Modeling Supply and Demand in the Chinese Automobile Industry[1]

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June 2017

Abstract

China is experiencing rapid economic growth and, along with it, rapid growth in vehicle ownership. The rapid growth in vehicle ownership and vehicle usage is linked to increasing global warming, emissions, air pollution, and other problems. We analyze the supply and demand for automobiles in China, and the effects of government policy on the supply and demand for alternative vehicles. To do so, we develop and estimate a structural econometric model of a mixed oligopolistic differentiated products market that allows different consumers to vary in how much they like different car characteristics on the demand side and that allows state-owned automobile companies to have different objectives than private automobile companies on the supply side. We apply our model to a comprehensive data set on the sales, prices, and characteristics of the majority of vehicle makes and models in China, including electric vehicles, hybrid vehicles, and alternative-fueled vehicles. The parameters we estimate enable us to better understand what factors affect the demand and cost of vehicles in China, and how consumers in China trade off various vehicle characteristics (such as fuel efficiency, whether the vehicle is an electric vehicle, etc.) with each other and with price. We use the model to simulate the demand and cost for new vehicles, and also the effects of various government policies on demand, cost, and welfare.

Keywords: automobile market, China, alternative vehicles, random coefficients model of demand, mixed oligopoly

***JEL* codes:** L62, L13, Q58

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1. Introduction

China is experiencing rapid economic growth and, along with it, rapid growth in vehicle ownership. Evidence from Chinese cities suggests average annual growth rates in per capita vehicle ownership of 10% to 25% (Darido, Torres, and Mehndiratta, 2014). According to data from the China Statistical Yearbook, vehicle ownership increased by nearly 56 times between 1990 and 2011. The rapid growth in vehicle ownership and vehicle usage is linked to increasing global warming, emissions, air pollution, and other problems.

For our research, we are developing and estimating a structural econometric model to estimate demand and cost parameters for all vehicles in China. Our structural econometric model of a mixed oligopolistic differentiated products market allows different consumers to vary in how much they like different car characteristics on the demand side and that allows state-owned automobile companies to have different objectives than private automobile companies on the supply side. We apply our model to annual data we have collected on sales, prices, and characteristics of the majority of vehicle makes and models in China, including electric vehicles, hybrid vehicles, and alternative-fueled vehicles, over the period 2004 to 2013. Our model enables us to estimate demand- and cost-side parameters, own- and cross-price elasticities, markups, and variable profits for alternative vehicles.

The parameters we are estimating enable us to better understand what factors affect the demand and cost of vehicles in China, and how consumers in China trade off various vehicle characteristics (such as fuel efficiency, whether the vehicle is an electric vehicle, etc.) with each other and with price. We use the model to simulate the demand and cost for new vehicles, and also the effects of various government policies on demand, cost, and welfare.

Our structural econometric model has several advantages over a survey approach. First, econometric models are estimated using actual data on actual vehicle purchase decisions, and therefore may be more accurate a depiction of consumer preferences, since these preferences are revealed by the actual decisions they make. In contrast, surveys are based on self-reported responses to questions and may be subject to many errors and biases that cause these responses to be inaccurate representations of the truth.

A second advantage of our econometric approach over a survey approach is that we estimate our econometric models using a comprehensive data set we have collected and constructed on sales, prices, and characteristics of the majority of vehicle makes and models in China, and will therefore base our models and analysis on the vehicle purchase decisions of all vehicle owners in China, not just those of the consumers that are surveyed. Our comprehensive data set not only provides more information, but also is not subject to sample selection issues that would plague a survey of a sample of the population.

A third advantage of our econometric approach over a survey approach is that our econometric model enables us to statistically control for multiple factors that may affect vehicle purchase decisions, including price; vehicle characteristics such as fuel economy, horsepower, and size; and consumer characteristics in a quantitative and rigorous manner.

A fourth advantage of the structural model is that the parameters we are estimating enable us to calculate consumer utility, firm profits, and welfare.

A fifth advantage of our structural econometric approach is that it enables us to estimate standard errors and confidence intervals for our parameters, and therefore to ascertain whether our parameters are statistically significant.

