Vehicle tax avoidance and environmental outcomes: Evidence from Mexico

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Abstract

This paper exploits Mexico's decentralization of vehicle registration fees to investigate how tax avoidance impacts vehicle fleet composition, environmental outcomes, and revenue collection. Using a difference-in-differences approach with synthetic controls across price bins, we assess changes in registration patterns, vehicle choice, and emissions. Our findings indicate that avoidance behavior softened the policy's distortionary impact on fleet composition, reducing the shift in higher tax bracket vehicles by 2.5% compared to an expected 10% shift under perfect compliance. Revenue losses from tax avoidance were substantial, with decentralization reducing annual fee collections by 10%. Additionally, the policy encouraged purchases of lower-priced vehicles just below the tax threshold, which were, on average, 3 miles per gallon more fuel-efficient but produced worse tailpipe emissions, especially nitrogen oxides (NOx). These findings underscore the complex interaction between tax design, avoidance behavior, and environmental outcomes, highlighting the need for coordinated policy enforcement to achieve fiscal and environmental objectives.

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1 Introduction

The prevalence of automobiles worldwide has significant implications for environmental policy, particularly in developing countries where vehicle emissions contribute substantially to air pollution and greenhouse gas emissions (Rapson and Muehlegger, 2023). In Mexico City, for instance, automobiles are a leading source of volatile organic compounds and nitrogen oxides, with the transportation sector increasingly becoming a primary contributor to global emissions (Molina and Molina, 2002). The challenge of regulating this sector is magnified by weak institutions, which often result in imperfect compliance. This paper investigates how vehicle regulation impacts the composition of the vehicle fleet and environmental outcomes in Mexico City, focusing on the effects of decentralizing vehicle registration fees. Understanding these dynamics is crucial as the region confronts rising emissions amid a rapidly growing urban population.

This paper investigates how tax policies with discrete cutoffs, specifically vehicle registration fees, shape the environmental and economic outcomes in a context of weak institutional enforcement. Focusing on Mexico City—a vast metropolitan area with one of the world's largest urban populations—this study provides a unique opportunity to explore how policy impacts change in a real-world scenario. Mexico City offers a compelling case study due to the observable tax avoidance behaviors and the distinct policy environment, making it an ideal setting to examine how registration fees influence vehicle purchases and, consequently, the composition of the vehicle fleet.

The primary research question is: How do discrete cutoffs in tax policy and imperfect compliance affect environmental outcomes? More specifically, this study assesses the impact of decentralizing the vehicle registration fee in Mexico, highlighting how avoidance behavior influences fleet composition and associated emissions. To address this, we separate vehicle registration data by price bins before and after the policy shift, constructing a synthetic control group through propensity score matching. Control zip codes were selected by minimizing differences in characteristics like the share of households with vehicles, average years of education, and insurance coverage—calculated at the zip code level using census data aggregated from the block level. This allows for a difference-in-differences analysis at the price bin level, isolating the policy's impact from other factors.

Our findings reveal that the shift in policy led to significant tax avoidance, with many owners of high-priced vehicles opting to register in neighboring states with lower fees. This avoidance, combined with a preference for cheaper vehicles under the exemption threshold, reshaped the vehicle fleet and decrease the collection of that revenue stream by

10%. As vehicle owners sought to avoid higher registration costs by registering elsewhere or purchasing vehicles just below the exemption cutoff, the resulting fleet exhibited changes in the distribution of vehicles, ultimately impacting overall emissions outcomes. While the average registered vehicle became more fuel-efficient, it also tended to have poorer tailpipe emissions and an older age profile. These outcomes are linked to changes in the distribution of vehicles by price, highlighting the distortionary effects of discrete tax cutoffs and imperfect compliance.

To better understand these dynamics, we developed a model to examine the interplay between avoidance responses and price responses. This model allows us to isolate the distinct effects of these two responses, offering insight into how tax design and enforcement shape the vehicle market. Furthermore, by running counterfactual scenarios—adjusting the tax rate or modifying the costs of cheating—we can explore how these changes influence avoidance behaviors and vehicle pricing within the fleet. We find that the presence of avoidance mitigates the distortionary effects on fleet distribution. Specifically, the difference in the share of registrations between the vehicles below and above the threshold was 10 % under the perfect compliance scenario against 7.5 % accounting for current avoidance.

These findings have broader implications for the developing world, where effective transportation regulation is critical to controlling emissions and improving urban air quality. They contribute to ongoing research in public finance, tax policy, and the environmental consequences of vehicle regulation, emphasizing the need to account for compliance issues in policy design. Understanding how discrete cutoffs and imperfect enforcement interact can inform the development of more effective strategies, especially in regions with institutional weaknesses.

Unlike (Ito and Sallee, 2018; Anderson et al., 2011; Whitefoot and Skerlos, 2012) which focuson the response of manufacturers to regulatory changes and notches in attribute-based regulation, our work studies the response to those notches but from the consumer response. In that sense our work focuses on the consumer choice of vehicles taking vehicle portfolios offered as given like (Anderson and Sallee, 2016). This unravels how individuals choose different vehicle options in the market as a response to the regulation.

Specifically, it documents and quantifies the extent of avoidance behavior in vehicle registration, providing insights into the missing registrations' implications for government revenue in a developing country. It estimates the magnitude of avoidance and its impact on the distribution of vehicle registrations, shedding light on how taxation policies influence vehicle purchase decisions in a context where institutions may be weaker.

In the realm of public finance, this paper documents the challenges of decentralization in the developing world contributing to the literature on the limits on state capacity in raising revenue and the prevalence of tax evasion. (Gadenne and Singhal, 2014; Slemrod, 2007; Brockmeyer et al., 2021; Baicker et al., 2012; Alstadsæter et al., 2022; Slemrod, 2019; Kleven et al., 2011; Saez et al., 2012). Additionally, we study bunching response to tax brackets finding how individuals strategically manage their tax positions (Kleven and Waseem, 2013; Saez, 2010; Kleven, 2016).

In the domain of cheating or gaming policies within transportation, there is a fair amount of work done (Reynaert and Sallee, 2021) documents the gaming of automobile carbon emission ratings in the EU, (Tanaka, 2020) examines the underlying incentives for falsifying fuel economy on part of the automobile industry, (Reynaert and Sallee, 2021) points that political environment resulted in firms' choices for abatement by technology adoption and gaming, (Marion and Muehlegger, 2008) examines tax evasion in the diesel fuel market, (Harju et al., 2020) points out at used car importers overstating the mileage to reduce tax liability. (Marion and Muehlegger, 2018) show tax evasion channel for fiscal externalities in multi-jurisdictional taxation in the context of diesel taxation which resembles the setting from this paper. Specifically in Mexico, (Davis, 2008) has studied the response to driving restrictions in Mexico City, and (Oliva, 2015) has focused on the cheating happening at the smog checks. Our research contributes by documenting avoidance behavior and its implications. Quantifying the number of missing vehicle registrations, we provide valuable insights into the unintended consequences and gaming strategies related to tax differentials, especially in the context of developing countries.

In summary, our study's contributions extend across these crucial research avenues, providing information about vehicle fleet dynamics, the challenges of decentralization, and gaming behavior in transportation policies. The remainder of this paper is organized first by the institutional settings, followed by data, empirical strategy, model, and concludes with the environmental implications and some policy simulations.

2 Institutional setting

The government of Mexico, in order to give greater fiscal autonomy to the states, decided to shift the administration of the vehicle registration fee, commonly known as "tenencia." The registration fee is a tax that vehicle owners pay annually. Until 2012, this tax was uniform across states and managed by the federal government. It was calculated based on the number of cylinders in a vehicle, resulting in an annual payment typically under 800 pesos. Which is less than 0.8% for more than 90% of the vehicles.

Following decentralization in 2012, the federal government transferred the responsibility for this tax to individual states. This led to varying tax policies across Mexico, allowing each state to design its own fee structure for vehicle registration.

The decentralization policy led to variation in tax schedules, even across adjacent areas within the same metropolitan region. For instance, Mexico City and the State of Mexico, the primary jurisdictions in this analysis, adopted progressive vehicle registration fee schedules based on price brackets, ranging from 3 percent for lower-priced vehicles to nearly 20 percent for higher-priced ones. A key difference lay in the exemption thresholds: Mexico City initially set its threshold at 250,000 pesos to support lower-income households, while the State of Mexico set theirs at around 400,000 pesos. Figure 1 shows the schedule adopted by Mexico City in 2012. At the time, these thresholds left more than half of the vehicles untaxed, with the policy aimed at ensuring progressivity by taxing only those able to afford more expensive vehicles. Despite inflation, these thresholds remained unchanged over the following ten years. Figure 1 shows the schedule adopted by Mexico City in 2012. Under the prior federal schedule, registration fees were a fixed amount of less than 40 USD (800 pesos), or less than 0.8%, applied uniformly across all states.

However, not all the states decided to adopt an increasing block schedule or any equivalent tax as high as Mexico City. Morelos, a neighboring state of Mexico City and State of Mexico, implemented a fixed fee of about 400 pesos (approximately 20 USD). This meant the more expensive a vehicle was, the smaller the tax liability was as a share of the vehicles value. See Figure 2 for geographical reference.

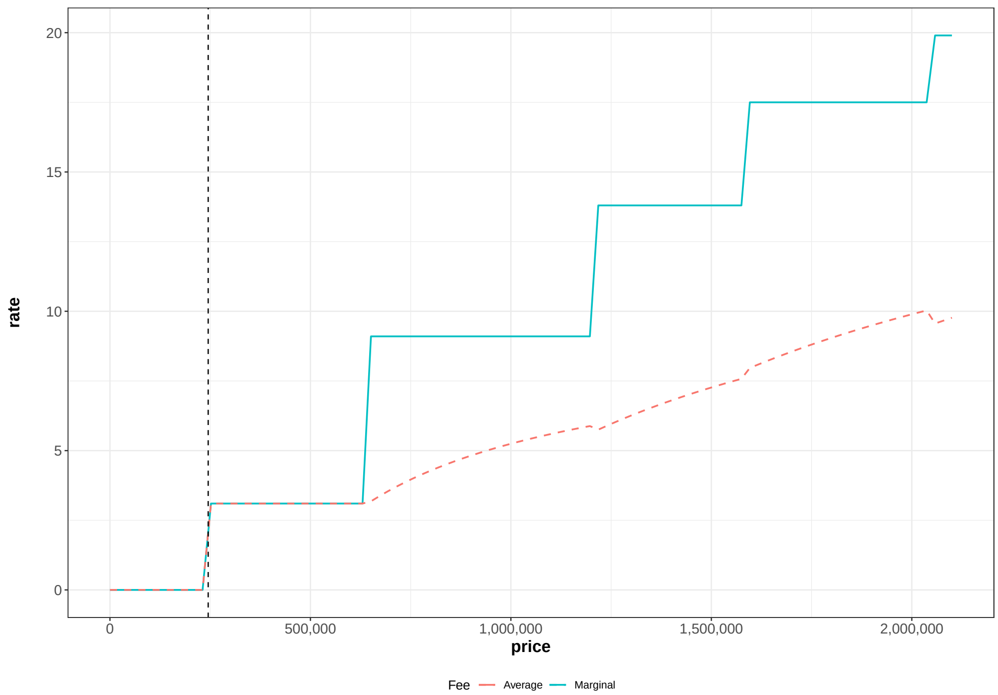
In both Mexico City and the State of Mexico, the calculation of the tenencia tax relied on a regulation value, a standardized vehicle value determined by regulations. This designated value is computed by taking into account the original purchase price of the car and applying two factors: inflation and depreciation. [1]

In addition to the tax differential among these three states, it was very easy for vehicle owners in Mexico City to register their cars elsewhere. Initially, they would use an address

1. Inflation is assessed by measuring the percentage change in the national price index, comparing it from the November of the vehicle's model year to the preceding November—the timeframe immediately preceding the tax assessment.

Depreciation follows a regulated schedule. According to this schedule, vehicles are subjected to an annual depreciation rate of approximately 10 percent. Consequently, after a ten-year period, vehicles reach a point of full depreciation, which results in their exemption from any further tenencia tax obligations.

Figure 1: Tax schedule implemented by Mexico City in 2012



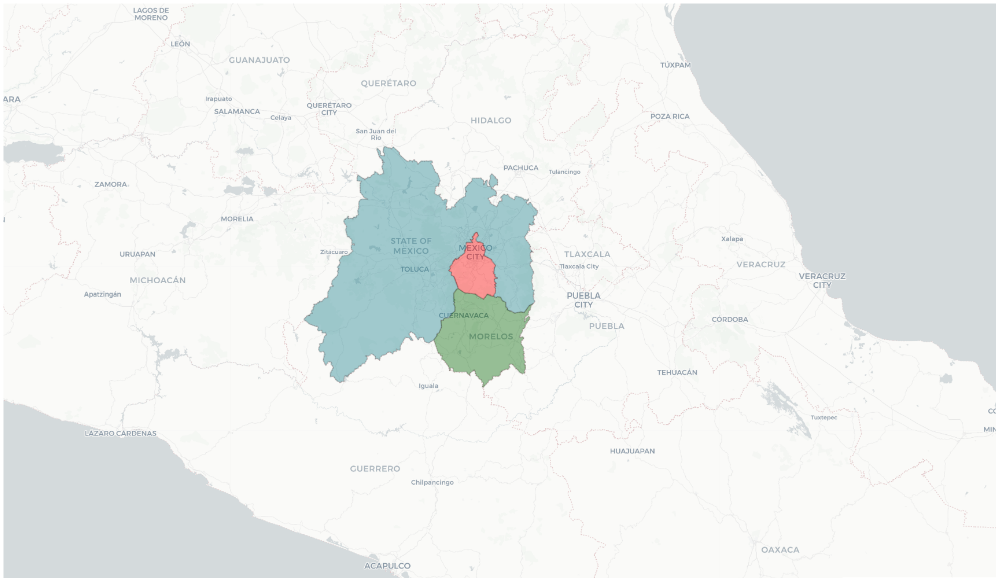
Tax rate implemented by Mexico City, where the dotted line represents the exemption threshold. Vehicles whose price was below this threshold would not pay registration fee. The price used in the regulation for the vehicles is the price these vehicles had when new adjusted by a published depreciation and inflation factors

they could borrow, but eventually the dealerships and some other independent providers began offering the service to register your car wherever you wanted. At the moment of writing this paper a simple online search asking how to register your car in Morelos if you lived in Mexico City gave a handful of sites offering such service, making avoidance of the registration fee for the vehicles above the exemption thresholds easy and convenient.

