Table 2. Column 1 displays the point estimates from the DiD estimation. Columns 2-4 display the standard errors at different clustering levels. Column 4 performs a bootstrap where the 16 *delegaciones* are the resampling clusters.

Table E.5: Robustness of Tax Rate Elasticity Estimations - Panel Regressions

	Mean tax rate (1)	Payment amount (2)	Payment in full (3)	Compliance share (4)
		A. Value Band FE		
PE Tax Rate		.694 ***	-.203 ***	-.132 ***
		(.086)	(.046)	(.045)
Tax Rate Elasticity		.694	-.551	-.292
		(.086)	(.125)	(.098)
Mean Tax Rate	49.53			
Mean		11301.63	.37	.45
Cadastral Value Band FE		Yes	Yes	Yes
Year FE		Yes	Yes	Yes
Band G, H, I * Tax Rate		No	No	No
Observations		80	80	80
		B. Heteregeneity by treated bands		
PE Tax Rate		.702 **	-.294 **	-.115
		(.275)	(.146)	(.142)
PE Treated Bands * Tax Rate		-.006	.072	-.014
		(.205)	(.109)	(.106)
Tax Rate Elasticity Control Bands		.702	-.799	-.254
		(.275)	(.396)	(.313)
Tax Rate Elasticity Treated Bands		.696	-.604	-.284
		(.038)	(.055)	(.044)
Mean Tax Rate	49.53			
Mean		11301.63	.37	.45
Cadastral Value Band FE		Yes	Yes	Yes
Year FE		Yes	Yes	Yes
Band G, H, I * Tax Rate		Yes	Yes	Yes
Observations		80	80	80

Notes: This table demonstrates the robustness of the estimates for the elasticity of tax compliance to the tax rate, displayed in Tables 1 and 2. Panel A here displays estimates for $Y_{it} = \beta_1 R_{it} + \gamma_i + \delta_t + \epsilon_{it}$, where Y_{it} is the average outcome for band i in year t, R_{it} is the log average tax rate for band i in year t , δ_t and γ_i denote year and value band fixed effects, and ϵ_i is the error term. Payment is in logs, the other outcomes are not. The elasticities are calculated as in Table 2. Standard errors are parenthesis. Panel B is similar to Panel A but includes an interaction between the tax rate and an indicator for bands G, H and I (treated bands in the RD and DiD estimations). The elasticity estimates are very similar to our main RD and DiD estimates.These results are discussed in Section 4.2.

F Real Response Appendix

A potential concern for tax rate increases is that, while they may raise revenue, they may also be accompanied by a reduction in real estate investment. One possibility is that owners of existing properties might be less likely to invest in maintaining or upgrading their properties. However, because the cadastral value of a given property would not be affected by maintenance or upgrades, raising property tax rates does not disincentivize these forms of investment. Nonetheless, it may be the case that higher property tax rates can decrease investment in new housing units.

One way in which developers can respond to the tax rate hikes is by using the cadastral value formula to design houses so that they fall below the threshold of a given value band. To test for this, Panels A and B of Figure F.1 plot the number of properties built after the 2010 and 2011 tax increases.[66] We group properties into small cadastral value bins around the lower threshold of each treated value band. If the tax rate increase dissuaded developers from building properties in this value band, we should see a bunching of new properties just below the lower threshold of the treated band. The graphs show that this is not the case: the number of new properties is weakly decreasing with property value and is smooth around the threshold of the treated band. That is, we find no evidence of bunching. To further investigate this type of response, Panels C and D of Figure F.1 plot the percentage change in new properties by bin, relative to the average number of new units in the previous two years. As in the previous graphs, there is no sign of bunching and no discontinuity at the threshold of the treated band.

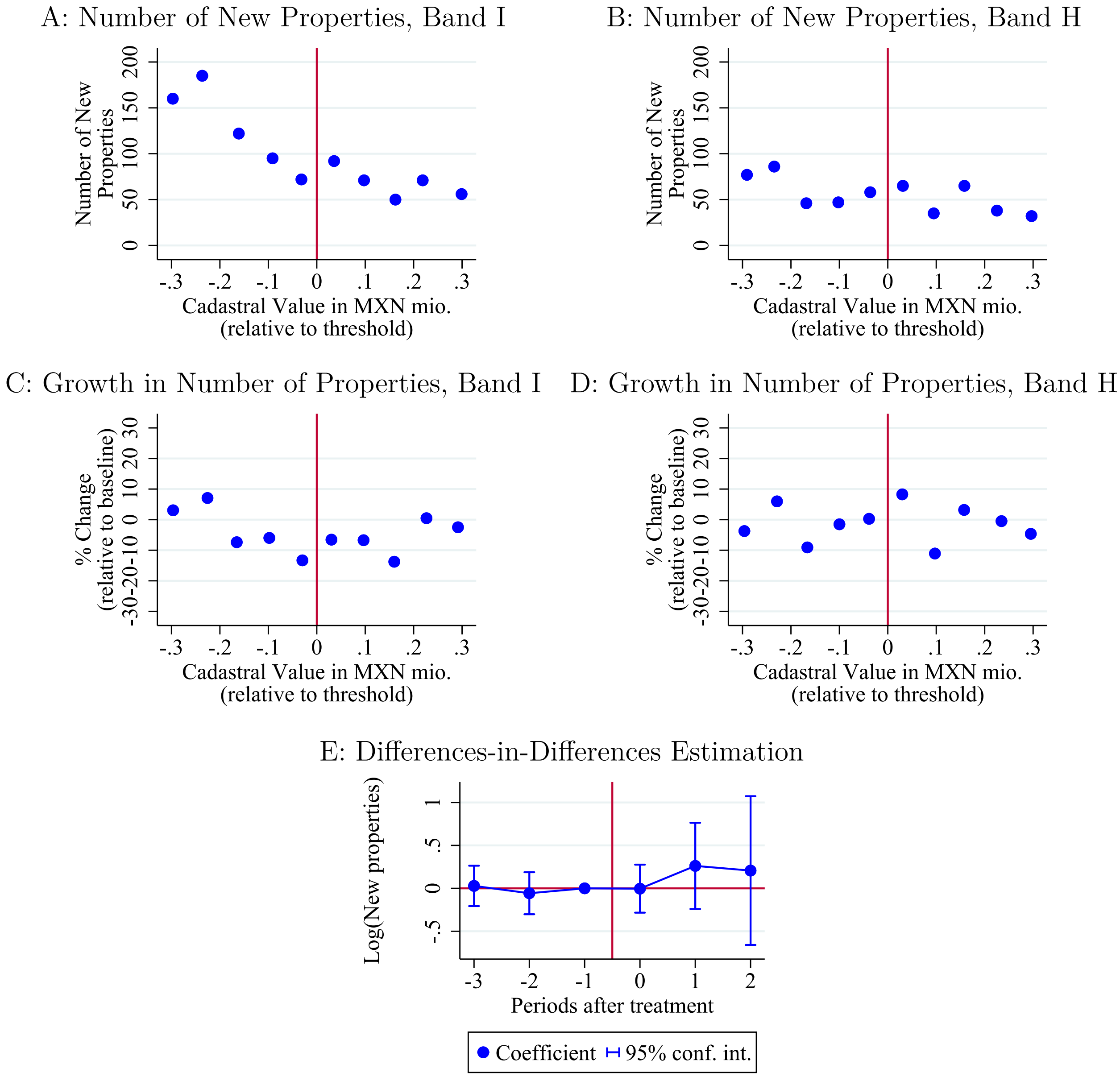
Building on our analyses in Section 4.2, we also conduct a DiD analysis on the number of new property developments. To do so, we first rank properties by cadastral value and divide each value band into 5 sub-bins of equal size. We then construct a count of the number of new properties in each sub-bin and year. Finally, we estimate a regression similar to Equation 6 where the outcome is the log number of new properties at the sub-bin–year level. Panel E in Figure F.1 shows the results of this estimation where we stack the 2010 and 2011 reforms and where we use properties in bands K and L as controls. This figure shows that we do not find a decrease in the number of new properties in bands that experience increases in property tax rates.

