Three Essays on Public Finance

by

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ABSTRACT

This dissertation consists of three essays on public finance. The first two are closely related to each other, studying the tax policies in Chinese car markets. The third one on the corporate income tax rate and firm innovation is not closely related to the first two. All three essays are answering how the tax systems affect consumer and firm behavior and its welfare implication. They demonstrate my interest in applying economic reasoning to the design and evaluation of public policy.

The first chapter is an empirical examination of how tax incentives stimulates the car market and its environmental cost. 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 chapter 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.

The second chapter, with Jianjun Li, studies tax incidence on its own product and close substitutes in a multi-product oligopoly setting. We study a tax change in China's car market that lowers the tax rate from 10% to 5% for cars with small engines. Using transaction-level tax administrative data we show that consumer price for small cars drops by approximately 4.3% and their competitors' price also dropped by 0.6%. We consider the pass-through on close substitutes in a multi-product oligopoly setting where firms need to take cannibalization effect into consideration when they respond to a tax change on some of their product. Our analysis shows market share of the target product matters for the incidence of its substitutes.

The third chapter, with Jing Cai and Yuyu Chen, exploits a tax reform on manufacturing firms in China to study the impact of taxes on firm innovation. The reform switched the corporate income

tax collection from the local to the state tax bureau and reduced the tax rate by 10%. The reform only applied to firms established after January 2002, allowing us to use regression discontinuity design as the identification strategy. The results show that lower taxes improved both quantity and quality of firm innovation. Moreover, the reform has a bigger impact on firms that are financially constrained and firms that engage more in tax avoidance.

CHAPTER 1

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

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 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

[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.

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.

1.1 Institutional Background

1.1.1 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 B.2 and A.2 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

[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.

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 current estimates.

1.1.2 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.

1.1.3 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.

1.1.4 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 1.1. In Figure 3.8 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 3.8, Table 1.1

Figure 1.2 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 1.2

1.1.5 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 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.

1.1.6 The Salience of the Policies

For the policy to be effective, the consumers need to be aware of the policy. Figure A.3 and A.4 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 A.3 and A.4

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

1.1.7 Other Determinants of the Car Market

In this section, we investigate how other determinants change with the timing of the tax incentives. In figure A.6 and A.7 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 A.6 and A.7

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 A.8, 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.

1.2 Data and Construction of Control group

1.2.1 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, buyer's 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.

1.2.2 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.

1.2.3 Summary Statistics

In Table 1.3 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 1.3

1.2.4 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 1.3, 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 A.5. 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 1.4 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 1.3 and our conversations with car dealers, we notice that a watershed in China's 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 1.4 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 1.3 and 1.4

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

$$\text{Low-end market}\begin{cases}\text{Tax holiday only group: never subsidized small cars}\\ \text{Tax holiday and subsidy group: subsidized small cars}\\ \text{Substitutable group: median or large cars that are also cheaper}\end{cases}$$

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

1.3 Graphical Evidence

We first look at the impact of the tax holidays on small car sales in Figure 1.5. 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 1.6. 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 car's sales spike is still in February.

Insert Figure 1.5 and Figure 1.6

Next, we show visual evidence of the substitution effect. In Figure 1.7, 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 1.8 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 1.7 and Figure 1.8

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 1.9 and subsidized cars (if a model is ever subsidized) in Figure 1.10. 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 1.10, 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 A.9.

We also observe a strong substitution effect from Figure 1.9, 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 1.9 and 1.10

In the last part of the graphical evidence, Figure 1.11 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 1.11: 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 1.11

1.4 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 substitute's tax rate, more specifically we use the following specification after aggregating data at the province-month-model level:

$$\text{Ln}(\text{sales}_{ijt}) = \beta_0 + \beta_1 Tax\_Own_{it} + \beta_2 Tax\_Compe_{it} + \theta_{t+p} \sum_{p=-k}^{k} \Delta Tax\_Own_{it+p} + \gamma_{t+p} \sum_{p=-k}^{k} \Delta Tax\_Compe_{it+p} + \beta_3 X_{gt} + \alpha_i + \alpha_j + \alpha_t + \alpha_{it} + \alpha_{gt} + \epsilon_{ijt} \quad (1.1)$$

$Ln(sales_{ijt})$ is the natural logarithm of model i car's 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 1.2 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 1.4 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 1.4 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 1.4 and Table 1.5, 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 1.4.

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 1.6 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 1.5, 1.6

1.4.1 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].

1.5 Robustness Checks

In this section we use stricter criterion to construct the control group and substitution group. In the first robustness in Table 1.7 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 1.8 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 1.9 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 1.5. The result does not change much compared with our baseline. Our result is not sensitive to the classification of control and substitutable groups.

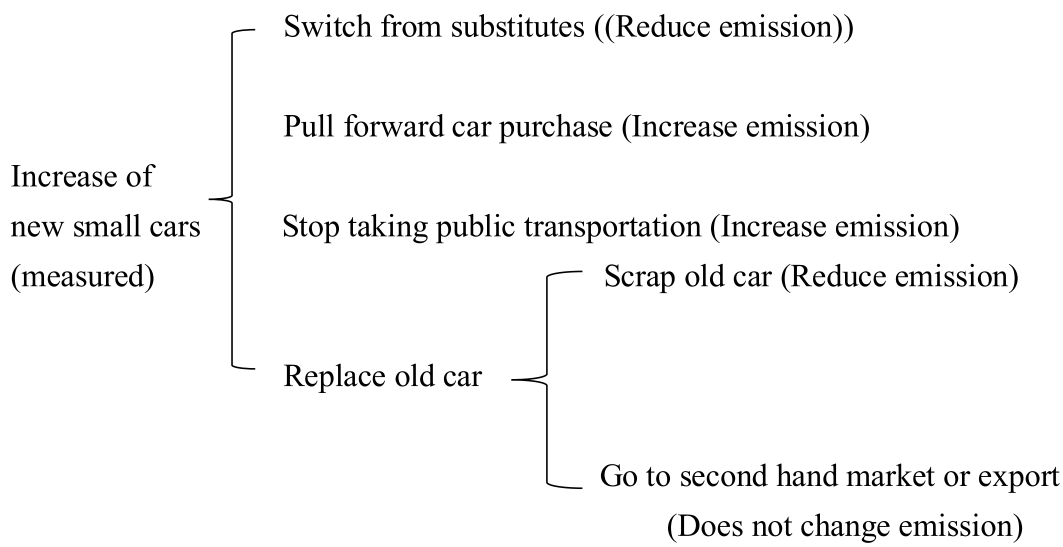
Insert Table 1.7 Table 1.8

1.6 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


Switch from substitutes ((Reduce emission))
Pull forward car purchase (Increase emission)
Increase of
new small cars
(measured)
Stop taking public transportation (Increase emission)
Scrap old car (Reduce emission)
Replace old car
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:

$$\text{Change of CO2 Emission}=\underbrace{(1-\alpha)\times\text{New\_Sale}\times\text{EM\_Small}\times\text{Lifespan}\times\text{VUI})}_{\text{Increase from extensive margin response}}$$
$$-\ \underbrace{\text{Decrease\_sale}\times(\text{EM\_Medium}-\text{EM\_Small})\times\text{Lifespan}\times\text{VUI}}_{\text{Decrease from substitution effect from larger cars}}$$
$$-\ \underbrace{\text{Decrease\_sale}\times(\text{EM\_Subsidized}-\text{EM\_Nonsubsidized})\times\text{Lifespan}\times\text{VUI}}_{\text{Decrease from substitution effect from Fuel efficient cars}}$$
$$\underbrace{-\text{Forward\_Sale}\times\ (\text{Months forward})/(\text{Lifetime EM})}_{\text{Increase from retiming effect}}$$

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

[5]Technical report from Ministry of Commerce

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 1.10 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 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 A.10 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 1.10 and Figure A.10

1.7 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.

[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

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.

1.8 Figures

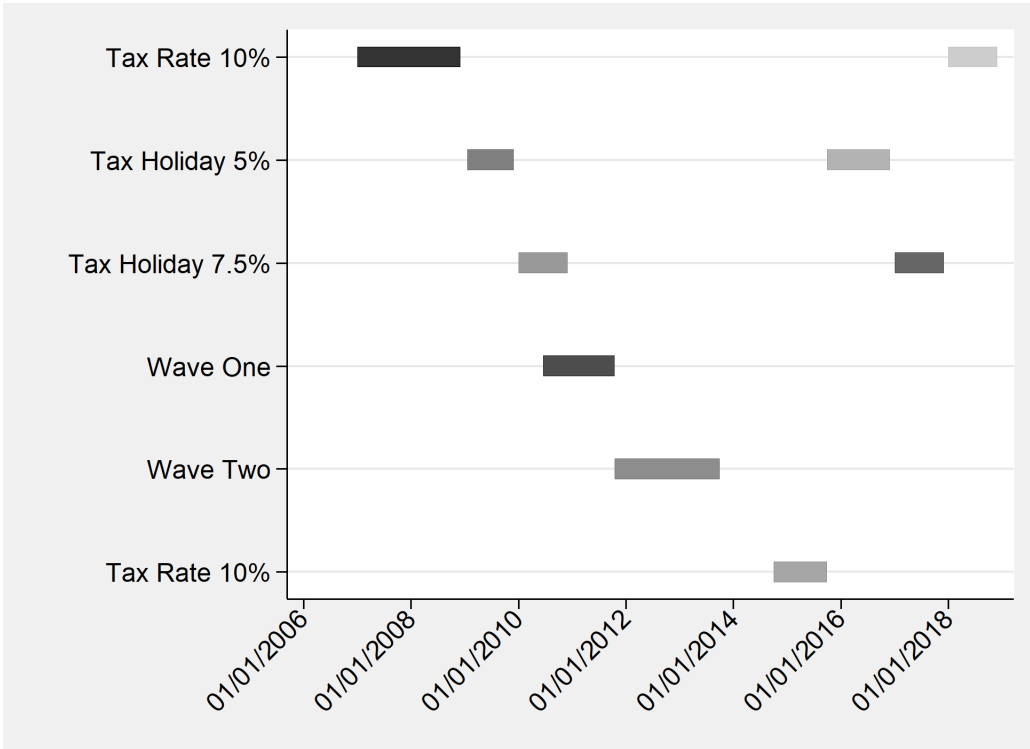


Figure 1.1: Tax Holidays

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

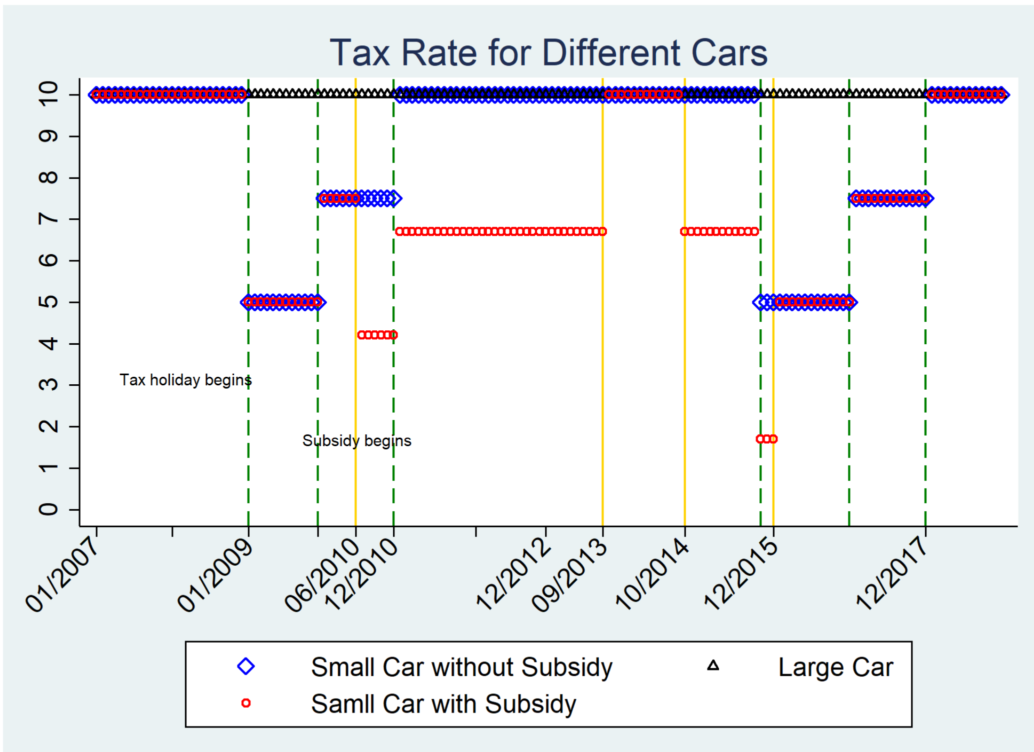


Figure 1.2: Tax Rate for Different Cars

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.