For example, someone living in Mexico City that owns a car with a regulation value of $350,000 could register that vehicle in State of Mexico or Morelos. Someone with a vehicle with a price of $500,000 would have to pay the tax in Mexico City and State of Mexico, but not in Morelos. We chose the state of Morelos because observations revealed that many vehicles driving in Mexico City carry Morelos plates. Among residents, Morelos is informally known as a "tax haven," and, as we show in our data section, registrations for the most expensive vehicles frequently appear there.

Mexico City metropolitan area encompasses municipalities in Mexico City and the State of Mexico. Making it difficult to see what registrations actually migrated due to city

Figure 2: Metropolitan area and its surroundings



Mexico City metropoliatan are includes municipalities in the state of Mexico and Mexico City jurisdiction. However, no municipality from Morelos belong to the metropolitan area.

growth and which ones due to evasion. However, there are no municipalities in Morelos that belong to the metropolitan area of Mexico City, hinting that mostly, the registrations that migrated here are avoiding the tax.

A study conducted by the government of Mexico City involved scanning vehicle license plates to evaluate the geographic distribution of vehicles traversing the city. The findings indicated that approximately 45% of these vehicles bore plates from Mexico City, 48% from the State of Mexico, and 5% from Morelos. It was noted that among higher-value vehicles, the proportion from Morelos was comparatively larger.These findings substantiate the focus on these three states—Mexico City, the State of Mexico, and Morelos—for analyzing vehicle registration dynamics.

3 Framework

This framework aims to evaluate the mechanism in response to the policy. Mainly we want to model vehicle owner's response and split in two main decisions. One would be to buy a cheaper vehicle to avoid paying taxes and the other one to register in another state. Our model then aims to study what is an avoidance response or a price response and see how aggregate consumer choice changes with change in some parameters such as cheating cost or tax rate.

The model considers two decisions that the agent can take when choosing to register a car. The first one is if they buy a lower-priced car to decrease their tax liability and the second one is where to register their vehicle depending on their cost to do so. The cost of where to register the car includes the value of their registration fees and other types of costs that we do not observe such as transaction cost or, in case they are avoiding by registering outside of their area for their home address, tax morale which is defined as nonpecuniary motivations for tax compliance as well as factors that fall outside the standard expected utility framework (Luttmer and Singhal, 2014). In our model that is all included in the cheating cost C_i.

We assume that individuals have a utility function where absent taxes or cheating costs they have an ideal vehicle choice. This vehicle choice is denoted as a random variable θ and for simplicity of the model we limit it to price. Price is usually one of the top ranked categories that individuals consider when buying a vehicle (Fujita et al., 2022). Furthermore, We assume that people aim to get the best car they can afford, maximizing utility within their budget. This approach is convincing because someone isn't going to buy a more expensive car if they can't afford it, and going for a cheaper option likely means giving up features they value, like safety or performance. So, when they choose a vehicle, it's essentially the utility-maximizing choice given what they can spend. They're getting the best they can within their budget, striking a balance between price and the attributes that matter most to them.

That is, everyone who wants to own a car has an ideal price for the car they want to get, and deviation from this car's ideal price results in disutility, the farther away they are from the ideal price the more disutility they experience. Following the same way the regulation is designed we add, linearly, into the utility function the tax liability which is a function of the vehicle's price. The individual then faces a utility function where the dis-utility of deviations from the ideal price increase the farther away they are from their ideal choice. We assume that if the utility from tax liability plus choosing a price different from their ideal one is greater than the cost to cheat, then the individual will cheat. Equation 1 represents a simple utility function, yet includes the features that we want.

$$\max_P[-\gamma_i(\theta_i - P)^2 - \tau P, -C_i] \tag{1}$$

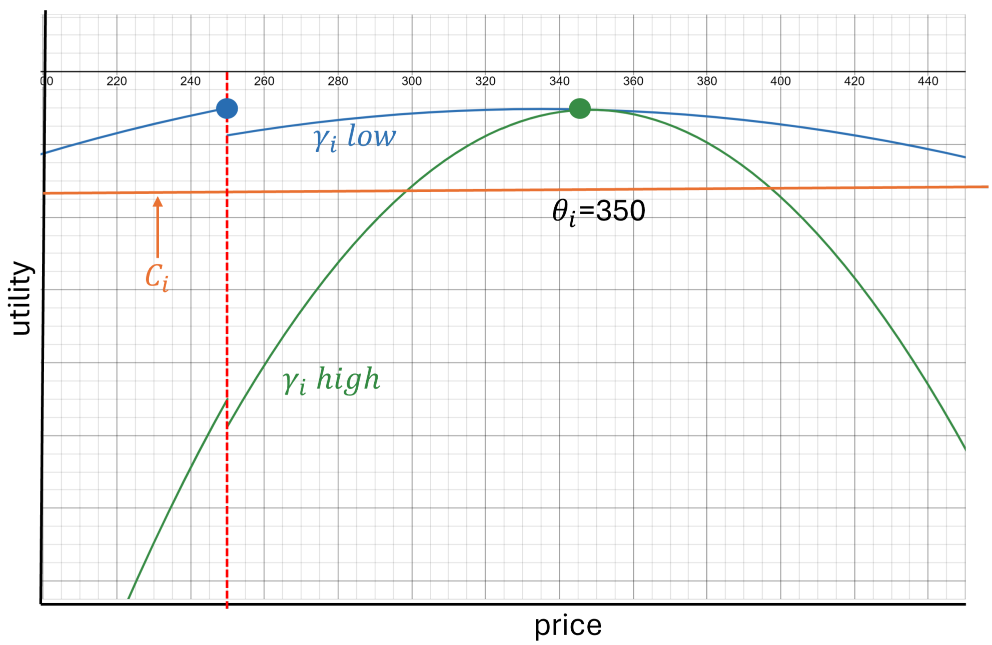
Where γ is a weighting parameter for how much dis-utility an individual i gets from any deviation in the price of the car they want from their ideal car price. The greater the value of this parameter the more dis-utility the individual gets from not getting the car they want. Individuals with low γ can be perceived as more flexible individuals who do not care that much about substituting the vehicle they want if that means paying lower taxes. As mentioned before, θ_i is the individual i ideal car price, τ is the tax rate which follows the same schedule as the Mexico City one, P the price of the vehicle the individual gets, and C_i is the individual's cost of cheating. Note that we model individual weighting parameters, ideal car price, and cost of cheating to allow for heterogeneous responses so that we see registrations in most of the price domains. Otherwise, we would see no registrations of vehicles of certain price at all in Mexico City for certain values of C_i or γ_i.

A representation of how utility shapes the price and cheating response can be seen in Figure 3. Here, we compare the effect of different values of γ. In this case, we can see that the one with a higher value of Gamma gets a lot of disutility from not choosing the ideal vehicle. However, those with lower Gamma values are more willing to substitute. In fact, in this case the individual gets more utility from choosing a cheaper car that is not the ideal price due to the lower tax liability.

In both cases, the individual decided not to cheat since the utility was higher than their cheating cost. However, if the orange line was above the the blue or green dot the indivual would cheat and choose a car with a price equal to their ideal price.

This values change for each individaul and once we estimate the distribution of all of them we can model different responses to policy scenarios. To estimate θ we use a distributional regression approach where all the parameters of the conditional distribution of the response variable are modeled using explanatory variables. In that sense, we fit a Beta distribution of the second kind on the price distribution before the change in policy. For Gamma, we take the distribution of prices in Mexico City post policy change and use them to solve the first order condition with respect to price of the utility function using the values drawn from the θ we already estimated. The values of γ mostly works as a weighting one in order to solve the first order condition. Once we have the values of γ and the distribution of θ we use them to compute the utility for individuals registered in Mexico City post policy. Then we use the discontinuity in the shares of vehicles registered in Mexico City below and above the thresholdin the post policy periods to get a share of missing registrations. This share is later used to fit a truncated normal that backs out the distribution of the cheating cost. Appendix B details such procedure.

Figure 3: Utility representation



This figure represents the utility dynamics of different γ_i values with one cheating cost value C_i and an ideal car price of $350. The red dotted line represents the exemption threshold in Mexico City tax schedule. The indivual in blue with the low γ_i maximizes their utility at the exemption threshold. However, the individual with a high γ_i in green maximizes their utility slightly below their ideal price. In both case the individual utility is higher than the cheating cost so they choose not to cheat.

4 Data

The data used for this paper comes from several sources. Administrative data for vehicle registrations collected from states' administrative records in Mexico from 2010 to 2018, smog check outcomes for Mexico City from 2010 to 2020, reported fuel efficiency for vehicles in Mexico posted by the Federal Ministry of Environment, 2010 and 2020 census data with socio-demographic characteristics.

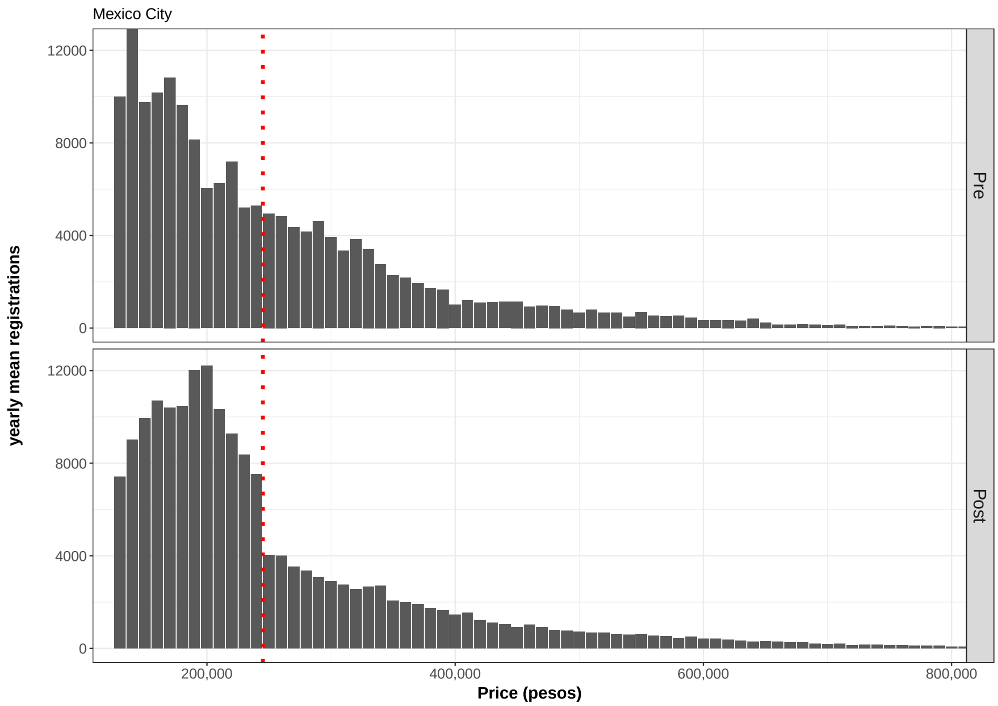
The main source of data for this paper is the administrative records on vehicle registration for 6 out of 32 states in Mexico which account for roughly 50% of the vehicle registrations in the country. The data was collected via information request to each state's government. The vehicle registration data contains variables such as date of registration, make, model, year, and price of the vehicle when new. For 5 out of the 6 states we have the zip code of the addresses where the vehicle was registered, and for the specific case of Mexico City, the plates of the vehicles are also accessible. We use the plate number as a key to merge it with the smog check outcomes dataset which was obtained via an information-request to the Ministry of Environment in Mexico City. The smog check outcomes dataset contains the time, date, vehicle plate and the readings for NOx, and HC, for each smog check done in Mexico City from 2010 to 2020 among other variables.

We further merge this data with reported fuel efficiency using string matching on the vehicle make-model. With this, we can link vehicle price to smog check outcomes and fuel efficiency which from our understanding has never been mapped out before and is a very relevant issue. Especially in our setting, where policies targeting the price of a vehicle affect other car-related attributes.

From Mexico City's vehicle registration data set, we can map the average number of vehicles registered before and after the policy change in 2012 as shown in Figure 4. In this figure, if we compare the upper facet against the lower, we can see a missing mass on the right side of the distribution. This is suggestive evidence that fewer registrations of vehicles above the threshold are happening.

When we map out the registrations for vehicles in the neighboring states of Mexico, we can see how the exemption threshold plays a role in the shape of vehicles registered in each state. Especially for those very expensive vehicles which show a big mass in the distribution from Morelos. Figure 5 shows the last year of our data and provides more evidence on how registrations are shifting. Figure A.2 in the appendix shows the raw data for all the periods. However, shifting the location of registrations is not the only thing happening. Vehicles priced close and below the threshold tend to become more

Figure 4: Mexico City aggregated vehicle registrations

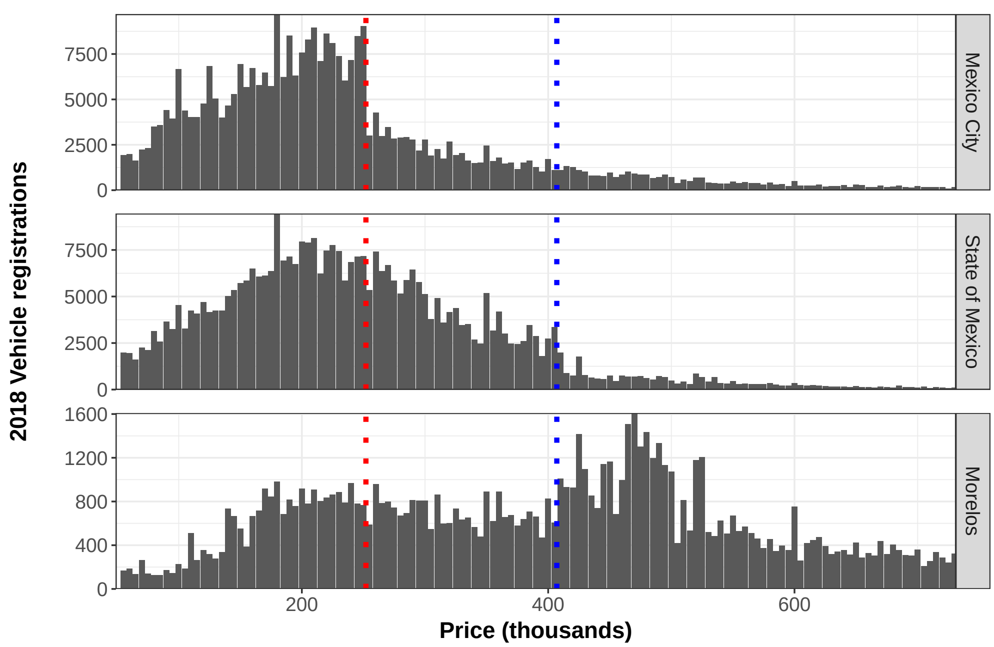


Pre period includes 2010-2011 and Post period includes 2012-2018. The red dotted line corresponds to the exemption threshold in Mexico City. The bins are $10,000 wide and represent yearly average

popular accounting for the small spikes right before the registration. This second fact is very relevant because it affects the fleet composition and in turn, the composition of the attributes of this fleet such as fuel efficiency,and smog check outcomes.