Although other studies have found evidence of real responses to property tax changes (e.g., Singh 2020), our results can be rationalized when considering the context. The quasi-exogenous tax rate increases we study apply to a very small range of property values. To determine whether their future properties would fall into one of the treated bands, property developers need precise knowledge of the tax code and clarity on the exact features of the property to be constructed. The applicability of the tax rate changes may be too narrow to warrant such an analysis. In addition, developers may anticipate future tax rate changes, reducing responsiveness to recent reforms.

Overall, we do not find evidence that increases in property tax rates disincentivized the construction of new housing units. Based on these results, we focus the policy analysis in Section 7 on the roles that compliance, enforcement, and liquidity constraints play in the administration of the property tax.

[66] We exclude the 2012 reform because our data ends in 2013, which limits the number of new units we observe.

Figure F.1: Absence of a Real Estate Response to Tax Rate Increases



Notes: This figure examines the effect of tax rate increases on real estate investment. Panel A plots the number of new properties constructed around the lower threshold of band I during the post-reform years 2011–2013. We plot the number of new properties in equally sized cadastral value bins in bands H and I, within a 0.3 million MXN cadastral value range around the threshold. Panel B is similar but plots the number of new properties in bands G and H, constructed in the years 2012 and 2013. Panels C and D are similar to panels A and B, respectively, but plot the growth rate in new properties. The numerator of the growth rate is the number of new properties plotted in panel A (B). The denominator is the yearly average number of properties in the last two (three) pre-reform years (we use an average to minimize noise). Panel E plots the results of the difference-in-difference estimation $Log(N_{bt}) = \alpha_b + \mu_t + \gamma \cdot Treat_b \cdot Post_t + \epsilon_{bt}$, where N_{bt} is the number of new properties constructed in property value bin b in year t and α_b and μ_t are bin and time fixed effects. Each value band is divided into equally sized bins, and standard errors are clustered at the bin level. Value bands I, H, and G are treated; value bands J, K and L serve as controls. The other bands are omitted. The reforms are stacked, so that t is the time relative to reform.

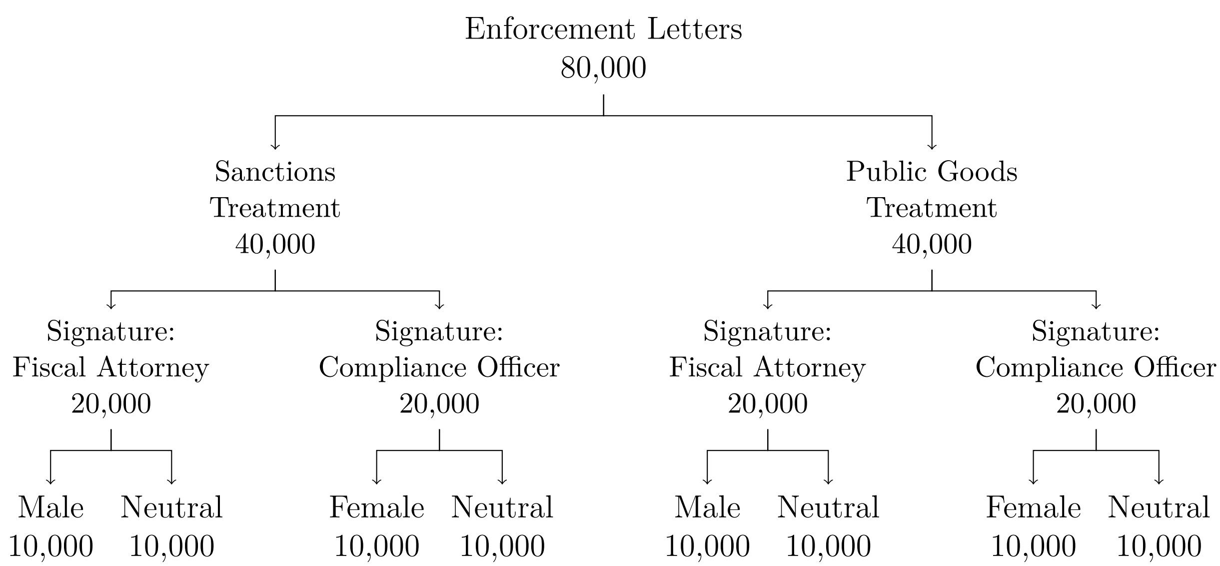
G Experiment Appendix

Table G.1: Cadastral Value Distribution of Experiment Sample

	All Taxpayers	Experiment Sample
Mean	589,530.8	533,087.3
SE	(636.2)	(2310.3)
Min	993.7	17,178.4
Max	11,711,063.3	11,670,532.6
20th Percentile	229,784.6	256,034.0
50th Percentile	391,487.2	419,170.5
80th Percentile	730,281.1	678,949.6

Notes: As discussed in section 5.1, this table compares the cadastral value between delinquent taxpayers targeted in tax compliance intervention and the full population of taxpayers, showing very similar distributions.