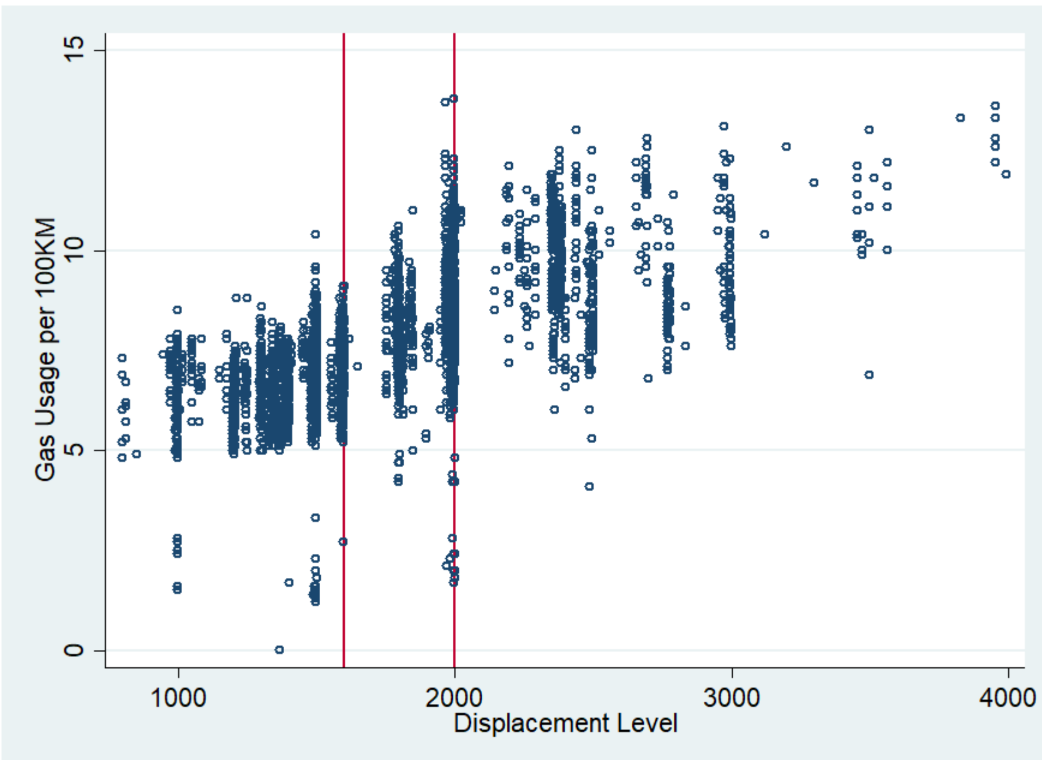


Figure 1.3: Relationship between Gas Use Per 100KM and displacement level

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

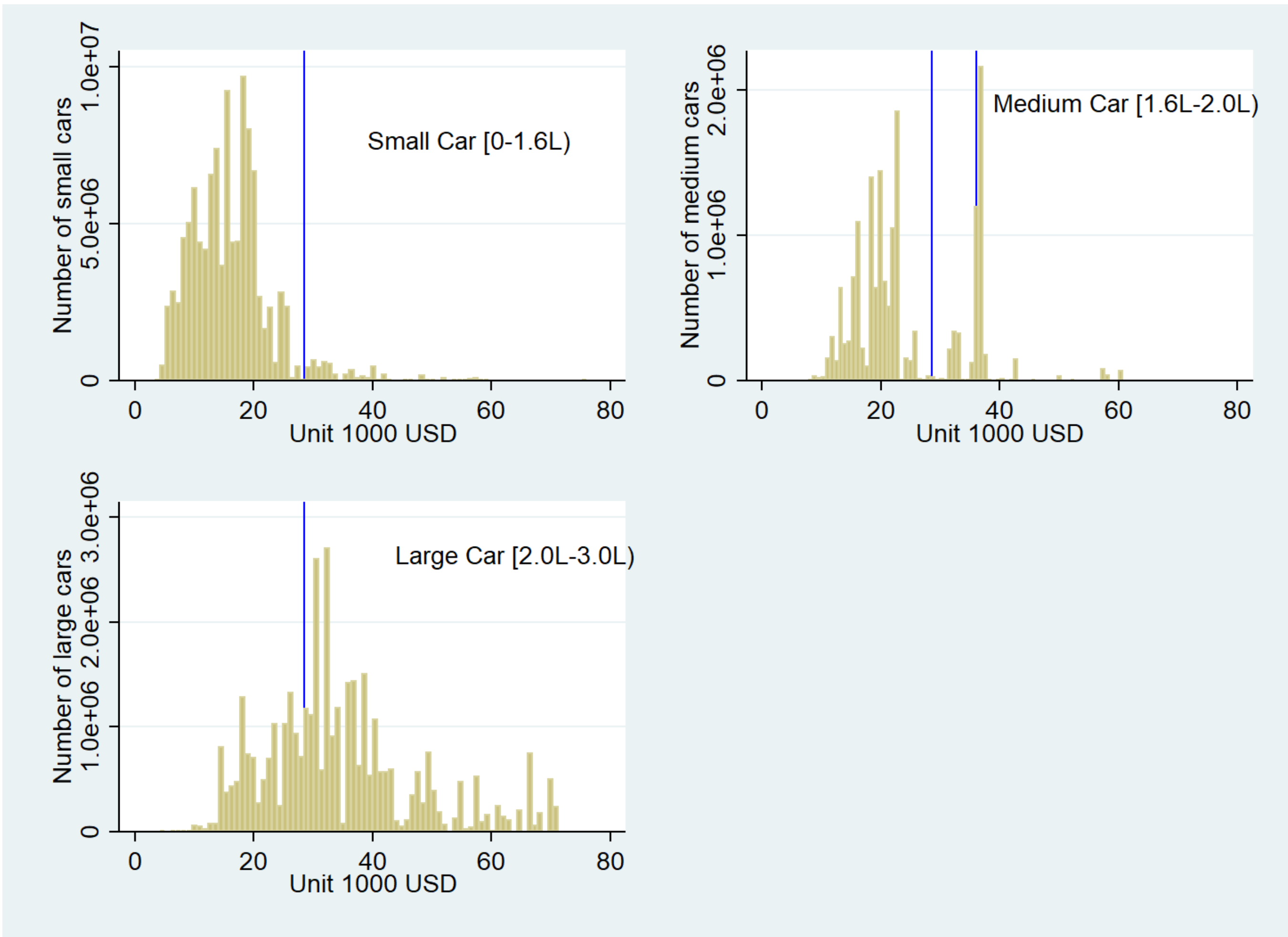


Figure 1.4: Price distribution for small, medium and large cars

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

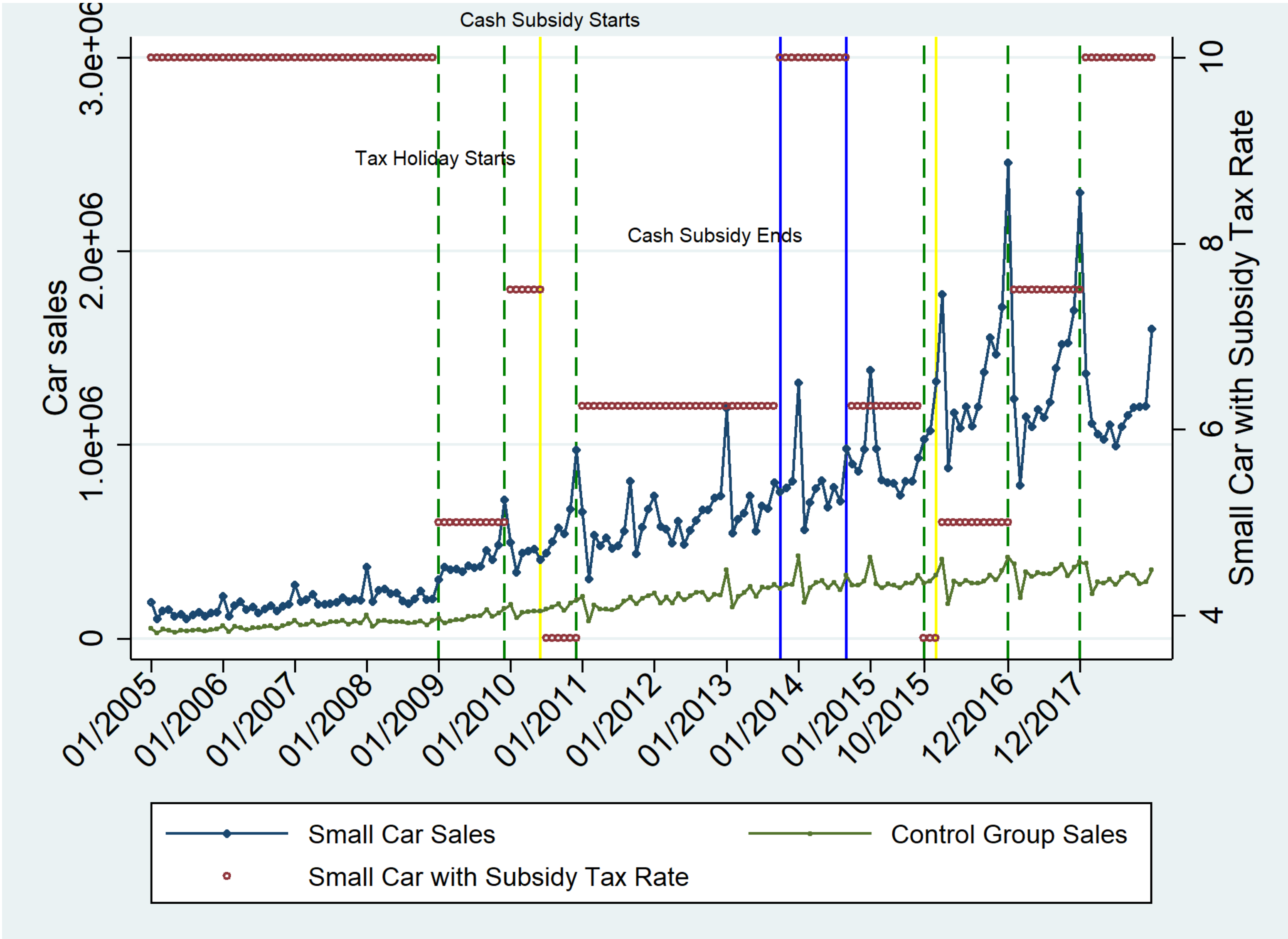


Figure 1.5: Car sales trend in China from Jan 2007 to Dec 2018

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

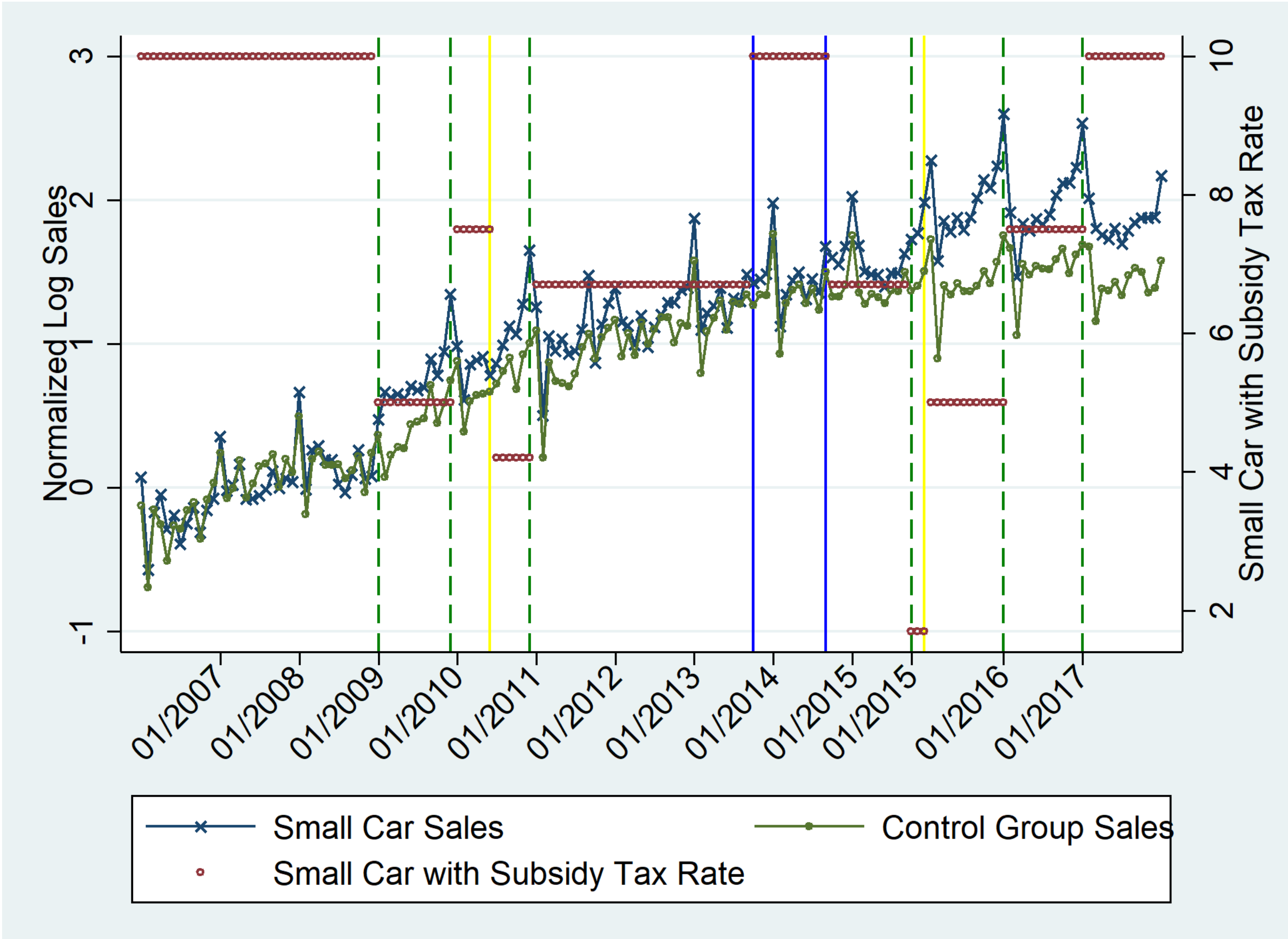


Figure 1.6: Log sales for small and large cars

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

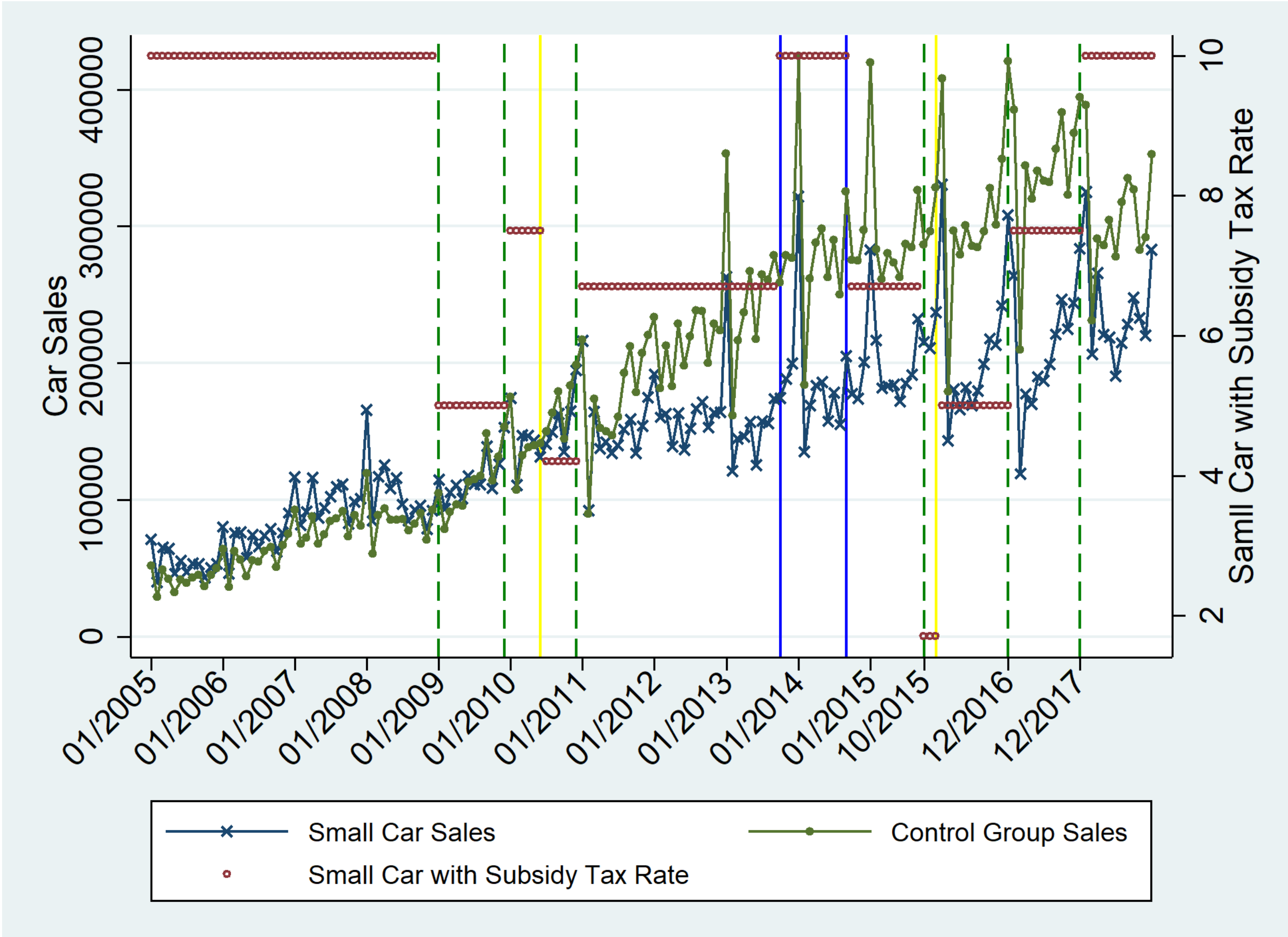


Figure 1.7: Impact of tax incentives on substitutable cars

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

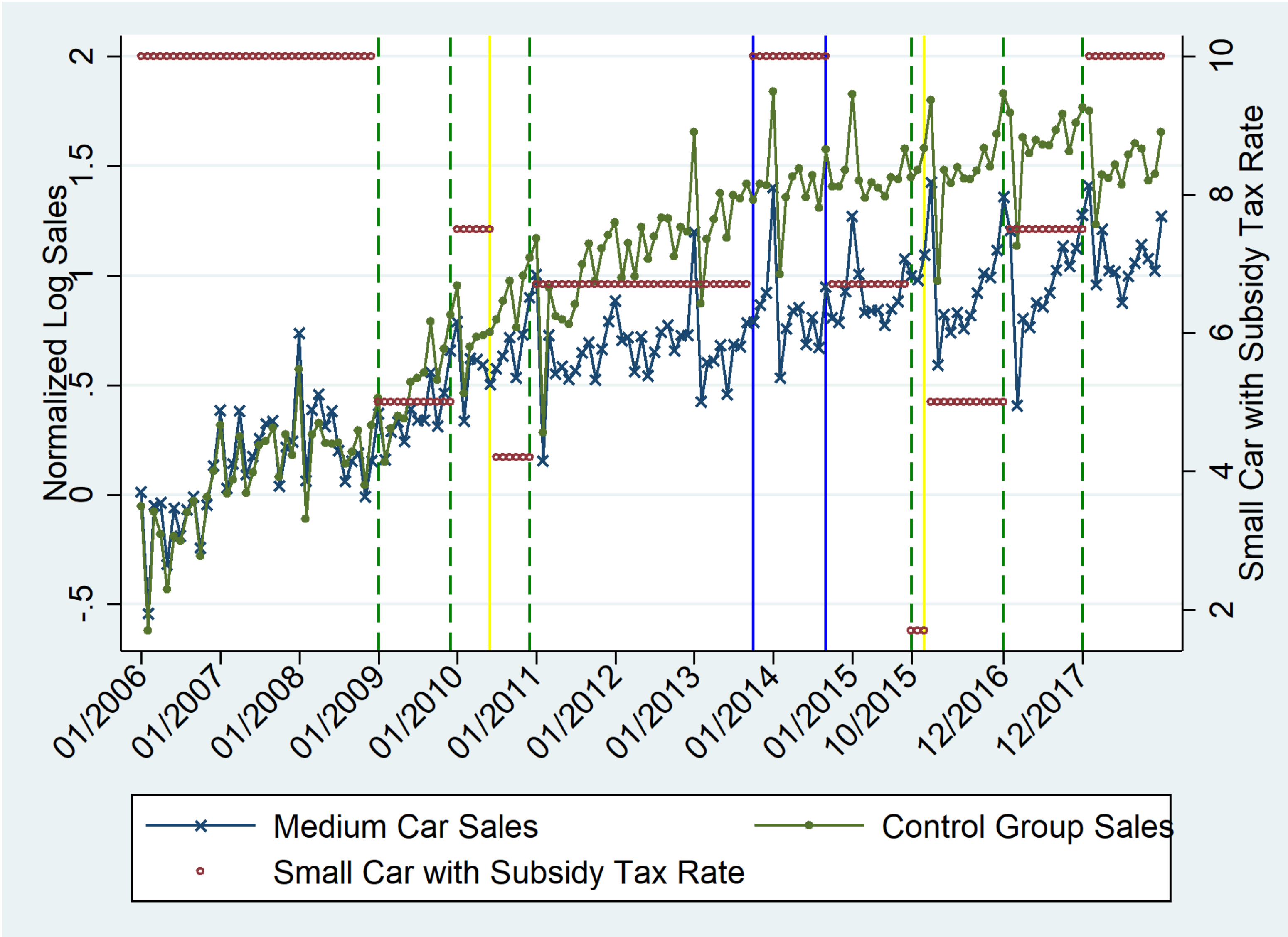


Figure 1.8: Impact of tax incentives on substitutable cars

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

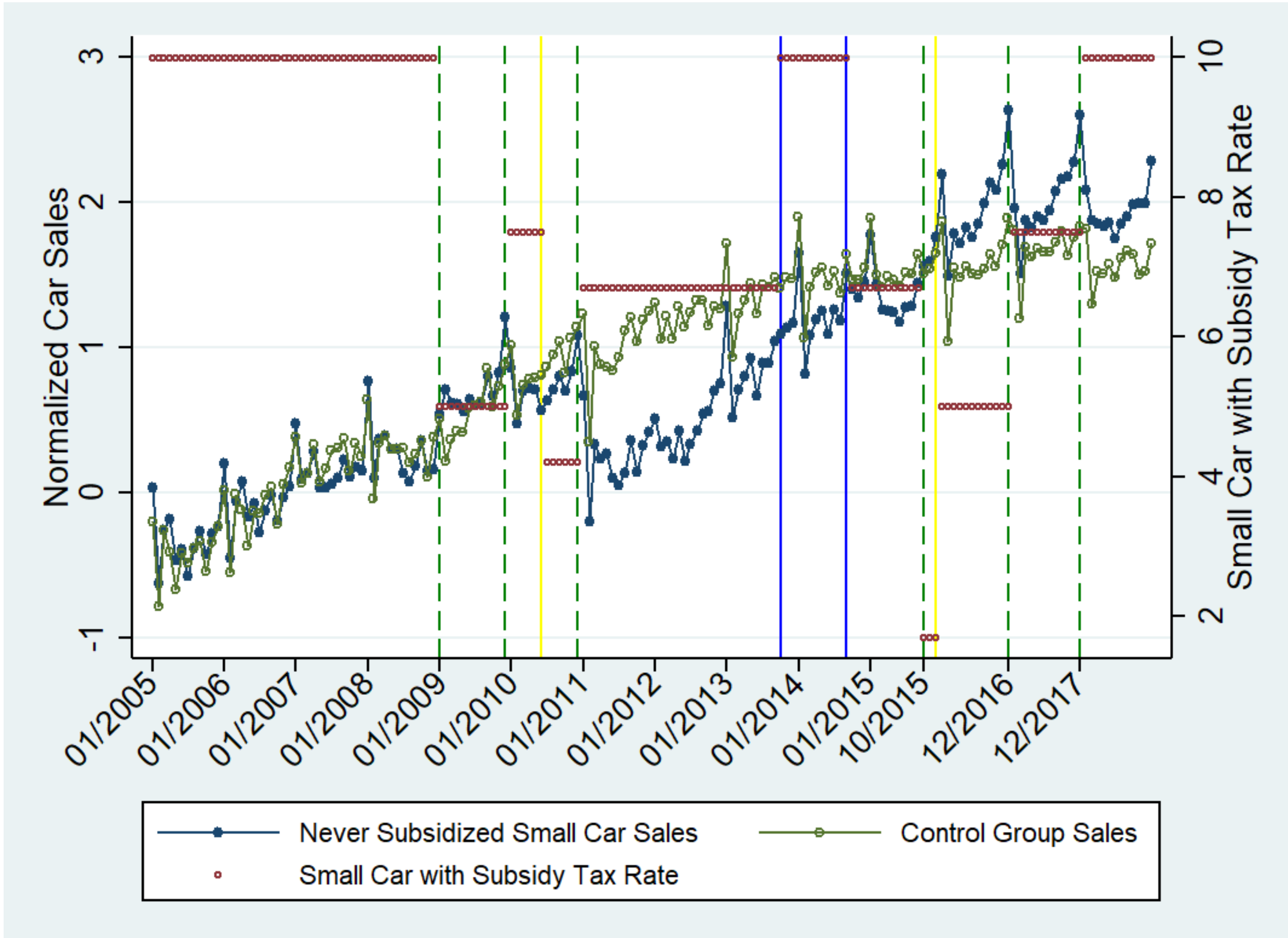


Figure 1.9: Impact of tax incentives on unsubsidized small cars

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

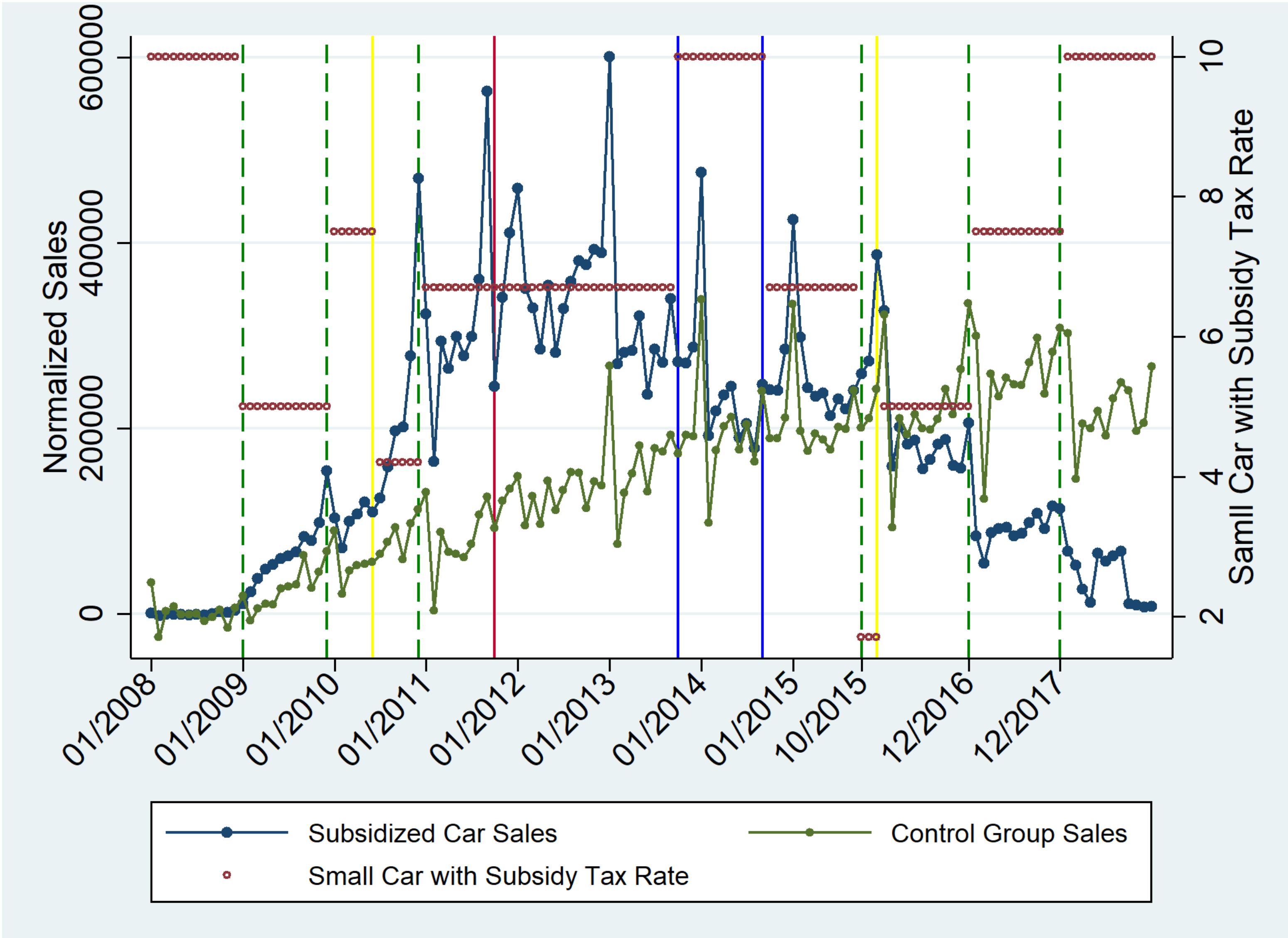


Figure 1.10: Impact of tax incentives on group three cars

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

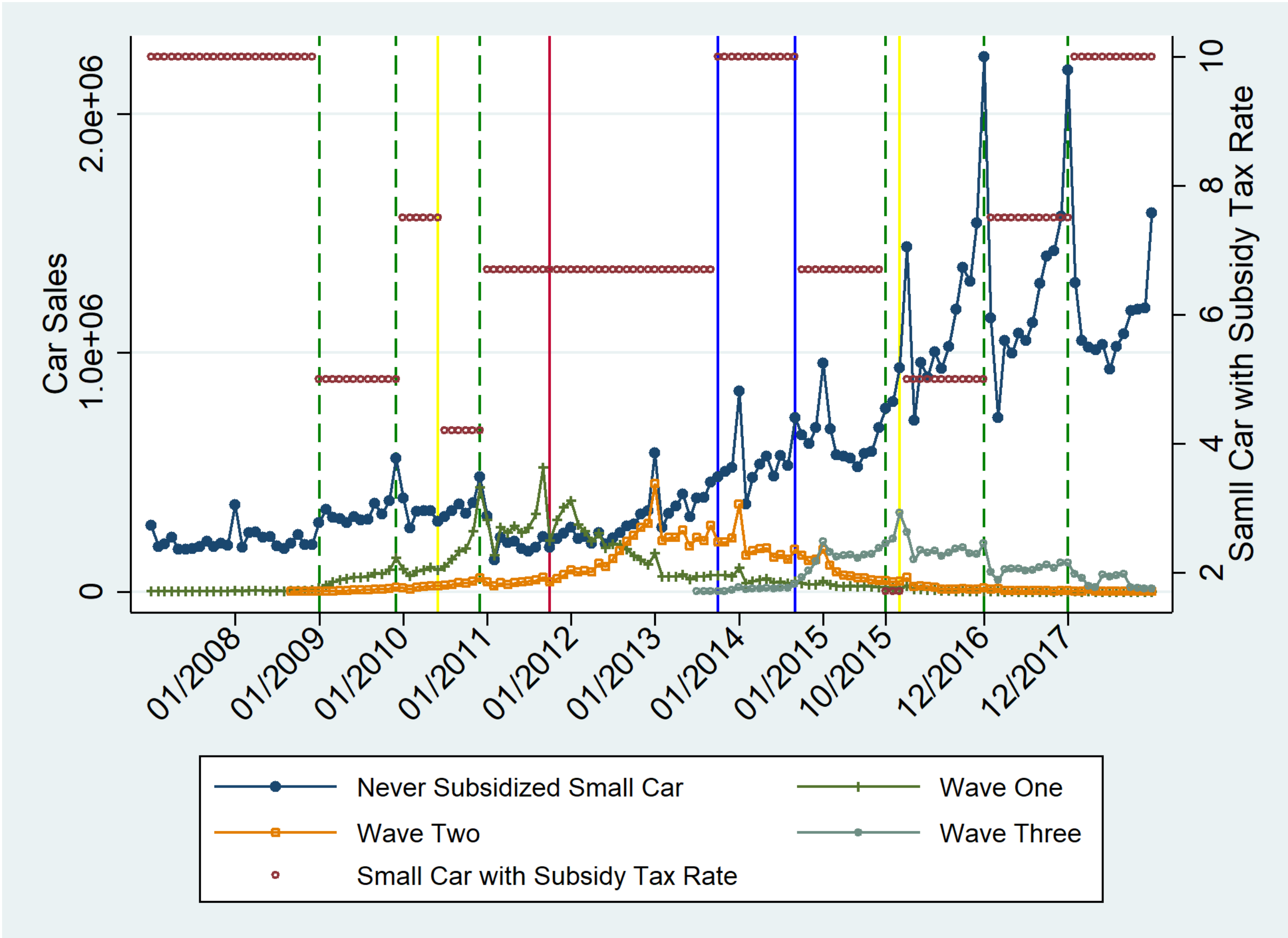


Figure 1.11: Sales for all the small cars

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

1.9 Tables

Table 1.1: 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 1.2: 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 1.3: 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 1.4: 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 1.5: 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 1.6: 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 1.7: 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 1.8: 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)
$\|\Delta Tax\|_{-1}$	10.68***	10.81***	4.919***	5.097***		
	(1.770)	(1.787)	(1.038)	(1.069)		
$\|\Delta Tax\|_{-2}$	2.183	2.205	-0.419	-0.369		
	(1.620)	(1.634)	(0.900)	(0.931)		
$\|\Delta Tax\|_{+1}$	-3.160*	-2.831*	3.647***	4.092***	-1.710***	-1.655***
	(1.640)	(1.668)	(1.057)	(1.083)	(0.611)	(0.618)
$\|\Delta Tax\|_{+2}$	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 1.9: 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)
$\|\Delta Tax\|_{-1}$	10.41***	10.58***	5.111***	5.262***		
	(1.535)	(1.544)	(1.025)	(1.057)		
$\|\Delta Tax\|_{-2}$	2.312	2.393*	-0.510	-0.482		
	(1.431)	(1.438)	(0.891)	(0.924)		
$\|\Delta Tax\|_{+1}$	-2.077	-1.769	3.748***	4.170***	-1.714***	-1.654***
	(1.601)	(1.629)	(1.041)	(1.066)	(0.614)	(0.622)
$\|\Delta Tax\|_{+2}$	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 1.10: 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				

CHAPTER 2

Tax Incidence on Substitutes: Evidence from China's Car Market

2.1 Introduction

One of the most fundamental research question in public finance literature is who bears the burden of taxes. The pass-through of indirect taxation is key to evaluate tax policy's welfare implication and how government can use tax tools to shape consumer behavior. The discussion of tax incidence in public finance literature has been focused a lot on the single product market. This simplification ignores the potential impact of the tax rate's change on its close substitute's price and the policies can not be precisely evaluated. For instance, the traditional model predicts that sellers will change their price when competitors' after-tax price changes. But little evidence has been provided of the cross-product pass-through of taxation and how it interacts with market structure empirically.

A large body of literature has studied how the tax change the final price consumers for the targeted item under single product partial equilibrium framework. However, little is known about the impact of one products' tax rate change on related products. Weyl and Fabinger [2013] extends the stand tax incidence analysis to more general imperfect competition settings. The theoretical perdition is ambiguous when we consider the multiproduct firms. As shown by some recent development of the cost pass-though studies Armstrong and Vickers [2018]. More the 60% firms are multiproduct firms in the U.S. and it is important to take the cross product effect into consideration when determining tax incidence. Hotelling [1932] on Edgeworth Taxation Paradox states that for multiproduct firms, imposing a tax on one product could possibly decrease the price for both products. Their work has motivated economists to think deeper about how the shape of demand curves and market structure characterize who bears the burden of taxation.

This paper explores a tax cut in the Chinese car market for small-engine cars. We first show that a five percentage point tax cut decreases the final price by approximately four percentage points. More importantly, we provide evidence on how tax rate change affects the price of close substitutes using administrative data. We propose a simple model to discuss what characterizes the incidence of a substitute. Our paper is the first empirical paper that provides a causal estimate of tax incidence under a multiproduct firm setting. Specifically, we study a tax cut for cars with an engine size smaller than 1.6 liters in the car market in China, car manufactures produce both small and large cars, and their pricing strategy must take cannibalization into account when setting its markups. Our results have broader implications and can be applied to more general settings when tax policies are targeted on certain products such as Soda taxes based on sugar per liter, cigarette taxes based on E-cigarette or not, the tariff on certain products and housing transaction taxes based on size of the house.

The empirical work on identifying pass-through faces several challenges: First we need to construct a substitutable group and the control group. Most sales tax changes apply to all products and it is often hard to find a control group from the same market; Second is the lack of administrative transaction price data. Our paper studies a policy change based on car engine size and it allows to separate cars into control and substitutable groups and we have information on each car's detailed daily transaction price.

We study a car sales tax holiday for vehicles with a displacement level smaller than 1.6L in China and estimate the incidence of tax-exempt cars and close substitutes. In October 2015, car acquisition tax was halved from 10 to 5 percent on small cars with engine size less than 1.6 liters to stimulate the market and spur clean cars. The tax was then raised to 7.5 percent in January 2017 and returned to the original 10 percent in January 2018. The beginning of the tax holiday is a surprise to the market, and it was only announced two days before implementation. And the end of the holiday is fully anticipated.

In order to identify the control and the substitutable group, we use engine size and price to separate all passenger cars into three groups. The tax exempted small cars whose engine size is smaller than 1.6L; substitutable group: the medium cars whose engine size is between 1.6L and 2.0L and whose price is close to the smaller cars or cars whose engine size is above 2.0L but with a price even closer to the small cars market; control group: the unaffected cars whose engine size is above 2.0L and whose price is high or engine size slightly above 1.6L but expensive enough. Using transaction-level administrative data from a major city in China and a difference in difference estimation strategy. We study how smaller car's tax rate change affects its sales and pre-tax price and how it affects the medium cars' sales and pre-tax price.

Our analysis yields several findings: First if we compare the pre-tax price within each product in the DID estimation, we find that consumers benefit approximately 80% of the tax cut. This is consistent with the large sales response of small car sales. Second, we find clear evidence on the incidence of medium cars: the tax cut for small cars decreased the sales for medium cars and lowered its pre-tax sales price. More interestingly, for each firm, we calculate the share of mall cars and we find among the firms with more sales from small cars, their medium cars price will decrease less. The intuition is if firms benefit more from the small car's tax cut they have less incentive to lower medium car price to avoid cannibalization. We also construct a measure of "distance between products" using the gap of average transaction price to capture how likely medium car consumers switch to smaller cars because of the tax cut. We find that the pass-through on substitutes becomes larger when the substitutes are more different from small cars.

We provide a simple model to rationalize our findings. In our setting, the consumers first choose a brand and then decide the size of the car. A nested logit model is consistent with the two-step car purchase decision. The supply-side follows standard oligopolistic multiproduct assumption. We have two firms that produce both small and large cars. In contrast to competitive firms, an oligopolistic multiproduct firm must take cannibalization into account, both when setting its markups and when deciding which products to offer. We propose a multiproduct oligopoly model that firms maximize the joint profit from both small and medium cars. When firms set price they need to balance the industry level shock from the tax changes and the cannibalization effect. In the last section, we will discuss tax incidence on substitutes under different model assumptions.

Our paper builds on and contributes to two main literature. First we provide new causal estimates of tax incidence from the world largest car market. Researchers have made huge progress on this topic under partial equilibrium framework [Besley and Rosen, 1999b, Carbonnier, 2007]. Kaul et al. [2016] studies the incidence of cash for clunkers program in Germany. We shed light to this literature by showing clear evidence that tax rate change also affect the price of close substitutes.

Second, we also speak to IO and marketing literature on cost path through. A tax change has similar implications on firm cost. In particular, our paper discusses the within-firm competition effect.The most closely related work is [Agrawal and Hoyt, 2019]. Their paper provides an nice angle in perfectly competition market when gen general equilibrium effect matters for incidence and focus more on the possibility of over shifting. While our paper focuses on estimating the impact on substitutes per se and we study the imperfect competition market conditions. Moorthy [2005] provides a general formulation of the channel pass-through problem focusing on brand and retailer differences. Related to findings in this paper Besanko et al. [2005] first investigate the determinants of cross product pass-through, they find that "trade promotions on large brands are less likely than small brands to generate positive cross-brand pass-through, i.e., induce the retailer to reduce the retail price of competing smaller products."

One concern about our main result is driven by tax evasion. When the tax rate for a small car is lower, dealers have less incentive to report a lower price to the tax authority, and thus we observe a higher pre-tax price. We use buyers' self-reported price scrapped from Qichezhijia; the most well-known national-wide car funs forum in China, In the forum the buyers self-report the transaction price, month and city of purchase as well as the trim of the car. They have no incentive to report a manipulated price due to tax evasion. We use the self-reported price to test The additional evidence comes from self reported price from a forum on cars where users discuss the price and quality of the car. The self reported price has no incentive to consider tax evasion. However, we are also aware that this is a highly selective sample. If the selection effect does not change due to the tax rate change we can trust more. We find that the empirical results from tax return data and self-reported data are quite similar and conclude that the increase of pre-tax price is not primarily driven by increased tax compliance due to lower tax rate.