When examining the correlation between a vehicle's price and various attributes like tail pipe emissions and fuel efficiency, it becomes evident that the relationship is not uniform across the entire price spectrum as shown in the following Figures.

Figure 5: Shifting registrations

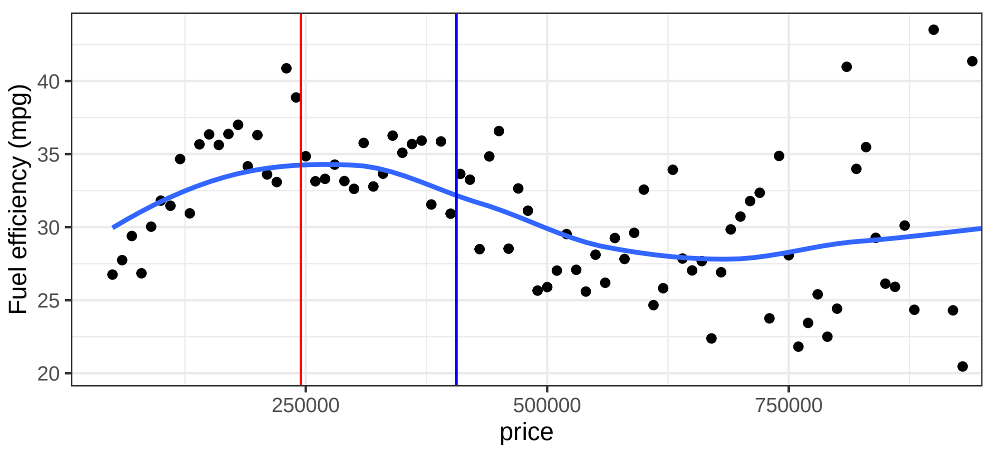


2018 yearly vehicle registrations for Mexico City and its neighboring states of Morelos and State of Mexico. The bins are $10,000 wide, and the red line is Mexico City exemption threshold and the blue one is for State of Mexico.

4.1 Fuel efficiency

Figure 6 shows the correlation between Fuel efficiency as Miles per Gallon (MPG) against price. As can be seen, the relationship between these two attributes is not homogeneous. Furthermore, vehicles right below the red line which corresponds to the Mexico City exemption threshold tend to have higher fuel efficiency. It can also be seen that as vehicle get more expensive they are less fuel efficient which is not surprising since the more expensive vehicles start to focus on other attributes such as power rather than cheap vehicle which tend to be more fuel efficient.

Figure 6: Fuel efficiency and price correlation



Reported fuel efficiency by the Ministry of Environment averaged out for all the vehicles in a price bin of size 10,000 (500 USD)

This non-constant correlation between MPG and price is particularly important since distortionary effects of taxes will have greater differentials the steeper the line of this correlation is.

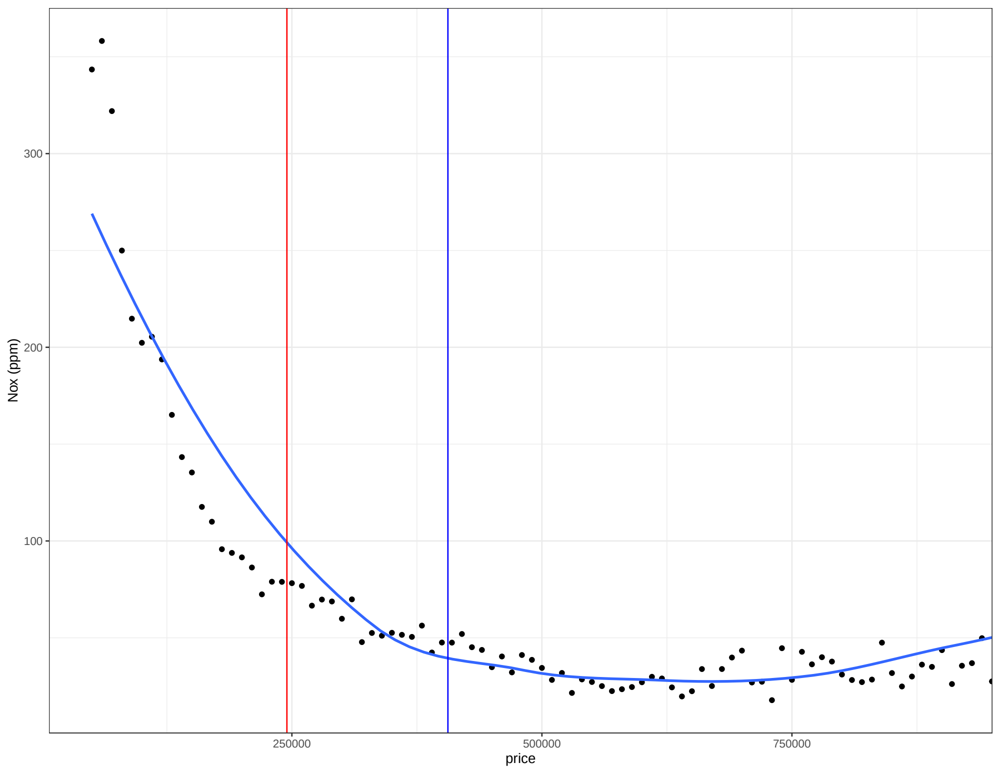
4.2 Tail pipe emissions

Figure 7 shows the correlation between price and Nitrogen Oxides (NOx) tailpipe emissions while Figure 8 show the correlation of price against hydrocarbon (HC) emissions. In these figures, we can observe that the relationship between these smog check outcomes is very steep for the lowest prices and then it flattens out. This is very relevant because if a policy with exemption thresholds is making cheaper vehicles close to the cutoff more popular, it would also be making vehicles that perform worse in the smog check more popular.

It has been documented that smog check repairs do not provide that much abatement (Mérel et al., 2014). We analyzed smog readings on the first smog check visit against reading in the close nearby period to document the effect of potential repair. We found that there is a slight improvement, however, the correlation between price is not affected it is just a parallel shift, meaning that the relation between price of vehicle and tail pipe emission on the first read or after a potential repair are unchanged.

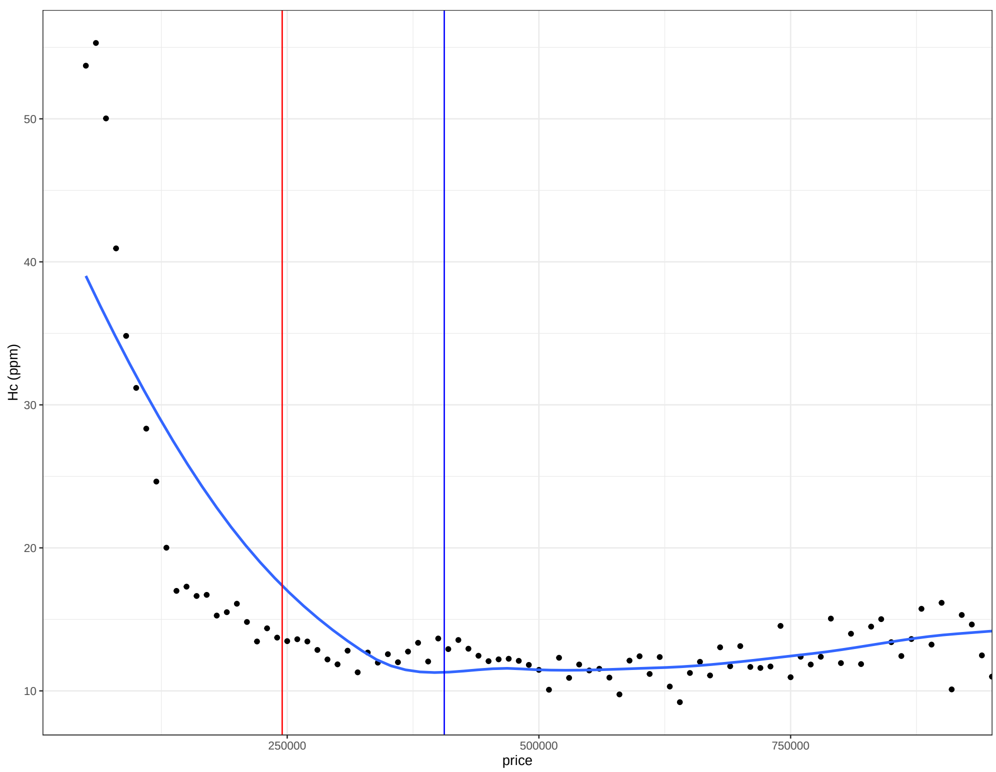
As for the two graphs presented; all the values for both figures are on average below the compliance standard for smog check pass. However, it is stark how much the correlation changes in the cheaper vehicles. As vehicles become more expensive their tailpipe emissions look more similar. Furthermore, we show only the results for smog check outcomes for vehicles registered before 2012 to avoid selection isssues. This selection is in the form of vehicles age. Vehicles right above the threshold registered after 2012 are older than the ones right below it as seen in Figure A1 in the appendix.

Figure 7: Tail pipe emissions and price correlation



NOx emissions readings from smog check outcomes matched to vehicle price via vehicle's plate and grouped by price in bins of 10,000 MXN

Figure 8: Tail pipe emissions and price correlation



HC emissions readings from smog check outcomes matched to vehicle price via vehicle's plate and grouped by price in bins of 10,000 MXN

5 Empirical strategy

To study the effect of the policy on the vehicle fleet composition we would like to see how the vehicle distribution in the Mexico City area would look in the absence of it. For it, we group vehicle registrations in price bins of width MXN 10,000 (500 USD) for Mexico City and a control group, before and after the policy change. With this, we run a simple difference in difference on each price bin to see how the composition of the fleet has changed. This approach is very convenient in the sense that a single estimation allows us to see several relevant results. For instance, the sum of the coefficients across the entire distribution can help us estimate if the policy's aggregate effect changed the number of vehicles registered in total. If we wanted to see the effect of the taxed against the untaxed we just redefine the size of the price bins so that there are only two, above and below the exemption threshold and compare both coefficient in what would look like a triple difference approach. If we want to have a better sense of revenue forgone rather than a lower bound we can use a smaller bin width so that we are able to recompose the missing revenue flow at each price bin since the tax is computed as a function of vehicle price. For our environmental outcomes, the multiple price bins that allow us for an effect at each defined price level allow us to estimate the environmental outcome of interest around exemption threholds.

An issue, however, is that there is no single state in the country that looks like Mexico City to use as a control. Mexico City is one of the most populous jurisdictions in the country where most of the population lives in urban zip codes and tend to have higher income and education levels. The following section details our approach to solving this issue.

5.1 Choosing a control

We expect the effect of the policy not only to affect Mexico City but the state of Mexico and Morelos since we expect the vehicle registrations to be moving around.Thus, we build a control group for each of this three states with nearest neighbor matching using 2010 census data following an approach similar to that of Fowlie et al., 2012.

Note that we could have used, in adittion to census data, vehicle registration data pre policy for the Mexico City. However, since the data for the state of Mexico did not include information at the zip code level we limit our matching excersise only to the variables that we can get from the census in order to keep consistency with the method for selecting a control. We must point out that we have also perfomed matching using vehicle registrations in adition to census data for those states where it was possible and the selected zip codes do not change that much.

In order to find a control for our treatment states (Mexico City, State of Mexico, and Morelos) we take census data from 2010 which is reported at the block level. We then geographically intersect zip code maps with block maps to find out which block belong to what urban zip codes and what share of it is included. Once we have this we are able to compute census variables at the zip code level.

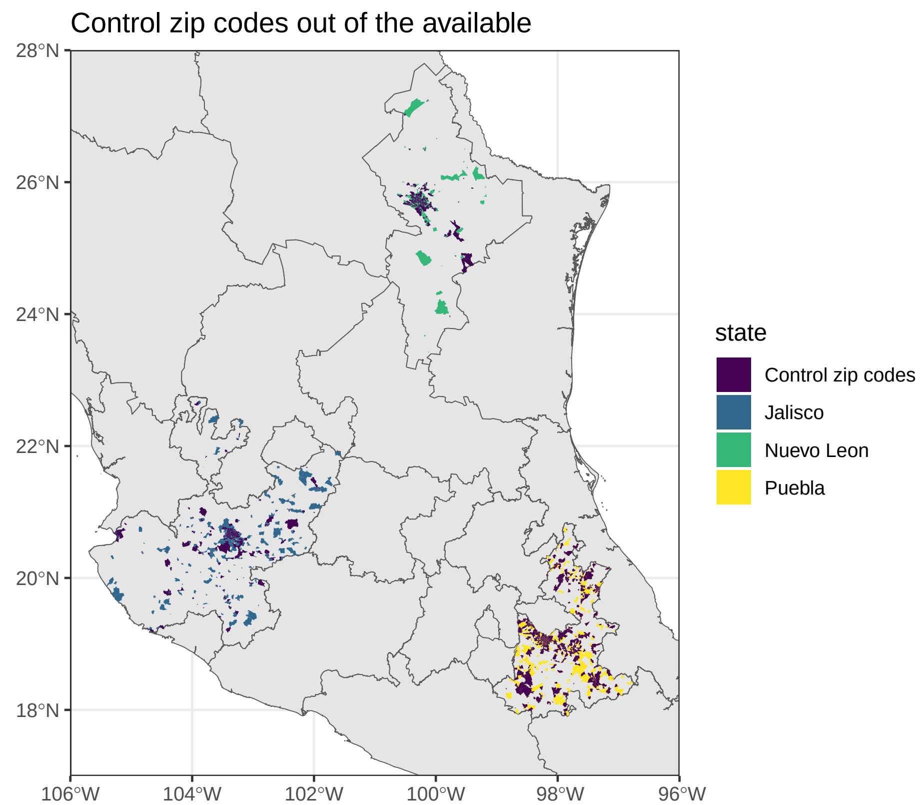
Once we have the zip code level data for all the urban zip code in the country, we proceed to select the controls using nearest neighbor matching. Although we have census data for all the urban zip codes, we only have vehicles registrations for 6 out of the 32 sates of the country and 3 of those are our treatment states. However, together this 6 states account for roughly 50% of the vehicles in the country. Furthermore, the top 5 biggest cities in the country are located in these states so the information they provide should be enough to build a control group. Figure A 9 show the available urban zip code we have to match while Figure 9 shows those that were selected in any of the 3 matching procedures. With a detailed map for each matching procedure in Figure A 10. We have also include in the Appendix A the figures showing the matching summary 3, 5, 7, as well as selected distributions for the variables that are matched 4, 6, 8.