A sixth advantage of our structural econometric approach is that we can use the estimated parameters to simulate demand, supply, and welfare under counterfactual policy scenarios. These counterfactual policy simulations will enable us to analyze the effects of vehicle-related policies in China, including those regarding alternative vehicles.

Our research builds on the work of Berry, Levinsohn and Pakes (1995), who develop a model for empirically analyzing demand and supply in differentiated products markets and then apply these techniques to analyze the equilibrium in the U.S. automobile industry. Their framework enables one to obtain estimates of demand and cost parameters for a class of oligopolistic differentiated products markets. Unlike traditional logit demand models, their random coefficients model allows for interactions between consumer and product characteristics, thus generating reasonable substitution patterns. Estimates from their framework can be obtained using only widely available product-level and aggregate consumer-level data, and they are consistent with a structural model of equilibrium in an oligopolistic industry. They apply their techniques to the U.S. automobile market, and obtain cost and demand parameters for (essentially) all models marketed over a twenty-year period. On the cost side, they estimate cost as a function of product characteristics. On the demand side, they estimate own- and cross-price elasticities as well as elasticities of demand with respect to vehicle attributes (such as weight or fuel efficiency).

We innovate upon the Berry et al. (1995) work by developing a model of the Chinese automobile market; by including alternative vehicles so that in addition to cost and demand parameters relating to gasoline-fueled vehicles, cost and demand parameters relating to alternative vehicles can be estimated; and by modeling the behavior of not only private automobile companies but also the state-owned automobile companies in China.

Our research is significant for industry, government, society, academia, and NGOs. Our model of the demand and cost in the Chinese automobile market will be significant for industry, particularly car manufacturers interested in better targeting cars, including alternative vehicles, for the Chinese market. Our estimates of the factors that affect demand and supply in the Chinese automobile market is significant for policy-makers interested in developing incentive policies to increase market penetration of alternative vehicles with potential environmental and climate benefits.

2. Background

In 2009, China's automobile market became the largest in the world, surpassing the U.S. automobile market both in sales and production. The annual gross product of the China's automobile industry has exceeded 5% of the country's annual GDP every year since 2002, and was as high as 7.4% of its GDP in 2010.[2]

The Chinese automobile industry underwent several phases of growth since the start of China's economic reform in 1978. At that time, automobile manufacturing was very low in productivity. In the year 1980, total vehicle output was around five thousand vehicles only. As incomes grew, household demand for passenger vehicle grew rapidly, which resulted in a large amount of cars being imported to China. In order to protect the vulnerable and immature domestic Chinese automobile industry, tariffs were set as high as 250% (Li, Xiao and Liu, 2015).

Several large state-owned automobile enterprises in China tried to partner with foreign auto manufacturers to form joint ventures to increase their capacity and enhance their technical

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[2] These statistics were calculated using GDP data from the National Bureau of Statistics of China and automobile industry gross product data from Chinese Automobile Industry Yearbook.

capabilities. However, foreign ownership was capped at 50% to protect domestic producers. In 1994, China's National Development and Reform Commission (NDRC) initiated an automobile industry policy encouraging state-owned firms to partner with international car makers to form joint ventures (Li, Xiao and Liu, 2015). Following this policy, more joint ventures were formed between large state-owned automobile companies and foreign auto manufacturers (Li, Xiao and Liu, 2015). Meanwhile, local and private producers also entered the market.

In 2001, China entered the World Trade Organization (WTO). In order to fulfill its commitment under the WTO, the Chinese government gradually cut the tariffs on foreign automobiles from 100% to 25% during the 5-year transition period. However, the market shares of imports further dropped from about 6% in 2001 to 3% in 2006 and it has stayed at that level since then (Li, Xiao and Liu 2015).

The Chinese manufacturers of passenger vehicles can be categorized into two different types: indigenous-brand manufacturers, such as BYD, Geely, and Chery; and joint ventures between domestic manufacturers and foreign manufacturers, such as Shanghai Automotive Investment Company (BAIC) with Hyndai, and Dongfeng with Honda.