We need to be careful when interpreting our difference-in-Differences estimator, it captures the total effect of the tax rate change on price. Note that for small cars this includes both the direct effect of tax rates change and indirect effect from cross price effect of the medium car price changes. We do not decompose the direct and indirect effect in this paper.

The scope of this paper is to study the short run effect tax rate change. We are interested in the price adjustment in equilibrium but not the product portfolio firms are offering. Different from Sallee [2011] where he looks at the data around the tax rate when the tax holidays expires. The research design requires him to address the the selection effect because more sophisticated consumers will forward their their purchase.

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; in section five we propose a simple model to rationalize our findings; finally, we conclude and offer suggestions for future research.

2.2 Institutional Background and Policy in China

2.2.1 Market Size and Structure

China's auto market grows rapidly and since 2009, it has been the largest global vehicle market, with yearly sales of passenger cars exceeding ten million. Please refer to my first chapter for more description of the market. Due to the support of local government, the competition of China's car market is fierce. The market share of the top 10 firms was over 90% in early 2000 but was reduced to 70% in 2010. In 2018 about 108 firms are active in the market.

For the city I am studying, the population is more than ten million. The city does not impose any licence registration restriction policies, congestion fee or other car purchase restrictions during the period of our study. Driven restriction policies based on the last number of licence plate is applied as in many other big cities in China. We do not have access to the information on licence plate.

2.2.2 Compliance of Car Acquisition Tax

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't get the license plate from traffic police unless s/he remits the tax. The whole process certificated by a chain a paper work from tax invoice to license plate. The potential corruption is easily detected if any.

There are some anecdotal evidence that among very expensive cars buyers and dealers collude and reported a lower price to IRS to evade the transaction tax. We will discuss the potential threat to our main results later.

2.2.3 Car Acquisition Tax and the Tax Holiday

The acquisition tax is only levied on first-time purchase car and based on the pre-value added tax price at a 10% rate. On Sep 30th, 2015 the official announcement came out saying from Oct 1st to December 31th, 2016 for vehicles with displacement level smaller than 1.6L acquisition tax rate will be 5%. Then at the end of the year 2016, the central government compromised with the car producer and extended the holiday for another year with a higher rate at 7.5%. Starting from Jan 1st 2018 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. One thing worth noting about the design of the threshold based tax policy is very common in commodity taxes and also well studied in the car market, see Gillitzer et al. [2017] and Sallee and Slemrod [2010].

2.3 Data and construction of control group

2.3.1 Daily transaction level data

We use transaction level data from a major city in China from 2015 to 2017 in this paper. The transaction record is obtained from the valued-added tax collection system. The sellers need to report the date of transaction, pre-tax price and the detailed information of each car to the local IRS. We know the model of the car and can identify the eligibility of tax holiday. We also have the information on which firm produced the car and the de-identified dealers' ID.Model is an important information here, unlike the U.S., in China auto market there's very little room for optionsBarwick et al. [2017]. We can treat cars with the same model as the same car. We take advantage of this setting to have a clear estimation of pass through of the tax by comparing the price change within the same product.

2.3.2 Cash subsidy program

Another important fiscal policy implemented during the sample period in this paper is the cash subsidy program in which eligible cars will get a 3,000 CNY cash subsidy. Unfortunately we can not compare the effect tax rate change and subsidy because we do not know exactly whether the transaction price is subsidy inclusive or not. Some dealers deduct the the price before the transaction and some will issue a check after the car is sold. To address the potential threat of the cash subsidy program we drop the subsidized car and the results does not change much compared with our main results.

2.3.3 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 retail price 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 2.8, 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 A.5. 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 **??** 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 2.8 and our conversations with car dealers, we notice that a watershed in China's 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.

Same as chapter one, the first observation 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 part, 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.

$$\text{Low-end market}\begin{cases}\text{Treated cars: small cars}\\ \text{Substitutable car: median or large cars that are also cheaper}\end{cases}$$

High-end market: Control Group: median or large cars that are expensive

2.4 Graphical Evidence

2.4.1 Main Effect on Prices

To provide the visual evidence of how tax change price we need to construct a price index using the transaction level data. We use the Laspeyres Price Index in our context. The idea is to compare the price change for the same set of product. We first restrict our sample on cars that have sales record in each week around the date of tax rate change (eight weeks before and after the tax rate change). We use the first four weeks' sales as the weight of the Laspeyres Price Index and construct the price index. This allows us to identity the overall price level change just from the price change from each product, excluding the product choice changes. From the graphs we can see that before the tax rate change, there is no difference for the three price index. And right after the tax rate decreased from 10% to 5%, the small car's pre-tax price increased by a very small amount hence most of the benefit of the tax cut is goes to the consumers. We find this pattern both in the short run and long run. Price of substitutable cars also increased a little. While when the tax rate increased, the pretax price of small cars decreased gradually and eventually the benefit was totally offset within six months. And we don't find evidence on price change of the medium cars.

We choose the six months window in our main result because one one hand we need a long enough period to allow for firm adjust their prices and on the other hand we need to make sure no other marketing strategy that will affect different cars differently. In the car market, dealers need to accomplish the year quota set by firms and the promotion strategies are different before and after 1st January; in the china's car market, Chinese Lunar year is an important factor for the business cycle. In the robustness check section we show the six months and also provide the estimation results using four months and two months window.

Insert Figure 2.1 and 2.5

2.4.2 Placebo Test

In Figure 2.5 we use data in 2014 and the same method to test if the result is driven by the national holiday (from Oct 1st to 7th) effects. We do not observe any similar pattern as in Figure 2.1.

2.4.3 Effect on Quantity

We also look at the total impact of the policy on car sales. The quantity response is consistent with the price behaviour. Figure 2.4 shows before October 1st 2015 the weekly sales for all groups are very stable and parallel. We observe a significant drop right after the tax rate changed. This is driven by the one week long National Day holiday when most people do not go to work and only few dealers still sell cars.

The data we use in this paper only cover one city and to better understand the implications of the stimulus impact we need to use national level sales data. In my first dissertation chapter, Wang (2020) estimates sales response of the tax policies in last decade in China using national car registration data.

Insert Figure 2.4

2.5 Identification Strategy and Empirical Results

To establish the causal effect of the policy we employ the difference-in-differences estimation strategy and use cars in high-end market as the counterfactual of treated and substitutable cars. In the robustness check section, we will use a different criterion for treated and substitutable cars. We model car sales and price as a function of its own tax rate and its substitute's tax rate, more specifically we use the following specification:

$$Ln(P_{it}) = \beta_0 + \beta_1 Ln(TaxOwn_{it}) + \alpha_i + \alpha_t + \epsilon_{it} \tag{2.1}$$

$$Ln(P_{it}) = \beta_0 + \beta_1 Ln(TaxCompe_{it}) + \alpha_i + \alpha_t + \epsilon_{it} \tag{2.2}$$

The outcome variable $Ln(Price_{it})$ is the natural logarithm of model i cars' sales price and sales in month t. α_i and α_t are the model and date-of-sample fixed effects. Controlling for the model fixed effect is crucial for our identification. By controlling for model fixed effect we focus on the variation within models. $TaxOwn_{it}$ is the tax rate for cars of model i in date t. $TaxCompe_{it}$ is the competitors' tax rate. We run two sets of separate regressions for (1) and (2) to identify the own and cross price pass-through. We also control for effect of gas price and group specific trend.

The estimates from Table 2.1 and 2.2 are the main parameters of interests this paper. The results are robust under different model specifications and different ways of standard error clustering. Following the standard literature on tax incidence calculation. Our result shows small car consumers bear more the 80% of the sales tax incidence.

Insert Table 2.1 and 2.2

In order to detect any anticipation effect and test the parallel trend before policy we also perform a event-study estimation. The week before tax change is set as baseline. As we see in Figure 2.2 and 2.3 the relative price did not change much before policy after we partial out the common shocks.

Insert Figure 2.2 and 2.3

On concern of the pre-tax price change of small car is that this might be driven by evasion response. We present our second evidence coming from self-reported price from a forum on cars where users discuss the price, quality and more details about the experience of the car. Only verified buyer who submit a certificate of car purchase can share their comments. The self reported price is more consistent with the real transaction price. But We are also aware that this is a highly selective sample. If the selection effect does not change due to the tax rate change we should not worry much about it. In Table 2.3 we replicate our main results using the self-reported prices. The coefficients do not change much in magnitude. Note here for the self-reported we only know the month of transaction and the car type information is at trim level which is higher than the IRS data. We control for city fixed effects in these two regressions.