5.2 Price bin difference in difference

This specification aims to see the effect of the policy on each price bin. The results shown are for price bins of width of 10,000 pesos (500 USD). The idea behind this is to use the interaction of the time post-2012 and the region of Mexico City as the treatment and the time before 2012 and the matched zip codes as control. The main motivation of using this method is that the tax exemption threshold is not only treating the taxed vehicles. Vehicles right below the cutoff also become more attractive and a change in the number of vehicles in this prices bin registered in Mexico City could be a response to the policy change.

Under this regression, I can say something about the entire distribution of the fleet because I see the response to the policy in the interaction outcome of the difference in difference. Furthermore, if I perform the same analysis with the regions where I suspect avoidance is happening I can get a sense of the effect on migrating registrations to other states or choosing cheaper vehicles. The specification is as follows:

Figure 9: Universe of zipcodes that were selected



Zip codes that were selected for Mexico City, State of Mexico, or Morelos as a result of a nearest neighbor matching algorithm choosing the top 3 nearest neighbors with replacement.

$$y_{p,t,z} = \alpha + \sum_{y=2010}^{2018} \gamma_m + \zeta_1 \text{time} + \zeta_2 \text{location} + \zeta_3(\text{time} * \text{location}) + e \tag{2}$$

Where $y_{p,m,z}$ is the number of registrations per month t for vehicles in price bin p aggregated for region z which is either Mexico City or the matched zip codes, *time* is dummy variable which is one after December 2011, and *state* is a dummy variable which takes a value of one if the state is Mexico City. In this regression I have n price bins, where $n = \frac{\text{Max(price) - min(price)}}{binsize}$ and I run a separate regression for each price bin. The coefficient of interest is ζ_3 which is the effect of the change in policy on the number of registrations in each price bin.

The results from this specification are quite useful. For one, I can multiply the coeffcients , which are in levels, for price bins above Mexico City cutoff times the expected revenue for a car in that price bin to get an estimate of how much revenue is forgone due to the avoidance. When looking at the environmental outcomes, I can use the predictions from the specification with and without the effect of the coefficient to calculate change in the weights of different price bins to estimate the effect of the policy on the average outcomes linked to the vehicles.

In our main result, We use a price bin of size 10,000. However this is an arbitrary number, it could change. On one hand, by decreasing the bin size I reduce the number of observations per bin. On the other hand, by increasing the number of bins I get more observation on each bin but start averaging the heterogeneous effects at more granular price levels. For example, if we go to the extreme and split the data into two price bins, price below and above the exemption threshold, such as in Figure 10, We are able to see the parallel trends between the control zip codes and Mexico City before the change in policy in 2012. Once the policy is implemented, we see that the lines are no longer parallel. Nevertheless, this bin size will not allow us to see the effect of the policy on the registrations of vehicles right below the cutoff.

5.3 Results

The following figures show a series of results. In this case, we graph the coefficient of ζ_3 which should be interpreted as the yearly average change in the number of registrations in Mexico City for vehicles in each price bin. Figure 11 shows the results for each price bin. As can be seen, there is an increase in the number of vehicles registered with a price right below the red line that corresponds to the exemption threshold for Mexico City. In this same figure, we observe that the coefficients for the price bin regressions above the exemption threshold are negative suggesting that these cars are missing because either people bought less of these cars or they registered them elsewhere to avoid the registration fee. However, we also see a negative effect for the cheapest vehicles. Our best hypothesis for this behavior is that Mexico City's jurisdiction (Federal District) is only a part of the metropolitan area. As can be seen in Figure 12 where the Mexico City metropolitan area is represented by the shaded region. Most of the outskirts of the metropolitan area are in the State of Mexico. Households with lower purchase power tend to live in these areas and they also tend to buy cheaper cars. Thus we expect that the missing cheaper car will show up in the results for the State of Mexico.

With the coefficients presented in Figure 11 we can estimate the forgone revenue from Mexico City which is close to 10% per year. That is, if there was no response to the policy,

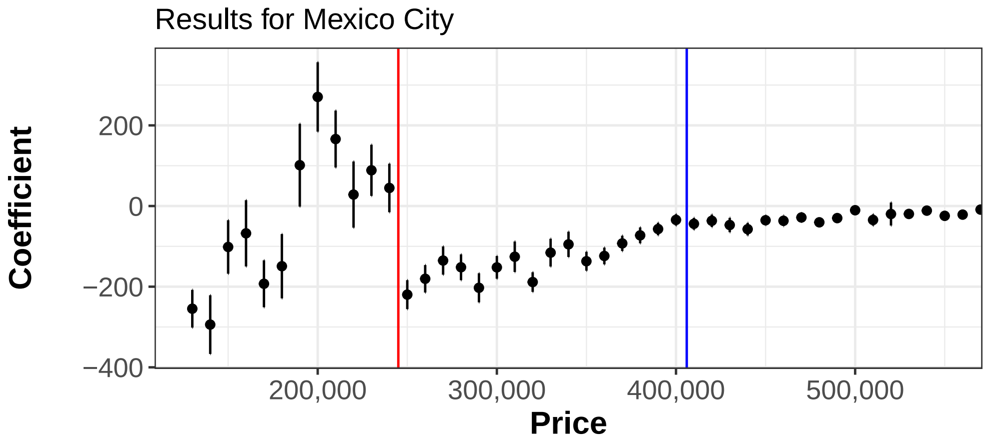
Figure 10: Parallel trends

Source: Vehicle registries from Mexico City and matched zip codes

either by avoiding and registering elsewhere or by buying a cheaper car, Mexico City would collect close to 10% more in revenue from registration fees. This by itself is an important result and with magnitude that is notable. To see how this policy response has environmental implications, we need to analyze the metropolitan areas since vehicles in Mexico City might start their trips in the state of Mexico. Thus are part of the environmental outcomes from vehicles in Mexico City.

When we run the regression specified in 2 but instead of using Mexico City as the treated jurisdiction we use the State of Mexico, we get the coefficients from Figure 13. In this figure we can see that all the cheaper vehicles increase, we also see an increase in the vehicle above the Mexico City cutoff but then a decrease for the registrations of the vehicles right above the state of Mexico cutoff (blue line). This suggests that registrations are migrating and that are very aware of the exemption. However, we cannot tell if the the changes in states of Mexico and Mexico City are from tax avoidance or actual migration

Figure 11: DID coefficients Mexico City



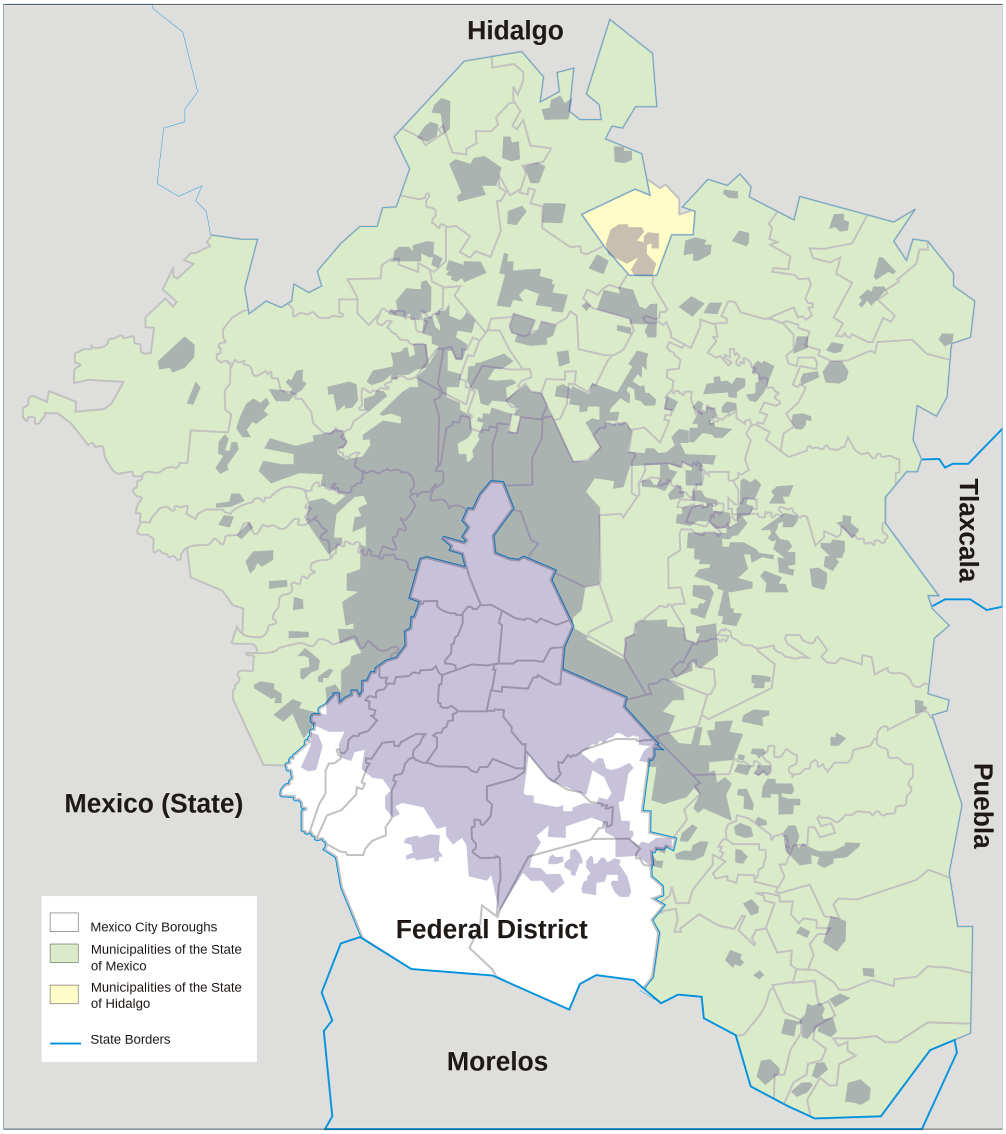
within the metropolitan area. If we add the effects of the 2 states, we see that the decrease of cheap vehicles for Mexico City disappears as well as the drop right after 250. Figure 14 shows the effects. However, for vehicles above the 400 exemption cutoff, we still see missing registrations. Pointing towards the avoidance hypothesis.

We also observe that the vehicle right at 250 or slightly below became more popular suggesting that there were individual that comply and decrease their tax liability by buying a cheaper car.

If we do the same process but now instead of Mexico City or the State of Mexico we run the regression for Morelos and add the coefficients of the three states we get Figure 15. In it, we see that there are no more missing registrations for the most expensive cars. However, we do see some increase in the number of registrations for the vehicles right below the price cutoff and some decrease for those that are slightly priced above the exemption threshold. Suggesting that there's a change in the composition of the vehicle fleet.

Now, this coefficients can be subtracted to the predicted values from the regression to get the weights of a current and counterfactual distribution. Figure 16 shows the change. In it, we can observe that as response to the policy we see a greater mass of vehicles right below Mexico City exemption threshold noted as the grey line above the purple one. There is a smaller effect in and opposite direction for vehicles right above the state of Mexico exemption threshold (blue line). In this case the gray line is below the purple line suggesting that if there was no response to the policy we would expect to have a greater share of expensive vehicles. Note that the effects as shares get smaller for both

Figure 12: Mexico City metropolitan area



Greater Mexico City. (2024, January 3). In Wikipedia

distributions as the price increases. This is consistent with this vehicles being less popular thant the cheap ones.

These results only show the effect of the policy. There is no way for us to tell how it would look like if registering elsewhere was not as easy. Would we see more people buying cheaper cars or would they buy what they are doing and pay the tax? These coefficients just show response they do not show if it is an avoidance or a price response.

Figure 13: State of Mexico Coefficient

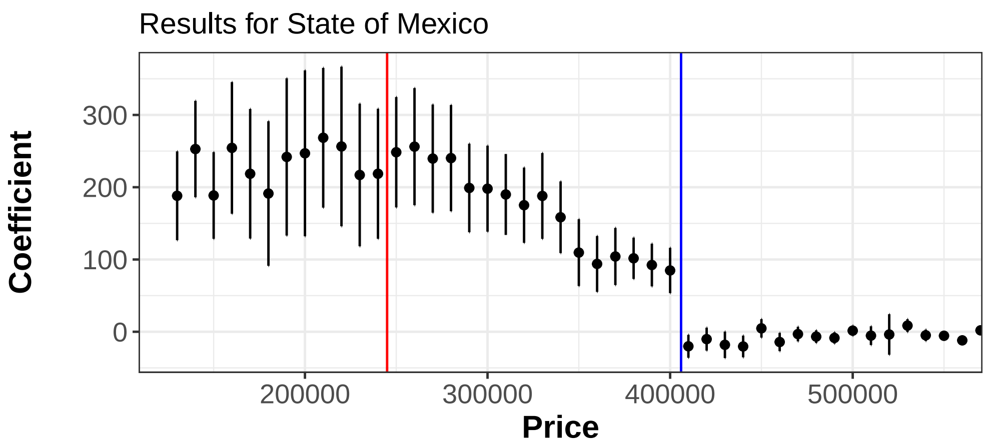
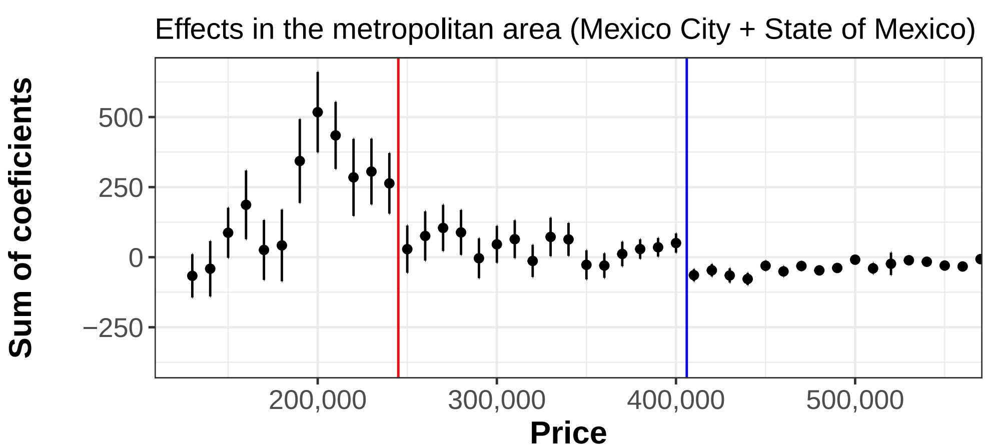


Figure 14: Extended Metropolitan area Coefficient



To isolate the price and avoidance response we have to impose some assumptions, calibrate a model and run counterfactual policies which we do in a further section.