Figure G.1: Experiment Design



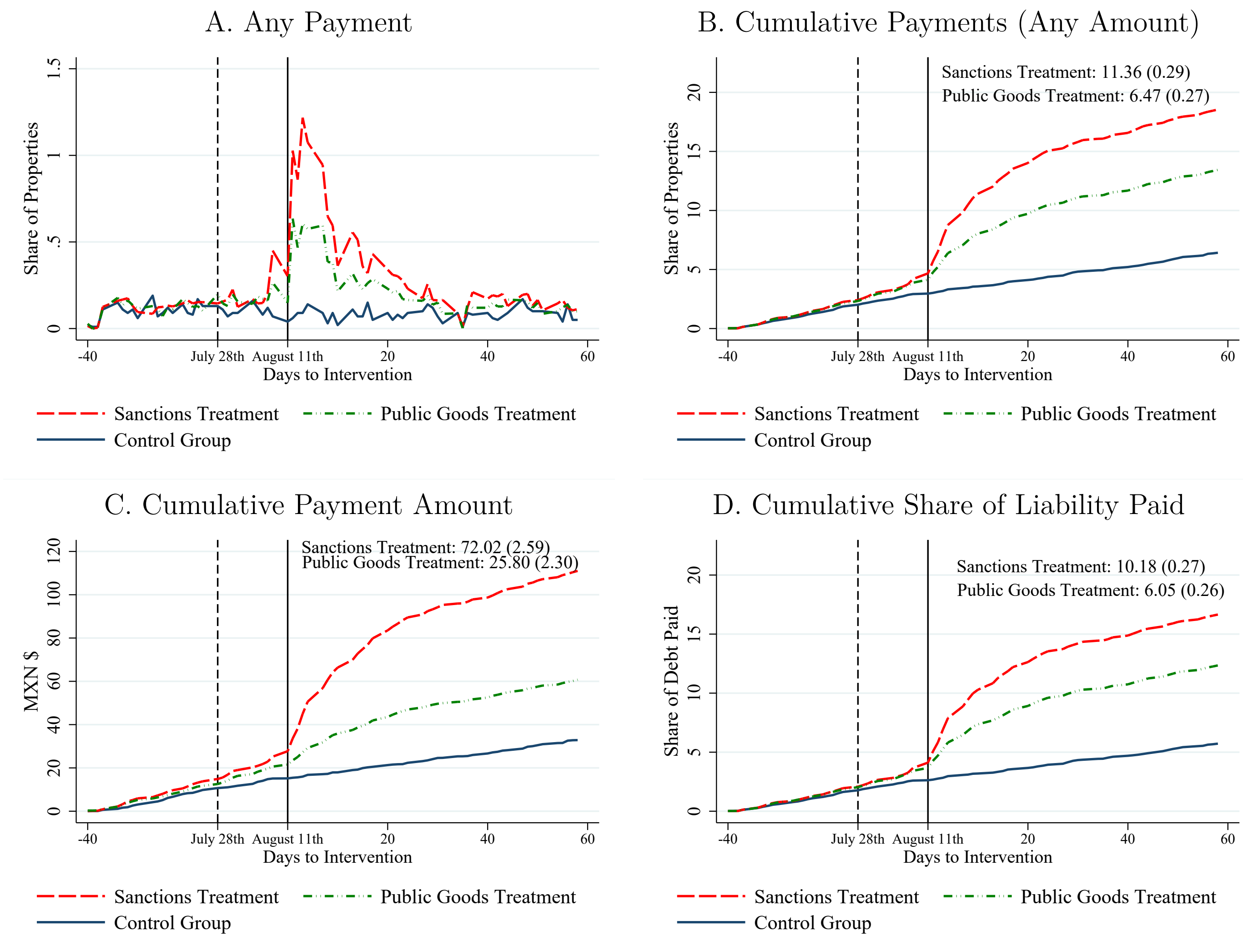
Notes: This diagram represents the different treatment arms of the enforcement intervention discussed in Section 5, in which the Minister of Finance sent letters to encourage payment of outstanding property tax debt. Letter recipients were selected from a pool of taxpayers who had become delinquent between bimester 4 of 2009 and bimester 3 of 2014. The letters were sent between July 28 and August 11, 2014. A control group of 10,000 delinquent taxpayers received no letter.

Table G.2: The Effect of Enforcement Letters on Tax Payment: Robustness

1: Letter Content		2: Sender Position		3: Male Sender		4: Female Sender	
Sanctions	Public Good	Fiscal Attorney	Compliance Officer	Male	Neutral	Female	Neutral
Panel A: Cross Sectional Regressions with Controls							
Panel A1: Any Payment							
9.463***	4.815***	7.585***	6.637***	7.059***	8.07***	7.039***	6.308***
(.312)	(.292)	(.304)	(.3)	(.361)	(.364)	(.357)	(.353)
Panel A2: Payment Amount (MX Pesos)							
39.018***	9.306***	28.95***	18.961***	27.041***	30.98***	21.843***	17.169***
(1.98)	(1.678)	(1.872)	(1.801)	(2.36)	(2.251)	(2.209)	(2.151)
Panel B: Difference in Difference Estimates							
Panel B1: Any Payment							
9.591***	4.975***	7.814***	6.751***	7.173***	8.455***	7.004***	6.499***
(.256)	(.238)	(.249)	(.245)	(.296)	(.302)	(.293)	(.291)
Panel B2: Payment Amount (MX Pesos)							
55.564***	16.049***	43.656***	27.956***	40.283***	47.029***	29.431***	26.482***
(2.292)	(1.957)	(2.192)	(2.075)	(2.642)	(2.648)	(2.454)	(2.444)

Notes: This table is similar to Table 3. Each column 1-4 and row displays results from one regression. Panel A displays estimates from a cross-sectional regression that includes the cadastral value and age of the property as controls in the estimation. Panel B displays estimates for β_5 and β_6 from the difference-in-difference specification $Y_{igt} = \alpha_i + \lambda_t + \beta_1 T1_{i20} + \beta_2 T2_{i20} + \beta_3 T1_{i40} + \beta_4 T2_{i40} + \beta_5 T1_{i60} + \beta_6 T2_{i60} + \epsilon_{igt}$, where Y_{igt} is the outcome for property i in treatment group g on day t, α_i and λ_t are property and day fixed effects, $T1_{i20}$ and $T2_{i20}$ are treatment indicators that switch on for the first 20 days after all letters were sent, $T1_{i40}$ and $T2_{i40}$ are treatment indicators that switch on between days 20 and 40, and $T1_{i60}$ and $T2_{i60}$ are treatment indicators that switch on between days 40 and 60.