In Figure A1 in Appendix A, adapted from Hu, Xiao and Zhou (2014), we present the market structure of the Chinese automobile industry. The car makers in large boxes are the top state-owned automobile groups in China. The ones in small isolated boxes at the bottom are indigenous local makers. According to Chinese automobile policy, a Chinese automobile company can form joint ventures with multiple foreign car manufacturers. For example, Shanghai Auto has cooperated with General Motors and Volkswagen. Dofeng Motors partners with Nissan, Kia, and PSA. On the other hand, under Chinese policy, a foreign car manufacturer is only allowed to form joint ventures with up to two Chinese automobile companies.[3] For example, Honda partners with both Donfeng Group and Guangdong Auto. Toyota, another Japanese automobile firm, cooperates with both Fist Auto Work and Guangdo Auto. Besides large stated-owned auto groups, private car makers also partner with foreign makers. Huachen Auto cooperates with BMW. Joint ventures with international car companies account for two thirds of the passenger vehicle market, with the rest mostly taken up by indigenous brands (Li, Xiao and Liu, 2015).

Figure A2 in Appendix A presents the location of the automobile firms listed in Figure A1 in Appendix A. Most of the automobile firms are located along the east of the continent. Two of the "China Automobile Group Four" are located in the east, with First Auto Work in the northeast, and Shanghai Automotive Investment Company (SAIC) in the Southeast. For the other two, Dongfeng Group is in the middle east of the country, while Chang'an Automobile Group is in central China. Two large indigenous firms Geely and Chery are located in the southeast part of China.

In 2005, CAAM, the statistical organization of the Chinese automobile industry that categorizes vehicles, reclassified vehicles into two broad categories: passenger vehicles and commercial vehicles. CAAM further divided passenger vehicle into four categories: Basic Passenger Vehicle (BPV), Sports Utility Vehicle (SUV), Multi-purpose Vehicle (MPV), and others (such as crossovers). In 2012, according to the China Automobile Industry Year Book, the total Basic Passenger Vehicle (BPV) output is 10.767 million and that for Multi-purpose Vehicle (MPV) and Sports Utility Vehicle (SUV) is 491.896 thousand and 1.999 million respectively. The

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[3] According to "Chinese Automobile Industry Development Policy, 2009 edited edition". *http://www.china.com.cn/policy/txt/2009-08/31/content_18430768_5.htm*

total output and sales for passenger vehicle in 2012 is 13.258 million and 13.239 million, respectively.

According to China's National Bureau of Statistics, from 2004 to 2014, the total number of civil passenger vehicles owned in China increased from 17.35 million to 123.27 million, with an annual growth rate of 21.69%. The total number of civil vehicle owned in China, including civil trucks, was 145.98 million in 2014.

In September 2004, China introduced its first fuel economy standards for light duty passenger vehicles (GB 19578-2004), targeting a fuel consumption of 6.9 L/100km by 2015, which translates to an estimated 167 g/km of CO_2 emissions. The standards were initially outlined in two phases with different national standards of "limits of Fuel Consumption of Passenger Cars". The national standard limits are set for 16 categories of curb weights and also differentiates manual transmission from automatic transmission.

The first phase began in July 2005 for new vehicle production, and a year later for existing vehicle production. Phase 2 began in January 2008 for new vehicle production, and full segment production compliance was implemented in 2009.

The cars initially included in the fuel economy standard were passenger cars, SUVs, and light commercial vehicles (LCVs). These vehicles are collectively defined as M1-type vehicles by the EU, and are defined in the Chinese standard as vehicles with a minimum speed of 50 km/h and a maximum weight of 3500 kg.

The third phase of the passenger vehicle fuel economy standard includes Corporate Average Fuel Consumption (CAFC) target (GB 27999-2011), which went into effect in 2012 and is intended to bind in 2015. Together with the passenger car fuel limits standard (GB 19678-2004), CAFC is designed to realize an ambitious average fuel consumption target of 6.9 L/100km by

2015. The fourth phase recently released is providing gradual implementation guidelines towards a 2020 5.0 L/100km binding target.

The CAFC uses vehicle model, year, and annual sales to calculate the following weighted average for fuel consumption based on the New European Driving Cycle (NEDC):

$$CAFC = \frac{\sum_i FC_i \cdot V_i}{\sum_i V_i},$$

where FC_i is the fuel consumption of model *i* and V_i is the annual sales of model *i*.