6 Counterfactual policies

As seen from our empirical findings, there is a shift in vehicle registration conditional on the price as a response to this policy. However, we cannot tell how much avoidance mitigates the effect of a discrete exemption threshold in vehicle fleet outcomes. Ideally,

Figure 15: Sum of three regressions

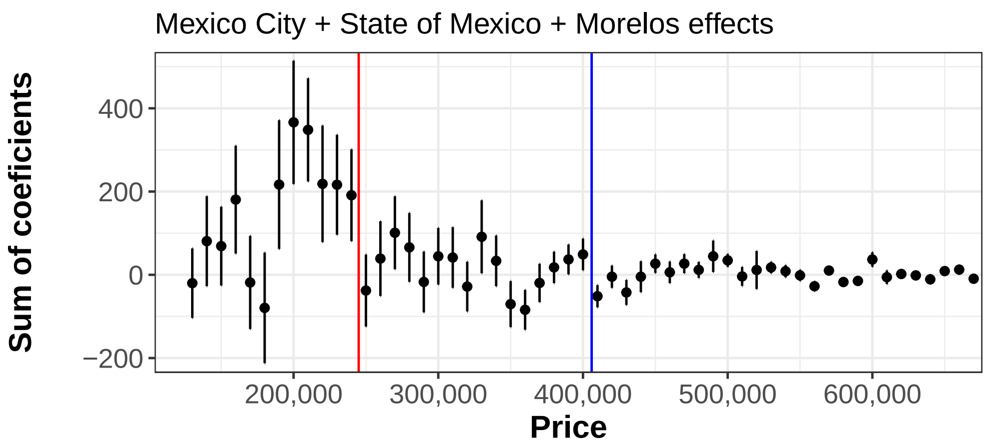
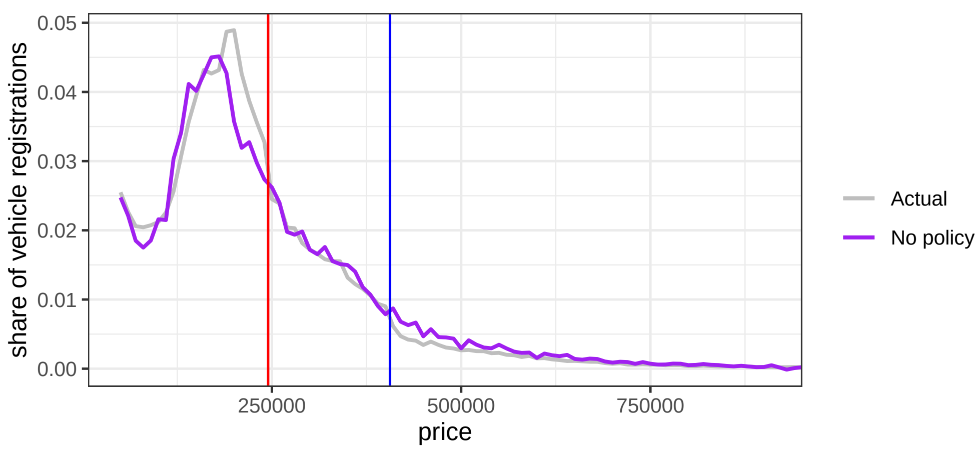


Figure 16: Weights of price bin in the vehicle distribution (actual vs no policy)



Actual line has the weights for the predicted values of the regression. The purple line is the counterfactual scenario where we subtract the coefficients from the prediction and recalculate the weight to show how the distribution would look like if there was no policy

we would like to isolate the avoidance effect from the price effect and run several policy scenarios to see what is the effect of better enforcement, or changes in the tax schedules in the composition of the vehicle fleet and the environmental attributes related to it. For that, we use the model we described in Section 3 with the parameters we estimated in Appendix B.

From the modeling and estimation sections we have utilities defined by a set of three parameters. θ coming from the Beta distribution of the second kind, cheating costs coming from a truncated normal, and γ come from the solution of the first order conditions. These results allow us to carry out the simulation scenarios.

In this section, we present two simulations along with the current policy setting. For the first scenario, we increased the cost of cheating and for the second, we made the tax schedule the same as the neighboring state of Morelos, that is, we decreased to 0 the exemption threshold and lower the tax rate. For the first one, we increased the mean value of cheating cost in the truncated normal by a factor of 10 and ran several draws to see how the response looked. As expected the number of avoidance registrations decreased and the number of vehicles right below the cutoff increased mitigating the effect in collection and exacerbating the effect on environmental outcomes. For the second one, we set the exemption to 0 and tax rate to be 0.025%, very close to the Morelos fixed fee. This change in policy results in a reduction of the distortionary effects of the policy mainly because we got rid of discrete cutoffs. Figure 17 shows the effect on the distribution of vehicles around where the current threshold is for Mexico City. It can be seen that avoidance mitigates the distortionary effects.

Figure 17: Distortion at cutoffs and avoidance effect

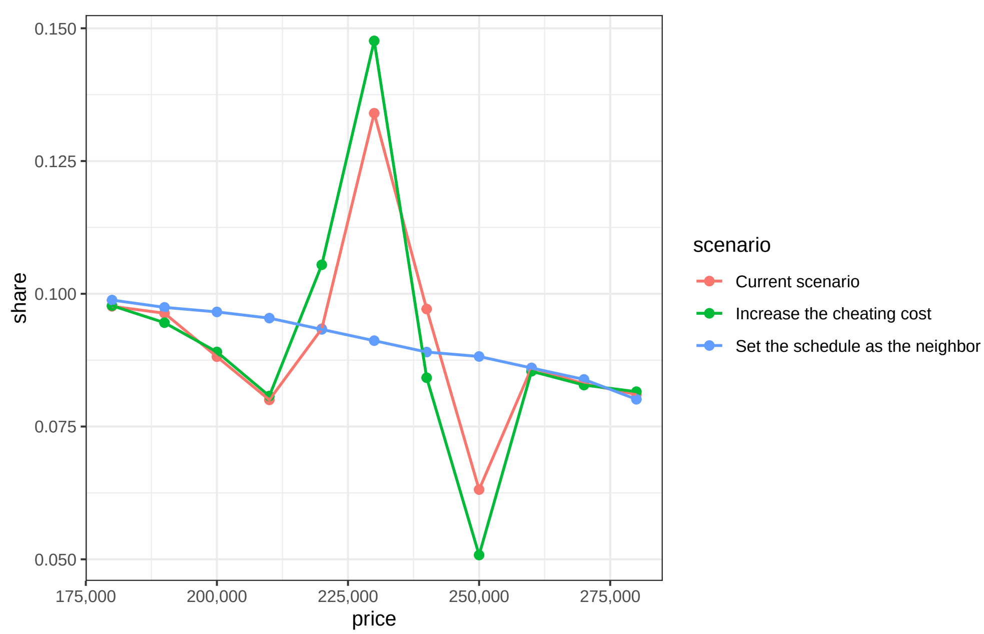


Figure shows the distortionary effects of discrete cutoff policies and how avoidance mitigates these effects

It is important to note that this changes in policy are to show the mechanisms of how individuals respond to policy and how that shapes fleet outcomes. In reality it would be hard to increase the cheating cost 10 times. One could thing of better enforcement or alternative methods to increase compliance, however this polices will most likely come at a cost.

7 Environmental implications

A tax based on one vehicle attribute such as price does not have a single effect in the vehicles fleet composition regarding price. As we showed in the data section price and other vehicle attributes have a non flat relationship. From our results in the previous section we can look at how vehicles attributes are different around the exemption threshold for Mexico City. Figure 18 shows the different values for the environmental outcomes below and above the exemption threshold for Mexico City. The last column includes the weighted average of that envrionmental outcomes around the threshold using the weights reported in Figure 17 for the three different scenarios.

As can be seen the values for fuel eficciency below the cutoff are close to 3 mpg better than those below the cutoff, while the tail pipe emissions are worse for those vehicles below the threshold, most notable in the case of NOx. When we compare the effects of the policy "current outcome" weighted average, against the "No exemption and reduce rate" the changes are minimal. That is becasue the change in the weights at most is a 10%, it is not a 0 to 1. Although the effects seem null, there is a subsitutuion that is happening at those attributes that gets washed out when we look at the averages.

At first glance, the results seem very small and of second order when we compare it with the revenue impact in Mexico City 2% vs 10%.

8 Conclusion

This study examines the fiscal and environmental consequences of decentralizing vehicle registration fees in Mexico, revealing significant impacts on revenue collection and vehicle fleet composition. Our analysis shows that decentralization facilitated tax avoidance, reducing annual registration revenue by approximately 10% as vehicle owners registered higher-value cars in neighboring states with lower fees. This widespread avoidance

Figure 18: outcomes with different policies

Results between $190,000 - 270,000			
	Below cutoff	**Above cutoff**	**Weighted average**
Fuel efficiency (mpg)			
Current outcome	36.54	33.67	35.73
Increase cheating cost	36.52	33.60	35.74
No exemption and reduce rat	36.09	33.78	35.36
NOX (ppm)			
Current outcome	7.29	5.64	6.82
Increase cheating cost	7.27	5.62	6.83
No exemption and reduce rat	7.43	5.68	6.88
HC (ppm)			
Current outcome	8.45	8.00	8.32
Increase cheating cost	8.44	8.00	8.32
No exemption and reduce rat	8.51	8.00	8.35

compare

highlights a critical challenge in achieving intended fiscal outcomes, especially in the context of decentralized tax systems.

The tax policy's discrete cutoffs influenced vehicle purchase behavior, as individuals increasingly opted for lower-priced vehicles just below the tax threshold to minimize fees. Although these vehicles are generally more fuel-efficient, they emit higher levels of nitrogen oxides (NOx), leading to unintended environmental impacts. This shift creates a fleet composition skewed toward vehicles with poorer tailpipe emissions per mile, highlighting how specific tax design elements—particularly cutoff thresholds—can lead to adverse environmental outcomes when combined with tax avoidance behavior. These results underscore the importance of aligning tax policy structure with environmental objectives to avoid unintended consequences that undermine the policy's original intent.

Our findings suggest that coordinated policy enforcement across jurisdictions is essential, particularly in the interconnected metropolitan areas of Mexico City and surrounding states. Implementing harmonized tax schedules or centralizing vehicle registration could help address the revenue losses and environmental degradation resulting from tax avoidance. Without these adjustments, the decentralized structure inadvertently incentivizes behavior that undermines both fiscal and environmental goals, underscoring the need for regulatory frameworks that anticipate and counteract avoidance tactics.

This research contributes to the literature on public finance, tax policy, and environmental regulation by highlighting the unintended outcomes that can arise from decentralized tax policies, particularly in the context of transportation. Policymakers in developing regions facing similar compliance challenges may benefit from these insights, as they consider strategies to balance revenue generation with environmental stewardship. Addressing compliance issues, especially in sectors where emissions have pronounced externalities, is critical to realizing the full potential of tax-based environmental policies.