Insert Table 2.3

2.5.1 Role of Cannibalization

To study the role of cannibalization on cross-product pass-through, we show how medium car share affect the price change of medium car. We add the interaction term of tax rate and medium car share into the baseline specification in Table 2.4. We also implement an alternative specification in which we create a set of dummy variable for medium car share in Figure 2.6. The dummy variable takes value of one if a firms medium car share belongs the first, second, third or fourth quantile. Both estimation results suggest that if the firm has more share of medium car, its medium car price response more to the competitors' cost shock.

Insert Table 2.4 and Figure 2.6

2.6 The Model for Multiproduct Firms

The classical IO models of cost pass-through adopt the linear demand curves to derive the analytical solutions. As Amir et al. [2017] noted the only way to obtain a micro-founded linear demand utility function that is to define the utility function quadratic in the n consumption goods and quasi-linear in the numeraire. One implication of the linear demand system is cross product pass-through is zero under constant marginal cost and symmetric multi-product firms assumptions [Friberg and Romahn, 2018].

The goal of the theoretical model part of this paper is to discuss under what conditions the cross product tax incidence is negative and how cannibalization effect involves in the model. We first adopt a logit demand function because it is a widely used discrete choice models and more realistic in the car market in section 7.1 and then change the symmetric firm assumption in 7.2. Both approaches generate consistent theoretical predictions that is consistent with our empirical findings.

2.6.1 Nest Logit Demand and Cross Product Pass-through

In reality most firms offer a wide range of product and they compete with each other as well as the competition with other firms. And this makes a commodity tax based on product characteristics more complicated. In a multi-product setting, when firms set price they need to balance the industry level shock from the tax changes and the cannibalization effect. In a extreme case, if a firm only sells medium cars they it needs to lower price a lot to compete with the low tax small cars. But if the firm produce both and its within firm cross price elasticity is high then it has less incentives to lower medium cars' price since the profit margin of small cars are higher.[1]

Consumers chose firm first then they decide to buy a small or medium car stage. That is, $Q_{ij} = NS_iS_{ij}$ for $i = 1, 2$ and $j = M, S$ where N is the size of the market, Q_{2S} and Q_{2M} are the

[1]The car sales tax is an ad valorem tax in practice, to have closed form solutions we start with unit tax in the illustrative models.

sales of small and medium car of Firm 2, Q_{1S} is the sales of small cars of Firm 1 and it does not produce medium cars. Here 1 and 2 indicate whether the firm produces one or two types of cars.

S_{ij} is product j' s share within firm i, and S_i is firm i' s share. In the nested-logit specification,

$$S_{ij} = \frac{\exp\left(\alpha_{ij} - p_{ij}\right)/\mu_b}{\sum_{k=1}^{2}\exp\left(\alpha_{ik} - p_{ik}\right)/\mu_b} \quad (1)$$

$$S_i = \frac{\exp\left(R_i/\mu_r\right)}{\sum_{k=1}^{2}\exp\left(R_k/\mu_r\right)} \quad (2)$$

where $R_i = \mu_b \ln\left[\sum_{k=1}^{2}\exp\left(\alpha_{ik} - p_{ik}\right)/\mu_b\right]$ for $i = S, M$ $\mu_r \geq \mu_b$ are the parameters to capture for firm choice and cartype choice, respectively, and the α_{ij} are parameters reflecting the utility of the firm-cartype combination ij. generated.

The nice feature of the logit demand structure allows us to write down the pricing strategy in an easier way, for each product at each firm the profit margin should equalize [Anderson and de Palma, 1992]. This result is an important technical reason for us to choose the nested logit struture:

$\mathrm{p}_{ij} - (t_i + c) = \frac{\mu_r}{1-S_i}$ for $i = 1, 2, j = S, M$

Note that we focus on the marginal cost of small car's tax rate change impact on medium cars' price, we totally differentiate these equations with respect to tax rate and get

$\frac{dP_{2M}}{dt_s} = \frac{1}{|\Delta|}(\frac{S_1}{S_2})^2(S_{2M})$ [2]

This model also predicts the own pass-through, overall we predict own pass-through is positive but medium car share have opposite effects. For firm 2, the pass-through is higher than 100% and for Firm Single the pass-through is lower than 100%. We have

$\frac{dP_{2S}}{dt_s} = 1 + \frac{1}{|\Delta|}\left(\frac{S_1}{S_2}\right)^2(S_{2M})$ and $\frac{dP_{1S}}{dt_s} = 1$- $\frac{1}{|\Delta|}(S_{2M})$

This paper's focus is on the cross product impact of a tax rate changes. However, our simple model also have predictions on the own-price effect.

2.6.2 Two Asymmetric Firms, Two Products

In this section we modify the assumptions in firm side. We consider a simple model where firm 1 is a single product firm and only produces small cars. Firm 2 is a multi-product firm and produces two products, small and medium cars. We assume a large enough upgrading cost for firm one such that it will not choose to produce medium car.

Firm 2 produces medium and small cars to maximize (p_m-c_m)q_m^2+(p_s^m-c_s^m-t_s)q_s^2. Firm 1 produces small cars to maximize (p_s^1-c_s^s-t_s)q_s^1 Firm 1 only produce one product, small cars; Firm 2

[2]where Δ=1 + $(\frac{S_1}{S_2})$ + $(\frac{S_1}{S_2})^2$ and this is greater than 1.

product two products, both small cars and medium cars. We use P_s^1 P_s^2 P_m^2 and c_m c_s to denote medium and small car prices and costs. q_m^2 and q_s^2 are firm 2's production for medium and small cars. q_s^1 is firm 1's production for small car. The three cars compete with each other. The inverse demand curves are P_m= α_m-$\beta_m q_m$+γq_s and P_s= α_s-$\beta_s q_s$+γq_m.

Firms choose quantity and compete with each other. We have three FOCs. If we take the differentiation of the system and rearrange we can show all the partial effect of the sales tax. We focus on the result of cross effect: $\frac{dp_m}{dt_s} = \frac{\gamma}{6\beta} > 0$. When the firms are asymmetric, we show that if tax rate of small car decrease, the price of medium cars will decrease as a result.

More importantly we study how this effect change with the share of medium car sales of firm M. For firm M we can calculate its medium car share: $\frac{q_m^2}{q_s^2} = (3\ \beta_s\ (-\alpha_m\ \beta_s + \beta_s\ c_s + \alpha_s\ \gamma - c_m\gamma))/(-2\ \alpha_s\ \beta_m\ \beta_s + 2\ \beta_m\ \beta_s\ c_m + 3\alpha_m\ \beta_s\ \gamma - 3\ \beta_s\ c_s\gamma - \alpha_s\ \gamma^2 + c_m\gamma^2)$[3].

We can prove that d $\frac{dp_m}{dt_s}$ / d $\frac{q_s^2}{q_m^2} > 0$. Together with $\frac{dp_m}{dt_s} > 0$ this implies when small car tax decreases price of medium car will decrease, and for firms with more sales from small car, the price of medium cars decreases more. Note here we do not have dp_m as a function of ds and $\frac{q_s^2}{q_m^2}$. Instead we have $\frac{dp_m}{dt_s} = \frac{\gamma}{6\beta}$ and when γ and β change they change share of small and medium cars and the incidence.

2.7 Conclusion

Tax incidence studies are central to public finance literature, however, almost no attention has been paid to the cross-product price impact and how it interacts with market condition and demand structure. This paper fills the gap in literature by exploring a tax rate change in China's car market that lowers the tax rate from 10% to 5% for cars with small engines. Using transaction-level tax administrative data we show that consumer price for small cars drops by approximately 4.2% and their competitors' price also dropped by 0.6%.

Next we consider how tax change close substitute's price in the multiproduct firm setting. The small car tax rate decrease first lowers the demand for competing cars and firms have pressure to charge a lower price for medium cars. They response differently based on how easy a medium sized car is substituted by a small car and how much they rely on medium car sales. Firms will respond more if they care less about the market stealing effect. We build a simple model to study the pass-through on close substitutes in a multi-product oligopoly world where firms need to take cannibalization effect into consideration when they respond to a tax change on some of their product. Our analysis shows the market share of the target product matters for the incidence of its

[3] let $\delta \equiv \frac{dp_m}{dt_s}$.Then we write $\frac{q_m^2}{q_s^2}$ as a function of δ, we got a quadratic equation with one unknown δ: $\frac{q_m^2}{q_s^2}$ = (δ (α_m - 2) + β_m/δ - 3 α_m)/(3*(α_m*δ + β_m). Solving for this we derive the relationship between $\frac{dp_m}{dt_s}$ and share of medium cars. $\frac{dp_m}{dt_s}$ = F($\frac{q_m^2}{q_s^2}$)

substitutes.

More than 60% firms (U.S. data in 2014) are multiple firms and tax policies are often based on product characteristics which could generate spillover effect on close substitutes provided by the same firm. Our paper provide the first evidence on this topic and it could be applied to more general settings when tax policies are targeted on certain products such as Soda taxes based on sugar per liter, cigarette taxes based on E-cigarette or not, tariff on certain product and housing transaction taxes based on size of the house. Our findings have more broad implications.

Figures

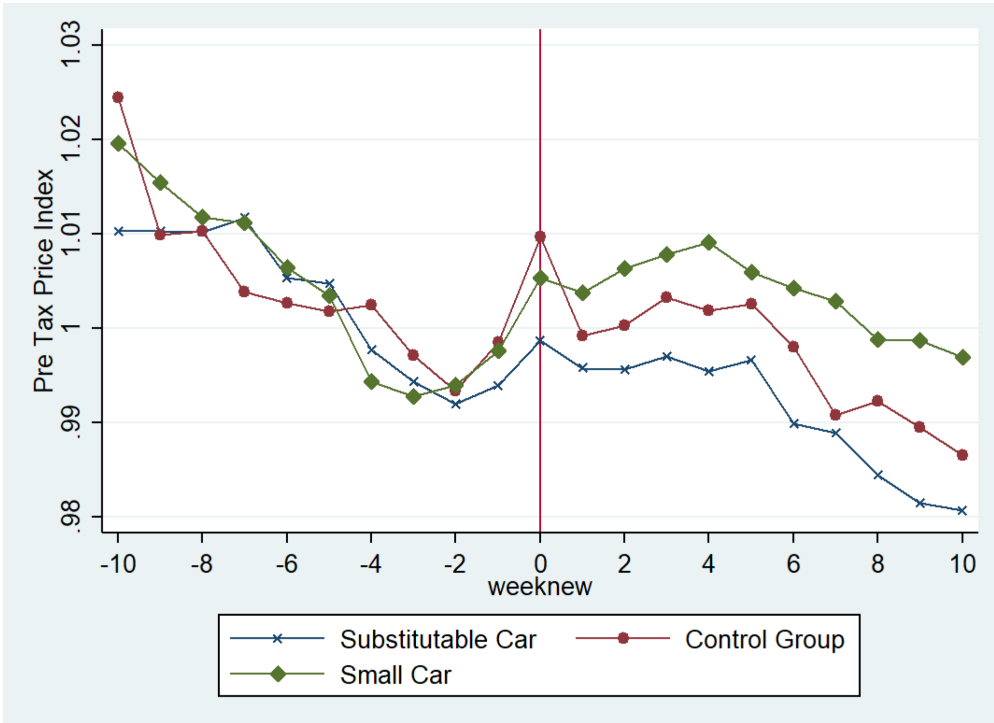


Figure 2.1: Incidence on small and substitutes

Note: In this figure we show the weekly Paasche Index of small cars, substitutable cars and control group. The red line indicates the week of tax rate cut.

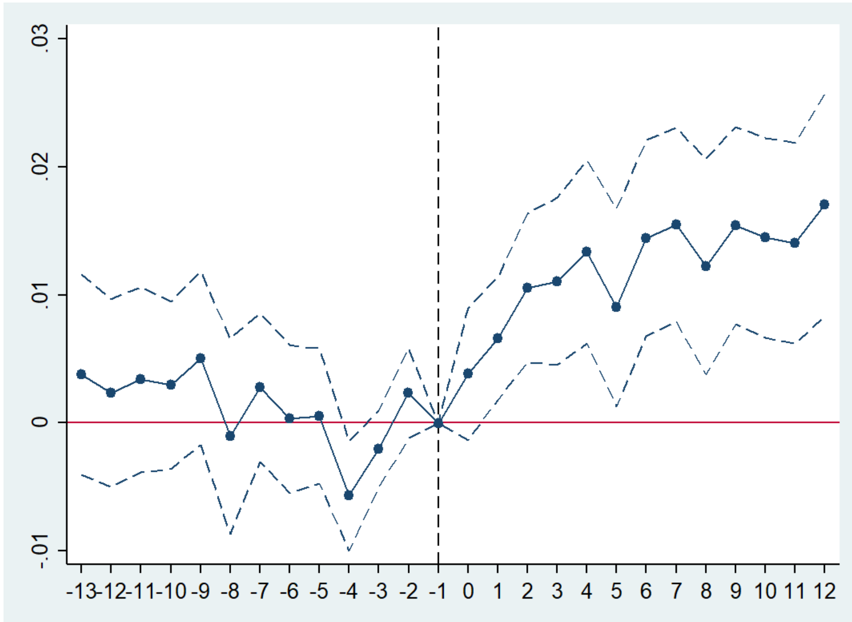


Figure 2.2: Event Study on Small Car Price

Note: In this figure we show the small car pre-tax price change relative to control group after the tax cut. The dashed line indicates the week of tax rate cut.

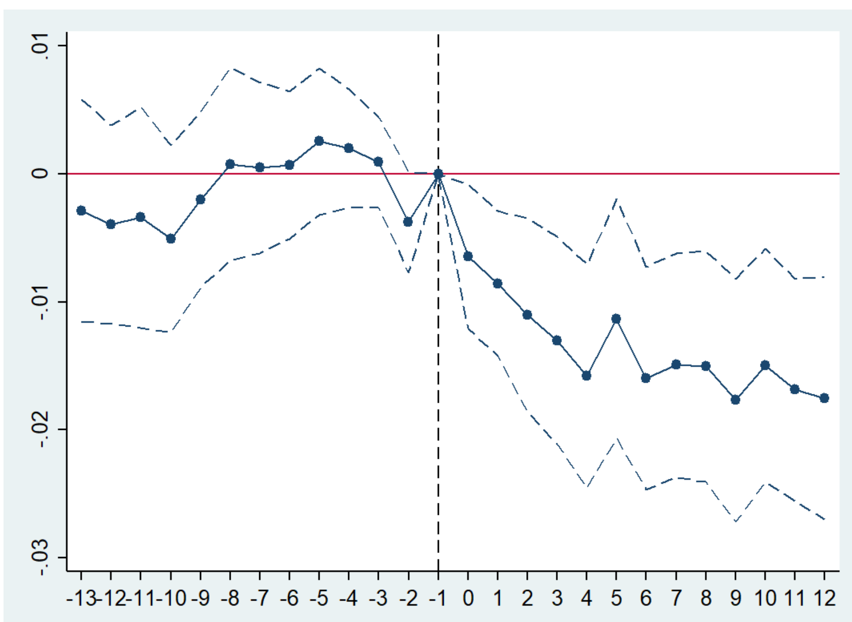


Figure 2.3: Event Study on Substitutable Car Price

Note: In this figure we show the substitutable car pre-tax price change relative to control group after the tax cut. The dashed line indicates the week of tax rate cut.

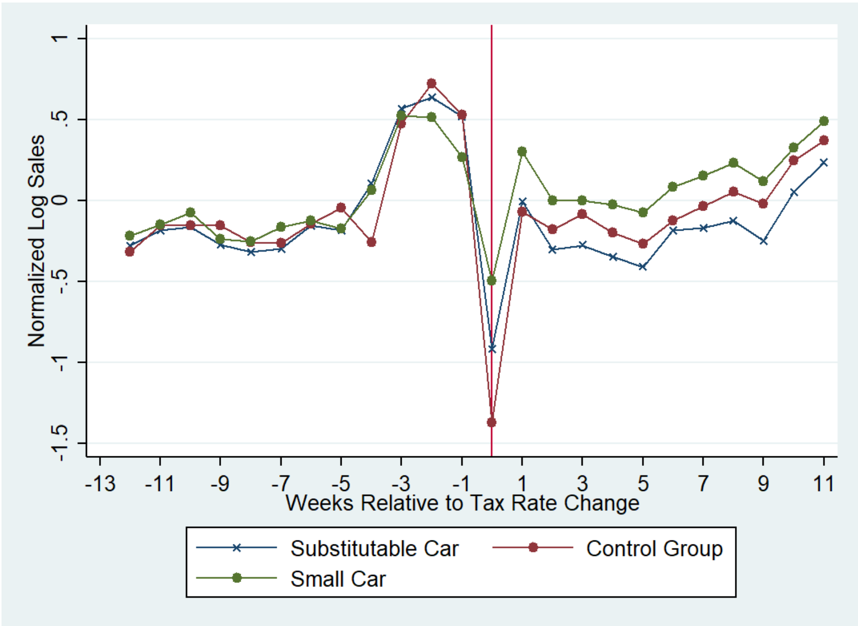


Figure 2.4: Impact on sales

Note: In this figure we show the weekly sales of small cars, substitutable cars and control group. The red line indicates the week of tax rate cut. We first take natural logarithm of the weekly sales for each group and then normalize the date using the average number of the first four weeks in the sample period of our study.

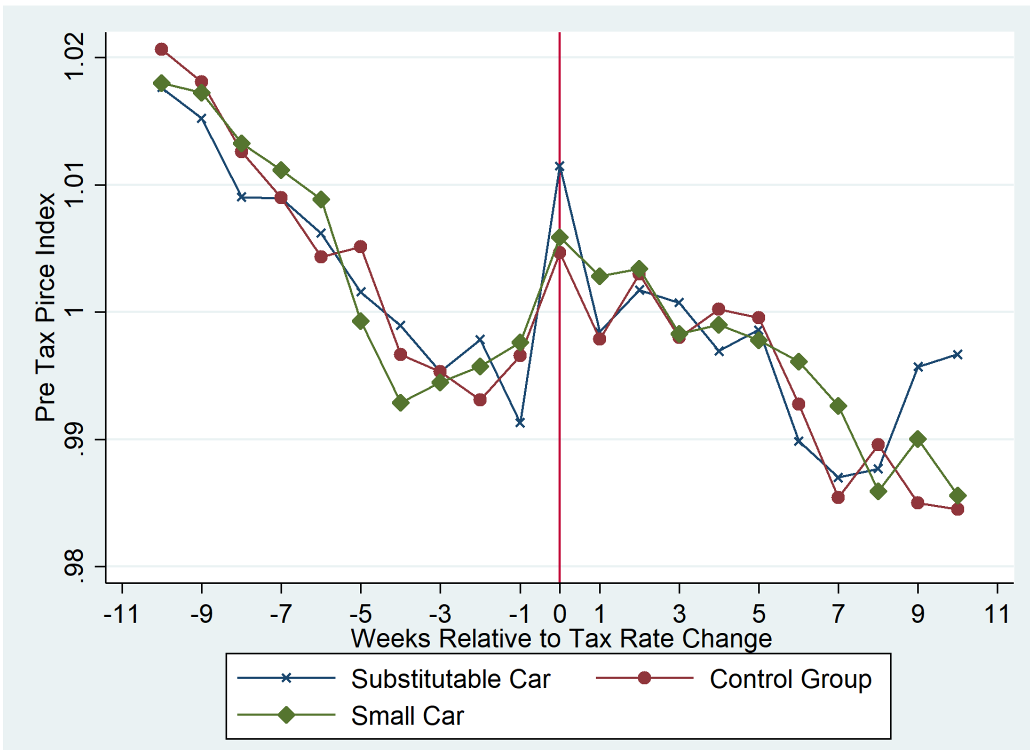


Figure 2.5: Placebo test: Price change around Oct 1st 2014

Note: In this figure we show the weekly Paasche Index of small cars, substitutable cars and control group. The red line indicates the week of one year before the tax rate cut.