Figure G.2: The Effect of Enforcement Letters on Tax Payment



Notes: This figure is identical to Figure 7 except that it displays the raw data before detrending and the estimates are from a regression run on the non-detrended data. This results in slightly larger treatment effect estimates than those of our preferred specification.

Figure G.3: Translation of Enforcement Letters

Taxpayer name
Taxpayer address

Sanctions Treatment

Avoid major inconvenience and regularize your tax status

Invitation Letter for Payment of the Property Tax

According to the registers of the Federal District's Treasury, you have outstanding **property tax** debt for the tax period(s) *****. We would therefore be grateful if you could update your tax status within 15 working days of receipts of this letter.

Delay in property tax payment can be sanctioned with fines and interest costs, and with interventions which the fiscal authority conducts to ensure effective tax collection, as per the Tax Code, **which can lead to the seizure of property.**

Avoid major inconvenience and regularize your tax status.

Public Goods Treatment

With our tax payment, we all contribute to improving our city

Invitation Letter for Payment of the Property Tax

As you know, a large part of the social programs and investments in infrastructure and security which the Government of Mexico City implements are financed by property tax revenues. Your contribution is therefore very important and we appreciate it if you can update your property tax account as soon as possible and cover the outstanding tax debt for the above mentioned building, for the tax period(s) *****, within 15 working days upon receipt of this letter. We ask you to update your account to avoid incurring surcharges.

With the revenues obtained from property taxes in your city, we finance the following public goods, among others:

- Food pensions for the elderly;
- School uniforms and school utensils for children;
- The operation of health centers and hospitals of the Government of Mexico City;
- Street lights and pavements in your neighborhood.

Boxed: Information about payment and further details on the back

Signature: Name, Title
(For gender-neutral signatures, only the initials of the first name are provided.)

H Liquidity Constraints Appendix

This appendix documents the inability of Mexico City's households to fully insure consumption and tax payments against idiosyncratic income risk. In general, imperfect or partial income insurance is taken by the literature as evidence of liquidity and credit constraints (see Attanasio, 1999). To test for partial income insurance, a usual practice in the literature is to use longitudinal data to regress household consumption on household income, as follows:

$$\log(\text{Consumption}_{it}) = \log(\text{Income}_{it})\beta + \gamma_i + \delta_t + \epsilon_{it}, \tag{H.1}$$

where γ_i are household fixed effects and δ_t are time dummies. The inclusion of household fixed effects and time dummies enables the interpretation of β as the elasticity of consumption with respect to temporary, idiosyncratic deviations of household income away from its mean. A significant β estimate constitutes evidence of partial income insurance because it indicates that consumption responds to temporary income shocks.

The estimation of equation H.1 is complicated by the fact that our consumption data for Mexico City from the *Encuesta Nacional de Ingresos y Gastos de los Hogares* (ENIGH) is a repeated cross-sectional survey. Hence we cannot control for household fixed effects in the above regression. To overcome this limitation, we follow the strategy proposed by Attanasio and Székely (2004) to test for partial income insurance. In particular, they propose regressing the variance of household consumption on the variance of household income by year-of-birth×education cohort, as follows:

$$\text{var}_g[\log(\text{Tax Payment}_{it})] = \text{var}_g[\log(\text{Income}_{it})]\beta + \gamma_g + \epsilon_{gt}, \tag{H.2}$$

where γ_g is a cohort-specific fixed effect. Note that the parameter β is the same across specifications H.1 and H.2 under the assumption that the covariance terms, resulting from taking variances from both sides of equation H.1, are constant over time, precisely the assumption made by Attanasio and Székely (2004). The advantage of this strategy is that we can calculate the cohort-specific variances of income, consumption, and tax payments from a nationally-representative cross-sectional survey, such as the ENIGH.

To estimate equation H.2, we use data from the 2008, 2010, 2012, and 2014 waves of the ENIGH for Mexico City. We include households where the year of birth of the head of household is between 1948 and 1982. We classify all households into 48 year-of-birth × age cohorts. In particular, we create 8 five-year age-of-birth categories and 6 education categories, which include: no formal education, primary school, middle school, high school, bachelor, and postgraduate.

Next, we calculate the cohort-level variance of log income and log consumption, as well as the variances of two additional outcomes that capture the extent to which idiosyncratic income risk affects property tax compliance: the log of one plus the annual property tax payment, and a dummy for positive property tax payments. We then estimate the equation H.2 via OLS, both in levels and in differences for each of the three outcome variables above.

Table H.1 presents the results from estimation. Column (1) shows that, in response to a negative yet temporary shock of 1 percent to household income, consumption drops by 0.617 percent, implying that Mexico City's households are able to insure consumption by only 0.383 percent against the shock. Column (2) shows the results from estimating the same equation by first differences instead of including cohort-specific fixed effects in the regression. The first-differences coefficient of 0.556 is statistically indistinguishable from the 0.617 obtained through fixed-effects estimation.

Column (3) shows that households are even less able to insure property tax payments than consumption against income shocks. In particular, a 1 percent temporary income shock reduces the annual payment amount by 0.787 percent. Once again, estimating the regression by first differences does not change the result, as the coefficient of 0.915 shown in Column (5) is statistically indistinguishable from the fixed-effects estimate of 0.787.

Finally, Column (5) shows that income shocks affect the extensive margin of payment, since a temporary income reduction of 1 percent decreases the probability of payment by 0.097 percentage points. Estimating the regression by first differences yields a similar coefficient of 0.12, as shown by Column (6). Overall, these results confirm the importance of liquidity constraints in explaining consumer and taxpayer behavior in Mexico City.

