Stimulating the Car Market at an Environmental Cost: Evidence from Fiscal Stimulus in China*

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Abstract

Stimulating durable goods purchases is especially crucial during recessions and many stimulus policies target environmental-friendly products. However, there is little evidence on the consequences of these policies, both in terms of stimulus and environmental impact. We seek such evidence by evaluating important recent fiscal stimulus programs in the Chinese passenger car market: tax holidays and cash subsidies for the purchase of new small engine cars. This paper shows the impact of tax incentives using national administrative car registration data from the years 2005-2018. The results show that a one percentage point sales tax decrease increases the total sales of targeted small cars by about 3.2% and decreases sales of their substitutes, cars with slightly larger sized engines, by 3.9%. Overall, the stimulus effect dominates the substitution effect and the total additional spending goes up by approximately 30 billion USD. In terms of environmental impact, the net increase in carbon emissions imposes a social cost as high as 11.4 billion USD.

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1 Introduction

Many governments use fiscal policies to smooth business cycles by affecting the purchase of capital goods or durable goods, for instance, bonus investment depreciation, 'Cash for Clunkers in the United States and Germany, and housing transaction tax holidays in the United Kingdom. Understanding behavioral responses to policies is important when debating whether the government can spur economic activity through fiscal interventions (Zwick and Mahon, 2017; House and Shapiro, 2008). How well fiscal stimulus works has gained more attention, especially when the interest rate is low. In practice, most fiscal stimulus design only targets selective environmental friendly goods such as fuel efficient cars and appliances. It is intended to substitute away from high energy consumption products; however, if the stimulus effect is substantial, it may impose an additional cost on the environment because induced purchases that would not happen without the stimulus could dominate the substitution effect. Improving policy design requires knowledge about the impact of taxation on targeted goods and their close substitutes. There is scant evidence of how tax incentives change consumption. The lacking of comprehensive microdata and the inability to construct counterfactual scenarios, makes it difficult to evaluate the policies' impact on stimulating and correcting negative externalities.

This paper uses administrative passenger car registration data in China from 2005 to 2018 to study two important temporary stimulus policies in China's car market and evaluates their impact on carbon emission. The stimulus programs are tax holidays, which occurred in two waves and cash subsidies, which occurred in three waves. Only cars with small engines sold in a certain period were eligible for the programs and both programs surprised the market. We use the variation in eligibility and time to identify the causal impact. The temporary changes in taxes and subsidies could affect consumer behavior in three ways: 1) The extensive margin effect: Consumers who were not planning to buy a car during the stimulus period prior to the policy enactment. They can be a first time owner of a vehicle or an existing owner who takes advantage of the policies to replace an old car. The additional sales inform

us about the strength of the fiscal stimulating effect. 2) The retiming effect: Consumers who were planning to purchase after the policy period are pulled forward into the policy period. 3) The substitution effect: Consumers who were going to buy larger cars during or after the policy period switch to an eligible small model because they are now relatively cheaper.

The two most important fiscal programs are implemented as follows. The first stimulus program consists of two waves of car acquisition taxes. To combat the financial crisis, in January 2009 the car acquisition tax was halved from ten percent to five percent on small cars with an engine size less than 1.6 liters. The tax was raised to 7.5 percent in January, 2010 and returned to the original ten percent in January 2011. The tax holiday was only announced a week before implementation, and included the end of the holiday. From October, 2015 to December, 2017, a similar tax holiday was again implemented .

The other stimulus program was a lump-sum subsidy to selected fuel efficient small cars from June, 2010 to September, 2015. To be eligible for a 3000 Yuan (442 USD) subsidy cars needed to meet several requirements; the most important one was engine size less than 1.6L. In addition to the engine size restriction the car also needed to meet certain fuel consumption standards (Chen et al., 2017). There are three waves with ten lists of cars for the subsidy program. More details on the policies and how they change the effective tax rates are provided in section two. The beginning of each subsidy is a surprise to the market and firms know when the subsidy expires at least one month before it is announced.[1]

A difference-in-differences methodology is employed to estimate the stimulus policies' causal impact on small cars and their substitute sales. The first step categorizes the unaffected cars into substitutes and control groups. The policies studied only target small cars with engine sizes smaller than 1.6 liters, an important determinant of car performance. However, engine size alone is insufficient to construct a valid control group since many other factors are also important considerations for consumers. We solve this problem by taking

[1]The subsidy program's timing was based on the total amount of money the government has and all information is publicly available. The first and second waves of the subsidy program didn't announce the ending date. However, industry experts and dealers know the total amount of funding the financial department has and infer the end date at least one month before the formal announcement.

both engine size and price into consideration. The vast majority of policy targets are relatively cheaper cars. We use larger and more expensive cars to construct the counterfactual of the small car sales. What is left in between the small cars and control group cars are mid-sized engine cars or larger cars whose prices are close enough to small cars. We study the substitution effect on these cars.

We classify cars into four groups based on the features of the two stimulus policies: group one only includes cars that are eligible for the acquisition tax holidays but not eligible for the cash subsidy program; group two includes all the subsidized smaller cars and we classify cars into this group if the car is ever selected; group three includes cars that are never eligible for any of the tax incentives but are competing with the treated smaller cars; the fourth group consists of cars that are not going to be affected indirectly by the policies, large and expensive cars.

Our empirical analysis yields several interesting findings. First, if the tax rate for smaller cars decreases one percentage point, their sales will increase by 3.2%, only less than 1% of the total increase comes from consumers who advance their purchase to enjoy the tax cut. This implies a large-scale stimulating effect. More important, fiscal policies also have indirect effects on ineligible cars that compete with small cars. The sales of substitutes of the small cars decrease by 3.9% when the small car tax rate decreases by one percentage point, which implies the tax holidays stimulated total sales by 11.2%.

Besides the important implications on fiscal stimulus, the findings shed light on another big issue: the net impact of a stimulus policy's impact on the environment, especially when both extensive and substitution effects work together. The automobile industry is an important part of fulfilling the promise of China's goal to contain carbon emissions. In the 2016 Paris climate agreement the Chinese government promised to reduce carbon emissions from 2005 levels more than 60% by 2030. In 2019 the carbon emissions for automobiles account for about 8% of the total carbon emissions in China. Promised policies need to balance the fiscal stimulus effect and any increased carbon emission from cars that would not have been

purchased without the policy. This paper aims to provide estimates to thoroughly evaluate the cost and benefit of the policies .

The tax incentives on smaller cars have an ambiguous impact on total emissions from driving (Andersson, 2017). On one hand, lower taxes on smaller cars attract medium car buyers and reduces carbon emission; on the other hand, the stimulus effect increases carbon emissions by putting more cars on the road. The net impact on carbon emissions remains an empirical question that can be answered by three effects we identify in our paper. We use the estimated effects on car sales to calculate the impact on carbon emissions and find unintended consequences of the green stimulus: net carbon emissions increase because of the sizeable extensive margin response. The total increase of carbon emissions is approximately 2.1% of total emissions in 2014.The implied social cost could be as high as 11.4 billion USD, supposing the estimated marginal social cost of carbon emission per metric ton is 68 USD at a discount rate of 2.5%.

Our paper builds on and contributes to three main literatures. First, we contribute to a growing literature that studies the effect of tax policy on stimulus. Mian and Sufi (2012) evaluate the impact of the 2009 U.S. Cash for Clunkers program on short-and medium-run auto purchases. They find the effect was significantly more short-lived than previously suggested. The stimulus effect is reversed within ten months after the policy. Unlike the Cash for Clunkers Program design, consumers in China did not need to trade in their old car to get the subsidy. We focus on tax incentives for all new car purchases that potentially attract more marginal consumers who would not buy a new car without the policies. Tax incentives are also widely used to stimulate other durable goods consumption. Best and Kleven (2017) and Berger et al. (2018) study the housing market and found substantial extensive margin response to temporal tax incentives. The temporary tax exemption is also provided to encourage investment. House and Shapiro (2008) and Zwick and Mahon (2017) study the investment response on equipment of 2001 to 2004 temporary tax incentives. Another contribution to the body of literature that examines the Chinese auto market,

which is the largest market in the world today but still barely studied by the literature. Other emerging market may benefit from the knowledge we learnt from China.

Our second contribution is identifying the effect of taxation on close substitutes. It is generally believed cross product tax effect is negative, the theoretical prediction is unambiguous in standard industrial organization models. Models that focus on search cost also predict a decrease in small car prices could have a positive effect on medium car sales: Because consumers start to pay more attention to the car market and as they acquire more knowledge for cars, some of them will decide to buy a medium-size car (Ke and Lin, 2020). The cross product effect of taxation remains an empirical question and little attention has been given to the magnitude of the cross elasticity of taxation on close substitutes. Chen et al. (2017), for example find the impact of the first two waves of the subsidy programs on fuel efficient cars reduced sales of non-subsidized cars. We contribute to the public finance literature by adding clear evidence on the cross product effect. Understanding the cross product impact of tax policies has broad implications since many tax tools are targeted on certain products such as soda taxes based on sugar per liter, cigarette taxes based on E-cigarette or not, and tariffs on specific products and housing transaction taxes based on the size of the house. We show the importance of considering the overall impact of such policy changes.

This paper also contributes to the growing environmental literature by evaluating the net effect of green stimulus policies. The 'Cash for Clunkers' program has been widely implemented and studied in developed countries (Li et al., 2013; Mian and Sufi, 2012). We provide a full evaluation of similar programs in developing countries. Some studies have already pointed out that the green stimulus may actually increase emissions if not carefully designed (Davis et al., 2014). We find a similar undesired consequence on carbon emissions. To our best knowledge, this is the first paper that carefully incorporates the impact on the used car market to analyse the overall environmental consequences. Our results deliver a clear policy implication: A fiscal stimulus policy on car market can impose an environmental cost because it induces substantial additional purchases. However, if the induced scrapping

rate is high enough we can keep the environment cost at a low level.

This paper only considers the additional carbon emission effect from driving cars. Data limitation do not allow further investigations to the production side. Without knowing the alternatives if consumers do not buy cars, we cannot have precise estimates the emissions from the the production side. If car production emits more carbon dioxide than possible alternatives, our result tell us a lower bound estimates of the environmental cost.

A key feature of our analysis is the use of high-quality microdata. For this analysis we were granted access to transaction-level car sales data from 2005 to 2018 in China. The most important advantage of Chinese data we have product code for each car and in China auto market there is very little room for options. We can treat cars with the same product code as the same cars. In contrast, the primary source of data used in most other countries does not have this feature.

The rest of the paper is organized as follows: In the next section, we briefly describe the Chinese passenger car market and the policy details; in section three we introduce our data and construction of the control group; next we show our empirical strategy and present results in detail; finally, we conclude and offer suggestions for future research.

2 Institutional Background

2.1 China's Passenger Car Market

China's automobile market started to grow with the economic reform of the 1980s. The automobile industry is capital and technology intensive, the central government treats it as the pillars of the economy. In 1994 the National Development and Reform Commission initiated a program on Development of Automotive Industry aiming to giving priority to foreign investors with advanced technologies to create joint ventures with SOEs (state-owned enterprises). Attracted by these policies, most global car manufacturers began to establish joint

ventures in China, and after China's entrance into the World Trade Organization (WTO) the number of them surged eve further.

China's passenger market has been growing rapidly and features a strong seasonal pattern. Over the last two decades, the sale of passenger vehicles has increased by an annual growth rate of 20%. Vehicle sales stepped up from 1.3 million in 1994 to 24.2 million in 2017. Since 2009, it has been the largest global passenger car market, with yearly sales exceeding ten million[2]. In figure A1 and A2 we compare size of car market over time across countries. The car industry is especially important for China as more than 92% of cars are domestically produced. The volatility at the end of each year is due to the Chinese lunar year, a one-week-long holiday most important national holiday in January or February, and most business stops. As a result, the sales during the month of the Chinese lunar year drop because people advance their purchases the month before. The number of makes increased dramatically from less than 30 in 1995 to more than 70 in 2001 then to 396 in 2009. The number of car producers became stable after 2004. The top 10 firms' market share was over 90% in early 2000 but was reduced to 70% in 2010. There are 101 car companies in 2018 in total. Foreign firms must become a joint venture if they produce in China before 2019, and they can not hold more than 50% of the share.

Hu et al. (2014) finds no evidence for within or cross-group price collusion in China's auto industry, which suggests that the benefit is likely go to consumers. Small cars consumers are price sensitive, according to (Barwick et al., 2017) the price elasticity for small cars is around 4.2. Together these give us a prior that the potential response of the stimulus policy is not too small.

To the broader literature on the auto industry study, we compare our results with the estimates of price elasticity with respect to tax rate is the product of tax incidence and price elasticity. We do not have available in China's market. Estimates from other scholars suggest a high pass-through to consumers in this market. Our results are in line with the

[2]Light trucks are not included in this figure. The market size of light trucks is as large as the passenger car market and they are used for commuting.

current estimates.

2.2 Efforts to Mitigate the Environmental Cost

With the rapid development of auto industry, China is also facing the challenge from air pollution associated with cars. For example, according to China's Ministry of Environmental Protection (Ministry of Environmental Protection, 2010), vehicle emissions have become the main source of air pollution in Chinese cities, Both central and local governments have made efforts to mitigate the negative externalities. Xiao and Ju (2014) evaluates the consumption-tax based on engine size and fuel-tax adjustments in the Chinese automobile industry and did not find evidence supporting that the consumption tax can decrease fuel consumption. One possible explanation is the change of consumption tax only affect very small share of cars in the market. While in our paper the tax policies are targeting more than 70% of cars.

Besides the measures in tax policies, some local government implement more strict restrictions on vehicle usage. Beijing applied the odd-even license plate rule (Chen et al., 2013) and later on started to directly limit the number of new car registration. Shanghai, Tianjin and Hangzhou followed Beijing's policy on car ownership (Xiao et al,2017; Li, 2017). The above studies have shown that car usage restrictions indeed reduced the car sales and remarkably reduce pollution. By construction the car registration restriction policy does not allow for the tax reduction to be an effective stimulus policy. In our estimation we also use the sample that excludes the cities with car registration policies.

2.3 Car Acquisition Tax and Cash Subsidy Policies

The acquisition tax is only levied on first-time car purchasers and based on the pre-value added tax price. There are two waves of tax holidays: On January 14th,2009, the official announcement came out saying from January 20th to December 30th, 2009, for vehicles with displacement level smaller than 1.6L, the acquisition tax rate will be 5%. At the end of 2009, the central government compromised with car producers, and extended the holiday

for another year with a higher rate at 7.5%. Starting from January 2011, the tax rate goes back to its original level at 10 percent. The beginning of the holiday is a surprise to the market, but the expiration is fully anticipated. The second wave is structured in the same way. It is announced on September 29th, 2015 and implements a 5% tax rate from October 1st, 2015 to Dec 31st 2016, and 7.5% until Dec 31st 2017.

The policy effect also depends on the compliance of the acquisition tax. The acquisition tax is enforced by the traffic police, which is part of China's security system. The owner can not get a license plate from traffic police unless he/she remits the tax. Chain paperwork certifies the whole process from the tax invoice to the license plate. The potential corruption is easily detected, if any. We should not worry much about compliance with the acquisition tax regarding whether paying anything or not. However, the intensive margin of tax avoidance is still possible. The dealer can report a lower transaction price to the IRS and make a cash transfer under the table.

2.4 Fuel efficient Car Subsidy Program

To encourage the purchase of more fuel efficient cars, China's Department of the Treasury and Ministry of Industry and Information Technology decided to give a lump-sum subsidy to all selected Fuel efficient cars as an independent program of the tax holiday. The average market suggested retail price (MSRP) for the eligible cars is about 80000 Yuan, and the subsidy is equivalent to a 3.375% sales tax deduction. To be eligible for the 3000 Yuan (450 USD) subsidy, the car needs to meet several requirements 1) displacement level smaller than 1.6 liters; 2) MPG (Miles per gallon), and emission level meets some national standard. If the car meets these criterion, firms can apply for the subsidy and get the money once they are sold. The dealers will deduct 3000 Yuan from sales price and get it back from the finance department in practice. The program was announced in May 2010, and the first list was published on June 21st 2010. The list got extended every two or three months. At the end of the first wave subsidy, there are six lists in total. In October of 2011, the central

government decided to put a higher criterion for eligibility and renewed the list. The number of subsidized models dropped from around 423 to around 49 when the listed got renewed, and 30 models from the first wave remained. Several months later, the list got extended again. The second wave stopped on Sep 30th, 2013. The third wave of subsidy started one year later, from October 1st, 2014 to Dec 31th, 2015. We summarize the whole schedule of the three waves of subsidy program in Table 1. In Figure 1 we show the timeline of the tax holiday and subsidy programs and how they interact with each other.

To qualify for the program, car manufacturers need to submit applications for their vehicles to the government. After receiving an application for a particular vehicle model, the government would verify its attributes and decide whether the vehicle model was eligible.