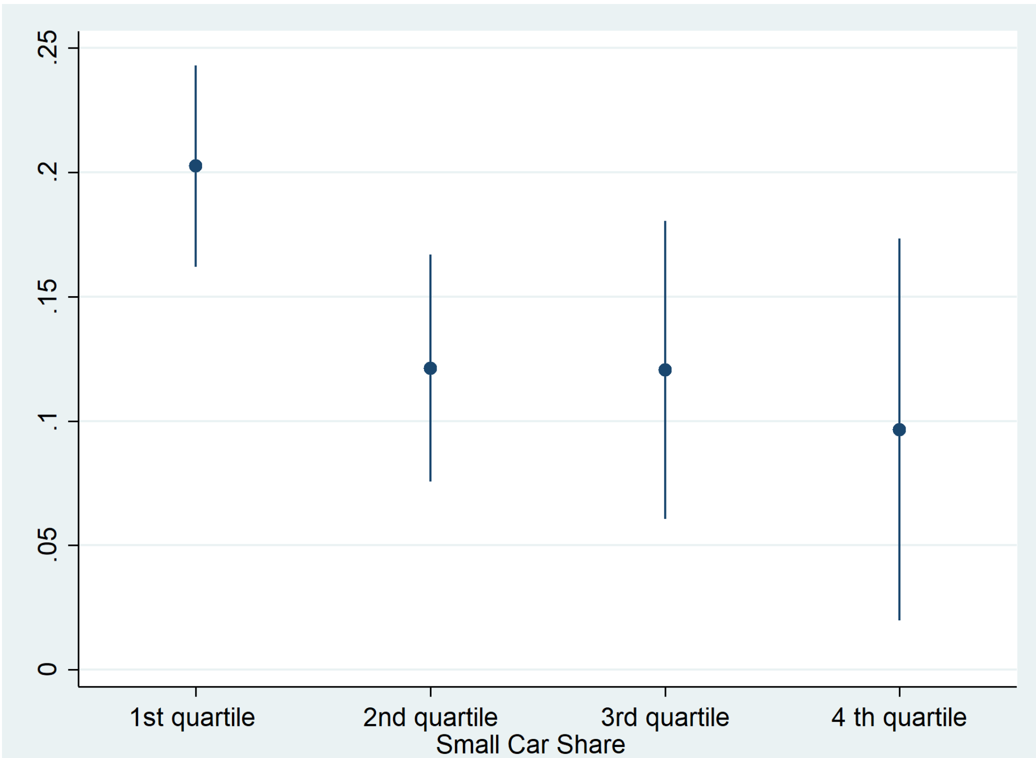


Figure 2.6: Small car share matters for cross price pass-through

Figure 2.7: Search Index for Car Acquisition Tax Holiday

[Source] Baidu Search Engine

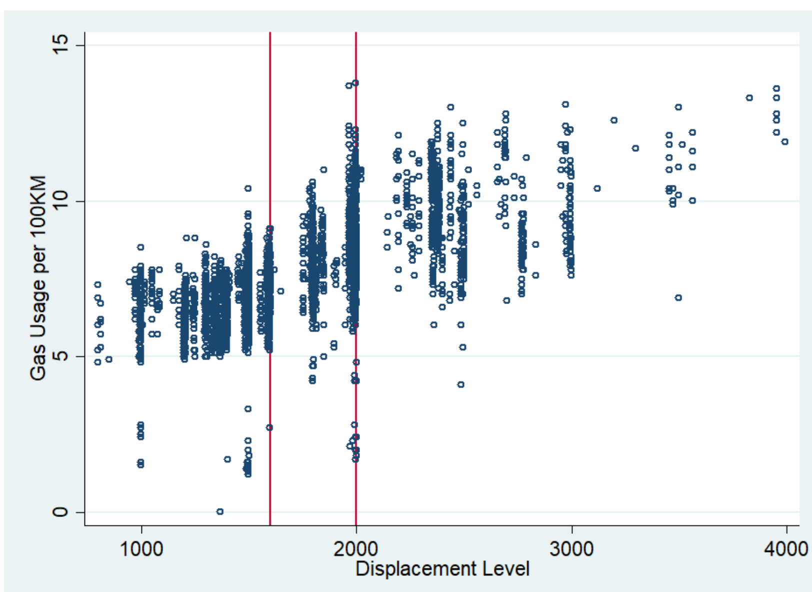


Figure 2.8: Relationship between fuel efficiency and displacement level

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

Tables

Table 2.1: Small Car Price Change

	(1)	(2)	(3)	(4)	(5)	(6)
			Ln(price)			
ln($\text{Tax}_r ate + 1$)	-0.138***	-0.138***	-0.133***	-0.111***	-0.111***	-0.158***
	(0.0139)	(0.0242)	(0.0400)	(0.0162)	(0.0249)	(0.0372)
Product and date of sample FE	Y	Y	Y	Y	Y	Y
Group specific trend	N	Y	N	Y	N	Y
Window	Three Months	Three Months	Three Months	Two Months	Two Months	Two Months
N	211689	211689	211689	164134	164134	164134
R-sq	0.990	0.990	1.000	0.990	0.990	1.000

Note: This table uses car transaction record from July 2015 to December 2015, in even number columns we control for the group specific time trend. We control for product and date of sample fixed effect in all regression. Standard errors are clustered at model level. In columns (1)-(3) we use date three months before and after the tax cut, in columns (4)-(6) we use date two months before and after the tax cut.

Table 2.2: Average Effect on Close Substitutes

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(price)					
ln(taxrate+1)	0.119***	0.119***	0.0909*	0.101***	0.101***	0.0944**
	(0.0164)	(0.0287)	(0.0466)	(0.0192)	(0.0301)	(0.0433)
Product and date of sample FE	Y	Y	Y	Y	Y	Y
Group specific trend	N	N	Y	N	N	Y
sd cluster	Robust	Product	Product	Robust	Product	Product
Window	Three Months	Three Months	Three Months	Two Months	Two Months	Two Months
N	79822	79822	79822	63607	63607	63607
R-sq	0.985	0.985	1.000	0.985	0.985	1.000

Note: This table uses car transaction record from July 2015 to December 2015, in even number columns we control for the group specific time trend. We control for product and date of sample fixed effect in all regression. Standard errors are clustered at model level. In columns (1)-(3) we use date three months before and after the tax cut, in columns (4)-(6) we use date two months before and after the tax cut.

Table 2.3: Tax incidence estimation using self-reported price

	(1)	(2)	(3)	(4)	(5)	(6)
	Small V.S. Control			Substitutable V.S. Control		
lntax	-0.155***	-0.155***	-0.122***	0.177***	0.177***	0.185***
	(0.0253)	(0.0415)	(0.0380)	(0.0271)	(0.0584)	(0.0582)
N	30552	30552	27177	33904	33904	30522
Window	Three Months	Three Months	Two Months	Three Months	Three Months	Two Months
S.E. Cluster	Robust	Model	Model	Robust	Model	Model
R-sq	0.993	0.993	0.992	0.986	0.986	0.985

Note: This table uses self-reported car price from July 2015 to December 2015, in even number columns we control for the group specific time trend. We control for product and date of sample fixed effect in all regression. Standard errors are clustered at model level. In columns (1)-(3) we use date three months before and after the tax cut, in columns (4)-(6) we use date two months before and after the tax cut.

Table 2.4: Share of small cars by firms matters for the incidence on substitutes

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(price)					
ln(tax+1)	0.242***	0.242***	0.147***	0.172***	0.172***	0.141***
	(0.0254)	(0.0429)	(0.0555)	(0.0291)	(0.0441)	(0.0540)
ln(tax+1)*share_small	-0.153***	-0.153***	-0.152***	-0.109***	-0.109*	-0.109*
	(0.0341)	(0.0552)	(0.0552)	(0.0394)	(0.0587)	(0.0588)
Product and date of sample FE	Y	Y	Y	Y	Y	Y
Group specific trend	N	N	Y	N	N	Y
se cluster	Robust	Product	Product	Robust	Product	Product
Window	Three Months	Three Months	Three Months	Two Months	Two Months	Two Months
N	73166	73166	73166	58616	58616	58616
R-sq	0.985	0.985	1.000	0.985	0.985	1.000

Note: This table uses car transaction record from July 2015 to December 2015, in even number columns we control for the group specific time trend. We control for product and date of sample fixed effect in all regression. Standard errors are clustered at model level. In columns (1)-(3) we use date three months before and after the tax cut, in columns (4)-(6) we use date two months before and after the tax cut.

Table 2.5: Share of small cars by firms matters for the incidence on small cars

	(1)	(2)	(3)	(4)	(5)	(6)
	ln(price)					
ln(tax+1)	0.560***	0.560***	0.534***	0.523***	0.542***	0.261***
	(0.0459)	(0.0861)	(0.0940)	(0.106)	(0.0939)	(0.0952)
ln(tax+1)*share_small	-0.816***	-0.816***	-0.816***	-0.822***	-0.823***	-0.508***
	(0.0517)	(0.101)	(0.101)	(0.124)	(0.100)	(0.102)
Product and date of sample FE	Y	Y	Y	Y	Y	Y
Group specific trend	N	N	Y	N	N	Y
se cluster	Robust	Product	Product	Robust	Product	Product
Window	Three Months	Three Months	Three Months	Two Months	Two Months	Two Months
N	211689	211689	211689	164134	164134	164134
R-sq	0.985	0.985	1.000	0.985	0.985	1.000

Note: This table uses car transaction record from July 2015 to December 2015, in even number columns we control for the group specific time trend. We control for product and date of sample fixed effect in all regression. Standard errors are clustered at model level. In columns (1)-(3) we use date three months before and after the tax cut, in columns (4)-(6) we use date two months before and after the tax cut.

CHAPTER 3

The Impact of Corporate Taxes on Firm Innovation: Evidence from the Corporate Tax Collection Reform in China

3.1 Introduction

Innovation has been increasingly recognized as the main engine for economic growth [Solow, 1957, Romer, 1990, Grossman and Helpman, 1991, Aghion and Howitt, 2014]. Policy makers in both developed and developing countries have started to use tax incentives to encourage investment in innovation. But we know very little about the impact of such policies on firm innovation and the underlying mechanisms. Theoretically, taxes can have either positive or negative impacts on firm innovation. On the one hand, when RD expenditure is not fully tax deductible, lower corporate tax may lead to lower user cost of RD and a higher optimal level of innovation. Moreover, lower taxes can increase the after-tax profit of firms, so that they have better capacity to invest in new technologies or products; moreover, lower taxes may reduce resources that firms spend on tax avoidance, such as costs of bribing tax officers, which can be instead used on innovation activities. On the other hand, lower taxes may also have a negative impact on innovation because they decrease government revenue, and in turn may reduce government spending on public goods such as research, education, and infrastructure. As a result, whether providing tax incentives can improve firm innovation is ambiguous. This paper investigates the impact of taxes on firm innovation using a natural experiment in China. In November 2001, China implemented a tax collection reform on all manufacturing firms established on or after January 2002, which switched the collection of corporate income taxes from the local tax bureau to the state tax bureau. Because of differences in management and incentives of those two types of tax bureaus, the reform changed the enforcement of tax collection, resulting in a reduction of corporate income tax rates by almost 10% among treated firms. Since firms registered before 2002 were not affected by the reform, the policy change created exogenous variations in the tax rate among similar firms established before or after 2002.

We can thus apply a regression discontinuity design (RD) and use the generated variation in the tax rate to identify the impact of taxes on firm innovation. To test the impact of taxes on innovation, we combine a comprehensive dataset of all medium and large enterprises in China between 1998 and 2007 with patent data from the State Intellectual Property Office (SIPO) including all patents applied in China by the year 2014. We use the data to measure three dimensions of innovation activities: input (RD expenditure and skilled labor ratio), output (number of patent application), and quality (type and characteristics of patent application). The key assumption of the RD analysis is that firm cohort should have a significant impact on corporate tax rate; however, all other unobserved determinants of firm innovation are not correlated with firm cohort. We provide three pieces of evidence to validate the estimation strategy. First, the reform did significantly reduce the tax rate: the tax rate is almost 10% lower among firms established after 2002 compared with those registered before 2002. Second, there's no significant difference in firm entry around 2002, suggesting that the reform was a surprise to firms and they did not selectively postpone the registration date. Third, we don't see significantly higher firm re-registration after 2002. Our analysis yields several interesting results. First, we show a strong and robust causal relationship between tax rate and firm innovation: decreasing the tax rate by one standard deviation (0.01) increases the average number of patent application by a significant 5.7%. The reform also stimulated RD expenditures and increased the skilled-labor ratio. Second, the impact of the reform on patenting mainly comes from its effect on invention and utility patents, suggesting that the improvement in innovation outcomes is not merely driven by the low-quality design patents. Third, we show that a low tax rate can stimulate firm's innovation by alleviating financial constraints and by reallocating resources from tax avoidance activities. Our work builds on and contributes to three main literatures. First, this paper sheds light on the impact of taxes on firm decision-making and economic growth. Existing research studied the influence of tax policies on economic growth [Romer and Romer, 2010, Barro and Redlick, 2011], firm investment [Hines and Rice, 1994, Cummins and Hubbard, 1996, Djankov and Shleifer, 2011, Mertens and Ravn, 2012, Zwick and Mahon, 2017, Chen et al., 2021], corporate financial policy [Auerbach, 2002], entrepreneurial risk-taking [Cullen and Gordon, 2007, Haufler and Persson, 2014] and location decisions [Moretti and Wilson, 2017]. However, the impact of taxes on firm innovation is not well explored. Mukherjee and Zaldokas [2017]and Atanassov and Liu [2016] exploit the effect of staggered changes in state-level corporate tax rates on innovation behavior of publicly listed firms in the United States, and find significant impact of taxes on innovation, mainly through relieving firms' financial constraints. In two recent working papers, Akcigit and Stantcheva [2018] uses data on both inventors and firms and shows that higher personal and corporate income taxes negatively affect innovation; Chen et al. [2021] finds that cutting corporate taxes for high-tech companies significantly improved firm productivity and RD investment in China. Our paper differs from those papers in several ways. First, we are the first paper to look at the impact of changes in tax enforcement rather than explicit tax reduction on firms' innovation behavior. Second, our data covers a broad range of firms and a comprehensive set of innovation outcomes, and we answer the question in a developing-country's context. Second, the paper relates to the literature on the determinants of innovation. Existing evidence shows that product market competition [Aghion and Howitt, 2005], institutional ownership [Aghion and Zingales, 2013, Ferreira and Silva, 2014], minimum wage [Geng et al. 2018], laws [Acharya and Subramanian, 2014], investors' attitudes towards failure [Tian and Wang, 2011], managerial incentive [Manso, 2011], and financial development and regulation [Hsu and Xu, 2014, Amore and Žaldokas, 2013, Fang and Tice, 2014, Cornaggia and Wolfe, 2015], all affect innovation. Another branch of papers study the effect of RD tax credit or subsidies on RD investment [Hall and Reenen, 2000, Bloom and Reenen, 2002, Wilson, 2009, Rao, 2016]. We contribute to this literature by showing that corporate tax policies are also a first order determinant of firm innovation. Third, the paper also contributes to the literature on tax enforcement. The tax-to-GDP ratio is substantially lower in poor countries compared with developed countries [Gordon and Li, 2009, Besley and Persson, 2014]. One important reason of low tax revenue is weak tax enforcement, and several theory papers suggest that policy-makers can use tax enforcement instead of explicitly changing tax rates as a tax instrument [Kaplow, 2016]. There are a growing number of papers showing that tax enforcement can be improved by providing performance pay incentives to tax inspectors [Besley and Rosen, 1999a, Khan et al., 2019], introducing third party reporting to improve information available on tax payers [Naritomi, 2019, Pomeranz, 2015], and offering auditing [Slemrod and Christian, 2001]. However, another important but not well-explored factor affecting tax enforcement is the incentive of local governments and tax agencies. Chen [2017] uses China's 2005 agricultural tax abolition as a natural experiment to study the impact of county governments' incentives on tax enforcement, and shows that the revenue loss is largely offset by tougher tax enforcement on value-added taxes. Our study adds to this literature by showing that the management and incentives of tax collection agencies play an important role in tax enforcement and the tax capacity of a country. The rest of the paper is organized as follows. Section 2 describes the background of China's tax collection system and the reform. Section 3 presents data and summary statistics. Section 4 explains the identification strategy. Section 5 presents the results, and Section 6 concludes.

3.2 Institutional background

3.2.1 China's Tax collection system

Before the economic reform started in 1979, tax administration in China was simple because there were no personal or corporate income taxes. Most of the tax revenues came from profit remittance of state-owned enterprises. Local governments were in responsible for tax collection, but all revenues were consolidated to the central government, who sets spending priorities and redistributes the revenue based on local spending needs. Such a system, called "unified revenue collection and unified spending" (also known as "eating from one big pot"), provides very little incentives for the local government to develop their local economies. In 1980, the "fiscal contracting system" (also known as "eating from separate kitchens") was introduced. Under this system, local revenue was divided between the central and local governments based on pre-determined sharing schemes. The new system not only guaranteed the central government a certain flow of revenue from local governments, but also provided local governments with incentives to build up local economies and the revenue base. The share of local expenditure increased from 45% of the total in 1981 to 72% in 1993. However, since the sharing rule can be continuously negotiated and changed, local governments view this as a lack of commitment from the central government and they tend to divert funds from budgetary to extra-budgetary revenues, which were not subjected to sharing with the central government. Since the central government relies on local authorities to collect tax, it is hard to monitor and correct such manipulation. From 1980 to 1992, the extra-budgetary revenue to budgetary revenue ratio increased from 48% to 120%. This greatly dampened the central government's fiscal capacity. In order to strengthen the central government's control on taxation, a major fiscal system reform was introduced in 1994. In the reform, taxes were classified into central, local and shared taxes, which explicitly specified the tax sharing rules between the central and local governments. Specifically, the central taxes include customs duties and consumption taxes; the local taxes include corporate income taxes, real estate and property taxes; and the shared taxes include value-added taxes (75% central, 25% local) and personal income tax. Moreover, the central government also established its own tax-collection department to centralize the revenue system, preventing the local governments from intervening central and shared taxes. Since then, the tax collection system is divided into two bureaus: the state tax bureau and local tax bureau. The state tax bureau collects central taxes and shared taxes, while the local tax bureau collects local taxes. Both bureaus have branches on the province, city, and county levels. The most significant difference between these two bureaus is in the management system. The state tax bureau adopts a vertical reporting model: each state tax bureau is directly responsible for the tax bureau at level above. For example, the director of a province-level state tax bureau is appointed by the director of the State Bureau of General Taxation (headquarter of the state tax bureau); the provincial government have very limited power on the state tax bureau of any level. In contrast, the local tax bureau is managed by the local government: the provincial government manages the province-level local tax bureau, appoints their director and provides funding for operation. Under such a system, the interference of local governments in the collection of central and shared taxes is minimized.

3.2.2 The corporate income tax collection reform in 2002

Since the 1994 tax reform, the local tax bureau collects the corporate income tax of all firms except for foreign and state-owned enterprises, and all the revenue goes to local government. In 2001, the central government decided to change the corporate income tax to a shared tax. The main objective of the reform was to raise additional central tax revenue to support the "western development strategy" proposed in the year 1999. The plan was to promote the growth of the underdeveloped western provinces, which would need financial transfers from the east. Since all shared taxes should be collected by the central government, a collection reform also needs to be implemented. The government was planning to switch the collection of corporate income tax of all firms to the state tax bureau. However, because local and state tax bureaus use completely different tax collection and record systems, it was very difficult to transfer the tax collection on existing firms. As a result, only new firms established after 2002 were covered by the tax collection reform. In January 2002, the corporate income tax collection reform was implemented, which switched corporate income tax collection of all domestic private firms established on or after January 1, 2002, to state tax bureau. However, the tax collection for firms registered before 2002 did not change. The reform was a shock for firms, because the decision was not made until December 2001. This is very important for our identification: it ensured that firms did not have enough time to manipulate their registration time. After the reform, similar firms established before or after 2002 could pay very different tax rates because of the following reasons. First, the incentives of corporate tax collection were different between the local and central tax bureaus. Just as the target of GDP growth rate is set by the central government every year, tax collection agencies are also assigned with a targeted tax growth rate, and whether the target can be achieved or not may influence the promotion of the tax bureau leaders. As Chen (2017) suggested, local government tend to raise tax revenue by stronger enforcement if they face revenue loss. The collection reform broadened the tax base for the state tax bureau, while local tax agencies lose potential tax revenue from new firms to fulfill the target, so they have more incentives to enforce corporate tax collection on old firms after the reform. Second, the local tax bureau is managed by the local government, so they have more power and information on local firms, which may help to enforce tax collection. However, although local tax bureaus have more incentives and information advantages to enforce corporate tax collection, local governments may protect local firms for long-term growth by encouraging local tax bureaus to loosen the enforcement of tax collection or by offering favorable tax policies . As a result, the tax collection reform may have either positive or negative effects on firms' tax rate.