The government sets higher weights for alternative fuel vehicles to encourage their production. Until 2015, in the CAFC calculation, a multiplier of 5, 5, 5, 3 of the quantity sales are used for pure-electric, fuel-cell electric, plug-in hybrid, and energy saving vehicles respectably. The weights gradually decrease thereafter.[4]

The CAFC target T_{CAFC} is based on individual vehicle fuel consumption targets, which use the quantity of annual sales of each model to calculate a weighted average as follows:

$$T_{CAFC} = \frac{\sum_i T_i \cdot V_i}{\sum_i V_i},$$

where T_i is the fuel consumption target of model *i* and V_i is the annual sales of model *i*.

The national standard (GB 27999) target implementation status is indicated by $\frac{CAFC}{T_{CAFC}}$. The CAFC requirement was enacted in 2012 and allows automobile manufacturers until 2015 to

[4] 2015 annual report of Chinese passenger vehicle fuel consumption 2015 by Innovation Center for Energy and Transportation

gradually reduce the fuel consumption levels (3% each year), towards the CAFC binding period starting in 2015 (100% compliance).

In addition to fuel economy standards, in 2010 the Chinese government established a project called "energy saving projects", which uses a fiscal subsidy to encourage energy saving. Some autos with low displacement (less than 1.6L) will receive a subsidy (directly to the car makers) such that the market price is the price after subsidized.[5]

3. Literature Review

3.1. Structural econometric models of demand and supply in differentiated products markets

The first strand of literature we build upon is that on structural econometric models of demand and supply in differentiated products markets. Berry (1994) develops techniques for estimating discrete choice demand models which involve "inverting" the market share equation to find the implied mean levels of utility for each good. Goldberg (1995) develops and estimates a model of the U.S. automobile industry in which demand is modeled with a discrete choice model estimated using micro data from the Consumer Expenditure Survey, and supply is modeled as an oligopoly with differentiation. Feenstra and Levinsohn (1995) demonstrate how to estimate a model of oligopoly pricing when products are multi-dimensionally differentiated.

Berry, Levinsohn and Pakes (1995) develop techniques for empirically analyzing demand and supply in differentiated products markets and then apply these techniques to analyze the equilibrium in the U.S. automobile industry. The framework they present enables one to obtain estimates of demand and cost parameters for a class of oligopolistic differentiated products

[5] Announcement published by the Ministry of Finance of the People's Republic of China. http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201006/t20100601_320724.html

markets, using only widely available product-level and aggregate consumer-level data, which are consistent with a structural model of equilibrium in an oligopolistic industry.

Innovations, extensions, and refinements to Berry, Levinsohn and Pakes (1995) have been made by Petrin (2002), Berry, Levinsohn and Pakes (2004),Hoderlein, Klemela and Mammen (2008), Dube, Fox and Su (2012), Knittel and Metaxoglou (2014), Reynaert and Verboven (2014), Berry and Haile (2014), Berry and Haile (2016), Bajari et al. (2015), and Armstrong (2016).

3.2. Vehicle markets and policy

The second strand of literature we build upon is that on vehicle markets and policy, particularly for alternative vehicles. A more detailed review of this literature is provided in Chen, Lin Lawell and Wang (2017).

One sub-branch of this literature is the literature on vehicle demand. Sallee, West and Fan (2016) measure consumers' willingness to pay for fuel economy using a novel identification strategy and high quality microdata from wholesale used car auctions. Anderson and Sallee (2016) present a simplified model of car choice that allows them to emphasize the relationships between fuel economy, other car attributes, and miles traveled.

Understanding demand in the new plug-in hybrid electric vehicle (PHEV) market is critical to designing more effective adoption policies. Sheldon, DeShazo and Carson (2016) use stated preference data from an innovative choice experiment to estimate demand for PHEVs relative to battery electric vehicles (BEVs) and to explore heterogeneity in demand for these vehicles. Deshazo, Sheldon and Carson (forthcoming) assess the performance of alternative rebate designs for plug-in electric vehicles.