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A Appendix figures

this is the appendix

Figure 1: Age and price correlation

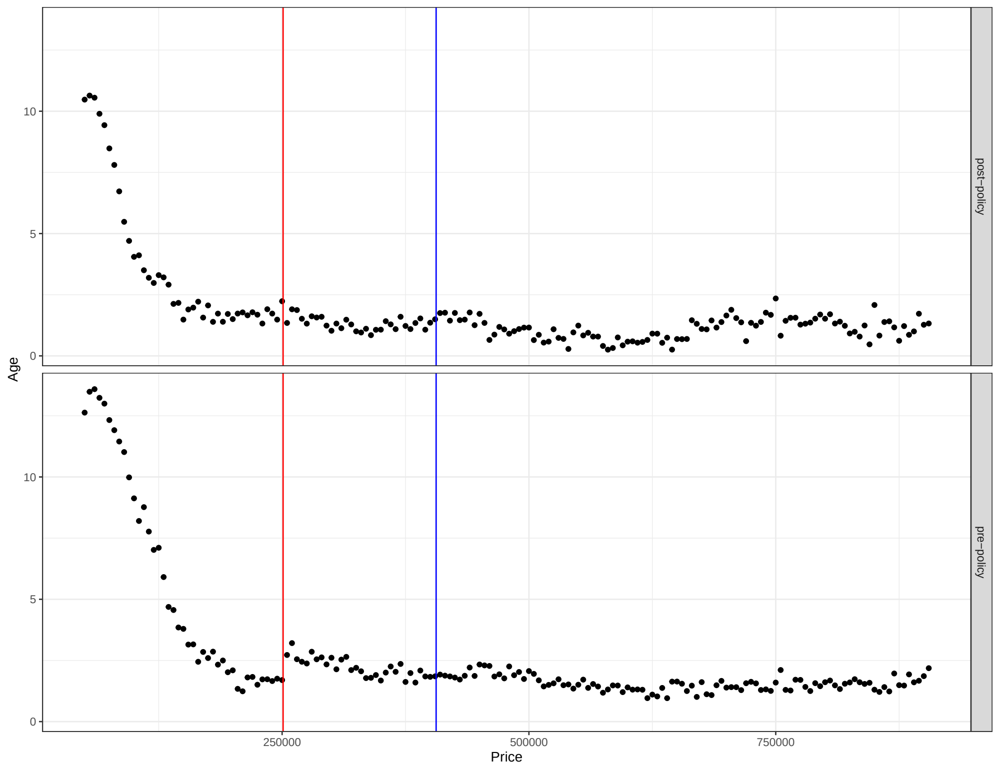
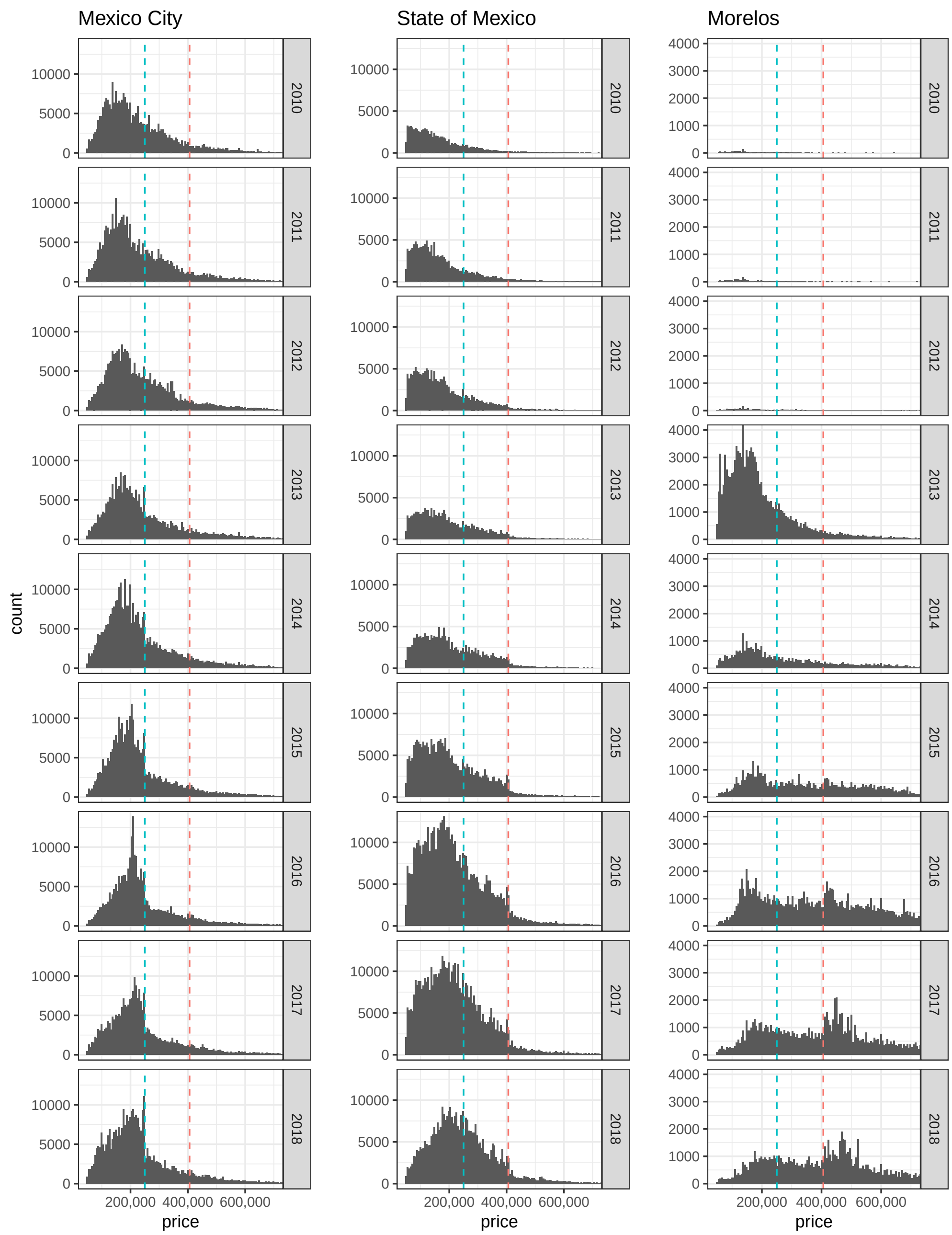
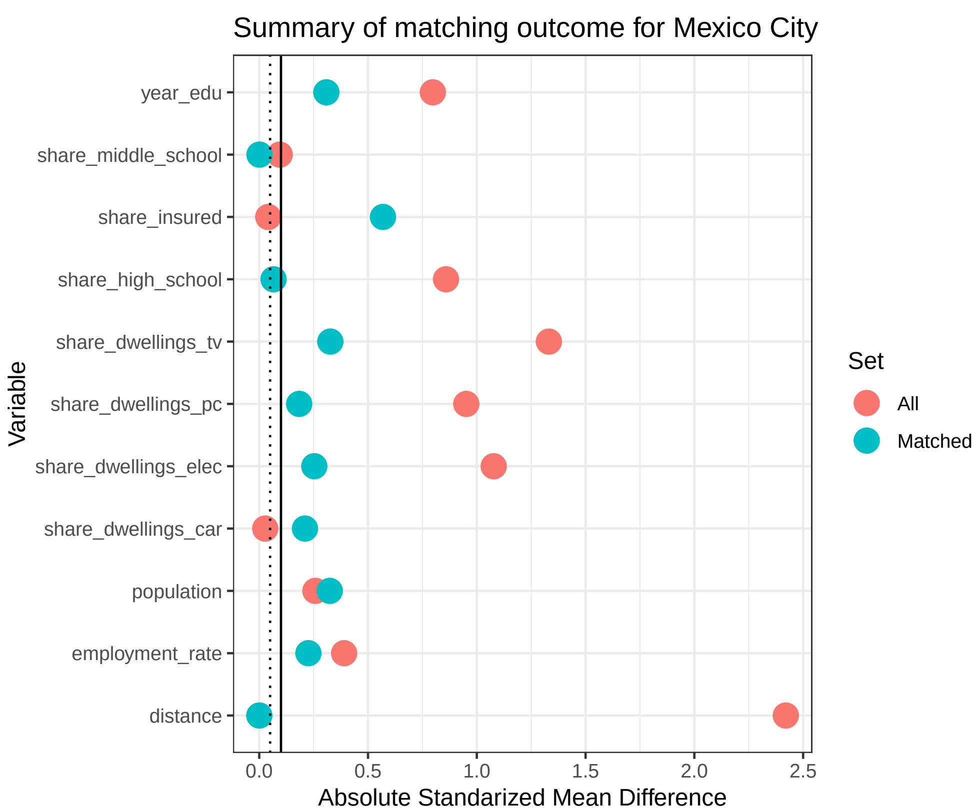


Figure 2: All registrations around Mexico City



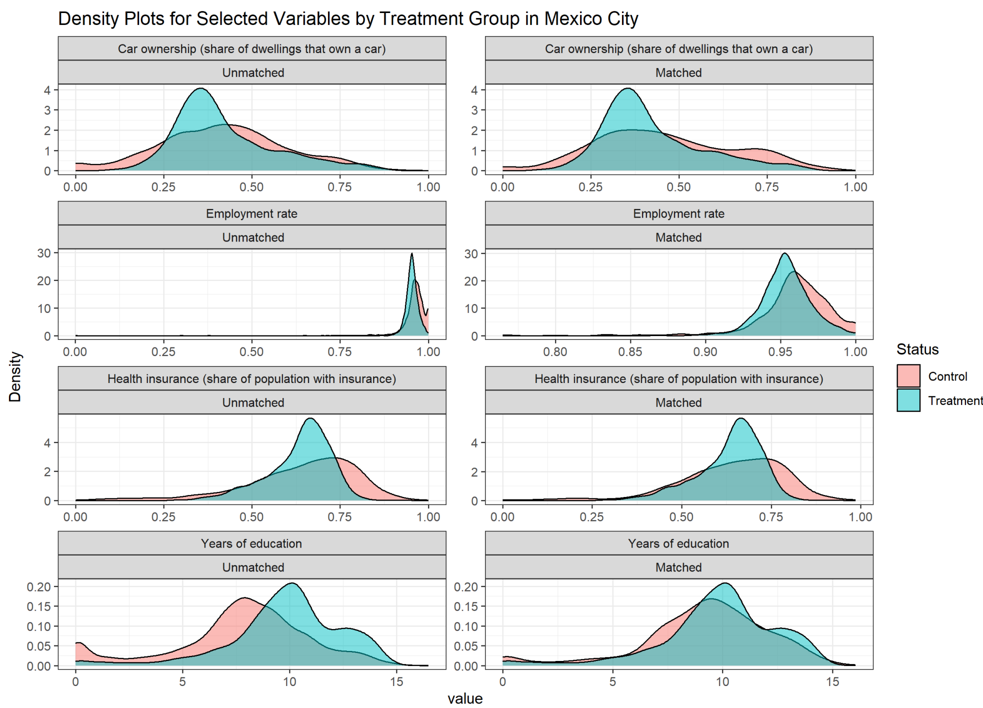
Morelos enforced a re-registration mandate in 2013 and that's why we see a greater amount of vehicles registered. When we look the data at vintage level the pattern does not change. It just had very few registrations

Figure 3: Matching summary Mexico City



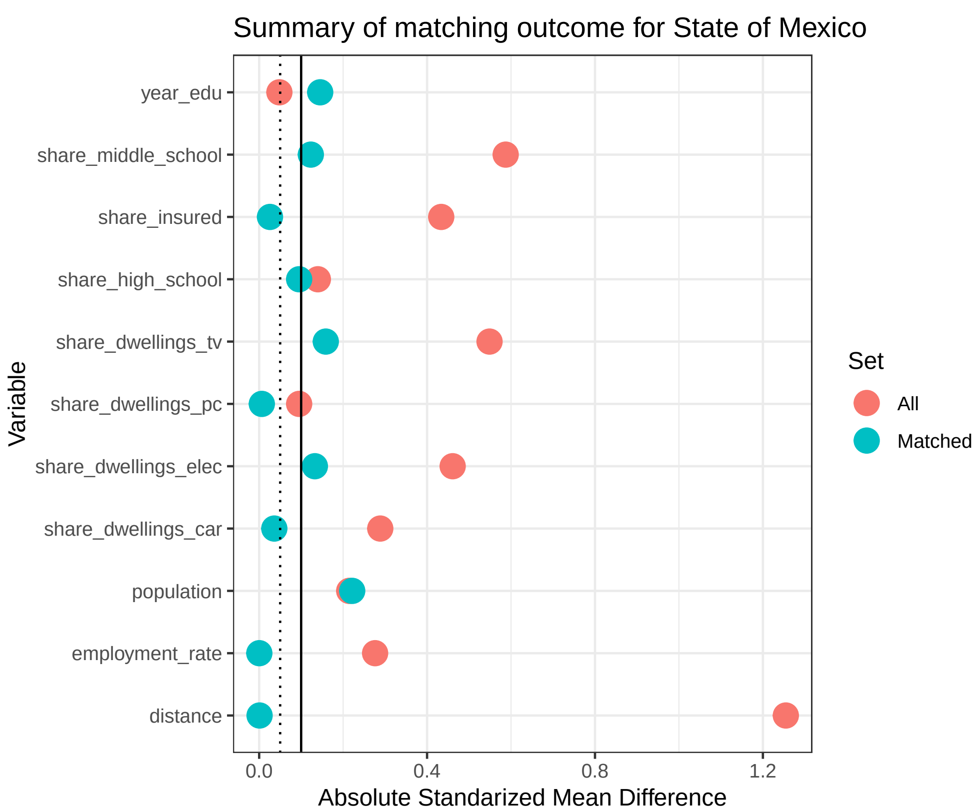
summary of the matching

Figure 4: Matching densities Mexico City



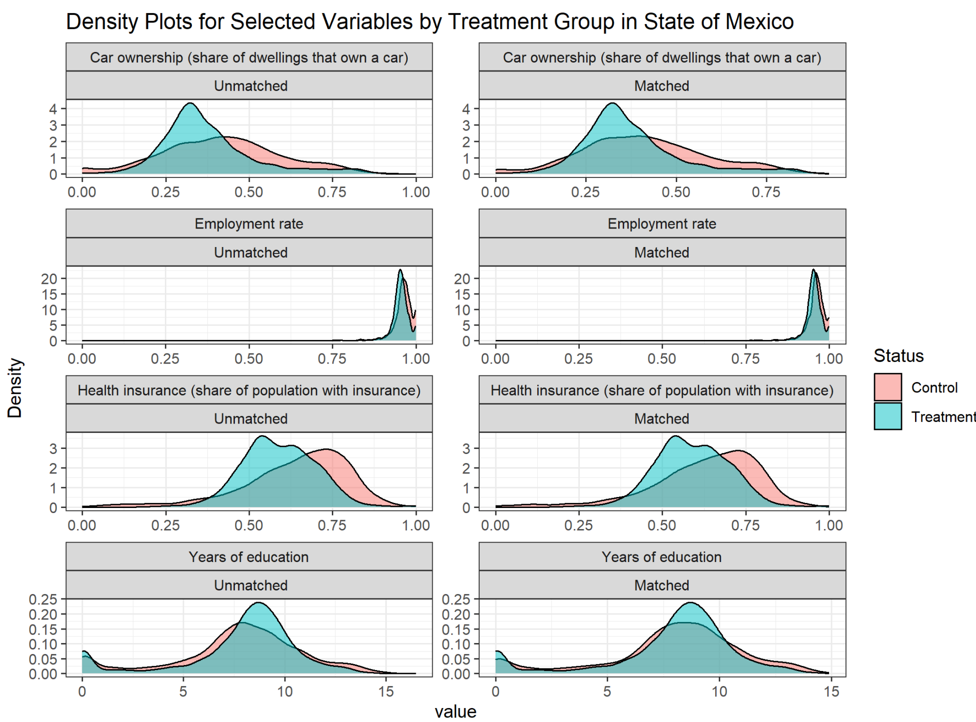
density of control against treatment before and after matching