3.3 Data and Summary Statistics

The empirical analysis is based on two main data sources. The first one is the annual firm survey data developed and maintained by the National Bureau of Statistics of China (NBS). The NBS data contain annual survey data of all "above scale" industrial firms with annual sales of more than 5 million RMB. On average, around 220,000 firms per year from 1998 to 2007 are included in the dataset, spanning 37 manufacturing industries and 31 provinces or province-equivalent municipal cities. Firms included in this survey accounted for almost 50% of China's industrial value-added, and 22% of China's urban employment in 2005. The original dataset includes 2,226,104 firm-year observations. Since this paper focuses on manufacturing firms, we eliminate non-manufacturing observations. Moreover, because only firms established in and after the year 2002 were covered by the tax collection reform, we only use firm survey data from 2002 to 2007. We also excluded firms in Shanghai, Tibet, and foreign firms because they are not covered by the reform. To further clean the sample, we deleted observations where firm identifiers, county code, sector id, or year of establishment are missing, as well as observations whose value of fixed assets or total sales is below RMB 5 million, or if the number of employees is smaller than 30. In addition, observations are dropped if total assets are less than liquid assets or total fixed assets, if inputs are larger than output, if the firm is less than one year old, or if key variables such as corporate tax, input and total wages are negative or zero. After implementing these data cleaning procedures, we obtain a sample of 473,255 observations for analysis. The second data source is patent data from the State Intellectual Property Office (SIPO). We obtained all the records of patents approved as of May 1, 2014, from SIPO. The database contains 4,060,392 observations covering all patents applied in China, including 1,097,000 invention patents, 1,620,069 utility model patents, and 1,343,323 design patents. A typical patent entry includes the following information: application number, patent name, applicant, inventor, application date, publishing date, granting date, main International Patent Classification (IPC) number, filing agent's name and institution, applicant address, patent origin (provinces in China or other countries), and a short description of the patent. We also have characteristics of patent including number of characters in the application file, number of claims and exclusivities, number of figures. We don't have citation data because SIPO began to track citations only in recent years. We use firm name, address, and CEO name to merge the patent data with the firm survey data. In Table 1, we provide summary statistics for key variables. In our sample, about 45.3% firms are private firms established after January 2002, and thus received the policy treatment. Panel A on firm characteristics shows that in the year 2007, average firm age was about 8.09 years, and that 76.4% of firms were domestic private enterprises. We also have about 1.4% State-owned enterprises and 22.2% foreign firms in the sample, who are not influenced by the reform regardless of whether they were registered before or after 2002. The average firm size was about 184 employees, and firms export about 16.7% of their sales. Panel B presents data on accounting measures of firm performance. Average sales were 66.76 million RMB (about 10 million USD), and the average output was 68.46 million RMB. While firms remit three major types of taxes, including value-added tax, corporate income tax, and business tax, only corporate income tax was affected by the tax collection policy reform. We thus focus on this type of tax in the paper and define the tax rate as the corporate income tax to sales ratio. In the year 2007 the average tax rate was about 1.13%. We use sales instead of profit to measure the tax rate for two reasons. First, there are many zero or negative values of profit; second, firms may underreport profits in order to pay less tax. Differences in tax enforcement could affect the possibility of misreporting. If weaker enforcement makes it easier for some firms to evade tax by reporting less profit, the tax to profit ratio cannot capture the variation of tax rate due to changes in enforcement. In Table A1 and Figures A1 and A2, we show that firms established after 2002 report more costs and less profit (columns (1) and (2)), while there's no significant difference in imputed profit between firms established before and after 2002 (column (3)), suggesting that tax avoidance (defined as the difference between imputed and reported profit) is higher among new firms (column (4)). Panel C reports measures of innovation. We use three indicators of innovation. The first and main indicator we look at is firm-level patent applications. The data shows that during the three years 2007 to 2010, 7.1% firms applied for patents; and among those firms, the average number of patent application was about 8.86 and the approved number of patent was around 2.52. The second indicator is the RD expenditure. In the NBS firm survey data, information on RD expenses is only available in years 2005-2007, and the average RD expenditure to sales ratio in year 2007 was around 0.002. Lastly, we also look at the skilled labor ratio, defined as the share of workers with an above-college-level degree. Information on worker education is only available in the year 2004, and the average skilled labor ratio is 0.11.

3.4 Empirical Strategy

The main challenge of identifying the causal impact of tax rates on firm innovation is that tax policies can be endogenously determined. Some unobserved factors could affect both tax rate and innovation. For example, high-tech firms are more likely to innovate and can normally get RD tax reductions from the local government; more productive firms are more advanced in technology and may also be more skillful managing taxations. Reverse causality is also a problem: more innovative firms charge higher product prices and make more profits at the same sales level. The introduction of the corporate income tax collection reform was only targeted on private firms established after the year 2002. If the reform indeed changed tax enforcement, two firms established before or after January 2002 but which are otherwise similar should face significantly different tax rates. In that case, we can use the regression discontinuity (RD) design to identify the impact of taxes on firm innovation. The key assumption of the RD analysis is that firm cohort should have a significant impact on the corporate tax rate; however, all other unobserved determinants of firm innovation are not correlated with firm cohort. With this assumption held, causal inference could be achieved after adjusting for a sufficiently flexible polynomial of cohort. We firstly check whether the policy reform has any impact on firm tax rate. In Figure 1, we restrict the sample to firms established right before (2001) and after (2002) the reform and compare their tax rates. The figure suggests that firms established after the reform pay lower taxes in all years after 2003. We then plot the tax rate by firm birth month, normalized by setting December 2001 as 0, using the 2007 data and focusing on firms that were born two years before or after the policy change. As shown in Figure 2, the tax rate paid by firms formed after 2002 is significantly lower than that of firms established before 2002. To check whether such discontinuity in tax rate was driven by the tax collection reform rather than other policy changes, we also plot the figure using a sample of foreign firms, who are not supposed to be affected by the reform. Figure 3 shows that among foreign firms, the tax rate is not influenced by firm establishment year. Moreover, value-added tax should not be affected by the reform because it is always remitted to state tax bureau. Figure 4 shows that the value-added tax rate is not affected by firm cohort as well. To show whether the impact of the reform on tax rate is statistically significant, we estimate the following equation:

$$\text{TaxRate}_{it} = \alpha_0 + \alpha_1 Treatment_i + \alpha_2 F(Age)_{it} + \alpha_3 X_{it} + \epsilon_{it} \qquad (3.1)$$

Here i indexes firms, t indexes years, and $TaxRate_{it}$ is the corporate income tax to sales ratio. $Treatment_i$ is an indicator for the policy treatment, which is time-invariant and equals one if the firm was established after January 2002. $F(Age)_{it}$ is a polynomial function of firm birth month, where birth month is normalized by setting December 2001 as zero. We also include the interactions of the treatment variable with polynomial terms. X_{it} is a set of firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share. Table 2 reports the results. The three columns present results using a 60-, 48-, or 24-months window, respectively. As we discussed in the background section, the reform may have either a positive or negative effect on tax enforcement. Results suggest that the negative impact dominates: the tax rate is about 0.1% lower among firms established after 2002. Since the average tax rate was about 0.011 before 2002, this suggests that the reform reduced the tax rate by almost 10% . Although we observe a significant discontinuity in tax rate around the policy cutoff on firm birth month, this could be driven by the fact that firms anticipated the policy change and selectively postponed their registration date. To check whether that is the case, we use the 2007 data to plot the density of firm birth month in Figure 5. The result shows that there's no significant difference in firm entry around 2002. In addition, we also check whether firms re-registered after the reform to take advantage of the policy. We define re-registration by firms with the same name and owner but a different ID in different years. Figure 6 plots the distribution of re-registration for firms observed in 1998. We don't see significantly higher re-registration after 2002. Lastly, another identification assumption is that all unobserved determinants of firm innovation are continuously related to the firm birth month. Figure 7 graphically assesses this by testing whether the predicted number of patents, calculated as the fitted value from an OLS regression of patenting on all covariates in subsequent regressions , differs between firms born before or after January 2002. The figure suggests that there is no significant discontinuity in the predicted number of patent at the firm cohort cutoff. Based on the above evidence, we believe that in our context RD is a valid identification strategy. Since the policy rule relating firm birth time to treatment is not deterministic but only changed the probability of tax enforcement changes, we apply a fuzzy regression discontinuity estimation, instrumenting firm tax rate by the policy treatment. Specifically, to estimate the impact of the tax reform on firm innovation, we run the following 2SLS regression :

$$\text{Innovation}_{it} = \beta_0 + \beta_1 Tax\hat{R}ate_{it} + \beta_2 F(Age)_{it} + \beta_3 X_{it} + \nu_{it} \qquad (3.2)$$

Where $Innovation_{it}$ is an outcome variable measuring firm innovation behavior, such as the number of patent applications, RD expenditure, or skilled-labor ratio. $TaxRate_{it}$ is instrumented by the policy treatment (first-stage in equation (3.1)), and represents the fitted values from estimating equation (1). Our coefficient of interest is β_1, which measures the impact of changes in tax rate on firm innovation.

3.5 Results

3.5.0.1 Effect of Taxes on Firm Innovation

We firstly provide graphical evidence in Figure 8, which plots the number of patent applications against firm birth month. The figure shows that there is a discrete increase in patent applications at the firm age cutoff, which mirrors the decrease in the tax rate as shown in Figure 2. Figures 2 and 8 reveal a sharp decrease in taxes and a sharp increase in patenting at precisely the cutoff of firm cohort that was influenced by the tax collection reform. Table 3 reports the 2SLS estimation results for patent as the indicator of firm innovation . Starting with columns (1)-(3), where the outcome is the probability of applying for a patent, results show that a higher tax rate has a significantly negative effect on innovation, and the effect becomes stronger as time evolves. We mainly focus on the patent applications for the next 3 years because innovation is a process that needs long-term investment, and many innovating firms do not apply for patents every year. Specifically, column (3) suggests that, increasing the tax rate by one standard deviation (0.0122) can decrease the probability of having any patent application in the next 3 years by more than 10%. Similarly, column (6) shows that the average number of patent application increased by a significant 5.7% if the tax rate decreased by 0.01 . In Table 4, we explore another two indicators of firm innovation: RD expenditure and human capital. Results suggest that firms facing higher corporate taxes spend less money on RD and hire less skilled labor, although the impact on RD expenditure is not statistically significant. Please note that the sample size is smaller in this table because we only have RD expenditures in years 2005-2007 and worker education information in the year 2004. To further rule out the concern that the effect might be driven by confounding variables, we use pseudo regressions to test those possibilities. In practice, we generate policy dummies and replicate the regressions in Tables 2. The results in Table A4 suggest that if the cutoff is not 2002, we don't see a drop in the tax rate, suggesting that the policy effect is not just by chance. In summary, the results show a strong and robust causal relationship between tax rate and firm innovation. The tax collection reform reduced tax enforcement, and the resulting lower tax rate stimulated both input (measured by RD expenditure and human capital) and output (measured by the number of patent application) of firm innovation . While the quantity of innovation is important, the quality of innovation is also crucial. We use two ways to measure the quality of innovation . First, the type of patent is a good indicator of the value of patent. There are three main types of patent in China: invention, utility, and design patent. The invention patent is the most difficult one because it needs to contribute very original ideas. For a utility patent, there must be some significant improvement to an existing product or technology. The design patent only requires a modification in product appearance . Among the merged data we have, 16.6% are invention patents, 35.0% are utility patents, and 48.4% are design patents. We use the same 2SLS specification in equation (2) to test the impact of taxes on the likelihood and number of different types of patent applications. Table 5 presents the results. The impact of tax reform on patent applications mainly comes from its effect on invention and utility patents: decreasing the tax rate by one standard deviation (0.0122) improves the probability of having an invention patent application by 4.4% and increases the number of utility patent applications by 4.7%. This suggests that the improvement in innovation outcomes is not merely driven by the low-quality design patents. Second, we also use the detailed information of patent applications as proxies for the patent quality, including number of claims, number of independent claims , and the amount of effort that was spent on the patent application (length of the application document, number of figures, and length of abstract). In our patent data, only invention and utility patents have the above information, and results in Table 6 suggest that a reduction in tax rate significantly improved patent quality. Overall, the above results show that the tax reform not only increased the quantity of patents, but also improved the quality of innovation activities.

3.5.1 Mechanisms

After seeing a positive and significant impact of a tax rate reduction on firm innovation, the next question is: Why is firm innovation affected by the tax reform? Since RD expenditure is not fully tax deductible in our context, a direct explanation is that lower tax rate reduced the user cost of RD, so that the optimal level of RD investment increased. We also test two other potential mechanisms here. First, if firms are under financial constraints so that they do not have enough funding to invest on innovation, reducing tax cost can help by alleviating financial constraint, and firms can use the money saved to carry out innovation activities. Under a neoclassical framework, if RD expenditure is fully deductible, the tax rate should not affect innovation since it does not change the after-tax marginal benefit and cost of innovation. However, when the financial market is incomplete or inefficient and a firm mostly relies on its own after-tax profit, a lower tax rate could affect innovation investment. One challenge to test this channel is that it is hard to measure financial constraint. Fowling Cai and Liu [2009], we use the financial charges, which mainly include interest payment and fees, as the indicator for access to credit. From the late 1990s to the mid 2000s, although the Chinese economy had been growing at a very fast pace and firms' credit demand grew rapidly, the banking sector and stock market had not developed quickly enough to keep pace with this growing demand. Thus Chinese firms were usually facing severe credit constraints. At the same time, banks in China have little discretion over interest rates they can charge and the corporate bond market is thin due to strict regulations. Therefore, our measure of access to credit reflects mostly how much a firm manages to borrow, not its endogenously chosen optimal capital structure. We test the financial constraint channel using the following estimation equation:

$$\text{Innovation}_{it} = \gamma_0 + \gamma_1 TaxRate_{it} + \gamma_2 AccessToCredit_{it} + \gamma_3 TaxRate_{it} * AccessToCredit_{it} + \gamma_4 F(Age)_{it} + \gamma_5 X_{it} + \mu_{it} \qquad (3.3)$$

Where $TaxRate_{it}$ is instrumented by the policy treatment, Access to $Credit_{it}$ is calculated by the ratio of financial charges to total assets. Our coefficient of interest is γ_3, which measures the variation of the policy impact by firm financial constraint. Results in Table 7 suggest that firms which face more severe financial constraint are more hindered by a higher high tax rate. The coefficient in front of the interaction between $TaxRate_{it}$ and $AccessToCredit_{it}$ is significantly positive for patent outcomes. This result suggests that a low tax rate can stimulate firms' innovation by alleviating financial constraints. Second, a lower tax rate could also release resources that firms spend on tax avoidance, which firms can in turn use on innovation. In that case, firms that are doing more tax avoidance can release more resources for innovation. To test this channel, we look at whether the pocicy impact changes with tax avoidance activities. We define tax avoidance by the difference between imputed and reported profit, and assume that firms spend more on tax avoidance if the gap is larger. Following the same estimation strategy as in equation (3), we then estimate the heterogeneity of the tax impact by tax avoidance. Results in Table 8 show that for all the four measures of firm innovation, the coefficient of the interaction between the tax rate and the tax avoidance measure is negative and statistically significant, suggesting that that lower tax rate has a stronger positive impact on innovation if firms are doing more tax avoidance. This is in line with the tax avoidance mechanism.

3.6 Conclusion

In this paper, we offer new evidence on the impact of corporate taxes on both the quantity and quality of firm innovation, and the underlying mechanisms. To estimate the causal impact of taxes on innovation, we take advantage of a tax collection reform applied to manufacturing firms in China established after the year 2002, which switched the collection of corporate income taxes from the local tax bureau to the state tax bureau. Based on a comprehensive dataset of all medium and large enterprises combined with the universal patent application data in China, we use a regression discontinuity design to study the policy impact. Our results suggest that, first, the reform effectively changed tax enforcement and reduced the tax rate by 10%. Using the number of patent applications, RD expenditure, and skilled labor ratio as indicators of firm innovation, we then show that there is a strong and robust causal relationship between tax rate and firm innovation: decreasing the tax rate by one standard deviation (0.01) can increase the average number of patent applications by a significant 5.7%. The reform also improved RD expenditures and increased the skilled-labor ratio. Moreover, the impact of the reform on patenting mainly comes from its effect on the invention and utility patent, suggesting that the improvement in innovation outcomes is not merely driven by low-quality design patents. Lastly, we show that a low tax rate can stimulate firm's innovation by alleviating financial constraints and reallocating resources from tax avoidance activities.

3.7 Figures

Figure 3.1: Tax Rate of Firms Established in 2001 and 2002

Note: This figure plots the tax rate in years 2004-2007 for firms established in years 2001 and 2002.

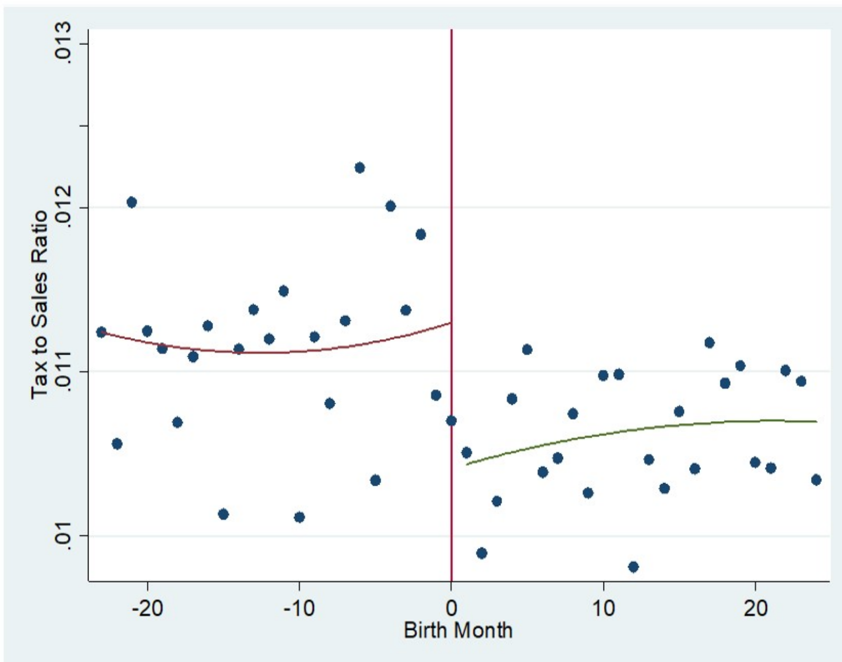


Figure 3.2: Tax Rate by Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the tax rate paid by firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0.

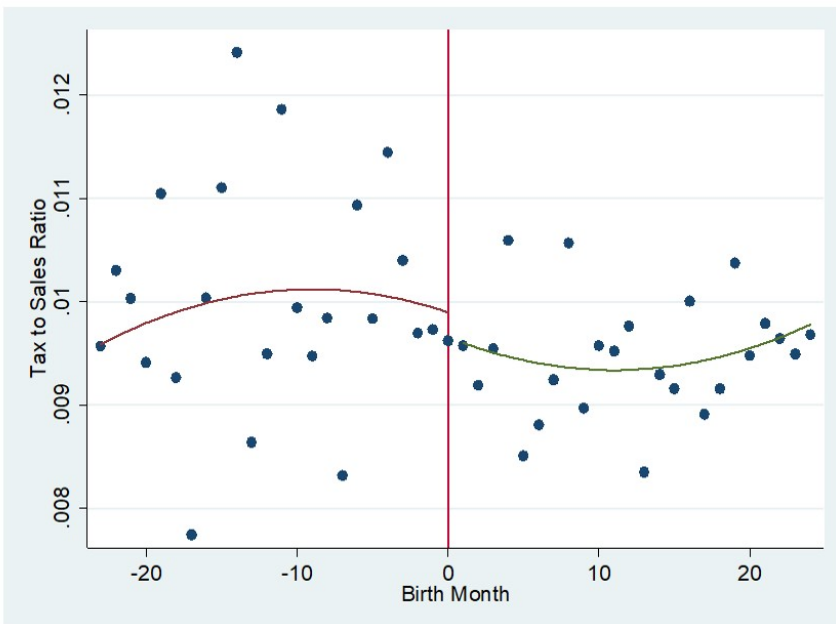


Figure 3.3: Tax Rate by Firm Birth Month: Foreign Firms

Note: This figure is based on data in the year 2007 and includes foreign firms only. It compares the tax rate paid by firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0.

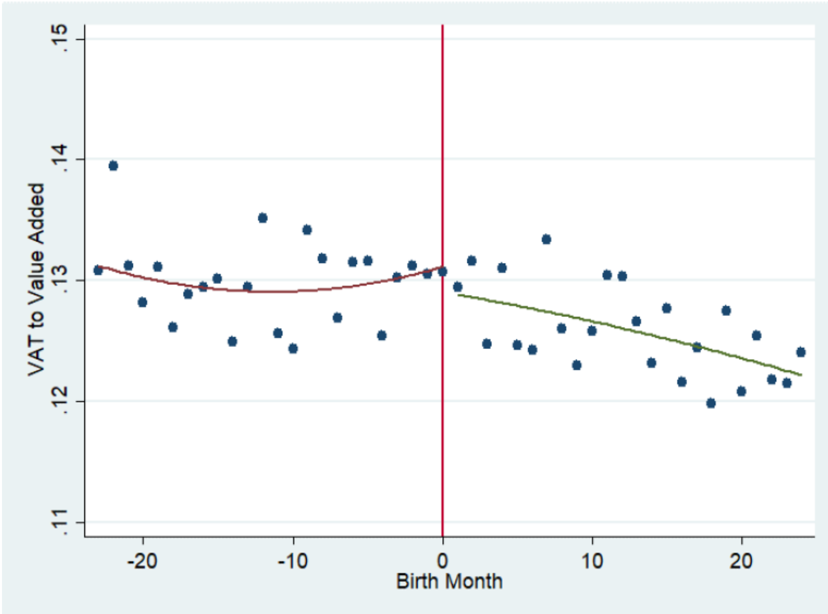


Figure 3.4: Value Added Tax Rate by Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the value-added tax rate paid by firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0.