Li and Zhou (2015) examine the dynamics of technology adoption and critical mass in network industries with an application to the U.S. electric vehicle (EVs) market, which exhibits indirect network effects in that consumer EV adoption and investor deployment of public charging stations are interdependent.

Holland, Mansur, Muller, and Yates (2016) combine a theoretical discrete-choice model of vehicle purchases, an econometric analysis of electricity emissions, and the AP2 air pollution model to estimate the geographic variation in the environmental benefits from driving electric vehicles.

Another sub-branch is the literature on the effects of government policy on vehicle demand, particularly for alternative vehicles. Gallagher and Muehlegger (2011) study the relative efficacy of state sales tax waivers, income tax credits, and non-tax incentives to induce consumer adoption of hybrid-electric vehicles. They find that the type of tax incentive offered is as important as the generosity of the incentive. Beresteanu and Li (2011) analyze the determinants of hybrid vehicle demand, focusing on gasoline prices and income tax incentives. They show that the cost effectiveness of federal tax programs can be improved by a flat rebate scheme. Sallee (2011) estimates the incidence of tax incentives for the Toyota Prius. Transaction microdata indicate that both federal and state incentives were fully captured by consumers. Jacobsen and van Benthem (2015) estimate the sensitivity of scrap decisions to changes in used car values and show how this "scrap elasticity" produces emissions leakage under fuel efficiency stands, a process known as the Gruenspecht effect.

Another sub-branch is the literature on vehicle supply, and the effects of policies on vehicle supply. Heutel and Muehlegger (2015) study the effect of differences in product quality on new technology diffusion. Using detailed vehicle specifications, Ullman (2016) analyzes the impact identifiable vehicle characteristics and technological progress has on fleet economy by vehicle type and class. He finds evidence that the stringent footprint-based standards create manufacturer incentive to increase vehicle size to lower the burden of compliance, which undermines the standards' potential to create expected fuel savings and lower emissions levels. Miravete, Moral and Thurk (2016) estimate a discrete choice oligopoly model of horizontally differentiated products using Spanish automobile registration data to assess the degree to which vehicle emissions policies impact the automobile industry, focusing on the European market where diesels are popular.

Another sub-branch is the literature on government policies related to vehicles. Despite widespread agreement that a carbon tax would be more efficient, many countries use fuel economy standards to reduce transportation-related carbon dioxide emissions. Davis and Knittel (2016) pair a simple model of the automakers' profit maximization problem with unusually-rich nationally representative data on vehicle registrations to estimate the distributional impact of U.S. fuel economy standards. The key insight from the model is that fuel economy standards impose a constraint on automakers which creates an implicit subsidy for fuel-efficient vehicles and an implicit tax for fuel-inefficient vehicles.

Economists promote energy taxes as cost-effective. But policy-makers raise concerns about their regressivity, or disproportional burden on poorer families, preferring to set energy efficiency standards instead. Levinson (2016) first show that in theory, regulations targeting energy efficiency are more regressive than energy taxes, not less. He then provides an example in the context of automotive fuel consumption in the United States: taxing gas would be less regressive than regulating the fuel economy of cars if the two policies are compared on a revenue-equivalent basis.

Sallee and Slemrod (2012) analyze notches in fuel economy policies, which aim to reduce negative externalities associated with fuel consumption. They provide evidence that automakers respond to notches in the Gas Guzzler Tax and mandatory fuel economy labels by precisely manipulating fuel economy ratings so as to just qualify for more favorable treatment. Jacobsen (2013) employs an empirically estimated model to study the equilibrium effects of an increase in the US corporate average fuel economy (CAFE) standards. Kellogg (2017) shows that the implications of gasoline price volatility for the design of fuel economy policies. Bento, Gillingham and Roth (2017) examine the effect of fuel economy standards on vehicle weight dispersion and accident fatalities

3.3. Vehicle markets and policy in China

The third strand of literature we build upon is that on vehicle markets and policy in China. Huo et al. (2007) develop a methodology to project growth trends of the motor vehicle population and associated oil demand and carbon dioxide emissions in China through 2050. Projections show that by 2030 China could have more highway vehicles than the United States has today.