Table H.1: Income shocks, consumption, and property tax payment variability in Mexico City

	$\text{var}_g[\log(\text{Consumption}_{it})]$		$\text{var}_g[\log(1+\text{Payment}_{it})]$		$\text{var}_g[\mathbb{1}_{\{\text{Payment}_{it}>0\}}]$	
	Levels	Diffs.	Levels	Diffs.	Levels	Diffs.
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{var}_g[\log(\text{Income}_{it})]$	.617 ***	.556 ***	.787 ***	.915 ***	.097 ***	.12 ***
	(.07)	(.071)	(.166)	(.286)	(.024)	(.022)
Outcome mean	.454	.023	2.026	-.012	.124	-.008
Group dummies	Y	N	Y	N	Y	N
N	167	115	167	115	167	115
R^2	.351	.282	.137	.148	.132	.173

Notes: Standard errors are clustered by bin. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The total number of bins is 192 (8 year-of-birth categories × 6 education categories × 4 years), but for 25 of these bins, there are no observations in the ENIGH for Mexico City.

I Payment Timing Appendix

As we show in Section 1, the interaction between property taxes and liquidity constraints implies that governments can improve tax administration by providing liquidity. The government of Mexico City provides liquidity by offering discounts for taxpayers who pay in full before a given deadline.[67] In this section, we study how the timing of payments is affected by changes in discounts—through both deadlines and rates—and use this variation to infer households' value for liquidity.

Households choose to pay the property tax on a given day by trading off a lower overall tax payment with the cost of giving up interest-bearing liquid assets and the hassle cost of paying taxes on a given day. In the absence of a value for liquidity, taxpayers would prefer to pay ahead of the deadline to avoid uncertain hassle costs and time constraints that might prevent them from obtaining the discount. If households face liquidity constraints, they may risk missing out on the discount for the benefit of holding on to liquid assets until immediately before the deadline.

The government offered up to three types of discounts between 2009 and 2013. Figure I.1 plots the discount rate and the histogram of property tax revenue for every year. The size of the discounts and the deadlines varied substantially over the years. These discount deadlines can be interpreted as "time notches" in the sense of Slemrod (2013). Figure I.1 shows a clear pattern where taxpayers

[67] Discounts provide liquidity by effectively lending money to those who do not take up the discount. Assuming the discount rate is d, households can pay $1 - d$ today or borrow from the government at the rate of $\frac{d}{1-d}$. Governments provide liquidity through several mechanisms, including unemployment insurance schemes or accelerated depreciation deductions for firms.

respond very strongly to these incentives by bunching payments immediately before the deadline. This strong response to discounts is consistent with a high value for liquidity.[68]

To quantify the value for liquidity, we use this variation to estimate a dynamic model of payment timing where households trade off discounts, interest income, and the hassle costs of paying the tax.[69] For a given date t in year y, households obtain utility $v_0(t,y)$ when they pay their taxes. $v_0(t,y) = \theta_{t,y} + \theta_1 \text{Tax}(t,y)$, where $\theta_{t,y}$ captures the benefit of paying taxes net of the hassle cost of paying on day t and where $\text{Tax}(t,y)$ equals one minus the discount applicable on day t and year y.[70] Alternatively, households can choose to delay paying taxes at time t. The value of this choice is given by $v_1(t,y) = \theta_2 \text{Interest}_y + \beta EV_1(t+1,y)$, which captures the interest income from delaying payment and the discounted value function in the next period. Finally, every day households face idiosyncratic hassle costs of paying taxes that follow a logistic distribution.

We study the timing of payments by modeling $P_0(t,y)$: the probability of paying on any given day conditional on not having paid yet. Following Hotz and Miller (1993), $P_0(t,y)$ captures the value of delaying payment since $EV_1(t+1,y) = v_0(t+1,y) - \ln P_0(t+1,y) + \gamma$, where γ is Euler's constant. The relative log-likelihood of paying on any given day is then:

$$\begin{aligned} \ln\left(\frac{P_0(t,y)}{1-P_0(t,y)}\right) &= v_0(t,y) - v_1(t,y) = v_0(t,y) - \beta v_0(t+1,y) - \theta_2 \text{Interest}_y - \beta \ln P_0(t+1,y) - \beta\gamma \\ &= -\theta_1 \{\text{Tax}(t,y) - \beta \text{Tax}(t+1,y)\} - \theta_2 \text{Interest}_y \qquad \text{(I.1)} \\ &\quad -\beta \ln P_0(t+1,y) + \theta_{t,y} - \beta\theta_{t+1,y}. \end{aligned}$$

The first line follows from the logistic distribution and the expression for $EV_1(t+1,y)$ above. The second line substitutes the definitions of choice value $v_0(t,y)$. To implement this model, we assume that the hassle costs $\theta_{t,y}$ have three components: a day-of-the-year effect, θ_t; a day-of-the-week effect, $\theta_{t,d}$; and a residual component, $\varepsilon_{t,y}$.[71] The identifying assumption of this equation is that conditional on day-of-the year and day-of-the-week fixed effects, the daily changes in residual time costs, $\Delta_t \varepsilon_{t,y}$, are unrelated to yearly variation in interest rates or in the size and timing of discounts. This assumption is plausible since Interest_y is set by the broader market and since the policy variation in $\text{Tax}(t,y)$ features significant changes in the number of deadlines, due dates, and magnitude of the discounts that are unrelated to daily hassle costs.

Given the rich variation in discounts, we estimate the parameters of the dynamic discrete choice model $(\theta_1, \theta_2, \beta)$ via non-linear least squares, where the fixed effects recover day-of-the-year and day-of-the-week hassle costs. Figure I.2 plots $P_0(t,y)$ along with the model fit and shows that this relatively simple model does a remarkably good job of matching the data patterns. Panel A of Table

[68] It is worth noting that leading behavioral models are not consistent with these data patterns. First, because deadlines change across years, the bunching patterns we observe are not consistent with the salience of specific dates—e.g., first-of-the-month effects. Second, because the bunching patterns are very pronounced, these patterns are likely not driven by "rational inattention." Finally, one may worry that these patterns are a result of hyperbolic discounting. Fang and Silverman (2004) develop a model of present-biased preferences to study the effects of time limits in public policy. A prediction of this model is that present-biased households would likely miss the deadline, which is inconsistent with the sharp bunching patterns in the data.

[69] Hassle costs include time spent withdrawing cash and traveling to a payment location. Note that automatic payments were not allowed and online payments are only now being introduced.