Insert Figure 1, Table 1

Figure 2 summarizes the complicated tax schedule due to the two policies using the first wave tax holiday and subsidy as an example. We divide cars into three groups: 1) smaller cars that get the partial tax exemption but no subsidy, 2) smaller cars that get both and 3) larger car with no tax rate change. The average price of a smaller car is 80,000 Yuan (around 11400 USD) and we convert the 3,000 Yuan (around 450 USD) subsidy into a tax deduction.

Insert Figure 2

2.5 Other Taxes Levied on Cars

There are three major indirect taxes on cars: consumption tax, value-added tax (VAT) and acquisition tax. In addition car producers also need to remit consumption tax in addition when selling a car to the retailer. The tax rate varies from 3% to 20%, depending on the engine size. The consumption tax rate also changed on Sep 1st, 2008. A 17% VAT is also levied on the sales price and remitted when the transaction happens. [3] The listed price of

[3]The VAT rate decreased to 16% since May 1st, 2018.

a car is the VAT included price, and it's the dealer's responsibility to remit VAT.

Acquisition tax remittance in practice: The dealer will provide a roughly estimated amount of tax based on the transaction price. The actual taxable value might be higher than the reported transaction price. This is because the IRS puts a guidance price for each model and updates it from a recent transaction record. The guidance price is designed to prevent potential tax evasion, so this information is not declared to dealers.

2.6 The Salience of the Policies

For the policy to be effective, the consumers need to be aware of the policy. Figure A3 and A4 in the appendix shows the search trend for "Car acquisition tax" in Chinese. We see two spikes in Jan 2009 and Jan 2010, suggesting that consumers know well about the policy. One thing worth noticing is that at the beginning of 2009 and the end of 2009 and 2010, the attention is much higher than other periods. This implies the potential short term timing response. Google search is not available in China after 2013, and we supplement the search trend using the domestic search engine (Baidu).

Insert Figure A3 and A4

2.7 Other Determinants of the Car Market

In this section, we investigate how other determinants change with the timing of the tax incentives. In figure A6 and A7 we show the correlation between small and large car sales and consumer confidence index (CCI) separately. We do see that CCI is an important predictor to explain the trend of car sales. CCI quickly bounces back after the financial crisis, and we see that sales of large cars also started to increase in January 2009 when the first tax holiday started. The decrease in CCI in 2018 also explains the drop in car sales in the same period.

Insert Figure A6 and A7

In addition, we are concerned that the gas price change potentially drives the effect of tax incentives. The increase in gas prices is also going to make smaller and fuel efficient cars more favorable. In figure A8, we show the evolution of the national gas retailing price, and we see the gas price had already started to rise in January 2008, and in later periods, it is not positively correlated with the tax rate changes.

3 Data and Construction of Control group

3.1 Car Registration Data

The best available data to capture car sales information in China comes from the Department of National Security registration level data. The data set is also called China Car Registration Data Set. We can access data from 2005 to 2018 to evaluate the impact of the policies. The data set contains information such as register year, month, province, producer, brand, model, vehicle type, fuel type, engine capacity, gearbox, car shape, color, usage, ownership, buyers age, and gender. Each car must register at the traffic policy department to get the license plate, and the law is well implemented. The register month is a good proxy of purchase time. Model is important information here; unlike the U.S. market, in the Chinese auto market, there is very little room for options. We can treat cars with the same model as the same cars. The only available information on price is the market suggested retail price (MSRP), and we know each car's MSRP when it entered the market. The MSRP is at the trim level and each trim may correspond to several models. We match all the possible products and take the mean of the highest and lowest price.

3.2 Other Data Sets

In our empirical analysis, we need to control for the potential impacts of other determinants of the car market including: consumer confidence index and gas price. We collect these information from CEIC database. The fuel emission data comes from the Ministry of Industry

and Information Technology. Since 2010, all new cars in China are required to disclose their fuel efficiency which is tested by a third-party research institution.

3.3 Summary Statistics

In Table 3 we provide summary statistics for the main variables at the vehicle level in the final sample. The average monthly sales number for a vehicle model in a province is 38.9. The average engine size, fuel inefficiency, gasoline expenditure, horsepower, and weight are 1.8 liters, 8 liters per 100 kilometers, 50 RMB per 100 kilometers, 93 kilowatts, and 1345 kg, respectively.

Insert Table 3

3.4 Constructing Control Group

The policy designs allow us to employ the difference-in-differences strategy to estimate the causal impact of the policies. Before showing the graphical and estimation result, we discuss how we construct the control and substitutable groups. We use the displacement level, and market suggested retail price (MSRP) to construct small cars' counterfactual. A valid control group should not be affected by the tax holiday and has a similar growth rate with the small cars absent from the policy. The natural criterion is engine size, given the policy. People care about displacement level because it is one of the most important parts of a car that determines car performance, such as fuel consumption and horsepower. In Figure 3, we plot the correlation between engine size and gas consumption per 100 kilometers (GPK). First, we observe a positive correlation between engine size and GPK; note that the variance conditional on engine size is also large. This motivates us to utilize more information to construct the control group. We need to know the top considerations for consumers and use them to separate cars into different markets. A tax policy targeted on some cars from the low-end market should not affect the high-end market. We went to the most popular

phone app in China "Dongchedi" (meaning Car Expert in Chinese) and took a screenshot as shown in Figure A5. When a consumer indicates that he or she is interested in buying a new car, the system asks for the preference for brand first then immediately requests desired price range and half of their space to collect this information. This fact indicates that the most important factor for market segmentation is price. Our conversations with sales people at dealership confirms this argument. In addition to engine size, we use price to construct the control group and substitutable group. Figure 4 shows the price distribution of three groups of cars with the same scale on the X-axis (Price). All cars above 1.6L are not directly affected by the policy. From Figure 3 and our conversations with car dealers, we notice that a watershed in Chinas auto market is 2.0L, and cars above 2.0L are generally considered to be more comfortable and luxurious. We call cars between 1.6L and 2.0L (including 2.0L) medium cars and those above 2.0L larger cars.

The first observation from Figure 4 is that most of the smaller cars (Up-left) are cheaper than 200,000 Yuan (28,000 USD), but larger cars (Down-left) are more expensive in general, but the overlap in price is still not negligible. We also observe a bimodal distribution for the medium cars, competing with both small and larger cars. Again, this fact justifies the importance of using price information to further classify cars into different markets. We use 1) cars that are above 2.0L and more expensive than 200,000 Yuan or 2) cars above 1.6L and more expensive than 250,000 Yuan as a control group. Furthermore, we treat the large cars with a price lower than 200,000 Yuan and medium cars with a price lower than 250,000 Yuan as substitutable cars. In the robustness check section, we drop some very close models to the cutoffs and use stricter or weaker criteria for constructing control groups. Our main result does not change much.

Insert Figure 3 and 4

Given the policy and car market structure we divide all cars into four categories:

Low-end market
- Tax holiday only group: never subsidized small cars
- Tax holiday and subsidy group: subsidized small cars
- Substitutable group: median or large cars that are also cheaper

High-end market (control group): median or large cars that are expensive

4 Graphical Evidence

We first look at the impact of the tax holidays on small car sales in Figure 5. The treatment group is all cars eligible for the tax holidays, and some selective models are eligible for the subsidy. The blue line represents the sum of sales of all cars with engine size smaller than 1.6L, and the green line represents sales of the control group. We observe that the monthly sales from 2005 to 2008 for both groups are stable and parallel. The three green dashed lines correspond to the beginning and end of tax holidays. The two golden lines correspond to the beginning and end of the three waves of subsidy programs, and there are no stimulus policies during the year between the two blue lines. We calculate the tax rate for small cars with the subsidy in the red dashed dots to capture the policy variation. We take the logarithm of the data to reduce the variance and make the time series linear in Figure 6. In January 2009, small car sales started to surge when the policy was implemented and immediately dropped a lot in January 2010 and January 2011, right after the exemption period. The second wave shows a very similar pattern. Note that the fuel-efficient car subsidy policy targeted on selective smaller cars starts in June 2010, and the amount of subsidy equals the amount of tax exemption. So we observe the gap between the treated and control group continues to grow even after the holiday.

We can also observe strong retiming effect. A spike in sales is always in January during years without holidays because of the Chinese Lunar Year effect described in section two. But during the tax holiday period, the end of year spike of small car sales is pulled to

December in the year before to enjoy the tax cut while the large cars sales spike is still in February.

Insert Figure 5 and Figure 6

Next, we show visual evidence of the substitution effect. In Figure 7, we compare the sales trend for substitutable and control groups. The blue line represents the sales of small cars' substitutes, and the green line represents sales of the control group. The effect is more clear demonstrated in Figure 8 after log linearization. Again we observe that sales trends are parallel before the first tax holiday starts. Furthermore, the sales start to diverge right after the tax holiday. However, from September 2013 to September 2014, we also see a gap when no stimulus policies are in place. The gap could reflect a difference in trends in the long term. To be conservative, we also controlled for group-specific trend and province-specific trend in our regressions to account for the growth rate difference.

Insert Figure 7 and Figure 8

We also look at the size and impact of the subsidy program separately by plotting sales of the small but never subsidized car (a model with a small engine but never selected into the subsidy program) in Figure 9 and subsidized cars (if a model is ever subsidized) in Figure 10. We compare with the control group to detect the causal impact. The first golden lines are the beginning and end of the policy. The first wave is from June 2010 (first golden line) to September 2011; the second wave is from October 2011 to October 2013 (the first blue line), and the third wave is from October 2014 (the second blue line) to December 2015 (the second golden line). The stimulus impact is clearly shown in Figure 10, the sales of subsidized cars increased significantly during the subsidy period. Because there were few sales in previous years for those models for the subsidized cars, we use the sales level instead of the natural logarithm. We also show the log of sales in Figure A9.

We also observe a strong substitution effect from Figure 9, right after the subsidy program began in June 2010, non-subsidy car sales start to drop. Note that the drop in sales during the subsidy period is large, but we also need to take model exit and entry decisions into account. Some models that are already available before the subsidy program will exit given the life cycle of nature. A more precise inference of the subsidy program's magnitude requires a within model fixed effect in the estimation. We show the results in the next section.

Insert Figure 9 and 10

In the last part of the graphical evidence, Figure 11 demonstrates how the three waves of subsidy phase in and phase out and how they interact with the tax holiday. The blue line represents the monthly sales of the never subsidized cars. The red, green, and orange lines represent the monthly sales of waves one, two, and three. If a model is ever included in wave one, no matter when it starts to be subsidized, it will be coded as wave one subsidized cars. The same rule applies to wave two and three. The first dashed blue line is the beginning of wave one, then in the month labeled by the red line, the list got renewed, and the second wave replaced wave one. Wave two stops at the second solid blue line. After one year, wave three started in Oct 2014 and lasted till December 2015.

By breaking down the three waves, we can detect clear evidence of the retiming effect in Figure 11: consumer advance their purchase the month before the subsidy expires. We also see a substitution effect on non-subsidized cars. For instance, when the wave two lists replaced wave one in October 2011, wave one subsidized cars dropped immediately.

Insert Figure 11

5 Empirical Results

To establish the causal impact of the policy we employ the difference-in-differences estimation strategy and the classification is consistent with the graphical evidence part. In the

robustness check section, we will use a different criterion for constructing control group. We model car sale as a function of its own tax rate and its substitutes tax rate, more specifically we use the following specification after aggregating data at the province-month-model level:

$$\text{Ln}(\text{sales}_{ijt}) = \beta_0 + \beta_1 Tax_Own_{it} + \beta_2 Tax_Compe_{it} + \theta_{t+p} \sum_{p=-k}^{k} \Delta Tax_Own_{it+p} + \gamma_{t+p} \sum_{p=-k}^{k} \Delta Tax_Compe_{it+p} + \beta_3 X_{gt} + \alpha_i + \alpha_j + \alpha_t + \alpha_{it} + \alpha_{gt} + \epsilon_{ijt} \qquad (1)$$

$Ln(sales_{ijt})$ is the natural logarithm of model i cars sales in province j during month t. α_i, α_j and α_t are the province, model and month-of-sample fixed effects, α_{it} and α_{gt} are the province and group-specific linear time trend. Controlling for the model fixed effect is crucial for our identification. Model entry and exit decisions can coincide with the policy change and affect sales in different groups. If more tax exempted models are introduced to the market when the tax rate decreases we will overestimate the policy impact. By controlling for the model fixed effect, we focus on the variation within models. Tax_Own_{it} is the tax rate for cars of model i in month t. Tax_Compe_{it} is the competitors tax rate. The vector ΔTax_Own_{it+k} and ΔTax_Compe_{it+k} are the change of tax rate corresponding to the k^{th} month before (when k takes negative values) or after (when k takes positive values) the tax holiday expiration date. They capture the anticipating effect and the reversal effect. X_{gt} control for the differential effects of CCI and gas price on different groups of cars. We run three separate regressions for the three groups of cars. Following the relationship in Table 2 we measure the tax rate for competitors as follows:

For the never subsidized small cars, Tax_Own_{it} only takes 0.1, 0.05, and 0.075 depending on t. For the subsidized car, they are eligible for both tax holiday and subsidy and for each model we convert the subsidy into a model specific tax deduction, Tax_Own_{it} equals tax

rate given by tax holiday subtracting 3000/MSRP. For group four Tax_Own_{it} is always 0.1.

Unsubsidized small cars are competing with subsidized small cars and medium cars; we only need to calculate Tax_Compe_{it} from subsidized cars since the tax rate for the substitution group did not change. The average price of a smaller car is approximately 80,000 Yuan, and we convert the 3,000 Yuan subsidy into a tax deduction. Note here we have ten lists of cars and for a given month only a fraction of subsidized small cars is eligible for the subsidy. The effective tax rate of the substitute is a weighted average of the subsidized and non-subsidized cars at a given month. One potential problem of this measure is when a model gets the subsidy its sales will increase, and we will put more weight on the subsidized car mechanically. To account for the endogeneity problem we only take the ratio of the subsidized vehicle from the first month after a list is renewed. Then we can estimate the intention to treatment effect. We use tax rate 3.75*(Share of subsidized cars in the first month when a list is released) as its effective tax rate on unsubsidized small cars. For subsidized small cars Tax_Compe_{it} is unsubsidized small cars' weighted average tax rate. For substitutable group we use the weighted average tax rate of unsubsidized small and subsidized small cars to construct Tax_Compe_{it}, and the idea is the same as how we construct Tax_Compe_{it} for unsubsidized small. For control group Tax_Compe_{it} always takes 0.1 since they only competes with other larger cars.

The specification in equation (1) also allows us to identify the timing effect of the temporary change of tax rate. θ_{t+k} and γ_{t+k} are a set of coefficients that capture the anticipated and lagged effect of the tax rate changes. More specifically, The coefficient on the k^{th} captures the additional sales at the end of the holiday. When i takes negative values, we call it advanced period. And coefficient on k^{th} captures the drop of sales right after the holiday expires, we call it reversal period when i takes positive values. We impose no prior on how long the advanced and reversal period should be, using a flexible specification here, we start with one month and keep adding controls until the last coefficient is no longer statistically and economically significant. In this way, we pin down the length of the advanced and

reversal periods. The beginning of the stimulus is a surprise to consumers, but they fully anticipate the end of it. We should expect some consumers were pulled forward and sales will drop immediately after the holiday.

We first look at the static elasticity of sales with respect to tax rates and discuss the timing response later. From column (2) in Table 4 if the tax rate decreases one percentage point total sales of unsubsidized small cars will increase by 9.6%. The effect is large and consistent with what we see in the graphical evidence. The tax holidays decrease the average tax rate for unsubsidized small car by 3.8=(1-0.05*24/(24+27)-0.75*27(27+24)), so the total sales of unsubsidized small car were stimulated by 36.5% by its own tax decrease than if its own tax rate does not change. The total sales of unsubsidized small car during the treated period (Tax_Own decrease) is $4.1 * 10^8$, so the stimulated sales are $9.7 * 10^7$ ($4.1 * 10^8$-$4.1 * 10^8/1.31$). We also account for the substitution effect from subsidized small cars, if the weighted average tax rate of subsidized small increase by 1 percentage point, the sales of unsubsidized small will decrease by 2.6%. The tax holidays decrease the average tax rate for subsidized small cars by 3.0% and thus decreases unsubsidized small car sales by 7.2%. The total sales of unsubsidized small car during the treated period (Tax_Compe decrease) is $6.4 * 10^8$, so the sales are decreased by $4.9 * 10^7$ ($6.4 * 10^8/0.93$-$6.4 * 10^8$). The net sales stimulated is $4.9 * 10^7$ cars. This is 7.6% of all small car sales during the stimulus period, and this finding mirrors our graphical evidence.