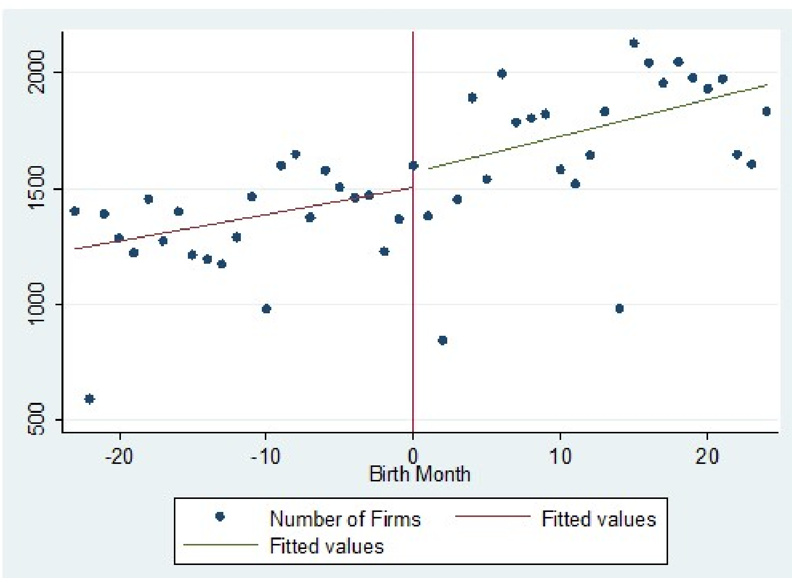


Figure 3.5: Density of Firm Birth Month

Note: This figure is based on data in the year 2007. Birth month of firms established in December 2001 is normalized to 0.

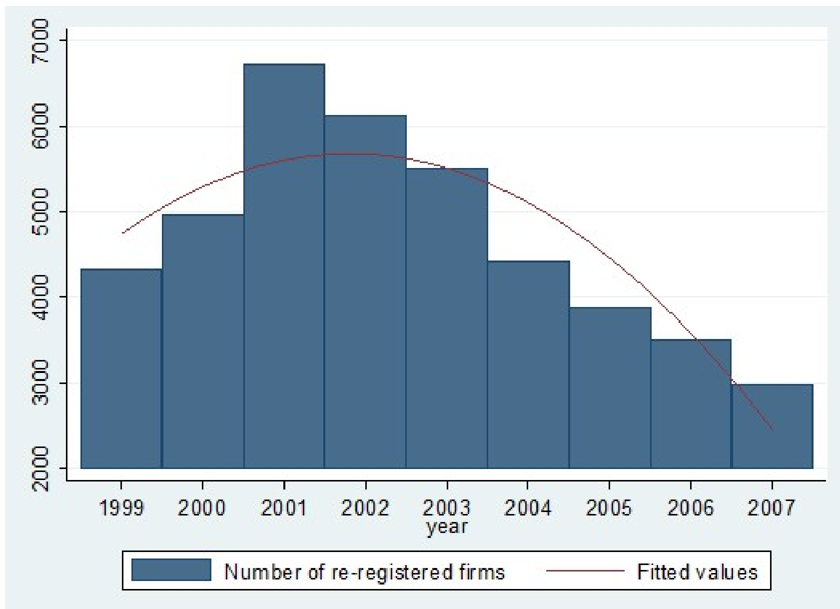


Figure 3.6: Distribution of Firm Re-registration

Note: This figure plots the distribution of re-registration for firms observed in 1998. Reregistration is defined as one for firms with the same name and owner but a different ID in different years.

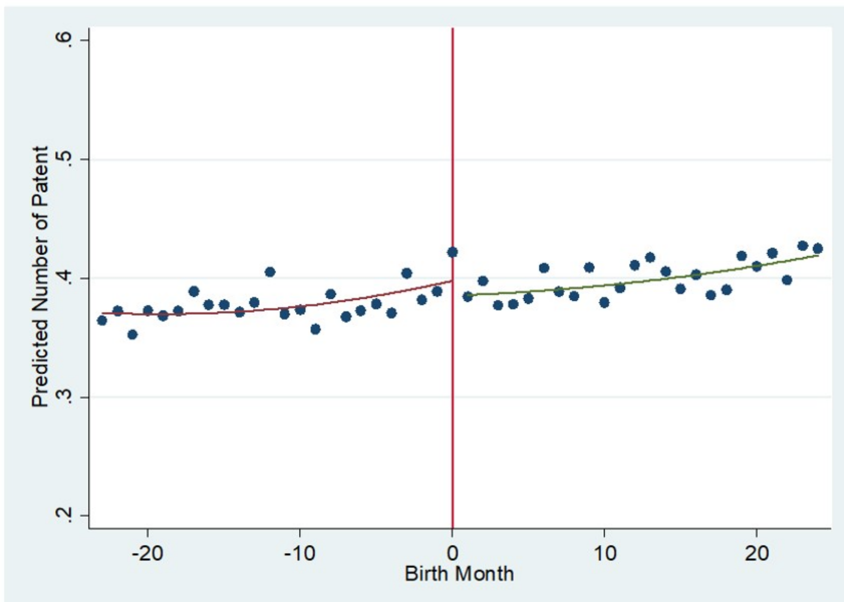


Figure 3.7: Predicted Number of Patent Application by Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the predicted number of patent applications (rescaled by firm size) by firms established before and after the policy change. The predicted number of patent applications is calculated as the fitted value from an OLS regression of patenting on covariates including capital to labor ratio, number of employees, export to sales ratio, and foreign share. Birth month of firms established in December 2001 is normalized to 0. Unit: Number of patent per 1M Yuan.

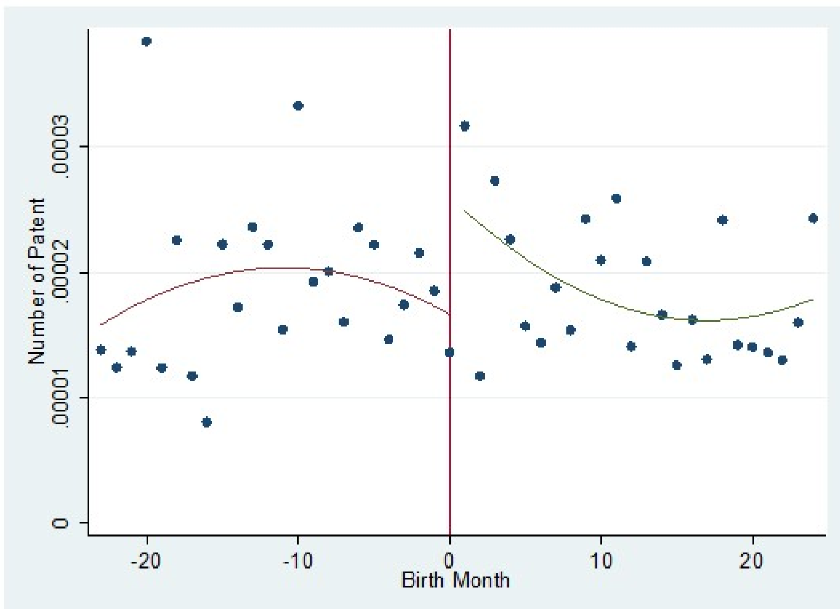


Figure 3.8: Number of Patent Application by Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the number of patent applications (rescaled by firm size) by firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0. Unit: Number of patent per 1M Yuan.

Table 3.1: Summary Statistics of Key Variables

	Mean	Standard Deviation
Policy Treatment	0.45	0.50
Panel A: Firm Characteristics (Year 2007)		
Firm Age	8.09	7.26
Ownership - State Owned Enterprises	0.01	0.12
Ownership - Domestic Private Firms	0.76	0.43
Ownership - Foreign Firms	0.22	0.41
Number of Employee	184.20	232.60
Expoert to Sales Ratio	0.17	0.34
Panel B: Accounting (Year 2007)		
Sales (1,000 RMB)	66,757	109,953
Output (1,000 RMB)	68,462	112,443
Fixed Assets (1,000 RMB)	13,641	31,461
Corporate Income Tax to Sales Ratio	0.011	0.012
Panel C: Innovation		
Patent Applications (2007-2010)		
Share of Firms Applied for Patent (%)	7.10	0.26
Average Number of Patent Application	8.86	24.68
Average Number of Approved Patent	2.52	5.39
R&D Expenditure/Sales (Year 2007)	0.002	0.016
Skilled Labor Ratio (Year 2004)	0.111	0.155

Note: Policy treatment equals one for firms established after the year 2002, and zero otherwise.

3.8 Tables

Table 3.2: Effect of the Tax Reform on Tax Rate

	Tax to Sales Ratio		
	(1)	(2)	(3)
Treatment	-0.00072***	-0.00098***	-0.00089**
(=1 if birth year>2002)	(0.00022)	(0.00028)	(0.00034)
Window	60 months	48 months	24 months
Number of Observation	178188	131515	67323
R-Squared	0.072	0.072	0.076

Note: This table reports the impact of the tax reform on the effective tax rate. Columns (1) to (3) use sample firms established 3, 2, or 1 year before and after the reform, respectively. Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.3: Impact of the Tax Reform on Firm Innovation: Patent

	Patent Application (1=Yes, 0=No)			Log (Number of Patent Application)		
	Next Year	Next 2 Years	Next 3 Years	Next Year	Next 2 Years	Next 3 Years
	(1)	(2)	(3)	(4)	(5)	(6)
Tax to Sales Ratio	-3.627***	-3.642	-8.210***	-2.633***	-4.229***	-5.719***
	(1.36)	(2.388)	(2.654)	(0.344)	(1.354)	(1.876)
Window	48 Months	48 Months	48 Months	48 Months	48 Months	48 Months
Number of Observation	131515	131515	131515	131515	131515	131515
Pre-2002 Mean of Dependent Variable	0.0203856	0.0351737	0.0494096	0.078	0.188	0.329

Note: This table uses sample of firms established two years before or after the policy reform and reports the impact of the tax reform on patent application. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3.4: Impact of the Tax Reform on Firm Innovation: R&D Expenditure and Skilled Labor

	R&D/Total Assets	Skilled Labor Ratio
	(1)	(2)
Tax to Sales Ratio	-0.273	-0.394**
	(0.294)	(0.167)
Window	48 Months	48 Months
Number of Observation	93024	28034
Pre-2002 Mean of Dependent Variable	0.002	0.102

Note: This table uses sample of firms established two years before or after the policy reform. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Column (1) is based on survey data in year 2005-2007 because data on RD expenditure is only available in those years; column (2) uses data in year 2004 which includes skilled labor information. Skilled labor ratio is defined as the sahre of workers with an above college degree. Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3.5: Impact of the Tax Reform on Different Types of Patent Application

	Patent Application (1=Yes, 0=No)			Log (Number of Patent Application)		
	Invention	Utility	Design	Invention	Utility	Design
	(1)	(2)	(3)	(1)	(2)	(3)
Tax to Sales Ratio	-3.570***	-1.068	0.192	0.791	-3.816**	0.0113
	(1.254)	(1.253)	(1.288)	(1.688)	(1.851)	(2.364)
Window	48 Months	48 Months	48 Months	48 Months	48 Months	48 Months
Number of Observation	131515	131515	131515	131515	131515	131515
Pre-2002 Mean of Dependent Variable	0.023	0.031	0.018	0.073	0.134	0.122

Note: This table uses sample of firms established two years before or after the policy reform. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3.6: Impact of the Tax Reform on the Quality of Patent Application

	log (Length of Document)	log (Number of Claims)	log (Number of independent Claims)	log (Number of Figures)	log (Length of Abstract)
	(1)	(2)	(3)	(4)	(5)
Tax to Sales Ratio	-48.78***	-13.57***	-9.137***	-11.73***	-33.57***
	(15.92)	(4.326)	(3.197)	(4.283)	(11.11)
Window	48 Months	48 Months	48 Months	48 Months	48 Months
Number of Observation	131515	131515	131515	131515	131515
Pre-2002 Mean of DV	676.855	1.089	0.429	0.761	49.156

Note: This table uses sample of firms established two years before or after the policy reform. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3.7: Mechanisms: Financial Constraint

	Patent Application Dummy (3 years, 1=Yes, 0=No)	Log (Number of Patent Application, 3 years)	R&D/Total Assets
	(1)	(2)	(3)
Tax to Sales Ratio	-5.976***	-8.554***	-0.313
	(1.899)	(2.754)	(0.289)
Interest Payment	-0.0041*	-0.0056	-0.0003
	(0.0024)	(0.004)	(0.0003)
Tax to Sales Ratio*Interest Payment	0.211	0.276	0.0317**
	(0.166)	(0.279)	(0.0154)
Window	48 Months	48 Months	48 Months
Number of Observation	131466	131466	92983
Pre-2002 Mean of Dependent Variable	0.0494096	0.329	0.002

Note: This table uses sample of firms established two years before or after the policy reform. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Column (3) uses survey data in year 2005-2007 only because data on RD expenditure is only available in those years. Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3.8: Mechanisms: Tax Avoidance

	Patent Application Dummy (3 years, 1=Yes, 0=No)	Log (Number of Patent Application, 3 years)	R&D/Total Assets
	(1)	(2)	(3)
Tax to Sales Ratio	-8.037***	-5.649***	-0.27
	(2.586)	(1.847)	(0.296)
Tax Avoidance	0.0005**	0.0003***	0.00001*
	(0.0002)	(0.0001)	(0.0001)
Tax to Sales Ratio*Tax Avoidance	-0.0309***	-0.0159***	-0.0008***
	(0.0112)	(0.0031)	(0.0002)
Window	48 Months	48 Months	48 Months
Number of Observation	131429	132429	92955
Pre-2002 Mean of Dependent Variable	0.0494096	0.329	0.002

Note: This table uses sample of firms established two years before or after the policy reform. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Column (3) uses survey data in year 2005-2007 only because data on RD expenditure is only available in those years. Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

APPENDIX A

Appendix in Chapter One

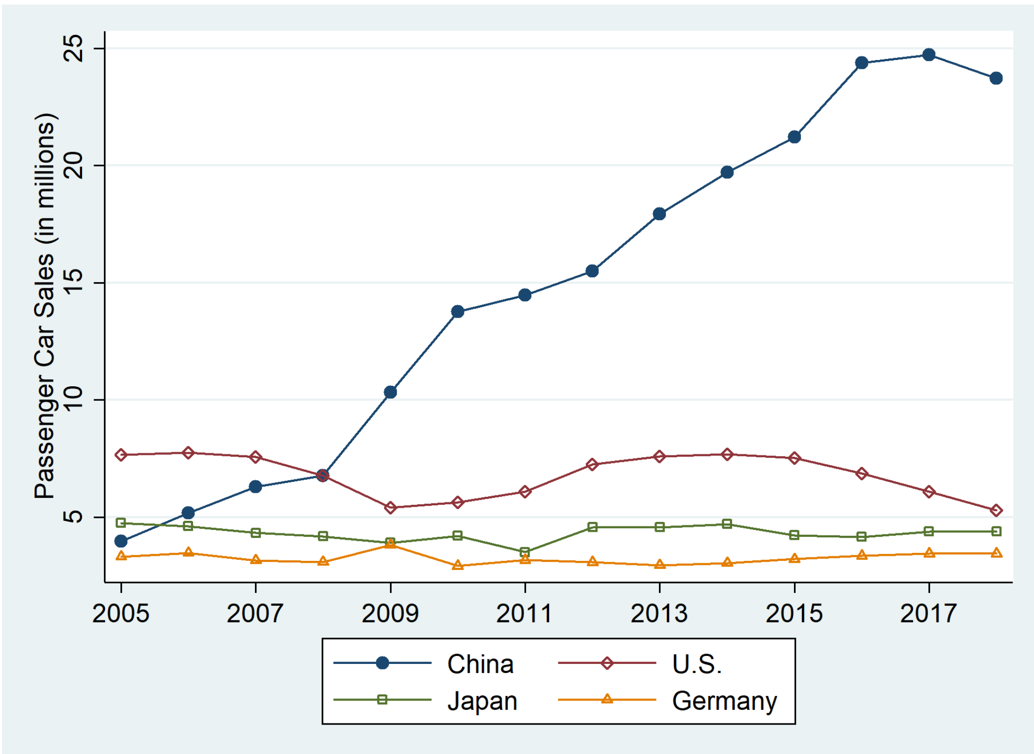


Figure A.1: Car Sales in Major Markets

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

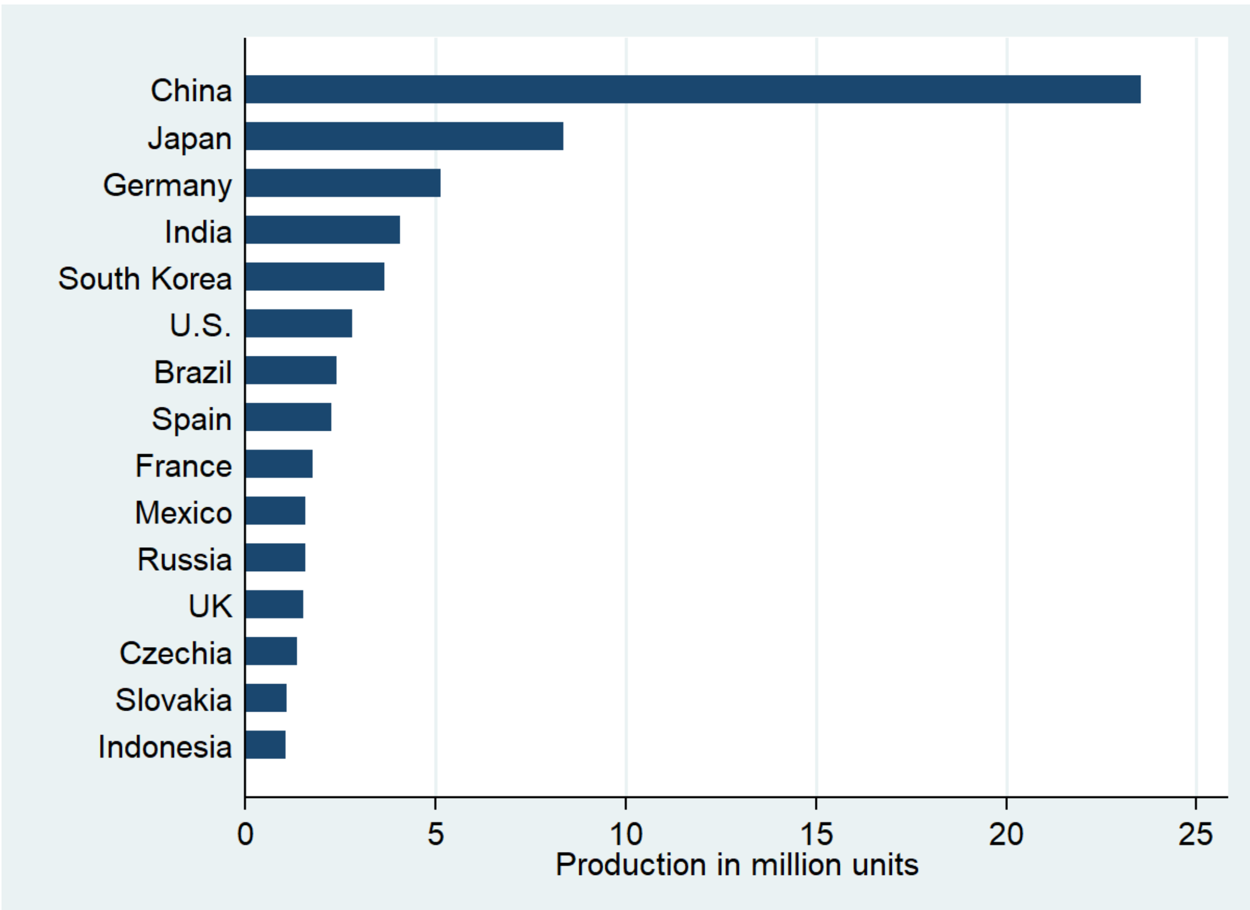


Figure A.2: World Car Production in 2018

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

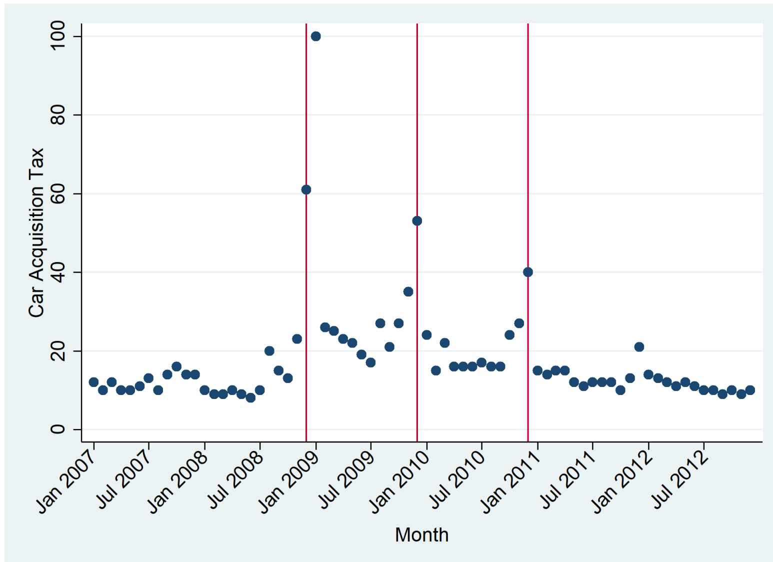


Figure A.3: Google Search Index for ”Car Acquisition Tax”