Figure 5: Matching summary State of Mexico



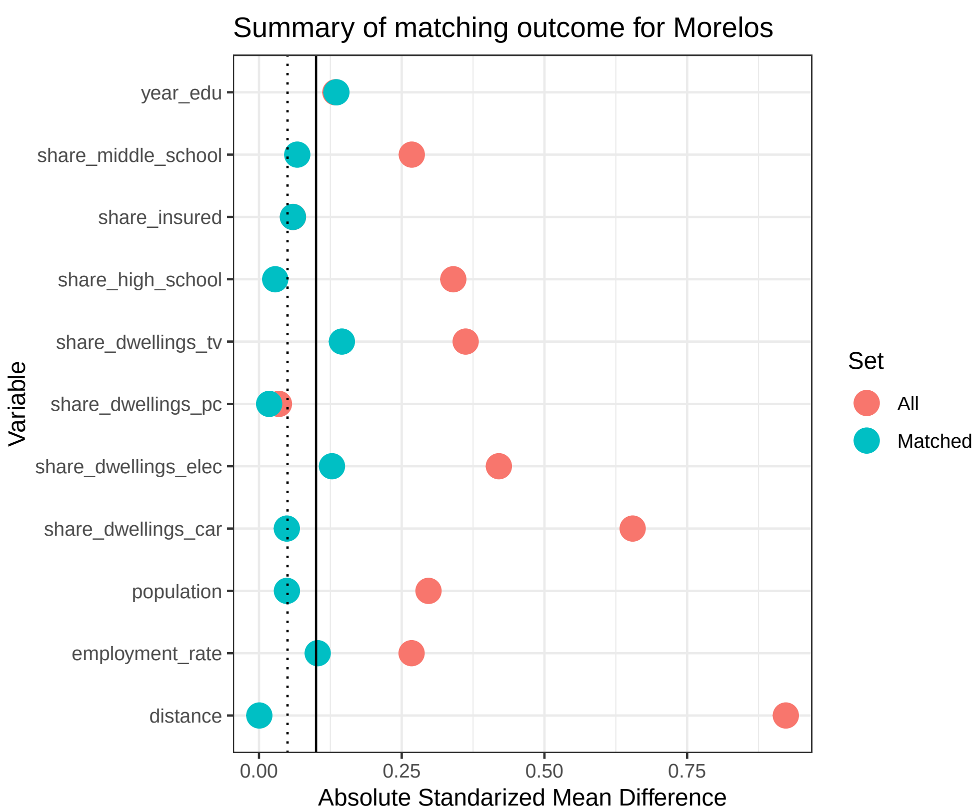
summary of the matching

Figure 6: Matching densities State of Mexico



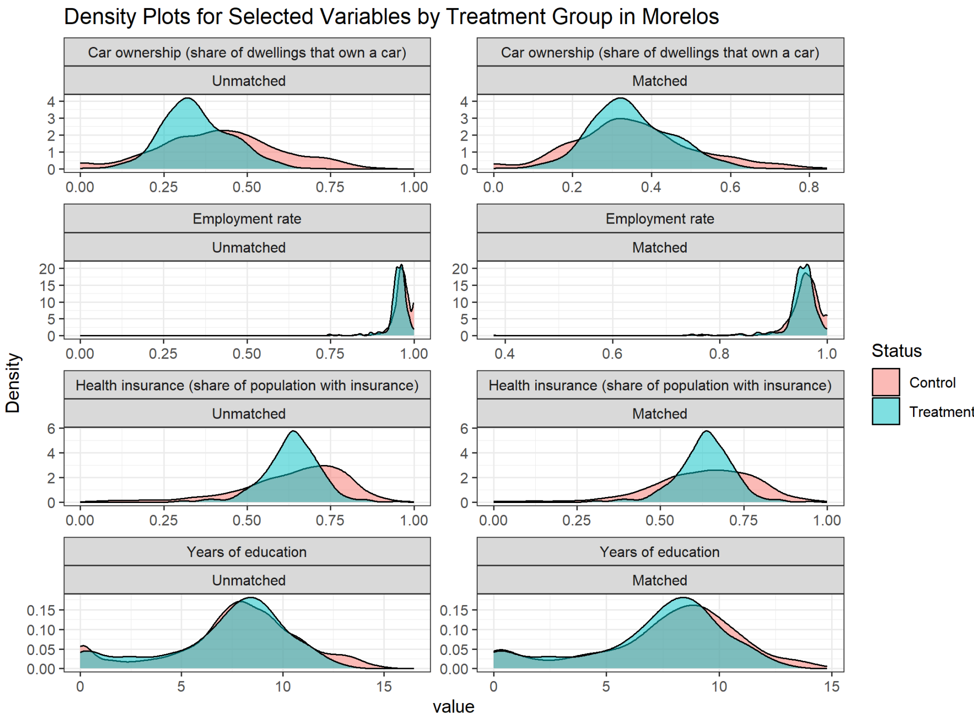
density of control against treatment before and after matching

Figure 7: Matching summary Morelos



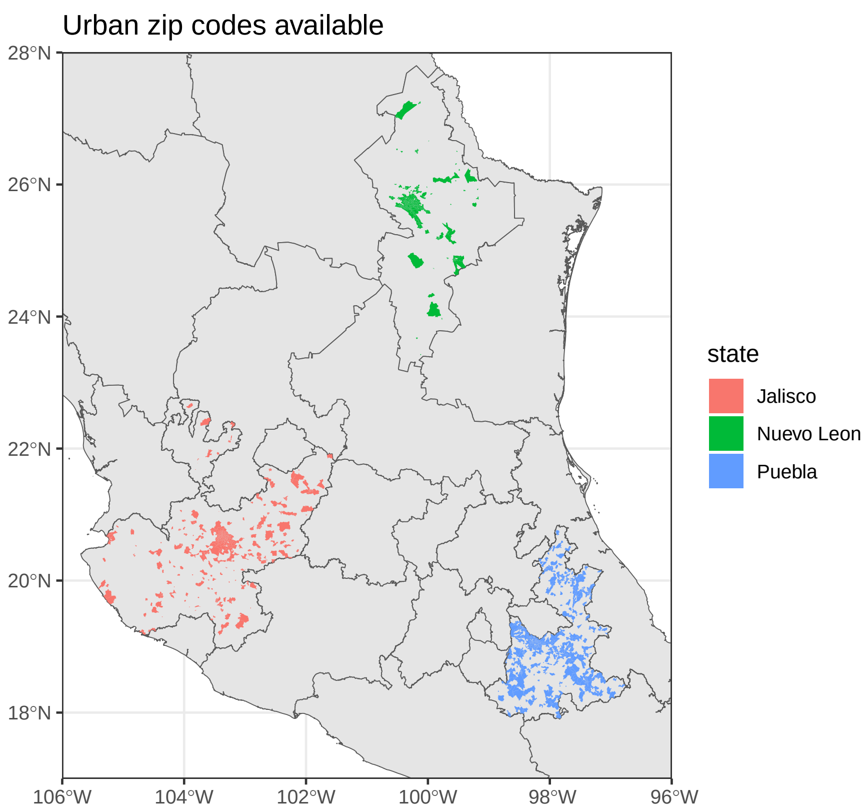
summary of the matching

Figure 8: Matching densities Morelos



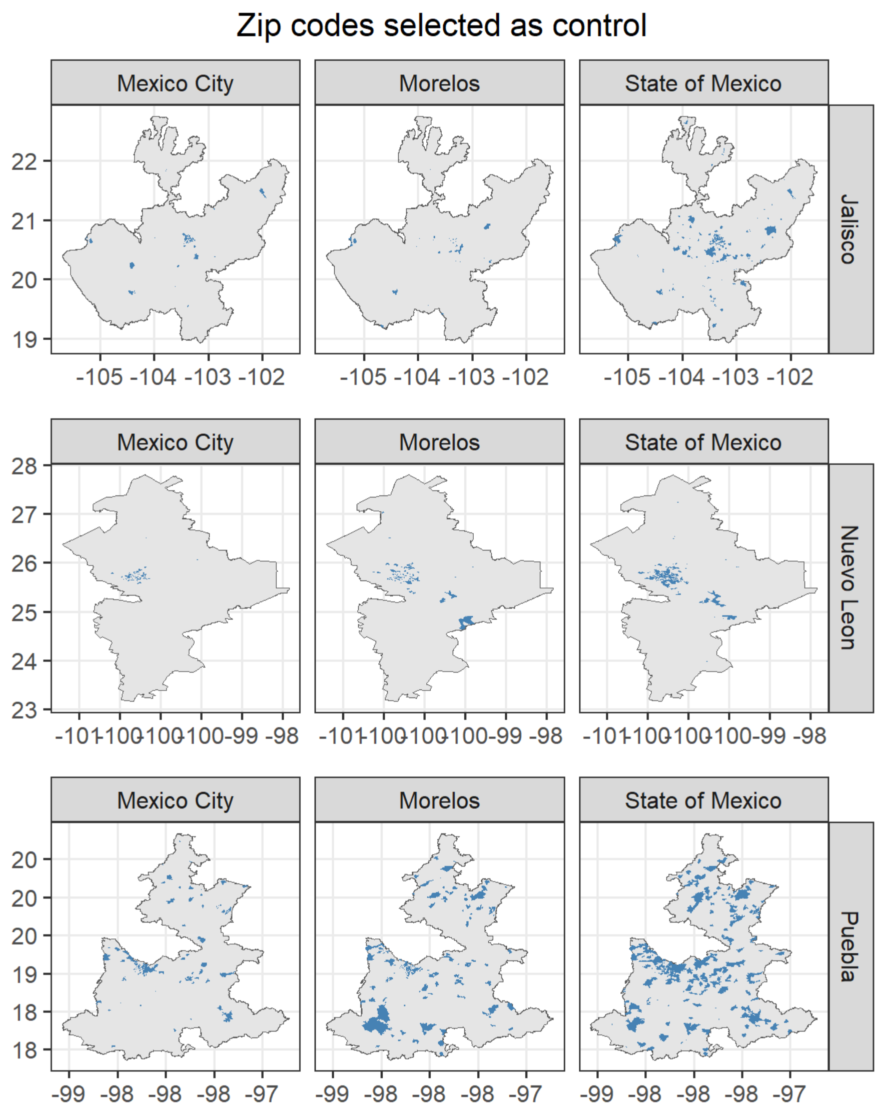
density of control against treatment before and after matching

Figure 9: Urban zipcodes available in the census



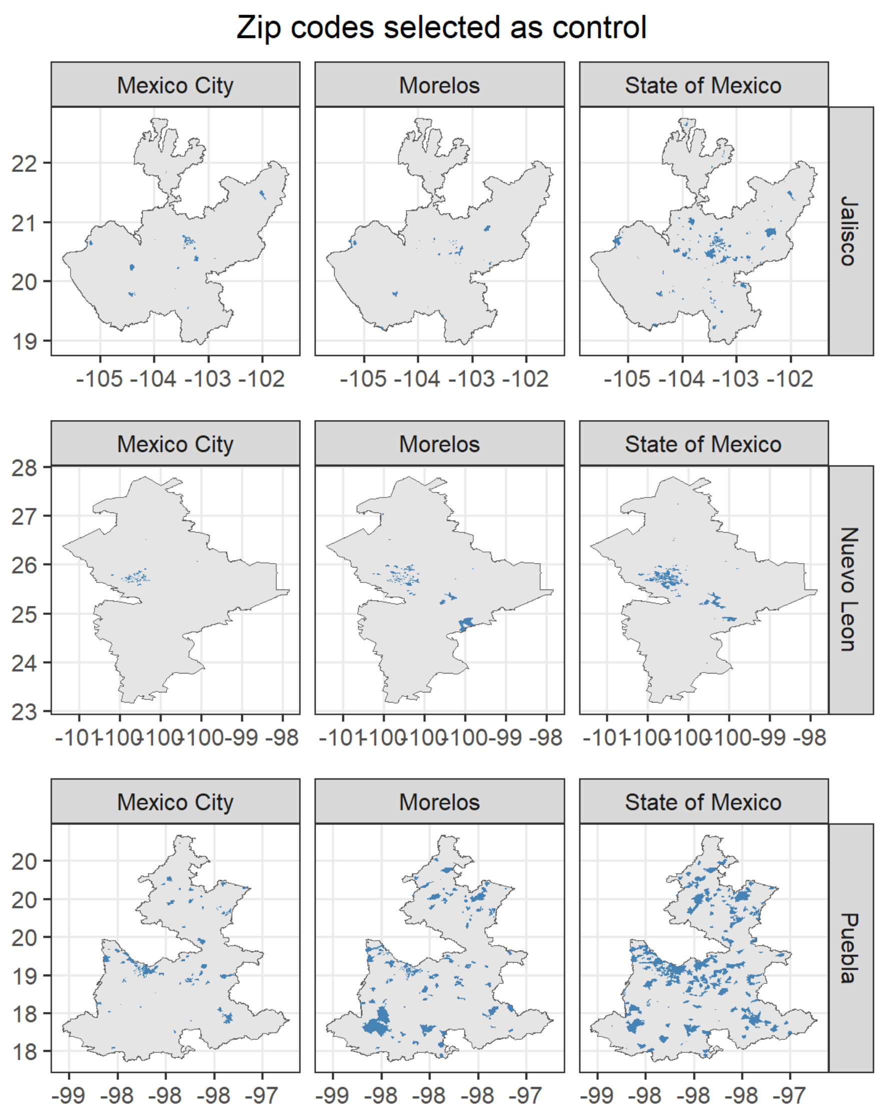
All the urban zipcodes available to contribute as control zip codes for Mexico City, State of Mexico, and Morelos

Figure 10: Zip codes selected as control groups for each state chosen as treatment



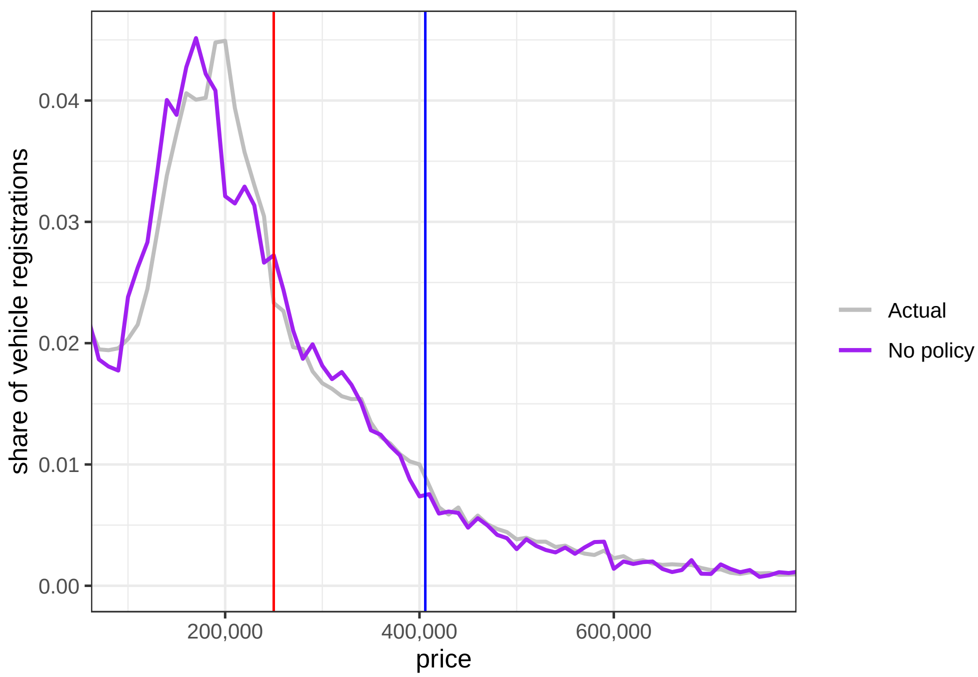
Zip codes that were selected for Mexico City, State of Mexico, or Morelos as a result of a nearest neighbor matching algorithm choosing the top 3 nearest neighbors with replacement.