Next, we look at the stimulating impact on subsidized smaller cars. From column (4) in Table 4 if the own tax rate decreases one percentage point total sales of subsidized small cars will increase by 6.1% and the average effective tax rate decreased by 5%, thus 30.5% more subsidized small was stimulated. The total sales of subsidized small car during the treated period (when Tax_Own decreases) is $2.5 * 10^8$, so the additional sales due to own tax rate decrease are $5.8 * 10^7$. We also need to account for the substitution effect from unsubsidized small car. The average effective rate decreases by 3.8% and the total substitution effect are 15.2%. The total sales of the subsidized small car during unsubsidized small car tax rate

decrease period is 7399457, so the decreased sales are $1.3 * 10^7$ ($7.4 * 10^7$/0.85-$7.4 * 10^7$). The net sales stimulated is $4.4 * 10^7$ cars. This is 6.9% of all small car sales during the stimulus period. Combining this number with the 7.6% from unsubsidized small we can calculate the 14.5% of smaller car sales is stimulated by the policy.

We still need to consider the loss of sales of medium cars. One percentage point tax decrease will decrease the sale of medium cars by 3.0% and 4.7%. The corresponding sales of substitutable cars of are $8.9 * 10^6$ and $1.25 * 10^7$, and around 15% of the sales are substituted away by small cars. The total sales of substitutable car are so $3.7*10^7$ ($2.1*10^7$/0.85-$2.1*10^7$) which equals 14.7% of total substitutable car sales during the stimulus period.

To evaluate the net impact of the tax holidays, we also need to know the retiming effect, especially whether the additional sales are reversed right after the policy expires. The identifying assumption is the advanced and reversal period is a continuum. From column (2) in Table 4 and Table 5, We see one month before holiday expires we have a 10% additional sales for unsubsidized small cars if tax rate is going to increase increase by one percentage point. There are still additional sales two months before tax rate increases, but three months before the increase is no longer economic or statistically significant. This implies consumers were only pulled forward to the last two months the holiday. Similarly we look at the coefficients that captures the lagged effects of tax rate changes and conclude that the temporary fiscal incentives only pull forward consumers by up to one month. The average sales of the month before tax holiday expires is $1.4 * 10^7$, and $2.0 * 10^6$ was pulled forward for each of these four months Part of the additional sales comes from the months right after tax holiday expires. The average sales of the month after the tax holiday expires is $6.2 * 10^5$ and $5.4 * 10^4$ cars are reversed. Note here the additional sales are not reversed. Due to the limitation of our data we have to treat the whole month before tax increase as the month for advancing purchase but this can be shorter and overestimate the advanced purchase. This finding is also consistent with (Chen et al., 2017).

We do similar calculations for the subsidized small car. 17492 ($2.4 * 10^6$-$2.4 * 10^6$/1.077)

average monthly sales were pulled forward and 62639 ($1.8*10^6/0.74$-$1.8*10^6$) average monthly sales were reversed. We also see a strong timing response to the 3000 Yuan lump-sum subsidy program. 26% more sales are due to the retiming effect which equals 90580 ($4.3 * 10^6$-$4.3 * 10^6/1.26$) for each of the three months. But for the subsidy program, we didn't see a drop in sales when it expires. One possible reason is the second and third wave ends right before October in which the first week is a national holiday and a big sales month for auto and housing market. The net timing effect for the subsidized small car is 153791 (17492*4-62639*3+90580*3).

For substitutable cars, the potential retiming response comes from buyers belonging to the post policy period who switched to a smaller car to enjoy the tax holiday. If this effect is substantial, we should expect a coefficient on the *Lag* of tax holiday and subsidy program to be significantly negative, and we see such effects from column (5) and (6) in Table 4.

Now we can combine the static elasticity and the timing effect. The size of additional car sales equals to $5.6 * 10^7$. The more meaningful is the direct spending effect, and we plug in the average MSRP to estimate the total spending impact. The total additional spending was 30 billion USD. When calculating the stimulus effect, we assume consumers who switches from medium-sized cars to small-engine cars will not adjust their total expenditure. So the net stimulus impact comes from the total additional consumption

In the main specification we use within model tax variations only to capture the sales change for the same model. This is an ideal way of estimating causal impact. However, if the model entry and exit decision also responses to the stimulus policies, this specification may underestimate the true effect if new eligible models are introduced because of the policies. We show the estimated result without model fixed effect to capture the effect from entry and exit. In Table 6 we don't control for model fixed effect. The estimated impact became even larger and implied the model entry, and exit dynamics won't spoil our baseline results.

Insert Table 5, 6

5.1 Car Characteristic Adjustment

We plot the engine size distribution in different years. As we have discussed in section II that 1.6 liter is a golden size. Bunching blow the 1.6 liter threshold is already there before the tax holidays. We look at the distribution of engine size. We do not find evidence on firms responding to the temporary tax incentives by adjusting their engine size. We also look at if firm adjust car weight to be eligible for the cash subsidy program and did not find evidence on that as in Chen et al. (2017).

6 Robustness Checks

In this section we use stricter criterion to construct the control group and substitution group. In the first robustness in Table 7 we drop models that are very close to the cutoffs to avoid potential inappropriate classifications. We drop all cars with engine size greater to 2.0 liter and smaller than 2.2 liter and we restrict all substitutable group models priced lower than 16,000 Yuan.

In the second robustness check in Table 8 we use weaker criteria for the control group: cars that are above 2.0L and more expensive than 220,000 Yuan or 2) cars above 1.6L and more expensive than 220,000 Yuan as a control group. Consequently, the large cars above 2.0L with a price lower than 220,000 Yuan and medium cars with a price lower than 220,000 Yuan are substitutable cars.

In the third robustness check in Table 9 we impose stricter criteria for the control group: cars that are above 2.2L and more expensive than 200,000 Yuan or 2) cars above 1.6L and more expensive than 250,000 Yuan as a control group. Consequently, the large cars above 2.2L with a price lower than 200,000 Yuan and medium cars with a price lower than 250,000 Yuan are substitutable cars.

In all of the three robustness checks above, we replicate all results in Table 5. The result does not change much compared with our baseline. Our result is not sensitive to the

classification of control and substitutable groups.

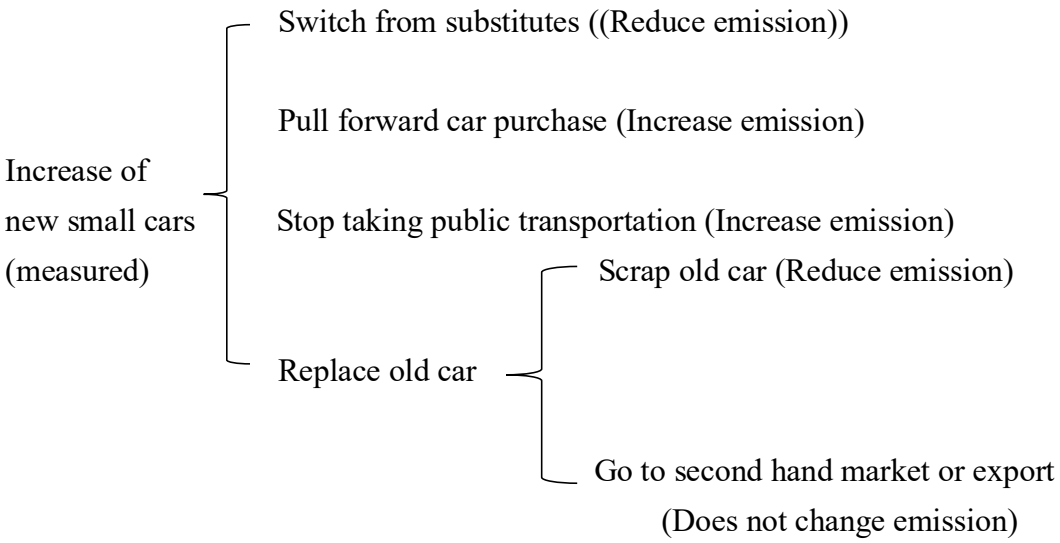
Insert Table 7 Table 8

7 Implication for Carbon Emissions

In this section, we discuss how the tax-induced behavior affects carbon emissions. The effect on the environment comes from three parts: 1) Extensive margin response. An additional smaller car only improves the environment if an old inefficient car is scrapped. Otherwise, it will only increase the total emission, no matter whether the old one goes to the second-hand market or not. The net impact depends on the fraction of used cars that are scrapped. We calculate the effect on emission under different possible scrapping rates. 2) Retiming effect. The advanced purchase of smaller cars will increase emissions due to the use in the advanced period. 3) Substitution effect. The small cars crowd out medium car sales and subsidized fuel-efficient cars substitute inefficient cars to reduce carbon emissions.

We obtain all the information on fuel-efficient cars from the Ministry of Industry and Information Technology in China.[4] Since 2010, all new cars in China are required to disclose their fuel efficiency which is tested by a third-party research institution. We calculate the simple average of fuel-efficient of all the models first and plug the common conversion factor that burning one Liter of gasoline emits 0.0023 metric tons of CO_2. In our calculation, we treat the emission from the public sector as a constant. We assume that the new cars' net change is not going to change the use of public transportation. Under the assumptions above, the change of CO_2 is given by:

[4]Source: www.miit.gov.cn


Increase of
new small cars
(measured)
Switch from substitutes ((Reduce emission))
Pull forward car purchase (Increase emission)
Stop taking public transportation (Increase emission)
Replace old car
Scrap old car (Reduce emission)
Go to second hand market or export
(Does not change emission)

Based on the analysis above, we calculate the change in CO_2 emission following the formula below:

$$\begin{aligned}\text{Change of CO2 Emission} = & \underbrace{(1-\alpha)\times\text{New_Sale}\times\text{EM_Small}\times\text{Lifespan}\times\text{VUI})}_{\text{Increase from extensive margin response}} \\ & - \underbrace{\text{Decrease_sale}\times(\text{EM_Medium}-\text{EM_Small})\times\text{Lifespan}\times\text{VUI}}_{\text{Decrease from substitution effect from larger cars}} \\ & - \underbrace{\text{Decrease_sale}\times(\text{EM_Subsidized}-\text{EM_Nonsubsidized})\times\text{Lifespan}\times\text{VUI}}_{\text{Decrease from substitution effect from Fuel efficient cars}} \\ & \underbrace{-\text{Forward_Sale}\times\ (\text{Months forward})/(\text{Lifetime EM})}_{\text{Increase from retiming effect}}\end{aligned}$$

Where New_Sale is the total net new sale from an extensive margin response. α captures the rate of scrapping when a new car is sold because of the stimulus policy. The average life span of cars in China is ten years, and we use data from 2008 to 2018 when the data is available to proxy the difference in fuel consumption. The (1-α) percent of the total net new sales will increase the emission. EM_Small and EM_Medium are the average emissions of small and medium cars from burning one liter of gas, respectively. Lifespan is the average life span of a car, and VUI is vehicle use intensity measured by how many kilometers a car travels per year. We follow Huo et al. (2012) and Chen et al. (2017) who set lifespan and VUI to be ten years and 16900KM. Decrease_sale is the decrease in sales for medium cars from the substitution effect. The gap between medium and small cars in emission will contribute to emission reduction through the substitution effect. This substitution effect also comes from the substitution of subsidized small cars on unsubsidized small cars. Also, the retiming response pulled 116483 cars forward for one month and emitted more CO_2. Forward_sale is the amount of car that has been pulled forward, and we calculate the emission for them by adjusting the length of forwarding (Months forward) and per month lifetime emission of a

car (Lifetime EM_small per month).

The only thing we are still missing in equation (2) is the scrapping rate of stimulated sales. From a report by China Center of Information, 20.6% of new purchased cars will replace an old car and the official statistics of the overall scrapping rate is about 20% from 2011-2016.[5]. What matters in our estimation is the total induced scrapped cars because the decrease of car prices. The the estimated scrapping elasticity with respect to price is -3 (Bento et al., 2018). If consumers bear all the burden of taxation, combining the average price decrease from small cars, the weighted average price decreased by 1.5%. The total scrapped car from 2009 to 2017 is approximately 40.2 million. We calculate the implied α is approximately 0.1.[6] We do not estimate how many cars are scrapped or recycled due to the tax holiday in literature. To be more conservative, we calculate the net carbon emission increase under different possible scrapping rate and Table 10 shows more details. As we can see here, even under a 70% scrapping rate, which means 70% percent of new purchases will push consumers to junk an old car, the net increase of carbon emission is still 0.06%.

We take 0.1 as our benchmark scrapping rate and conclude that the stimulating policies increased CO_2 pollution during year 2009 to 2017 on the environmental cost is approximately 2.1% CO_2 emission in year 2014 [7]

Other concerns about the estimation on carbon emission: 1) Rebounce effect. Other research suggests that people tend to consume more gas if they buy more Fuel efficient cars. We do not have access to individual level car usage data. However, the rebounce effect implies the reduction of carbon emission from switching to smaller cars is smaller then what we calculated. This means our result underestimates the net increase of carbon emission. We still draw a conservative conclusion.

2) Quality change. We also need to be careful about the fiscal incentive may change the quality of cars. On one hand, as (Gulati et al., 2017) points out, consumers may switch to

[5]Technical report from Ministry of Commerce

[6]Source:http://www.chyxx.com/industry/202001/831297.html

[7]In 2014 per capita CO_2 emission is 7.5 metrics ton in China.
Source: https://data.worldbank.org/indicator/en.atm.co2e.pc

better smaller cars because of income effect and the more expensive cars could be either more or less Fuel efficient. Another concern is consumers who took advantage of the tax holiday are more likely to purchase a lower quality car because of liquidity constraint. Similar to the upgrading concern this could also affect the Fuel efficient of additional sales. The overall tax holiday induced quality change is ambiguous, we need to empirically exam how it changed the average GPK over time. In figure A10 we show the relationship between price and GPK and we did not find correlation between them. This suggests that we should not worry much about the quality change concern.

Insert Table 10 and Figure A10

8 Conclusion

This paper evaluates the consumption response to China's two most important stimulus programs of small-engine cars. Using national car sales data from the years 2005-2018, we show that a one percentage point sales tax decrease increases the total sales of targeted small cars by about 3.2% and decreased sales of their substitutes by 3.9%. Overall, the stimulus effect dominates the substitution effect. We provide clear evidence on tax policies' stimulus and substitution effects and highlight its importance when evaluating the policy implications on environment.

Based on the own and cross elasticities we estimated in the paper, we can calculate the net impact on the fiscal programs' carbon emissions. We find that the net increase in carbon emission could impose a social cost as high as 11.2 billion USD. The optimal policy should take both the benefit of fiscal stimulus and environment cost into considerations.

How much the consumers bear the tax burden is another central question in the public finance literature. In the second chapter of my dissertation, we use a detailed transaction-level and show that small car buyers benefit about 80% from the tax reduction. The substitutes buyers also enjoy a lower price. In future work, I will evaluate the distribution effect using

a structural approach. By imposing more structures in the model, I can characterize which group of consumers benefit more from this policy.