Note: [Source] Google trend

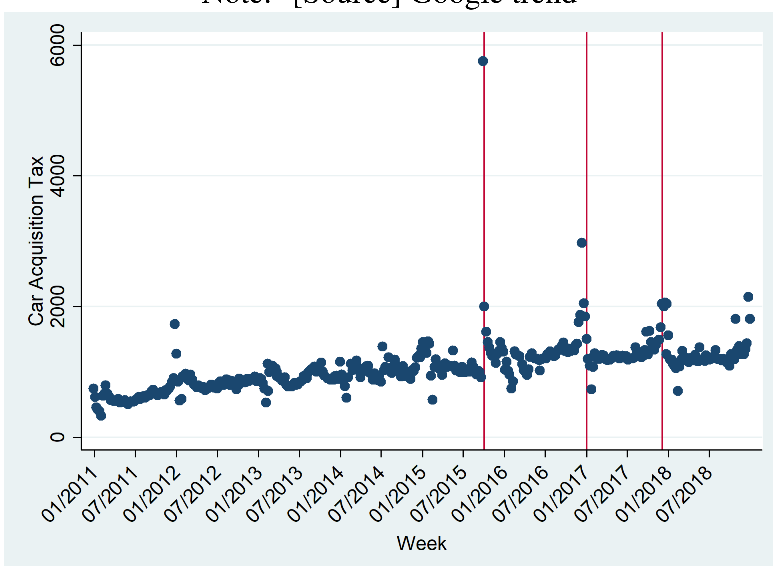


Figure A.4: Baidu Search Index for ”Car Acquisition Tax”

Note: [Source] Google trend

Figure A.5: Screenshot from the most popular phone app for car information in China

Note: [Source] From Phone App ”Dongchedi”

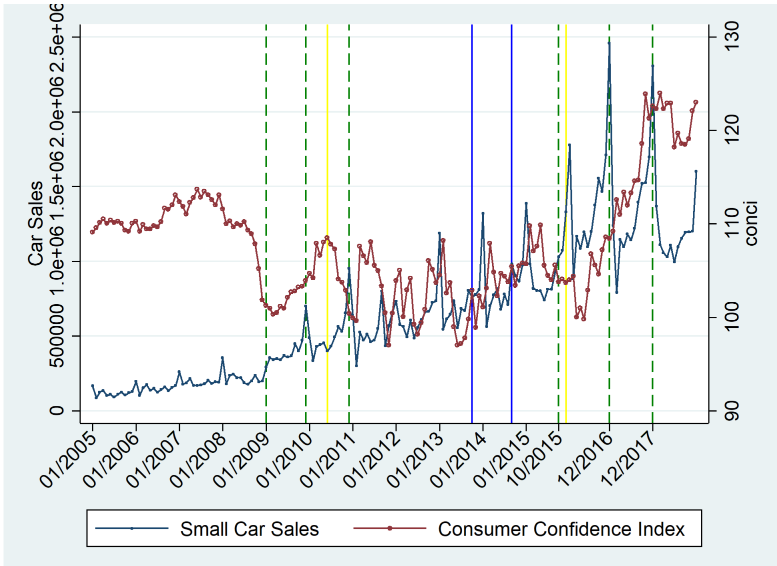


Figure A.6: Consumer Confidence Index and Large Car Sales

[Source] Calculated by authors from car sales data

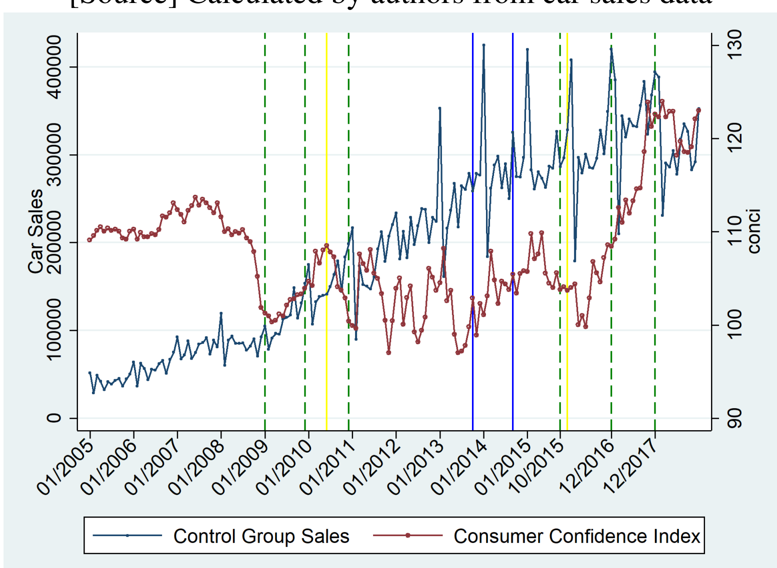


Figure A.7: Consumer Confidence Index and Small Car Sales

[Source] Calculated by authors from car sales data

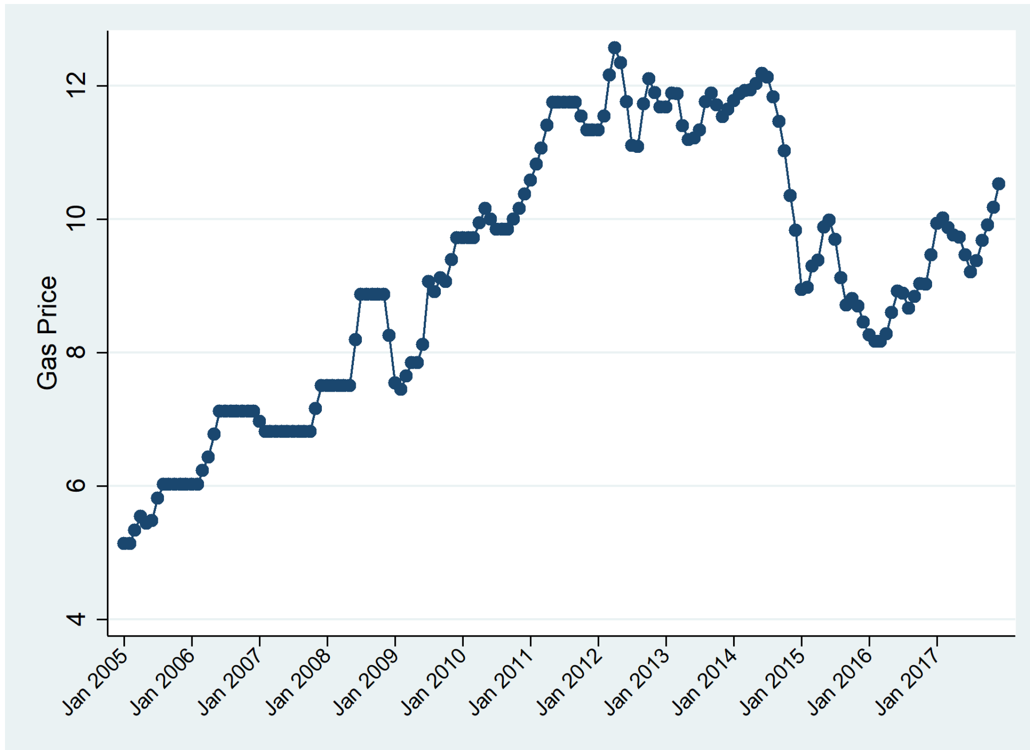


Figure A.8: National Average Gas Retail Price

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

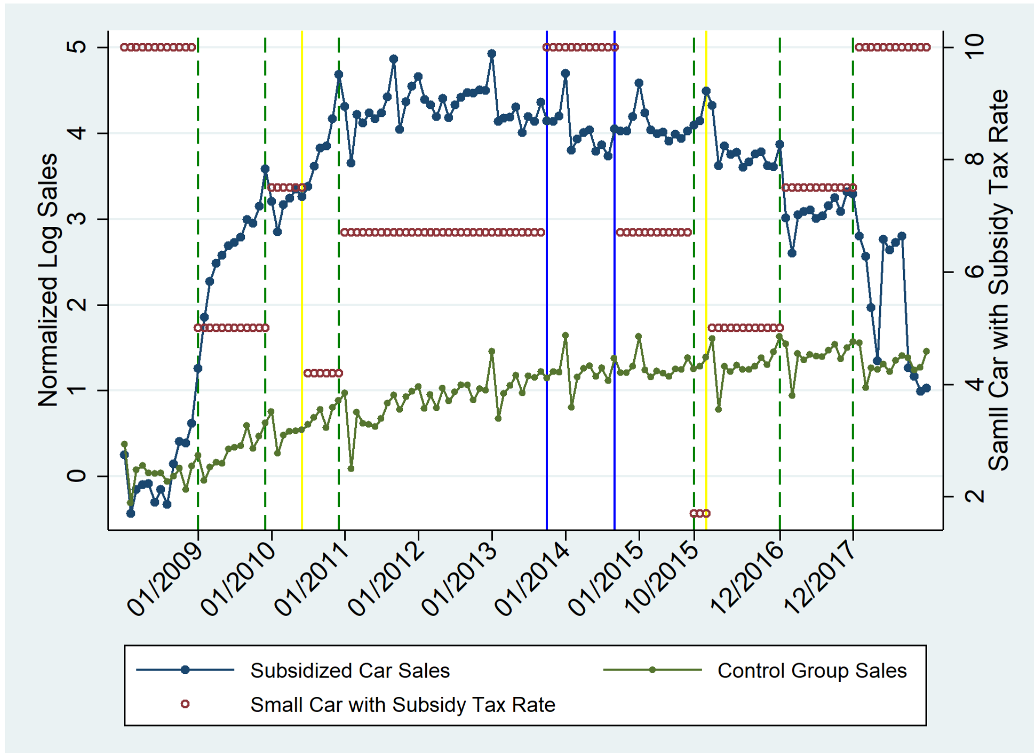


Figure A.9: Impact of tax incentives on group three cars

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

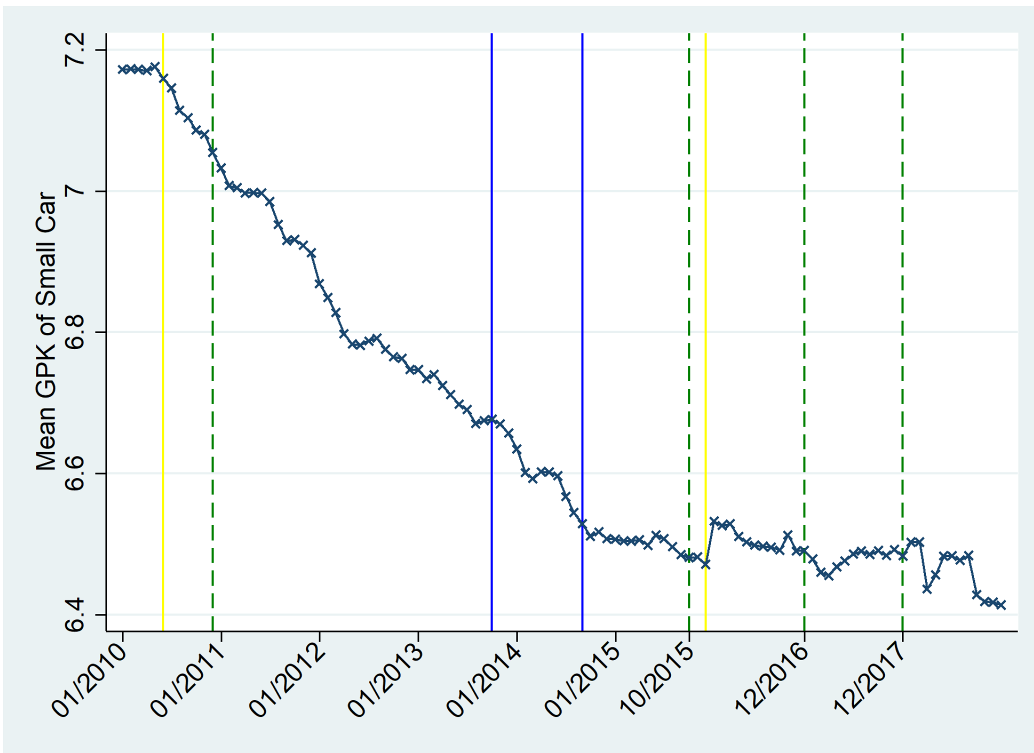


Figure A.10: National Average Gas Retail Price

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

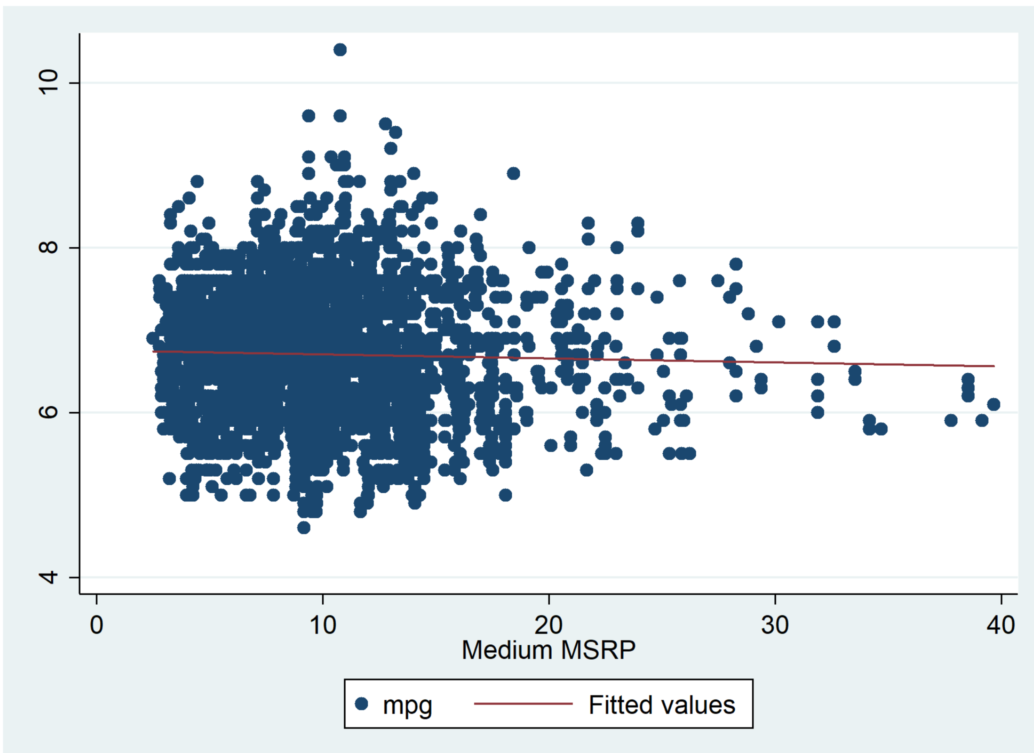


Figure A.11: Relationship between Price and Gas Consumption (MPG)

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

APPENDIX B

Appendix in Chapter Three

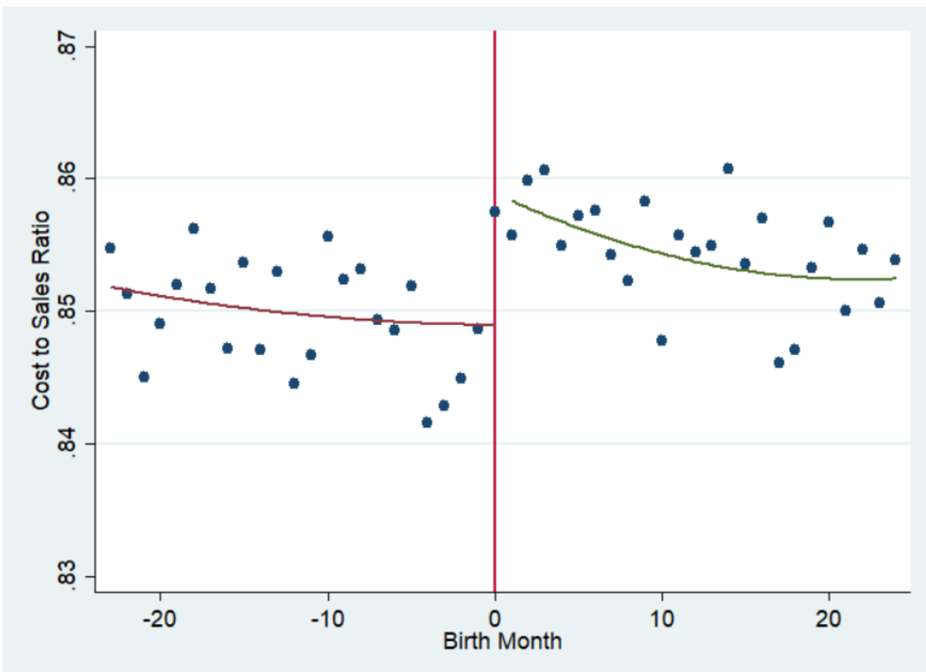


Figure B.1: Cost By Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the total cost of firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0.

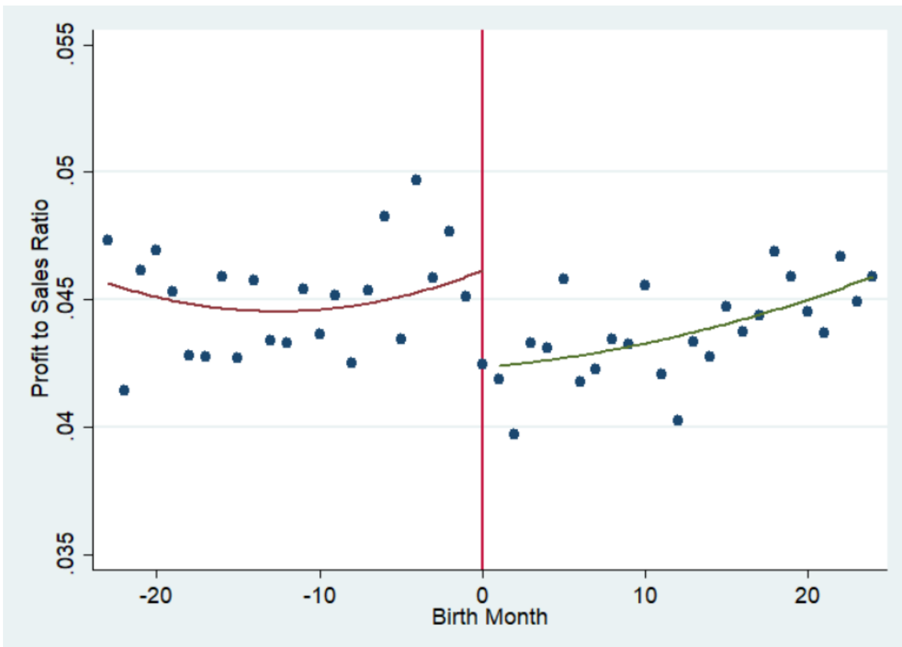


Figure B.2: Profit By Firm Birth Month

Note: This figure is based on data in the year 2007 and compares the profit of firms established before and after the policy change. Birth month of firms established in December 2001 is normalized to 0.

Table B.1: Pseudo Test

	Tax to Sales Ratio			
	(1)	(2)	(3)	(4)
Policy Dummy 2000	0.000858***			
(=1 if year>2000, =0 otherwise)	(0.00)			
Policy Dummy 2001		(0.00)		
(=1 if year>2001, =0 otherwise)		(0.00)		
Policy Dummy 2003			0.00	
(=1 if year>2003, =0 otherwise)			(0.00)	
Policy Dummy 2004				0.000641***
(=1 if year>2004, =0 otherwise)				(0.00)
Window	48 Months	48 Months	48 Months	48 Months
Number of Observation	120954	127805	117706	96016
R-Squared	0.071	0.073	0.074	0.078

Note: This table uses sample of firms established two years before or after the policy reform. Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. *** p<0.01, ** p<0.05, * p<0.1.

	Patent Application (1=Yes, 0=No)			Log (Number of Patent Application)		
	Next Year	Next 2 Years	Next 3 Years	Next Year	Next 2 Years	Next 3 Years
	(1)	(2)	(3)	(4)	(5)	(6)
Tax to Sales Ratio	-2.063***	-3.877***	-6.802***	-3.110**	-4.098	-10.12***
	(-3.04)	(-3.56)	(-3.88)	(-2.13)	(-1.57)	(-3.12)
Window	72 Month	72 Month	72 Month	72 Month	72 Month	72 Month
Number of Observation	178188	178188	178188	178188	178188	178188
Pre-2002 Mean of Dependent Variable	0.0202662	0.0347975	0.0495649	0.083779	0.201204	0.351908

Note: This table uses sample of firms established three years before or after the policy reform and reports the impact of the tax reform on patent application. The tax to sales ratio is instrumented by the policy treatment dummy (=0 for firms established before 2002, and =1 otherwise). Firm characteristics including capital to labor ratio, number of employees, export to sales ratio, and foreign share are controlled for in all regressions. Age, square of age, and their interactions with the treatment dummy are also included. *** p<0.01, ** p<0.05, * p<0.1.

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