Figure 11: Effects at thresholds



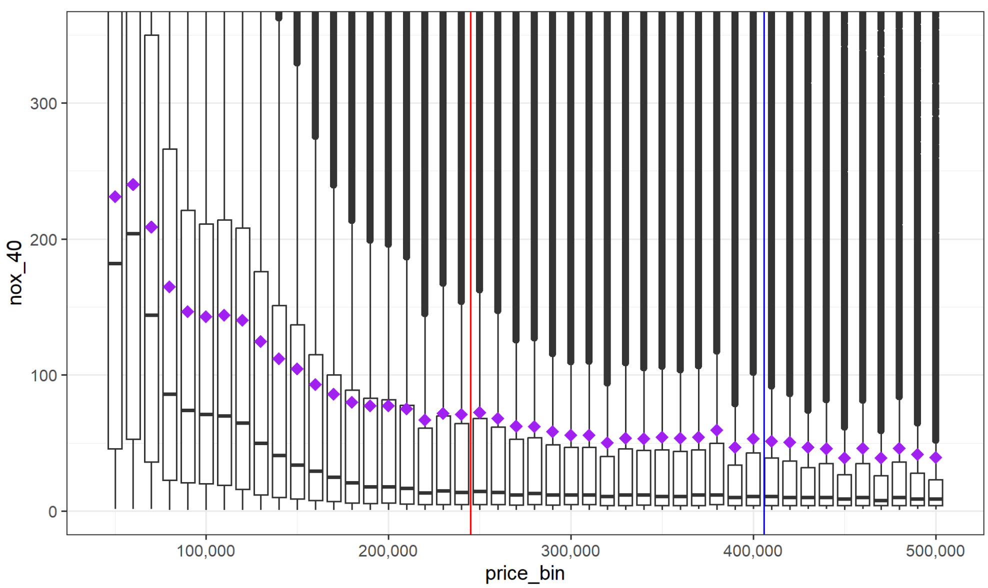
something something.

Figure 12: Counterfactual distribution



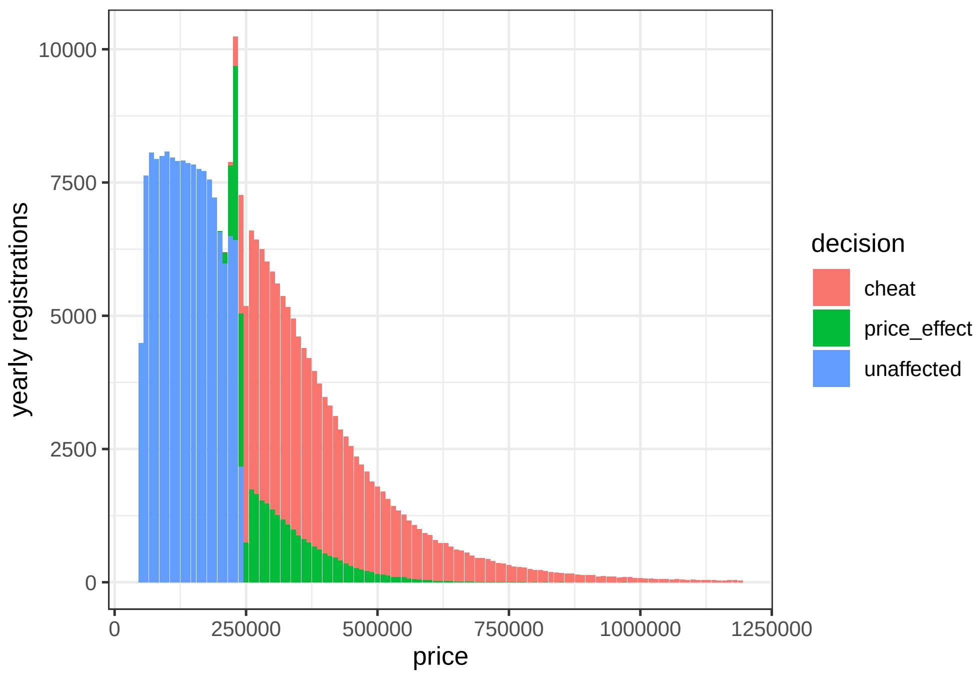
something something.

Figure 13: NOX distribution per price bin



data is filtering those values above 700 since that is the limit for a vehicle to pass the smog check otherwise they cant legally drive something.

Figure 14: Simulation from the model



dcurrent graph shows outcomes of the model under current policy scenario. this results illustrate the magnitude of avoidance and distortion on the vehicle fleet.

B Model Calibration

To be able to run counterfactual policy scenarios we need to find the values and distribution that best model the variables we mentioned on the framework utility function.

$$\max_{P}[-\gamma_i(\theta_i - P)^2 - \tau P, -C_i] \tag{1}$$

That is, we need a distirbution for the random variables for ideal price θ, weighting parameter for the disutility to substitutte γ, and the cheating cost C_i

We estimate θ following Generalized Additive Models for Location Scale and Shape from (Rigby and Stasinopoulos, 2005). The models use a distributional regression approach where all the parameters of the conditional distribution of the response variable are modeled using explanatory variables. For the explanatory variable, we use the empirical distribution of vehicle prices in Mexico City for the year right before the policy was implemented. This approach concludes that vehicle registrations in Mexico City for the year pre-policy mimics a beta distribution of the second kind consistent with how (Graf and Nedyalkova, 2014; Ye et al., 2012) have modeled income, and somehow expected since income and vehicle price should be closely related because the higher the income the more expensive the car an owner can afford. From fitting the data using the method of Maximum Likelihood estimation based on the full log-likelihoods we get that the four parameters for the distribution are a=4.18 b=323,338.7 p=0.24 q=1.03.

To estimate the weighting parameter γ_i, we assume that the prices we observe being registered in Mexico City in the post-policy period are the result of an utility maximization that chooses price instead of cheating and registering elsewhere. Based on how we characterize the utility function, if the individual decides to cheat they will choose $P = \theta_i$. However, if they don't and decide to register in Mexico City they choose a vehicle with a price that maximizes their utility and solve the first order condition from equation 2.

$$2\gamma_i(\theta_i - P) = \tau \tag{2}$$

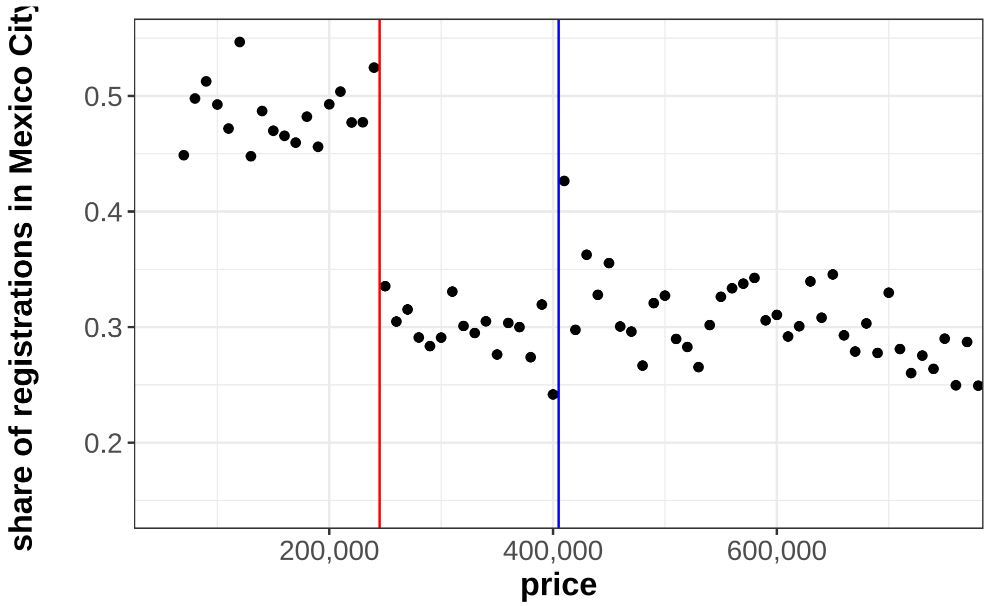
To get the γ_i values we take as many draws from θ as registrations in Mexico City in the post-policy period, multiply them times the inflation, and pair them with the price that we observe based on their rank. We then take the value of the marginal tax rate from the regulation depending on the price we observe and solve for γ_i from equation 2. The results give us n values of γ_i where n are the number of registrations. When we plot γ_i against price we do not observe any particular pattern so we further assume that they are uncorrelated so that now we can have the two parameters θ and γ. The first one comming from a random variable distribution and the second one from a set of values that solve equation 2

Now, for the cheating cost, we recognize the presence of heterogeneity otherwise there would be no registrations in Mexico City after a certain price. In the data there's a presence of cars registered in Mexico City even at the higher end of the distribution, suggesting a substantial cost associated with cheating for those individuals. These individuals opt to remain within Mexico City and pay the tax instead of registering elsewhere. However, the exact number of registrations that would fall within the higher price range remains uncertain; we only observe those who opt not to cheat. One approach could be to use all the registration in the post policy period for the states of Mexico , Morelos , and Mexico City. However, there are registrations in this state that actually belong there. In order to determine whats the share of this registrations that should actually be part of Mexico City, we plot the share of registrations that belong to Mexico City per price bin. We assume that the price bins below Mexico City's exemption threshold should not be affected. In that way, the share of vehicles we observe registered for price bins under $250,000 is the share of registrations out of the 3 states that should go to Mexico City. Figure 1 shows this effect. Furthermore it shows a stark difference for the share of registration that are above the threshold. We use this difference in shares to determine that the share of vehicles from the 3 states in Mexico City should be around 50%, but for the expensive vehicles it is around 30%.

Since we know that roughly 50% of the registration from the 3 states should be in Mexico City and we know the number of registrations each year. We take n draws from the θ distribution, such that n is 50% of the average number of registrations per year in the post policy period. To those price values from the draws of the θ we apply an inflation factor of 4% per year so that the prices that were estimated from a distribution in 2011 are now in prices for 2018. From this , we filter the data set for price bins above $250,000 and calculate at each price bin the share of honest registrations, that is vehicles registered in Mexico in the numerator and vehicles that should register in Mexico city in the denominator. The vehicles that should have registered in Mexico in a specific price bin is coming directly from the 50% draws of the inflated γ

From this, we get that roughly 40% of vehicles are cheating. Using the draws that should correspond to Mexico City, I have a price distribution and then I use a binomial distribution to make the draws so that 40% of those draws are assigned as 'cheated'. We

Figure 1: Mexico City share of registrations



Mexico City registrations divided by the total number of registrations in the states of Morelos, Mexico, and Mexico City per price bin of width 10,000 pesos

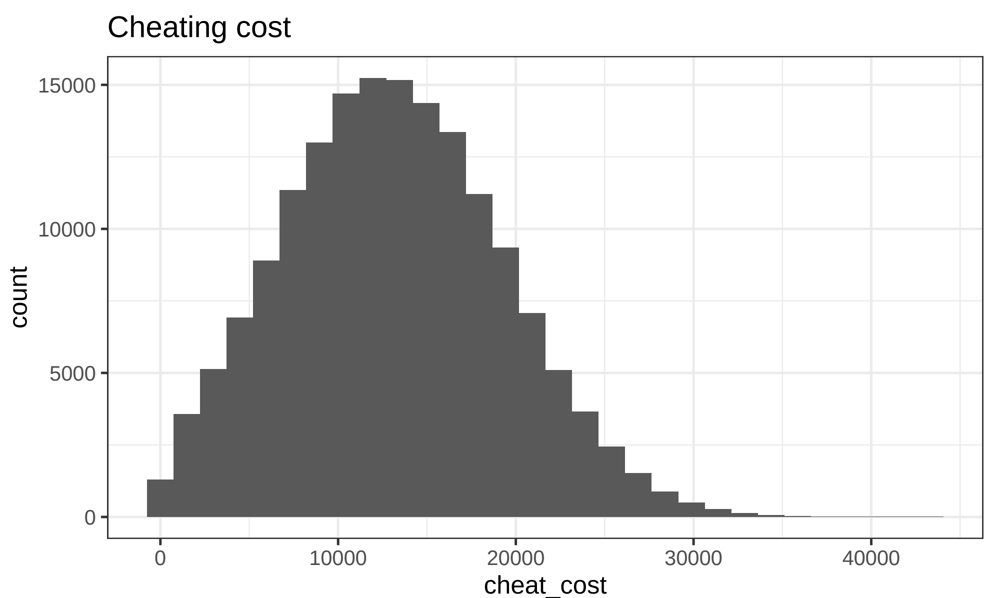
then compute the tax liability of each vehicle and which is paired with a cheat or no cheat variable.

According to (Khalmetski and Sliwka, 2019), cheating costs are distributed as a truncated normal. In our case we truncate the normal at 0 since we assume that there are no individual with negative cost of cheating. To estimate the mean and sd of this normal we perform non-linear optimimazation to minimize negative log-likelihood similar to how one does on the Kullback Leibler method.

This results in a truncated normal at 0 with a mean of 12720.094 and sd 6539.997. This is somewhat consistent with the information we found through mystery shopping. Agencies that register your car in Morelos charge around $7,0000, which is a value within less than a sd deviation of our estimation of the cheating cost.

With all this parameter estimated, we add a disturbance term which is distributed as a normal with mean 0 and variance of $10,000 pesos. This is to account for the fact that an individual might not always get that specific price but is reasonable to assume that it is within the range of the standard deviation of the disturbance term.

Figure 2: Cheating cost



Mexico City registrations divided by the total number of registrations in the states of Morelos, Mexico, and Mexico City per price bin of width 10,000 pesos