Figures

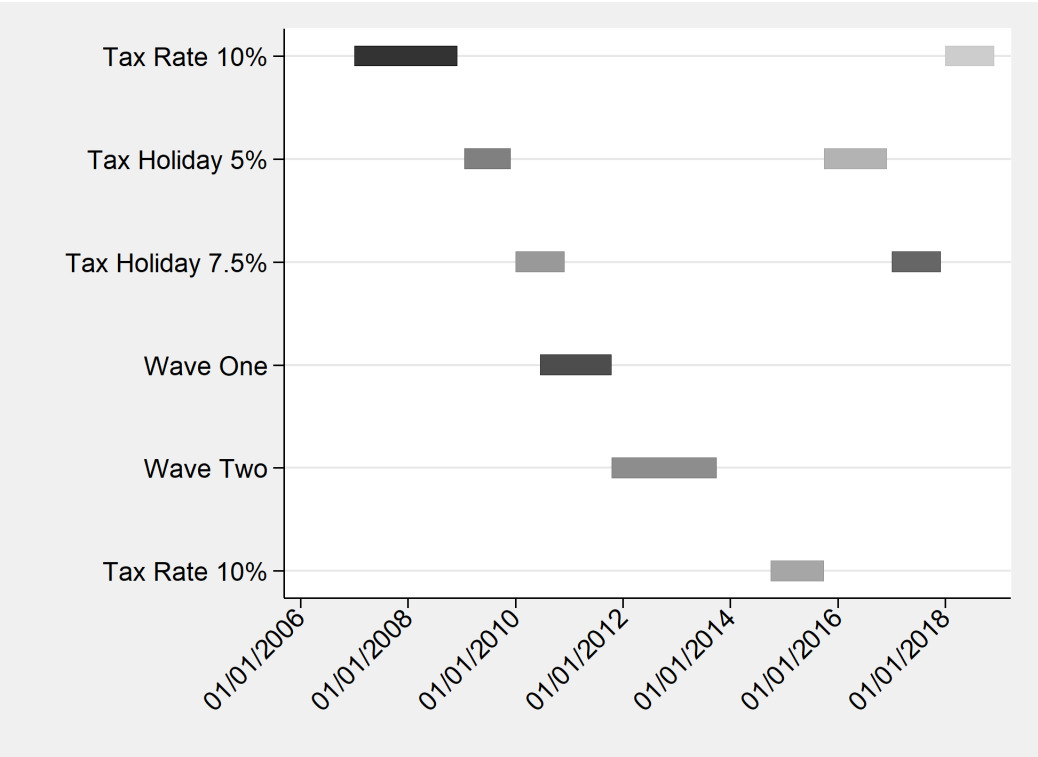


Figure 1: Tax Holidays

Note: This figure demonstrates how the tax holiday and subsidy program phased in and interact with each other. Tax rate is 10% if there's no policy. Policy event is labeled on Y axis and X axis shows the timing of each policy.
[Source] Website of China's Department of Finance

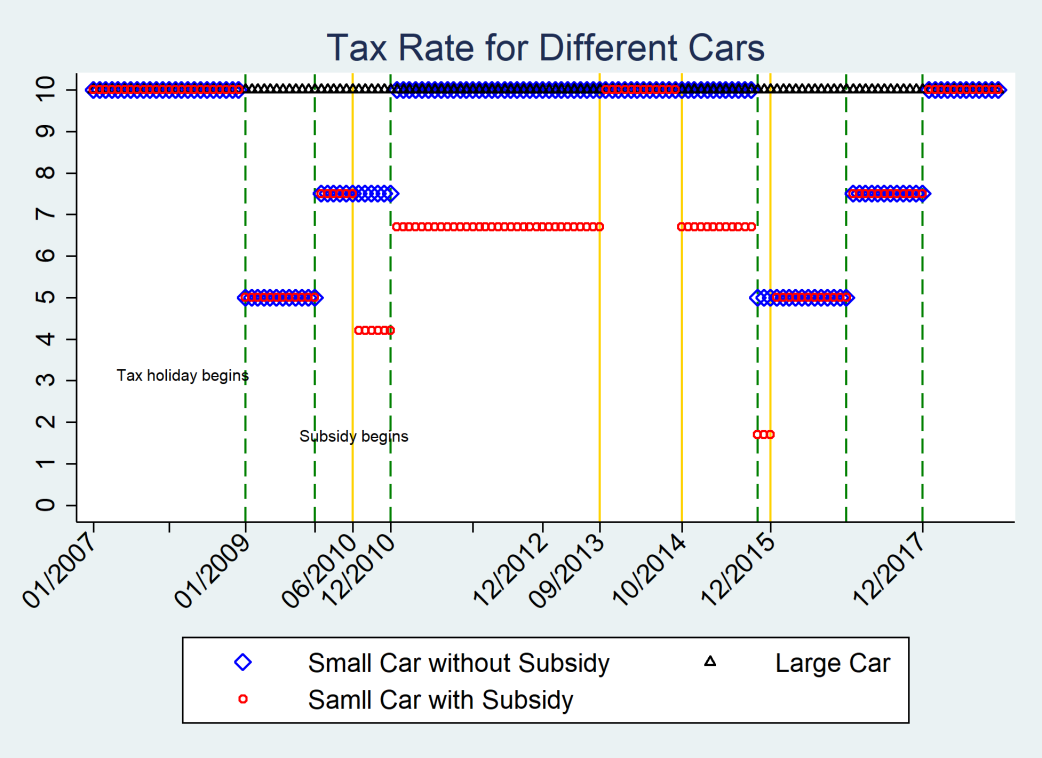


Figure 2: Tax Rate for Different Cars

Note: This figure shows the effect tax rate for different group cars which mirrors figure 1. For subsidized car we take the price as 80000 Yuan. The 3000 Yuan is equivalent to a 3.75% tax deduction. The green line corresponds to the tax holiday and yellow lines corresponds to the subsidy program.
[Source] Calculated by authors.

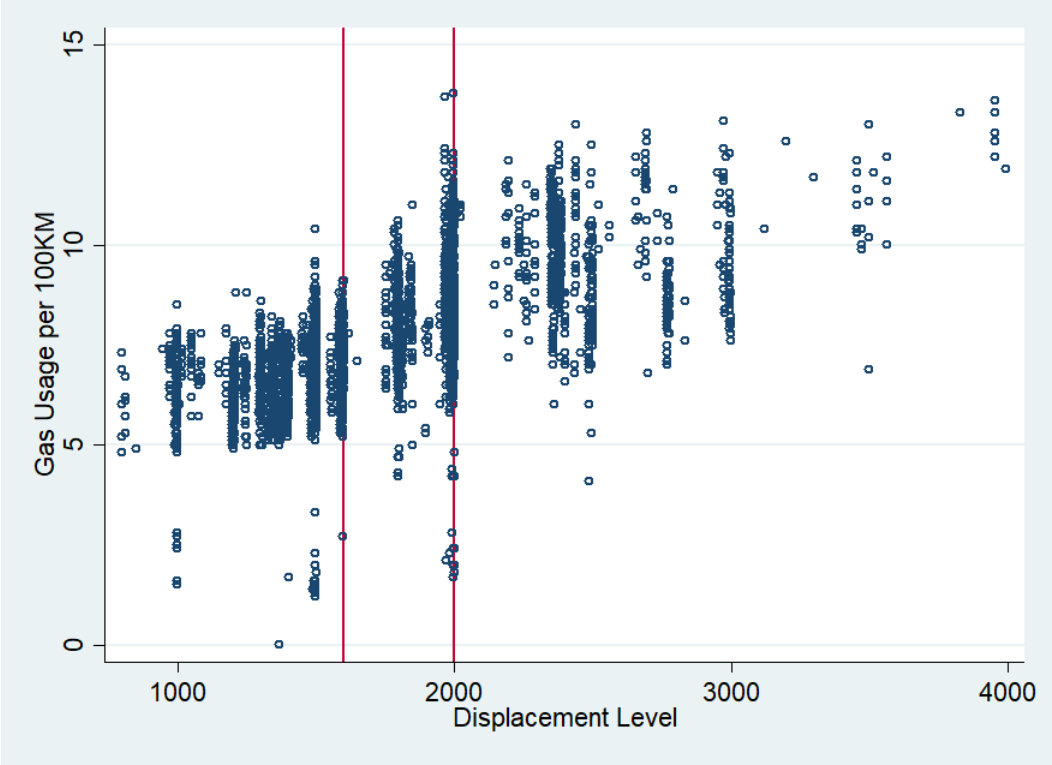


Figure 3: Relationship between Gas Use Per 100KM and displacement level

[Source] Website of China's Department of Industry and Commercial

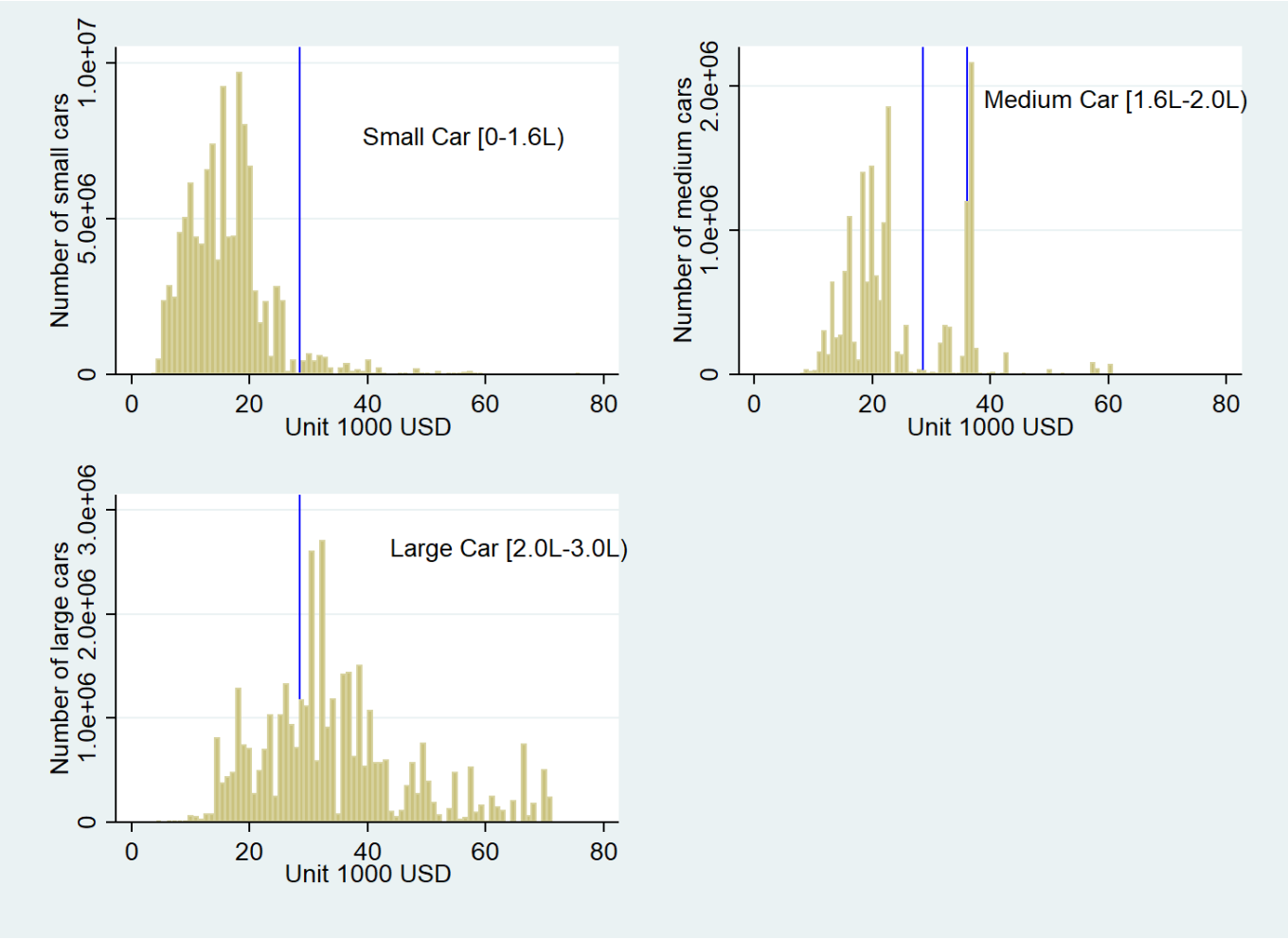


Figure 4: Price distribution for small, medium and large cars

Note: Small:<=1.6L Medium:>1.6L<2.0L Large:>2.0L
[Source] Calculated from Car Sales Data

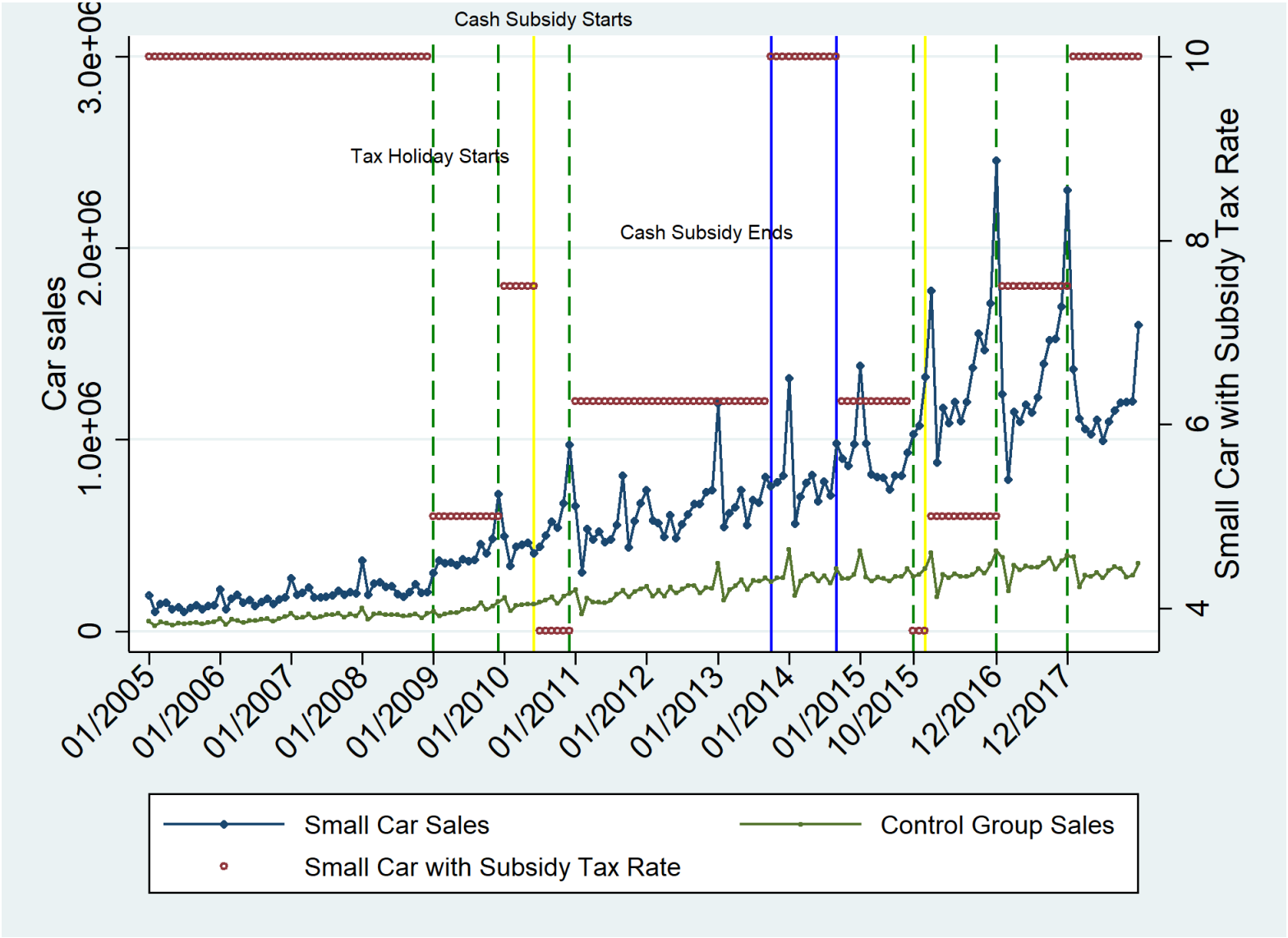


Figure 5: Car sales trend in China from Jan 2007 to Dec 2018

Note: This figure plots monthly sales of small and large cars. In this graph we don't include medium cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two blue lines.
[Source] Calculated by authors from car sales data

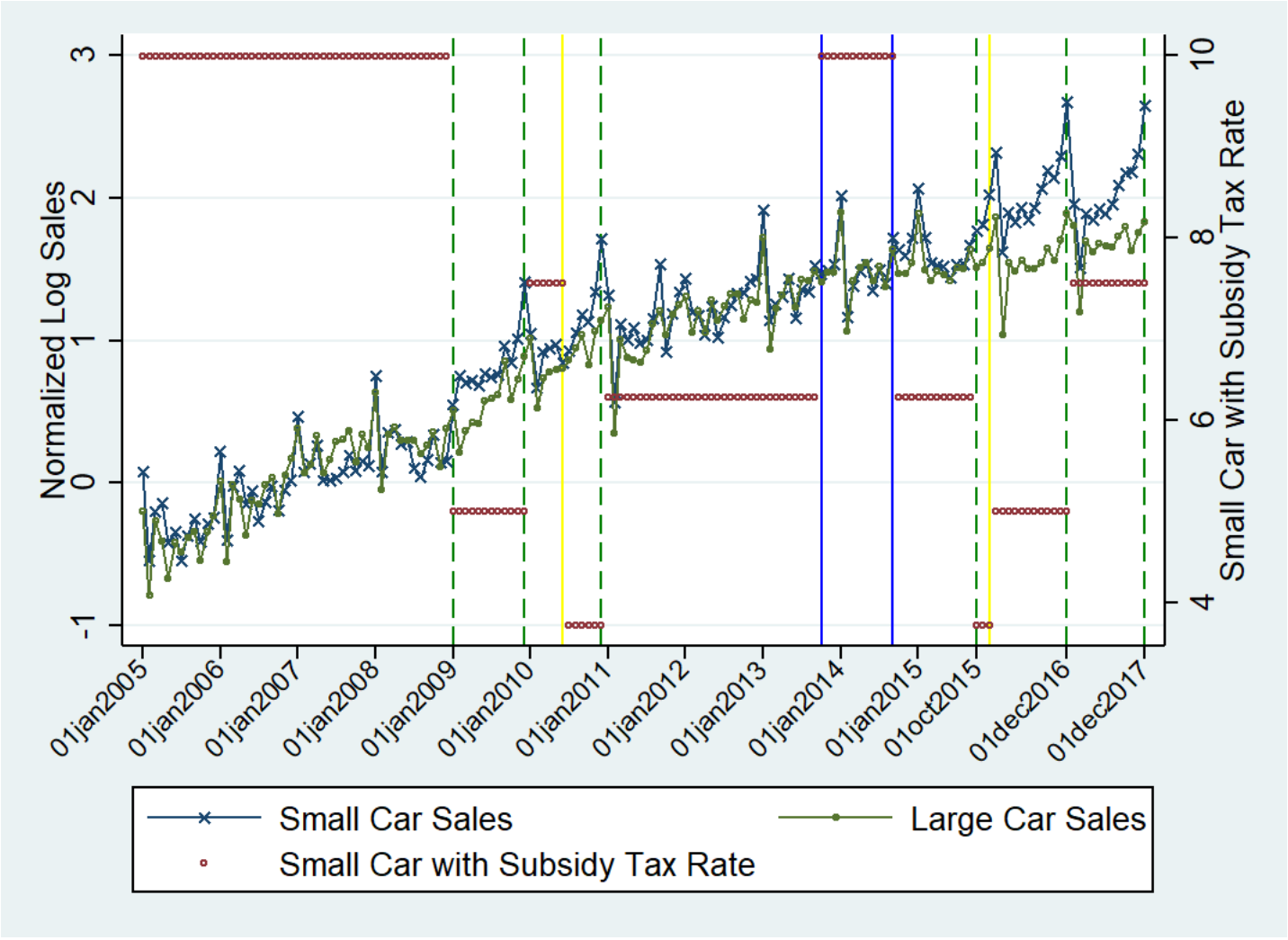


Figure 6: Log sales for small and large cars

Note: This figure we show the natural logarithm of monthly sales of small and large cars to visually test the parallel trend assumption. Data are normalized to zero for the pre-treatment period (2005-2008). In this graph we don't include medium cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two blue lines. We observe parallel trend for before tax holiday and the year without any tax holiday (between the two blue lines)