[70] The problem ends when households pay the tax, so that action 0 constitutes a terminal option.

[71] Day-of-the-year effects capture holidays that are tied to specific days of the year (e.g., January 6^{th} is the day of the Three Wise Men). Day-of-the-week fixed effects capture the fact that different days of the week have different hassle costs (e.g., taxpayers can remit taxes during weekends by paying at convenience stores).

I.1 reports the main estimates from this model. These estimates reveal the importance of liquidity concerns in a couple of ways. First, we can interpret the discount rate as implying that households would pay an interest rate of approximately 8%$(\frac{1}{\beta} - 1)$ to delay paying property taxes by a single day.[72] This very high rate of discounting highlights the value of liquidity. Second, the effect of changes in taxes is only about 10 ($\approx \frac{\theta_1}{\theta_2}$) times larger than changes in interest income. In a world without liquidity constraints, households would place a much smaller value on short-term interest relative to the value placed on a permanent discount to their taxes.

We now use the estimated model to quantify the liquidity value provided by the discounts. Panel B of Table I.1 shows the gain in consumer surplus relative to a world without discounts.[73] Column (2) shows that taxpayers value discounts at between 3.26 and 10.35 percent of the value of their property taxes. Comparing these values to the deadlines in column (3), we find higher values in years with later deadlines. This makes sense: discounts raise welfare more when they allow households to hold on to liquid assets longer. Later deadlines also lower the risk of facing a high hassle cost in the early days of the year. Column (4) lists the realized fiscal cost of the discounts as a percentage of the property tax. As would be expected, the value of the discounts in column (2) is positively related to the fiscal costs. Finally, column (5) displays the ratio of the value of the discounts to the fiscal cost (columns 2 over 4). This ratio would fall below unity if households incur higher hassle costs to obtain the discount. Conversely, this ratio would be greater than one if the value from liquidity exceeds both the additional hassle costs and the fiscal cost to the government. Column (5) shows that in years where households have a longer time to obtain the discounts, the value of the discount to households exceeds the fiscal cost of the discount. That is, when deadlines provide meaningful increases in liquidity, the welfare gains experienced by households exceed the fiscal costs to the government.

The results in this section provide further evidence that payments for property taxes interact with liquidity constraints. This result is evident both in reduced-form patterns that showcase the sensitivity of the timing of payments to discounts and in the estimates from the dynamic discrete choice model. Because we find a value for liquidity even among the households that are willing to pay in full, relaxing liquidity constraints for a broader set of households can lower the welfare cost of paying property taxes and improve the design of the property tax system.

[72] While this is a very high rate of discounting, it is also consistent with very high interest rates charged by payday lenders in the US.

[73] Following Train (2009), consumer surplus is given by $\ln\left[\sum_{j=0,1} \exp\{v_j(t=0, y|\{\text{Tax}(t,y)\}_t, \text{Interest}_y)\}\right] \times \frac{1}{\theta_2}$. We evaluate welfare on the first day of the year ($t=0$) given a daily profile of discounts $\{\text{Tax}(t,y)\}_t$. We divide the log-sum by the coefficient on interest income to interpret this quantity as a monetary measure of consumer surplus. Finally, we evaluate this expression setting Interest_y to the average value in our sample.

Table I.1: Dynamic Model of Payment Timing

Panel A. Model Estimates

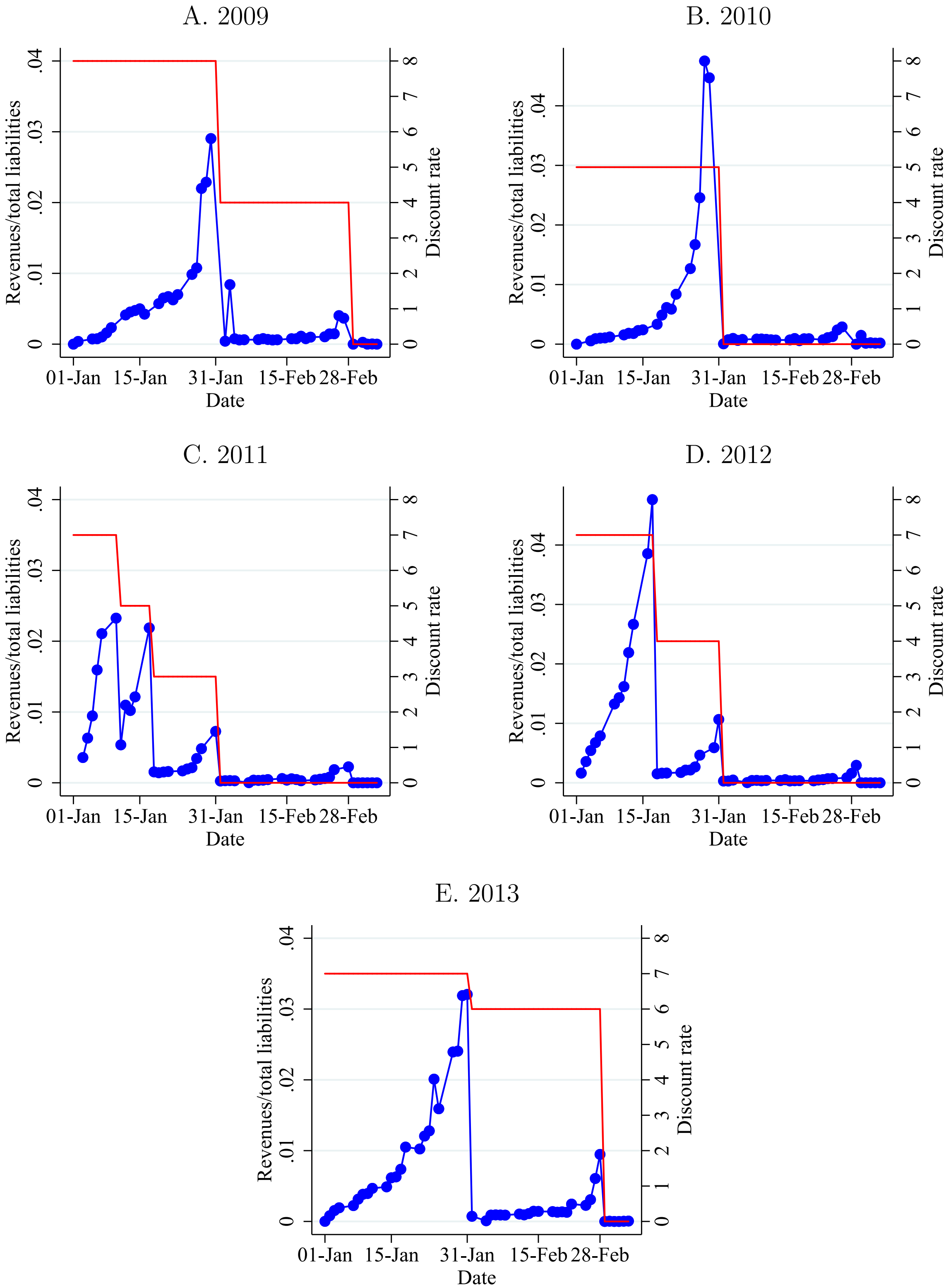
	(1) Tax Coefficient θ_1	(2) Interest Coefficient θ_2	(3) Discount Factor β
Estimate	0.936***	0.096	0.924***
	(0.180)	(0.064)	(0.041)