[Source] Calculated by authors from car sales data

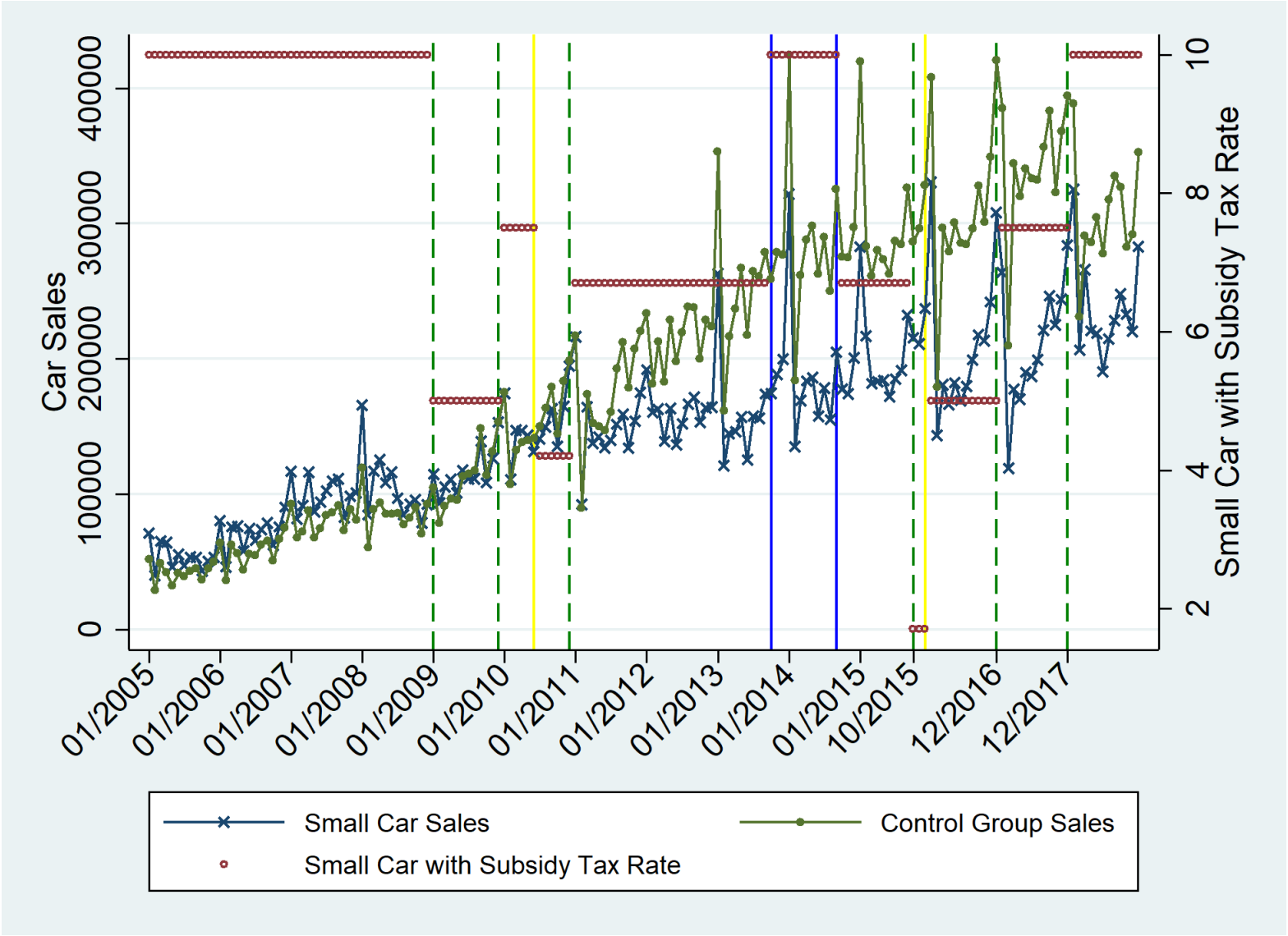


Figure 7: Impact of tax incentives on substitutable cars

Note: This figure we show the monthly sales of substitutable cars and large cars. Data are normalized to zero for the pre-treatment period (2005-2008). In this graph we don't include medium cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two blue lines. We observe parallel trend for before tax holiday and the year without any tax holiday (between the two blue lines)
[Source] Calculated by authors from car sales data

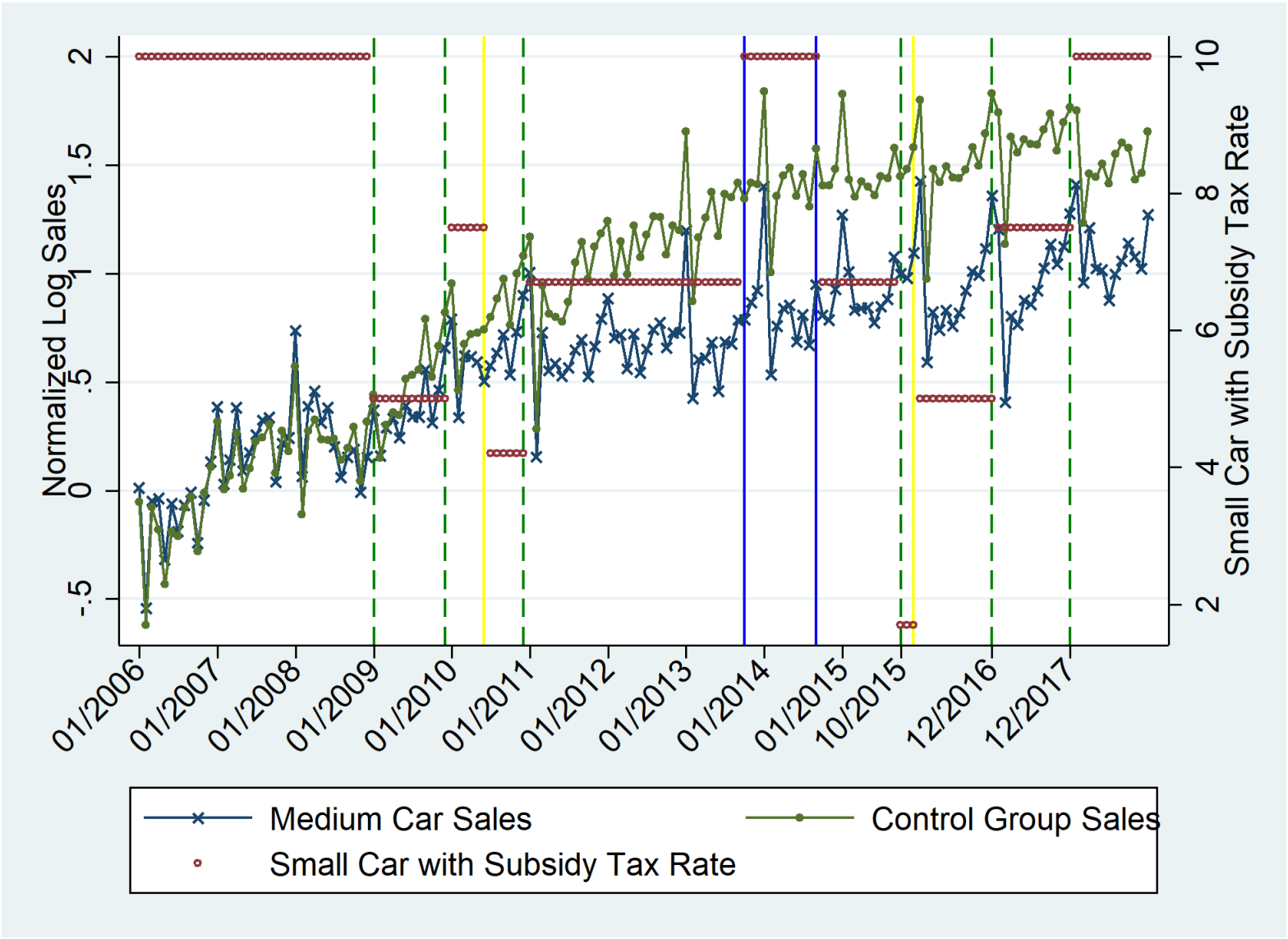


Figure 8: Impact of tax incentives on substitutable cars

Note: This figure we show the natural logarithm of monthly sales of substitutable cars and large cars. Data are normalized to zero for the pre-treatment period (2005-2008). In this graph we don't include small cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two golden lines. [Source] Calculated by authors from car sales data

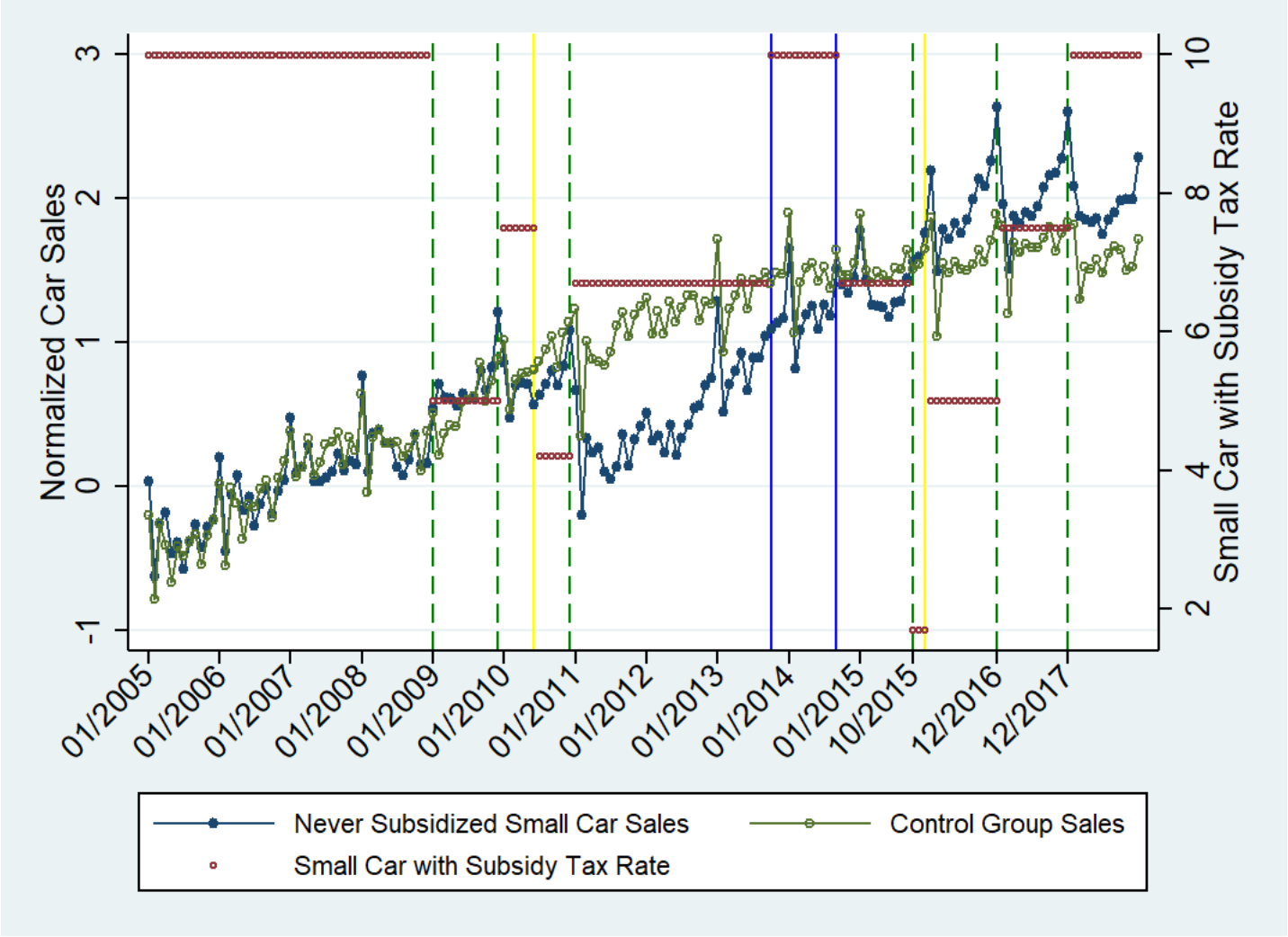


Figure 9: Impact of tax incentives on unsubsidized small cars

Note: This figure we show the natural logarithm of monthly sales of unsubsidized small cars and large cars. Data are normalized to zero for the pre-treatment period (2005-2008). In this graph we don't include medium cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two golden lines. We observe parallel trend for before tax holiday and the year without any tax holiday (between the two blue lines)
[Source] Calculated by authors from car sales data

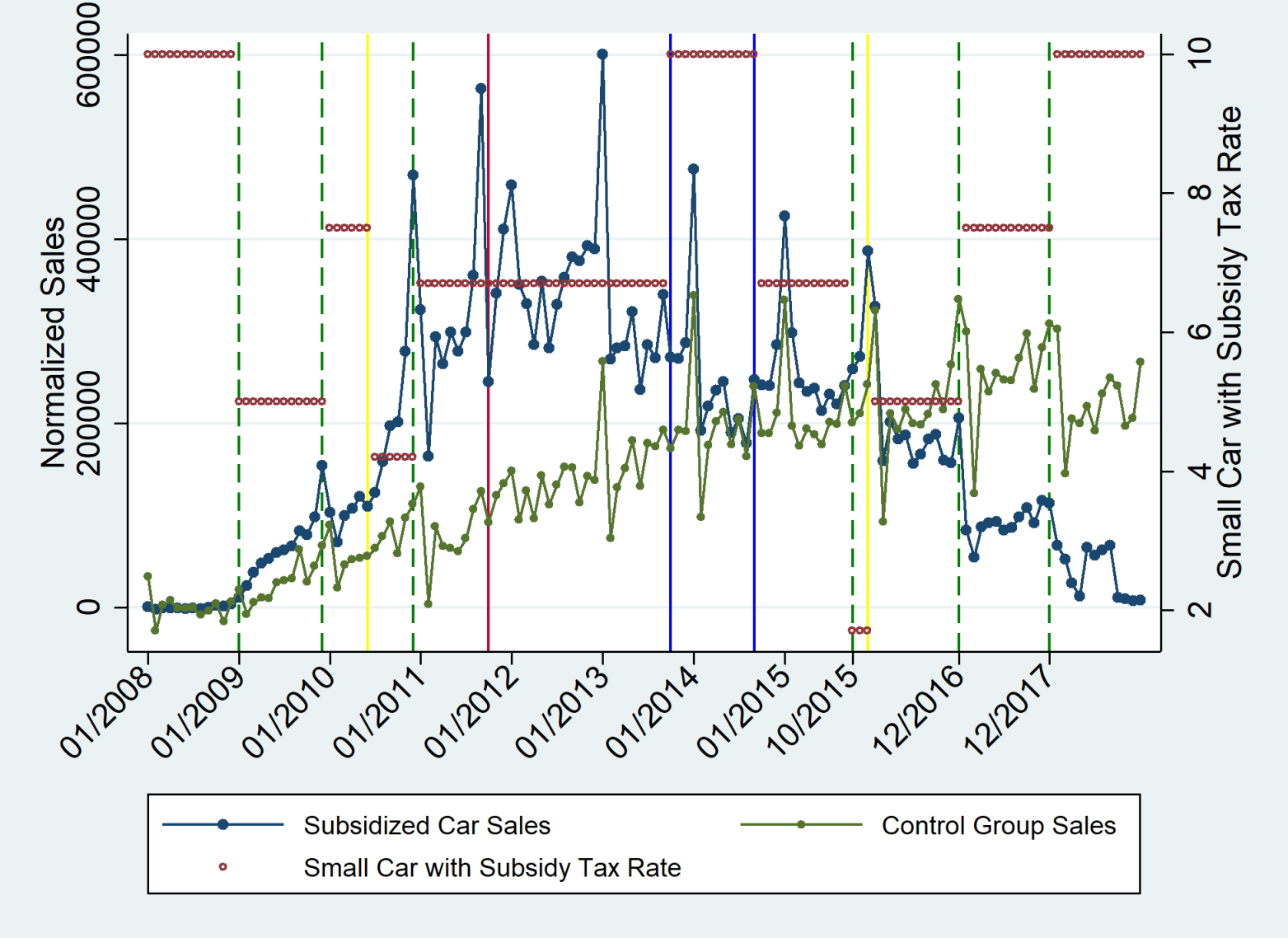


Figure 10: Impact of tax incentives on group three cars

Note: This figure we show the level of monthly sales of subsidized small cars and large cars. In this graph we don't include small cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two golden lines [Source] Calculated by authors from car sales data

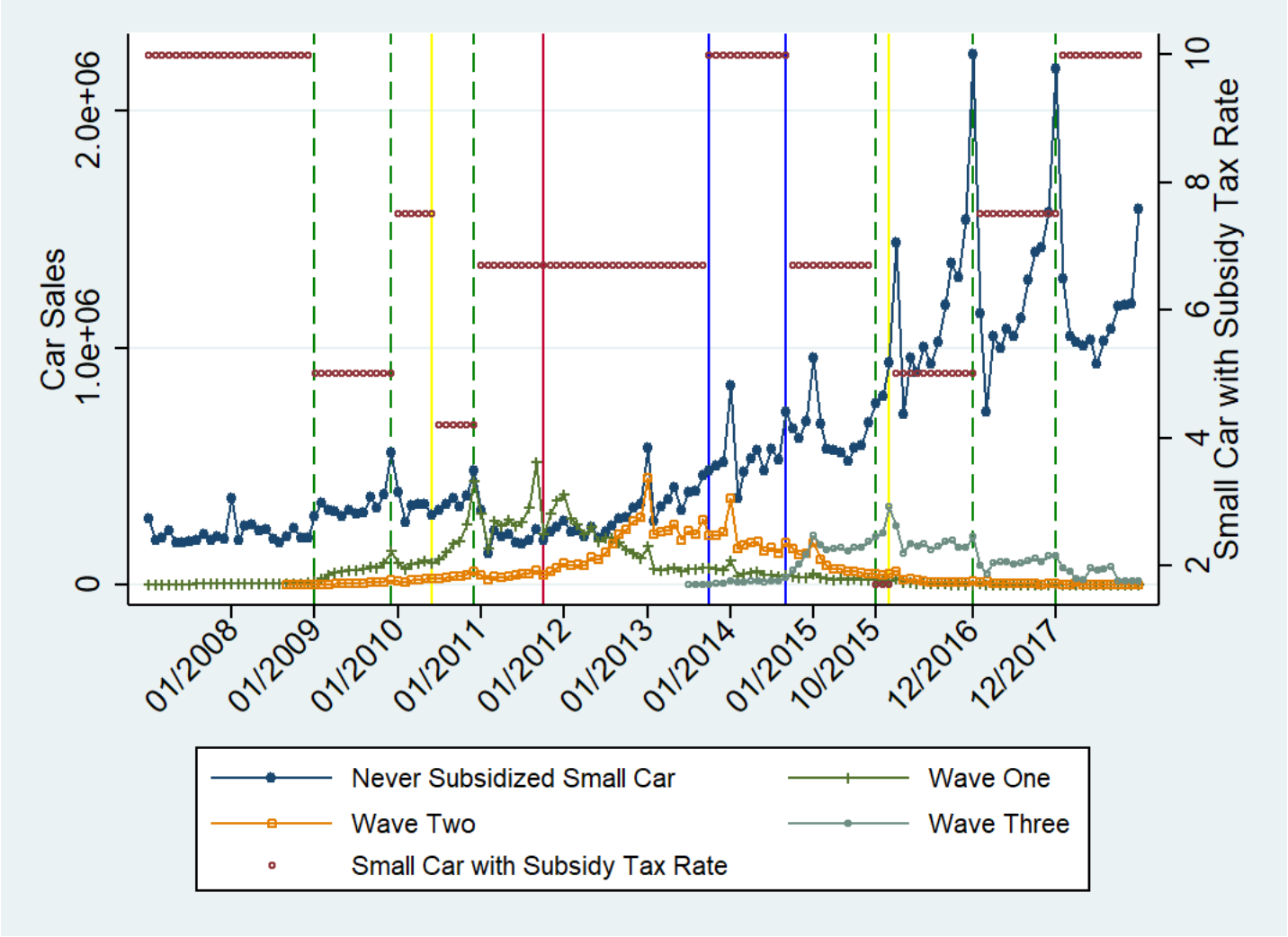


Figure 11: Sales for all the small cars

Note: In this figure we show the level sales of three waves subsidized cars to demonstrate how they response to the cash subsidy incentives. We also include the never-subsidized cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two golden lines. [Source] Calculated by authors from car sales data

Tables

Table 1: Details on the subsidy program

Round	Wave	Release date	Number of new subsidized model	Total number of subsidized model	Share in all smaller cars when announced	Note
1	1	June 18 2010	64	64	10.5%	
1	2	August 11 2010	61	125	24.1%	
1	3	September 25 2010	74	199	32.0%	
1	4	November 23 2010	66	265	41.7%	
1	5	February 11 2011	69	334	55.8%	
1	6	May 11 2011	86	420	59.6%	
2	7	October 17 2011	19	19	9.3%	Higher criterion for the eligibility and renewed the list
2	8	July 10 2012	145	164	24.6%	Ends on September 30 2013
3	9	September 1 2014	163	163	3.2%	
3	10	July 01 2015	109	272	19.0%	

Table notes environment without optional leadin. [Source] Table notes environment with optional leadin (Source, in this case).

Table 2: The relationship among different group of cars

Market	Group	Policy	Tax_Own	Competitor	Tax_Competitor	Displacement	MSRP
Low end	1	Tax holidy	Sales tax	subsidized small & 3	Tax rate of subsidized small	< 1.6L	No restriction
Low end	2	Tax holidy+Subsidy	Sales tax−subsidy rate	unsubsidized small & 3	Tax rate of group1	< 1.6L	No restriction
Low end	3	/	No change	unsubsidized small & 2	Weighted average of unsubsidized small & 2	1.6-2.0L	$<$ \$40,000
High end	4	/	No change	No change	No change	2.0-4.0L & $>$ \$32,000 Or 1.6-2.0L & $>$ \$40,000	

Table 3: Data Description

	N	Mean	s.d	Min	Max
Monthly sales in a province (Sales)	4339845	38.9	112.6	1	8659
Eligibility	4339845	0.3	0.35	0	1
Engine size (liters)	4339845	1.79	0.48	0	3
Fuel inefficiency (liters/100 km)	4339845	7.9	1.6	2.7	14.78
Horsepower (kw)	4339845	92.5	28	26.5	252
Weight (kg)	4339845	1344.7	273.6	645	2690

Table 4: Baseline result

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		Subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-9.584***	-9.754***	-7.031***	-7.515***		
	(1.98)	(2.02)	(1.18)	(1.22)		
Tax_compe1	5.834***	5.963***	5.203**	5.742**	3.064**	2.991**
	(1.87)	(1.89)	(2.51)	(2.62)	(1.19)	(1.22)
Tax_compe2					4.740***	4.793***
					(1.70)	(1.72)
$\|\Delta Tax\|_{-1}$	9.524***	9.666***	5.015***	5.196***		
	(1.53)	(1.55)	(1.01)	(1.05)		
$\|\Delta Tax\|_{+1}$	-2.703*	-2.486*	3.019***	3.402***	-1.340**	-1.276**
	(1.51)	(1.54)	(1.03)	(1.05)	(0.59)	(0.60)
Number of Observations	2792111	2551880	1335388	1213119	1925937	1755643
R square	0.825	0.83	0.839	0.841	0.814	0.816
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	Y	Y	Y	Y	Y	Y

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for model fixed effect, province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing, Tianjin and Hangzhou.

Table 5: Baseline result

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-9.630***	-9.805***	-7.350***	-7.860***		
	(1.98)	(2.02)	(1.18)	(1.22)		
Tax_compe1	6.054***	6.186***	5.313**	5.866**	3.064**	2.991**
	(1.87)	(1.89)	(2.51)	(2.62)	(1.19)	(1.22)
Tax_compe2					4.740***	4.793***
					(1.70)	(1.72)
$\lvert\Delta Tax\rvert_{-1}$	10.02***	10.17***	5.046***	5.238***		
	(1.53)	(1.55)	(1.01)	(1.05)		
$\lvert\Delta Tax\rvert_{-2}$	2.650*	2.660*	-0.284	-0.246		
	(1.43)	(1.44)	(0.87)	(0.91)		
$\lvert\Delta Tax\rvert_{+1}$	-2.288	-2.058	3.346***	3.761***	-1.340**	-1.276**
	(1.51)	(1.54)	(1.03)	(1.05)	(0.59)	(0.60)
$\lvert\Delta Tax\rvert_{+2}$	3.791***	3.943***	4.532***	4.994***		
	(1.42)	(1.45)	(1.03)	(1.05)		
Number of Observations	2792111	2551880	1335388	1213119	1925937	1755643
R square	0.825	0.83	0.839	0.841	0.814	0.816
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	Y	Y	Y	Y	Y	Y

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for model fixed effect, province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing Tianjin and Hangzhou.

Table 6: Without model fixed effect

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-8.749***	-9.092***	-7.994***	-8.498***		
	(2.36)	(2.38)	(1.59)	(1.61)		
Tax_compe1	5.917***	6.245***	2.018	2.623	2.646*	2.679*
	(2.174)	(2.184)	(2.412)	(2.493)	(1.53)	(2.18)
Tax_compe2					2.739	2.597
					(2.17)	(1.54)
$\lvert\Delta Tax\rvert_{-1}$	6.299***	6.621***	1.645	1.92		
	(1.72)	(1.73)	(1.22)	(1.23)		
$\lvert\Delta Tax\rvert_{-2}$	0.276	0.414	-2.845**	-2.753**		
	(1.56)	(1.57)	(1.11)	(1.12)		
$\lvert\Delta Tax\rvert_{+1}$	-2.016	-1.741	2.096	2.609*	-0.932	-0.847
	(2.25)	(2.28)	(1.31)	(1.34)	(0.82)	(0.83)
$\lvert\Delta Tax\rvert_{+2}$	0.13	0.327	2.902**	3.445***		
	(2.14)	(2.17)	(1.29)	(1.32)		
Number of Observations	2792111	2551880	1335388	1213119	1925937	1755643
R square	0.656	0.656	0.672	0.671	0.621	0.618
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	N	N	N	N	N	N

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing and Tianjin.

Table 7: Robustness Check: Omitting cars in the middle

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-7.897***	-8.020***	-7.906***	-8.455***		
	(2.134)	(2.158)	(1.192)	(1.234)		
Tax_compe1	4.634**	4.756**	6.385**	6.977**	4.770**	4.763**
	(2.081)	(2.099)	(2.619)	(2.742)	(1.956)	(1.973)
Tax_compe2					6.068***	6.042***
					(1.634)	(1.669)
$\lvert\Delta Tax\rvert_{-1}$	10.58***	10.70***	4.844***	5.018***		
	(1.775)	(1.792)	(1.039)	(1.070)		
$\lvert\Delta Tax\rvert_{-2}$	2.137	2.162	-0.481	-0.431		
	(1.625)	(1.639)	(0.901)	(0.933)		
$\lvert\Delta Tax\rvert_{+1}$	-3.233**	-2.913*	3.611***	4.057***	-2.061***	-2.001***
	(1.644)	(1.672)	(1.059)	(1.086)	(0.711)	(0.721)
$\lvert\Delta Tax\rvert_{+2}$	3.457**	3.703**	4.731***	5.256***		
	(1.550)	(1.582)	(1.053)	(1.078)		
Number of Observations	2600755	2377618	1144032	1038857	1396659	1273242
R square	0.824	0.829	0.838	0.841	0.813	0.815
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	Y	Y	Y	Y	Y	Y

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for model fixed effect, province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing, Tianjin and Hangzhou.

Table 8: Robustness Check: Weaker criteria for control group

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-7.889***	-8.009***	-7.870***	-8.417***		
	(2.121)	(2.145)	(1.191)	(1.232)		
Tax_compe1	4.695**	4.820**	6.445**	7.043***	1.971*	1.897
	(2.070)	(2.088)	(2.607)	(2.728)	(1.178)	(1.215)
Tax_compe2					4.855***	4.900***
					(1.719)	(1.739)
$\lvert\Delta Tax\rvert_{-1}$	10.68***	10.81***	4.919***	5.097***		
	(1.770)	(1.787)	(1.038)	(1.069)		
$\lvert\Delta Tax\rvert_{-2}$	2.183	2.205	-0.419	-0.369		
	(1.620)	(1.634)	(0.900)	(0.931)		
$\lvert\Delta Tax\rvert_{+1}$	-3.160*	-2.831*	3.647***	4.092***	-1.710***	-1.655***
	(1.640)	(1.668)	(1.057)	(1.083)	(0.611)	(0.618)
$\lvert\Delta Tax\rvert_{+2}$	3.471**	3.722**	4.712***	5.235***		
	(1.547)	(1.580)	(1.051)	(1.076)		
Number of Observations	2608027	2384386	1151304	1045625	1925937	1755643
R-sq	0.824	0.829	0.838	0.840	0.814	0.816
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	Y	Y	Y	Y	Y	Y

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for model fixed effect, province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing, Tianjin and Hangzhou.

Table 9: Robustness Check: Stricter criteria for control group

	(1)	(2)	(3)	(4)	(5)	(6)
DV(LnSale)	Unsubsidized Cars		subsidized Cars		Medium or Cheaper Large Cars	
Tax_Own	-9.786***	-10.02***	-7.681***	-8.222***		
	(2.107)	(2.136)	(1.186)	(1.229)		
Tax_compe1	5.962***	6.176***	5.484**	6.019**	2.413**	2.381**
	(1.950)	(1.964)	(2.601)	(2.723)	(1.153)	(1.188)
Tax_compe2					4.878***	4.931***
					(1.717)	(1.737)
$\lvert\Delta Tax\rvert_{-1}$	10.41***	10.58***	5.111***	5.262***		
	(1.535)	(1.544)	(1.025)	(1.057)		
$\lvert\Delta Tax\rvert_{-2}$	2.312	2.393*	-0.510	-0.482		
	(1.431)	(1.438)	(0.891)	(0.924)		
$\lvert\Delta Tax\rvert_{+1}$	-2.077	-1.769	3.748***	4.170***	-1.714***	-1.654***
	(1.601)	(1.629)	(1.041)	(1.066)	(0.614)	(0.622)
$\lvert\Delta Tax\rvert_{+2}$	4.445***	4.710***	4.918***	5.411***		
	(1.451)	(1.483)	(1.028)	(1.054)		
Number of Observations	2687432	2456554	1230709	1117793	1925937	1755643
R-sq	0.825	0.830	0.839	0.841	0.814	0.816
Controls	Fixed Effects, Linear Trends, Life Cycle, Gas, CCI					
Including SH BJ TJ	Y	N	Y	N	Y	N
Product Fixed Effect	Y	Y	Y	Y	Y	Y

Note: This table uses full sample from 2005-2018, in even number columns we exclude data from cities with licences restriction policies. ΔTax_{-i} in column (1) to (4) captures the impact of tax rate change in the anticipation and lagging effect of treated cars' own tax rate changes. ΔTax_{-i} in column (5) and (6) captures impact of tax rate change in the anticipation and lagging effect of treated cars' competitors' tax rate changes. We control for model fixed effect, province fixed effect and sample month fixed effect in all regression. Standard errors are clustered at model level. In columns (2) (4) and (6) we exclude Shanghai, Beijing, Tianjin and Hangzhou.

Table 10: Effect on CO_2 Emission

		Scrapping Rate							
New Sales	9.3M	0.1	0.3	0.5	0.7	Vehicle Use Intensity	Years remaining	Gas consumption per 100KM (Liter)	CO2 Emission in thousand metric ton
Decrease		0.93M	1.86M	4.65M	6.51M	16900KM/Year	2	7.13	3916.355706
Increase		8.37M	7.44M	4.64M	2.79M	16900KM/Year	10	7.13	176236.0068
Substitution for Medium Car	3.7M	\	\	\	\	16900KM/Year	10	8.23	13035.03157
Timing one month	116483	\	\	\	\	16900KM/Year	10	7.13	
	26.90204976					16900KM/Year			
Net Increase of CO2 Emission		163227.8773	124064.3202	84900.76314	45737.20608				

References

Julius Andersson. Cars, Carbon Taxes and CO2 Emissions. GRI Working Papers 212, Grantham Research Institute on Climate Change and the Environment, March 2017.