Panel B. Welfare Estimates

(1) Year	(2) Consumer Surplus From Discounts	(3) Discount Deadlines	(4) Fiscal Cost	(5) Relative Value of Discounts
2009	10.35	Jan 31, Feb 28	7.80	1.33
2010	3.92	Jan 31	4.95	0.79
2011	3.26	Jan 10, 17, 31	6.53	0.50
2012	5.23	Jan 17, 31	6.84	0.77
2013	7.76	Jan 31, Feb 28	6.95	1.12

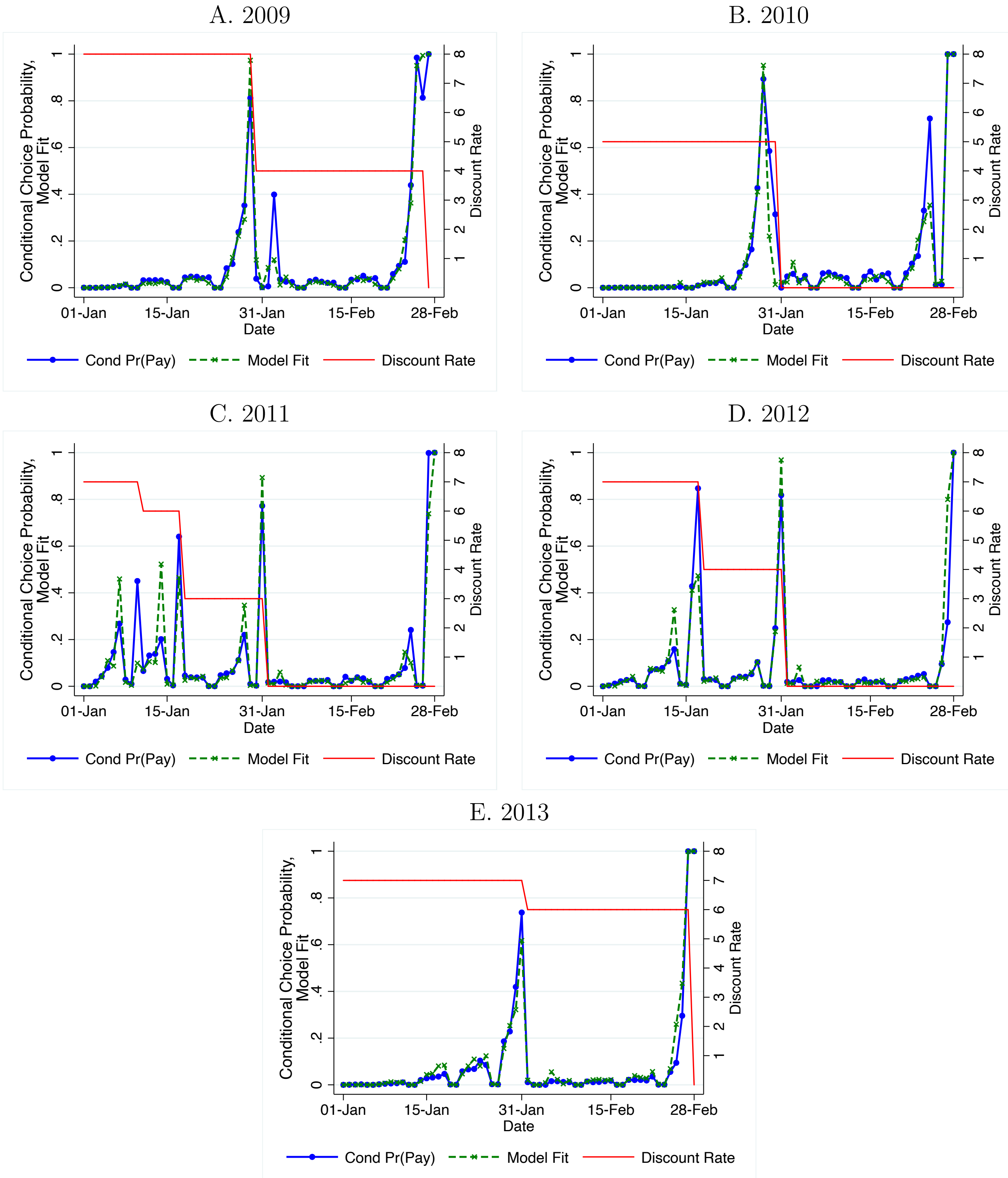
Notes: Panel A reports the parameter estimates from the dynamic discrete choice model presented in this Appendix. The parameters were estimated by solving Equation I.1 via non-linear least squares. The model parameters reflect the role of liquidity constraints through the low discount rate and the relatively high utility value of interest income. The underlying data on payment probabilities are weighted to reflect tax collections per day. Panel B uses the model estimates to compute the consumer surplus from discounts (as a percentage of tax payment). Discounts have a larger effect on consumer surplus when taxpayers face longer deadlines and when the discounts are more generous. In these cases, the value of the discounts is greater than the fiscal cost (also as a percentage of tax payment), showing that the government can lower the welfare cost of property taxes by providing liquidity to taxpayers.

Figure I.1: Taxpayer Response to Super-Early-Bird and Early-Bird Discounts



Notes: This figure plots the early-bird discount rates and the timing of property tax payments, as discussed in this Appendix. The red line in each panel represents the annual super-early-bird and early-bird discount rates. The blue dots represent the revenues of the government each day, expressed as a fraction of the total yearly liabilities in Mexico City.