Panle Jia Barwick, Shengmao Cao, and Shanjun Li. Local protectionism, market structure, and social welfare: China's automobile market. (NBER Working Paper 23678), August 2017.

Antonio Bento, Kevin Roth, and Yiou Zuo. Vehicle Lifetime Trends and Scrappage Behavior in the U.S. Used Car Market. *The Energy Journal*, 1, 2018.

David Berger, Nicholas Turner, and Eric Zwick. Stimulation House Market. *Working Paper*, 2018.

Michael Best and Henrik Kleven. Housing Market Responses to Transaction Taxes: Evidence From Notches and Stimulus in the UK. *Review of Economic Studies*, 85(1):157–193, 2017.

Chia-Wen Chen, WeiMin Hu, and Christopher R Knittel. Subsidizing Fuel Efficient Cars: Evidence from China's Automobile Industry. *NBER Working Paper No. w23045*, 2017.

Yuyu Chen, Ginger Zhe Jin, Naresh Kumar, and Guang Shi. Gaming in air pollution data? lessons from china. January 2013.

Lucas W. Davis, Alan Fuchs, and Paul Gertler. Cash for coolers: Evaluating a large-scale appliance replacement program in mexico. *American Economic Journal: Economic Policy*, 6(4):207–38, November 2014.

Sumeet Gulati, Carol McAusland, and James M. Sallee. Tax Incidence with Endogenous Quality and Costly Bargaining: Theory and Evidence from Hybrid Vehicle Subsidies. *Journal of Public Economics*, 155(C):93–107, 2017.

Christopher House and Matthew Shapiro. Temporary Investment Tax Incentives: Theory with Evidence from Bonus Depreciation. *American Economic Review*, 98(3):737–768, 2008.

Wei Min Hu, Junji Xiao, and Xiaolan Zhou. Collusion or Competition? Interfirm Relationships in the Chinese Auto Industry. *The Journal of Industrial Economics*, 62(1):1–40, 2014.

Hong Huo, Qiang Zhang, Kebin He, Zhiliang Yao, and Michael Wang. Vehicle-use intensity in China: Current status and future trend. *Energy Policy*, 43(C):6–16, 2012.

T Tony Ke and Song Lin. Informational complementarity. *Management Science.*, 66(8): 3699–3716, August 2020.

Shanjun Li, Joshua Linn, and Elisheba Spiller. Evaluating "Cash-for-Clunkers": Program Effects on Auto Sales and the Environment. *Journal of Environmental Economics and Management*, 65(2):175–193, 2013.

Atif Mian and Amir Sufi. The Effects of Fiscal Stimulus: Evidence from the 2009 Cash for Clunkers Program. *The Quarterly Journal of Economics*, 127(3):1107–1142, 2012.

Junji Xiao and Heng Ju. Market equilibrium and the environmental effects of tax adjustments in china's automobile industry. *Rev. Econ. Stat.*, 96(2):306–317, May 2014.

Eric Zwick and James Mahon. Tax Policy and Heterogeneous Investment Behavior. *American Economic Review*, 99(4):217–248, 2017.

A Appendix A

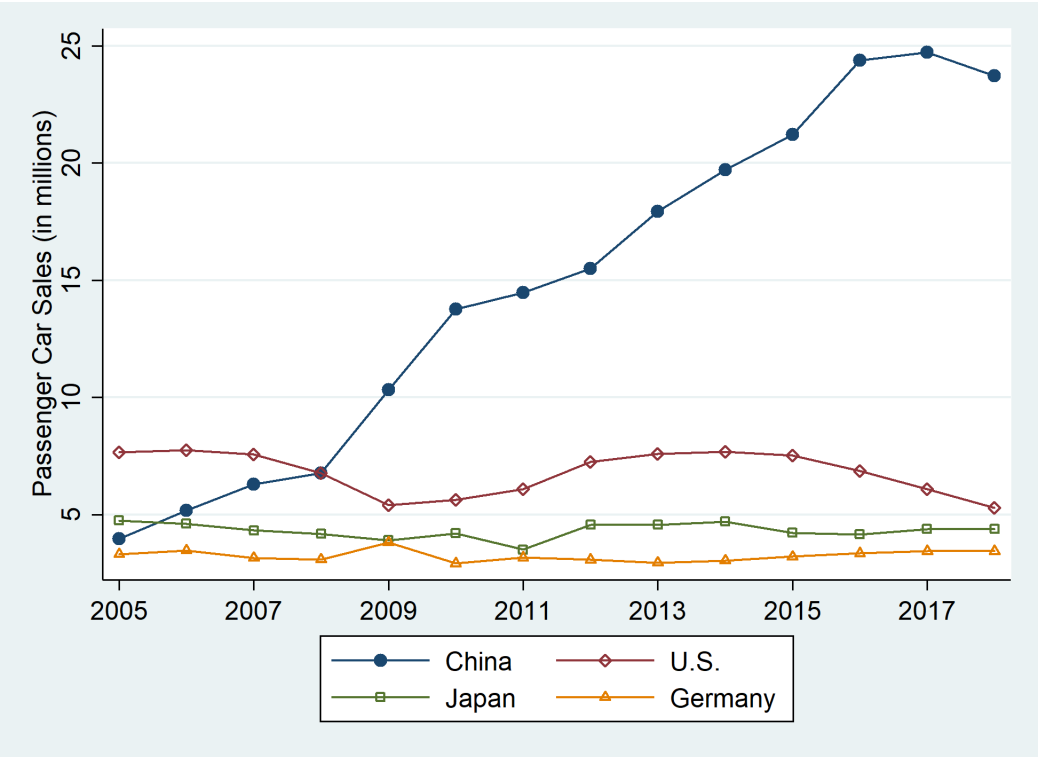


Figure A1: Car Sales in Major Markets

Note: This figure demonstrates passenger car pr
[Source] http://www.oica.net/category/sales-statistics/

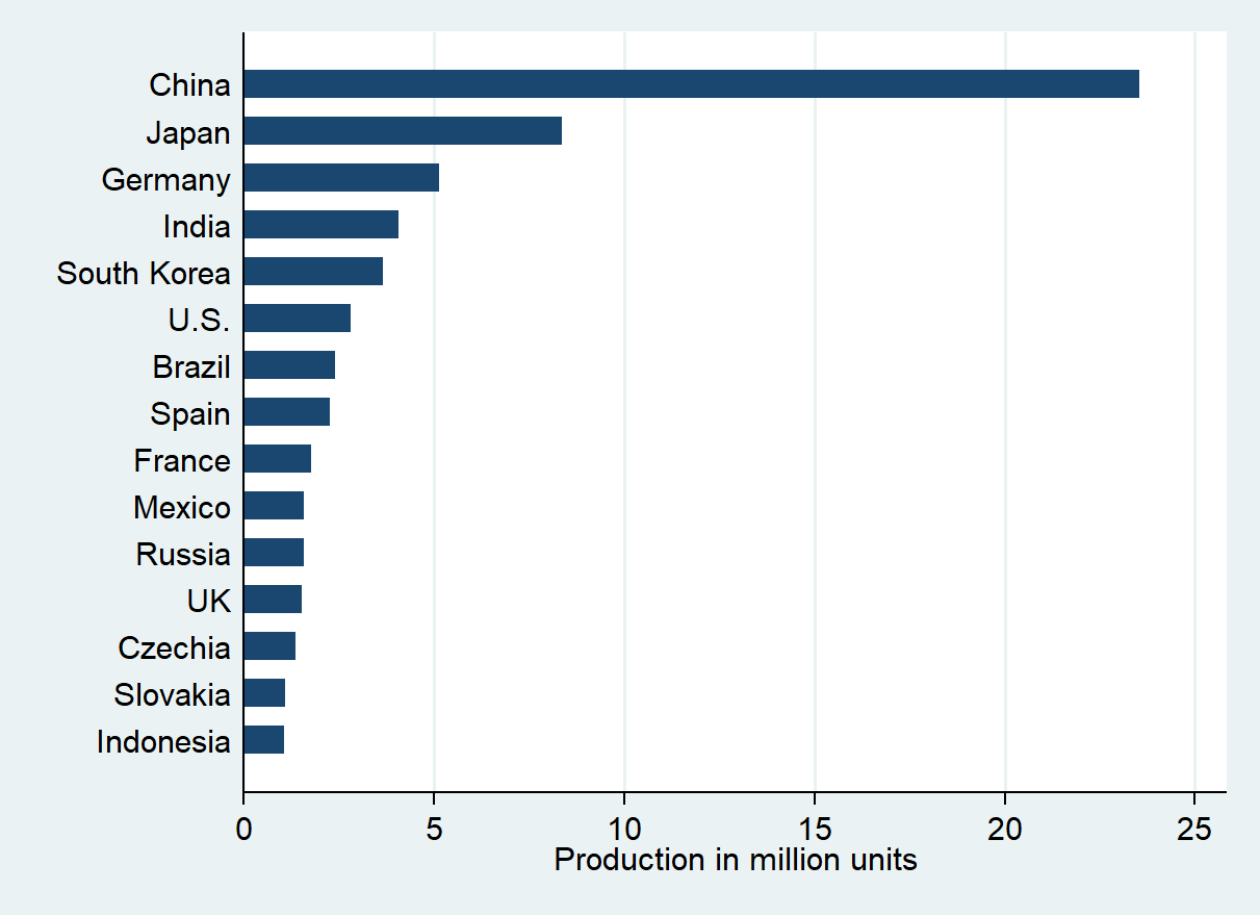


Figure A2: World Car Production in 2018

Note: This figure demonstrates passenger car production in 2018
[Source] http://www.oica.net/category/sales-statistics/

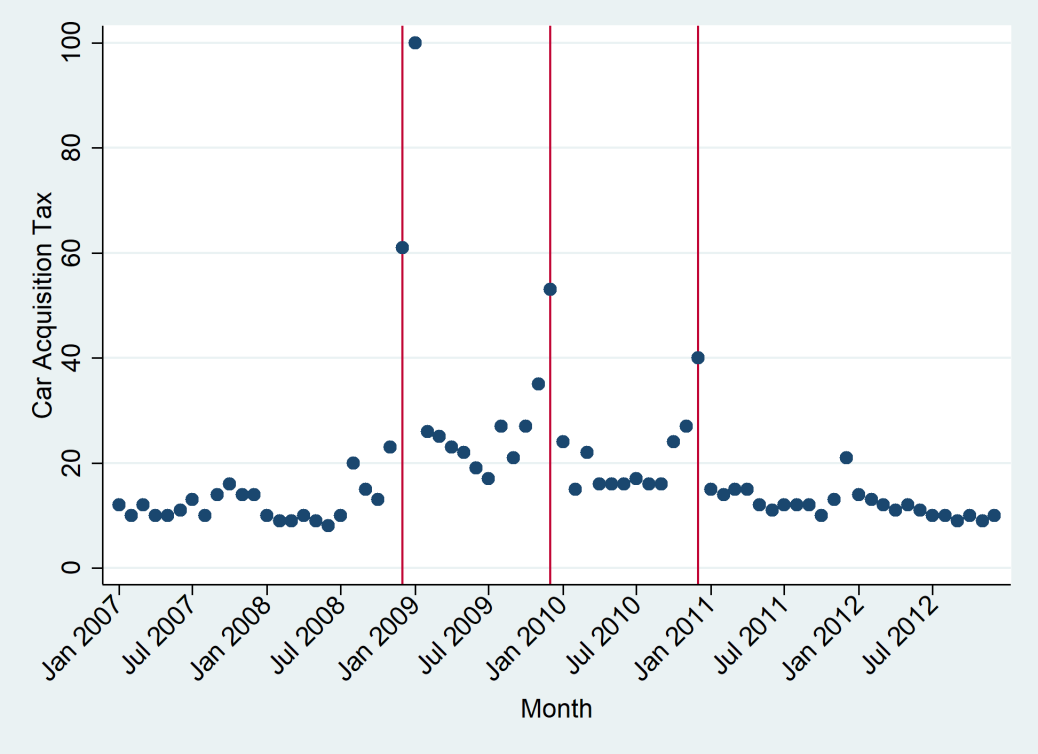


Figure A3: Google Search Index for "Car Acquisition Tax"
Note: [Source] Google trend

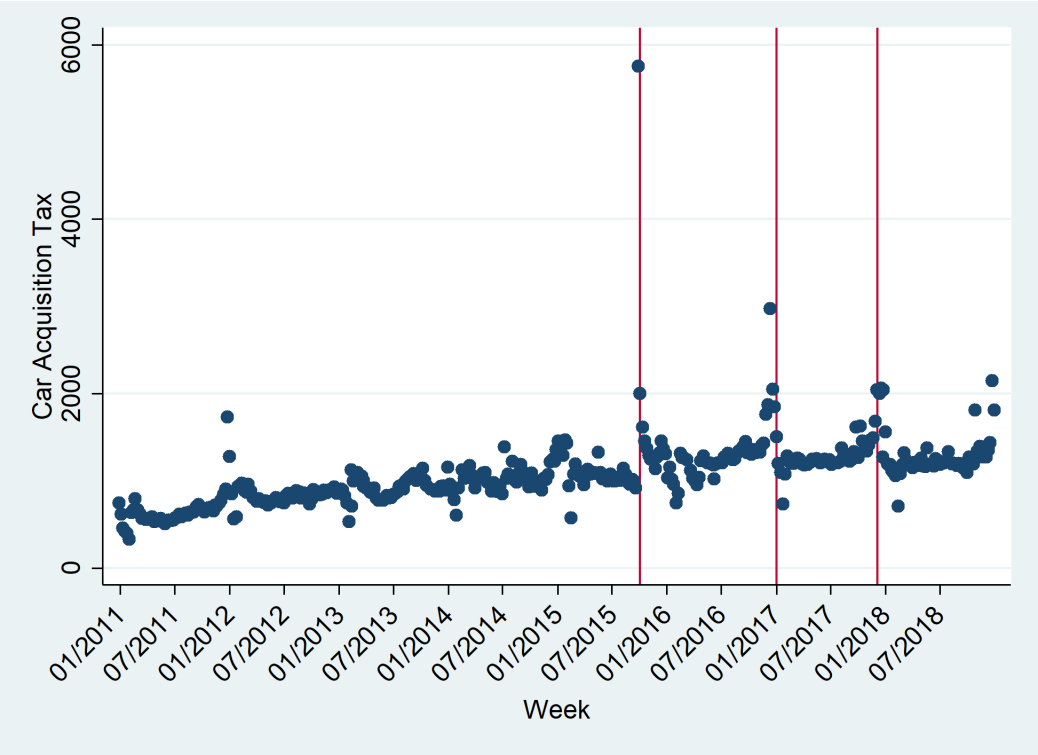


Figure A4: Baidu Search Index for "Car Acquisition Tax"

Note: [Source] Google trend



Figure A5: Screenshot from the most popular phone app for car information in China

Note: [Source] From Phone App "Dongchedi"

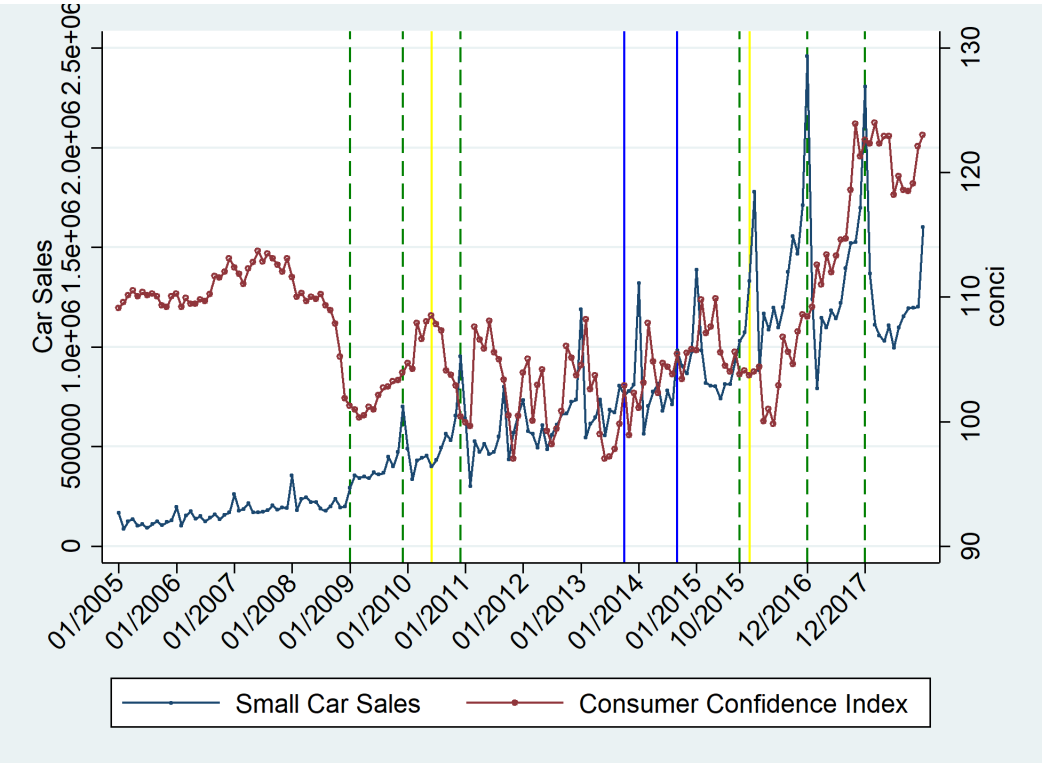


Figure A6: Consumer Confidence Index and Large Car Sales
[Source] Calculated by authors from car sales data

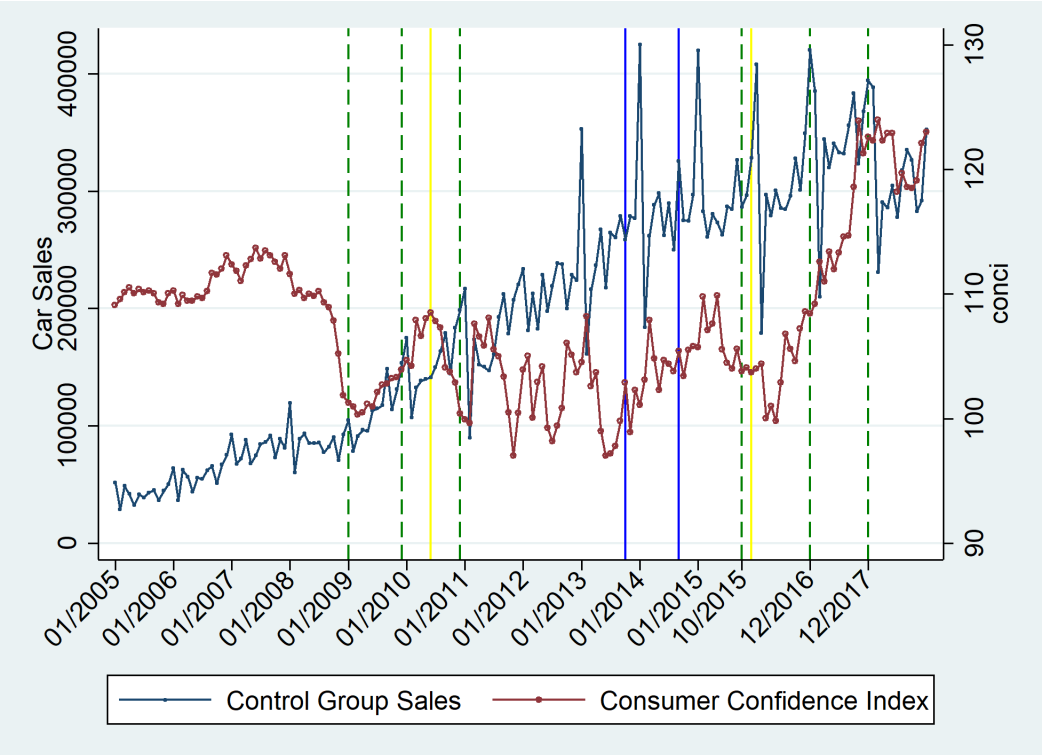


Figure A7: Consumer Confidence Index and Small Car Sales

[Source] Calculated by authors from car sales data

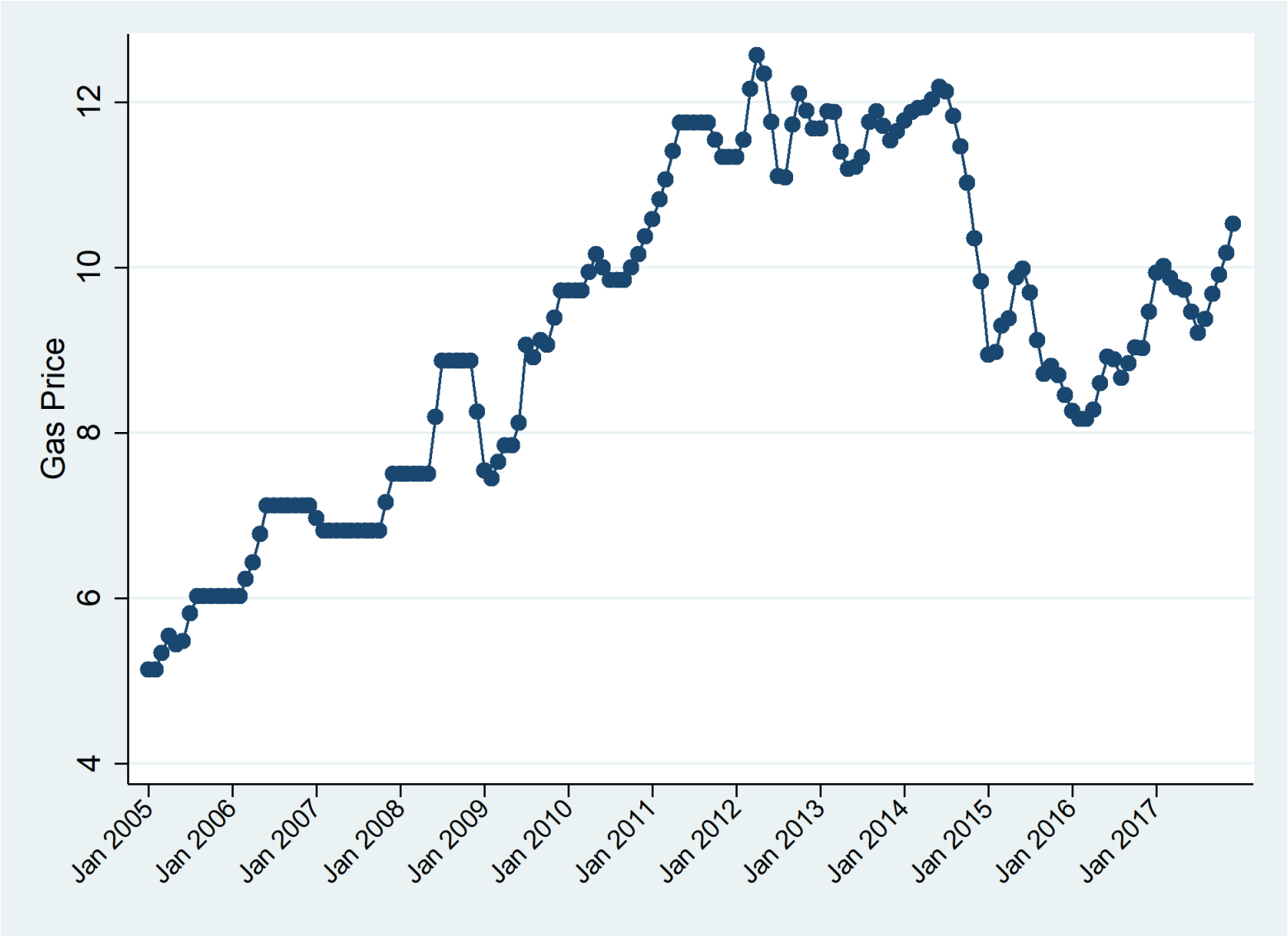


Figure A8: National Average Gas Retail Price

Note: [Source] Calculated by authors from car sales data

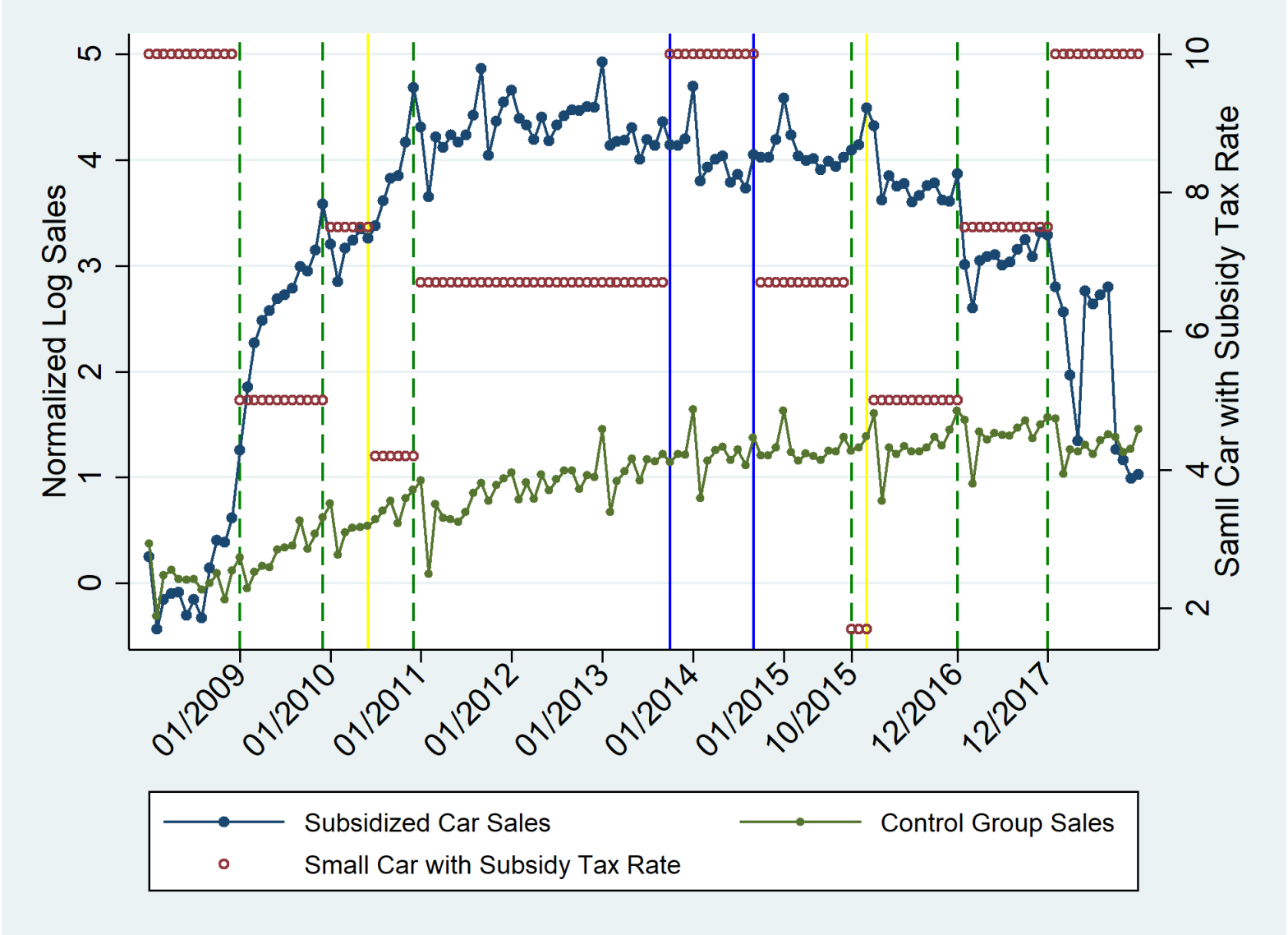


Figure A9: Impact of tax incentives on group three cars

Note: This figure we show the n of monthly sales of subsidized small cars and large cars. Data are normalized to zero for the pre-treatment period (2007-2008). In this graph we don't include small cars. The red dots corresponds to effective tax rate for subsidized small car and the effective tax rate for non-subsidized car is ten between the two golden lines. [Source] Calculated by authors from car sales data

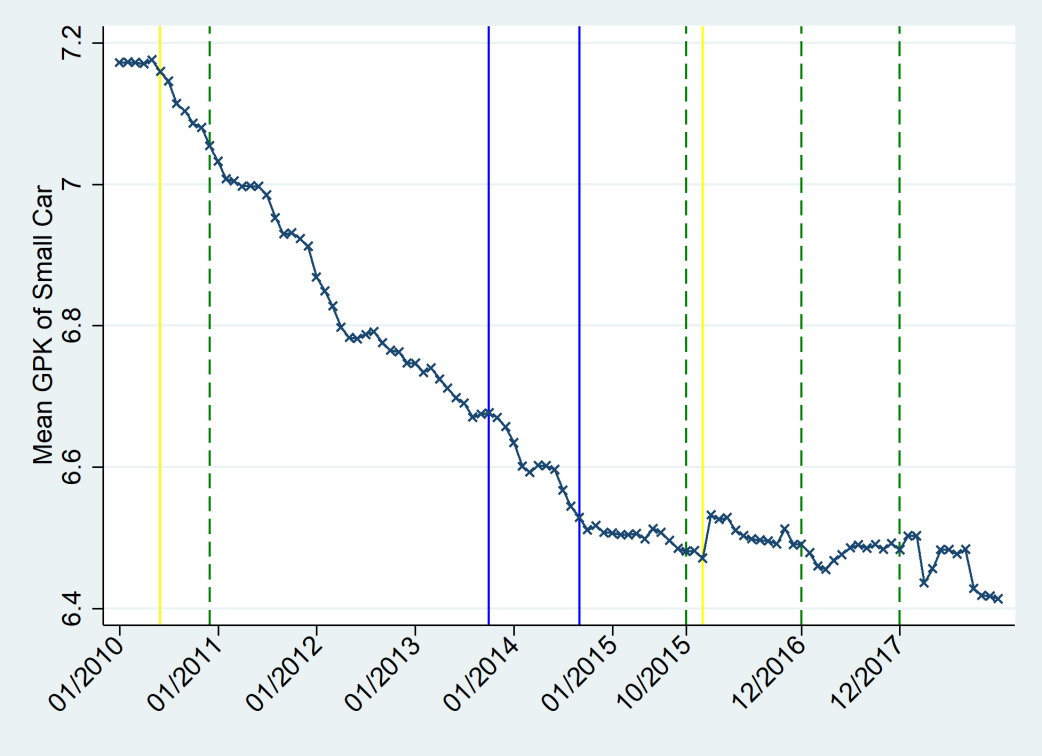


Figure A10: National Average Gas Retail Price

Note: [Source] Calculated by authors from car sales data and Fuel efficient data

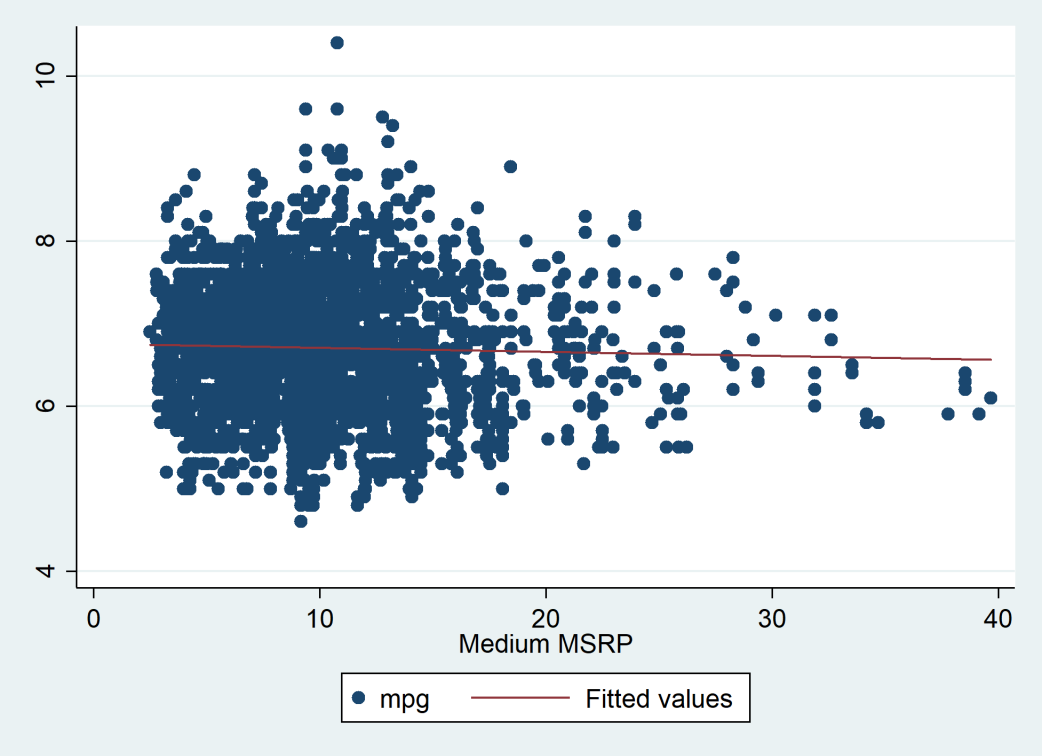


Figure A11: Relationship between Price and Gas Consumption (MPG)

Note: [Source] Calculated by authors from car sales data Fuel efficient data