Figure I.2: Estimates from Dynamic Model of Payment Timing



Notes: This figure displays estimates from the dynamic discrete choice model of payment timing presented in this Appendix. The red lines display $P_0(t, y)$: the probability of paying taxes on any given day conditional on not having paid. These probabilities are weighted to reflect tax collections per day. The blue lines display the corresponding model fit from the dynamic discrete choice model. The black lines display tax obligations net of discounts.

J IV Appendix

J.1 Construction of the Instrument for Property Tax Payments: Additional Details

Because the 2010 and 2012 waves of the ENIGH do not measure construction and land area, we use the 2008 wave, which includes these data along with the other variables in the 2010 and 2012 waves, to assign a value of Z_{it} to a given property. Specifically, we use a multinomial logit to estimate the probability that a property with a given number of rooms belongs to a given land-construction-age-municipality-year bin using the 2008 data. Using these predicted probabilities, we compute the expectation of the average change in tax liability for each property in the ENIGH.

Table J.1: The Effect of Property Taxes on Consumption
First-Stage IV Regressions – Predicting Property Tax Payment

	(1)	(2)	(3)
Z	.473 ***		.299 ***
	(.074)		(.084)
$\tilde{Z}$		-.741 ***	-.469 ***
		(.094)	(.115)
F-statistic (excluded instruments)	40.61	61.62	14.66
p-value (excluded instruments)	.000	.000	.000

Notes: This table reports the first-stage results from the IV estimation discussed in Section 6.2. The second-stage results are reported in Table 4. N=2,649. All regressions include *delegación* fixed effects and year dummies. Bootstrapped standard errors based on 1,000 replications are in parentheses. The outcome is log property tax payment. The instruments Z and $\tilde{Z}$ are the constructed predicted change in the property tax liability and the predicted probability that a household's property is part of the treated cadastral value band in 2010 (band I), respectively.

Table J.2: The Effect of Property Taxes on Consumption
Second-Stage Regressions With Alternative Instrument

	(1)	(2)	(3)	(4)
log(Pay)	-.028	-.049	-.021	-.038
	(.05)	(.053)	(.049)	(.052)
log(Pay) × log(pc income)		.098 ***		.075 **
		(.037)		(.037)
log(Pay) × Lack of credit			-.05 ***	-.041 ***
			(.008)	(.007)
log(pc income)	.829 ***	.262	.79 ***	.36 *
	(.033)	(.205)	(.031)	(.206)

Notes: This table is identical to Table 4 but reports results from using an alternative instrument $\tilde{Z}_{it}$: the predicted probability that a household's property is part of the treated cadastral value band in 2010 (band I). The results are qualitatively and quantitatively very similar to those in Table 4.

Table J.3: The Effect of Property Taxes on Consumption
Second-Stage Regressions With Both Instruments

	(1)	(2)	(3)	(4)
log(Pay)	-.021	-.03	-.011	-.018
	(.049)	(.05)	(.048)	(.049)
log(Pay) × log(pc income)		.063 ***		.043 *
		(.023)		(.023)
log(Pay) × Lack of credit			-.042 ***	-.035 ***
			(.007)	(.006)
log(pc income)	.824 ***	.455 ***	.789 ***	.544 ***
	(.033)	(.127)	(.03)	(.127)

Notes: This table is identical to Tables 4 and J.2 but uses both instruments Z and $\tilde{Z}$ to predict property tax payment. The results are qualitatively and quantitatively very similar to those in Table 4

Table J.4: Partial Effect of Tax Payment on Consumption
Evaluated at Different Income–Credit Access Combinations

	(1) Z	(2) $\tilde{Z}$	(3) Z& $\tilde{Z}$
Log-Income (25th pctile), Credit Access	-.038	-.085	-.043
	(.056)	(.062)	(.053)
	[-.11,.036]	[-.181,-.006]	[-.111,.026]
Log-Income (25th pctile), No Credit Access	-.073	-.119 *	-.078
	(.059)	(.063)	(.055)
	[-.149,.001]	[-.214,-.04]	[-.15,-.006]
Log-Income (median), Credit Access	-.013	-.064	-.019
	(.051)	(.057)	(.048)
	[-.079,.054]	[-.14,.01]	[-.086,.044]
Log-Income (median), No Credit Access	-.048	-.097 *	-.055
	(.055)	(.059)	(.051)
	[-.125,.023]	[-.173,-.02]	[-.128,.018]
Log-Income (75th pctile), Credit Access	.016	-.036	.008
	(.049)	(.053)	(.047)
	[-.049,.074]	[-.101,.034]	[-.052,.072]
Log-Income (75th pctile), No Credit Access	-.019	-.069	-.027
	(.053)	(.055)	(.05)
	[-.093,.043]	[-.139,.002]	[-.09,.044]

Notes: This table reports the partial effects of tax payment on consumption, estimated with the IV strategy discussed in Section 6.2 and reported in Table 4, evaluated at different income-quartile and access-to-credit combinations. Bootstrapped standard errors based on 1,000 replications are in parentheses, and 90% bootstrap confidence intervals are in brackets.

Table J.5: Classical Minimum Distance Estimates of Revenue-Maximizing Tax Rates

	(1) RD Estimates	(2) DiD Estimates
β_1	-0.005	-0.019***
	(0.020)	(0.007)
β_2	1.640	3.293***
	(2.347)	(0.738)
Mean Semi-Elasticity	0.010***	0.012***
	(0.002)	(0.001)
20th Percentile of τ^*	158.968	250.000
10th Percentile of τ^*	73.431	250.000
5th Percentile of τ^*	61.521	250.000

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Notes: This table reports results for the classical minimum distance estimates of revenue-maximizing tax rates discussed in Section 7.1. Column (1) uses estimates from the RD estimation to estimate β_1 and β_2, while column (2) uses estimates from the DiD estimation. In both cases, we find that $\beta_2 > 0$, indicating that current tax rates are substantially below the revenue-maximizing rates. For both cases, we report the mean semi-elasticity by evaluating the revenue curve at the average tax rate. Finally, the last panel reports estimates of revenue-maximizing tax rates τ^* from 10,000 simulated values of β_1 and β_2. We compute τ^* in each simulation and report the percentiles of this distribution. We top-code τ^* at 250 basis points when $\beta_2 > 0$.