China’s vehicle population is widely forecasted to grow 6-11% per year into the foreseeable future. Barring aggressive policy intervention or a collapse of the Chinese economy, Wang, Teter and Sperling (2011) suggest that those forecasts are conservative. They analyze the historical vehicle growth patterns of seven of the largest vehicle producing countries at comparable times in their motorization history. They estimate vehicle growth rates for this analogous group of countries to have 13-17% per year- roughly twice the rate forecasted for China by others. Applying these higher growth rates to China results in the total vehicle fleet reaching considerably higher volumes than forecasted by others, implying far higher global oil use and carbon emissions than projected by the International Energy Agency and others.

Lin and Zeng (2013) estimate the price and income elasticities of demand for gasoline in China. Their estimates of the intermediate-run price elasticity of gasoline demand range between -0.497 and -0.196, and their estimates of the intermediate-run income elasticity of gasoline demand range between 1.01 and 1.05. They also extend previous studies to estimate the vehicle miles traveled (VMT) elasticity and obtain a range from -0.882 to -0.579.

Lin and Zeng (2014) calculate the optimal gasoline tax for China using a model developed by Parry and Small. They calculate the optimal adjusted Pigovian tax in China to be $1.58 /gallon which is 2.65 times more than the current level. Of the externalities incorporated in this Pigovian tax, the congestion costs are taxed the most heavily, at $0.82/gallon, followed by local air pollution, accident externalities, and finally global climate change.

Hu, Xiao and Zhou (2014) apply a non-nested hypothesis test methodology to data on Chinese passenger vehicles to identify whether price collusion exists within corporate groups or across groups. Their empirical results support the assumption of Bertrand Nash competition in the Chinese passenger-vehicle industry. No evidence for within or cross-group price collusion is found. In addition, the policy experiments show that indigenous brands will gain market shares and profits if within group companies merge.

Xiao and Ju (2014) explore the effects of consumption-tax and fuel-tax adjustments in the Chinese automobile industry. Their empirical findings suggest that the fuel tax is effective in decreasing fuel consumption at the expense of social welfare, while the consumption tax does not significantly affect either fuel consumption or social welfare.

Li, Xiao and Liu (2015) document the evolution of price and investigate the sources of price decline in the Chinese automobile market, paying attention to both market structure and cost factors. They estimate a market equilibrium model with differentiated multiproduct oligopoly using market-level sales data in China together with information from household surveys. Their counterfactual simulations show that (quality-adjusted) vehicle prices have dropped by 33% from 2004 to 2009. The decrease in markup from intensified competition accounts for about one third of this change and the rest comes from cost reductions through learning by doing and other channels.

Liu and Lin Lawell (2017) examine the effects of public transportation and the built environment on the number of civilian vehicles in China. They use a 2-step GMM instrumental variables model and apply it to city-level panel data over the period 2001 to 2011. The results show that increasing the road area increases the number of civilian vehicles. In contrast, increasing the public transit passenger load decreases the number of civilian vehicles. However, the effects vary by city population. For larger cities, increases in the number of public buses increase the number of civilian vehicles, but increases in the number of taxis and in road area decrease the number of civilian vehicles. They also find that land use diversity increases the number of civilian vehicles, especially in the higher income cities and in the extremely big cities. Finally, they find no significant relationship between civilian vehicles and per capita disposable income except in mega cities.

Both market-based and non-market based mechanisms are being implemented in China's major cities to distribute limited vehicle licenses as a measure to combat worsening traffic congestion and air pollution. While Beijing employs non-transferable lotteries, Shanghai uses an auction system. Li (2016) empirically quantifies the welfare consequences of the two mechanisms by taking into account both allocation efficiency and automobile externalities post-allocation. His analysis shows that different allocation mechanisms lead to dramatic differences in social welfare. Although the lottery system in Beijing has a large advantage in reducing externalities from automobile use than a uniform price auction, the advantage is offset by the significant welfare loss from misallocation. The lottery system forewent nearly 36 billion RMB (or $6 billion) in social welfare in Beijing in 2012 alone. A uniform-price auction would have generated 21.6 billion RMB to Beijing municipal government, more than covering all the subsidies to the local public transit system.

3.4. Mixed oligopoly

The fourth strand of literature we build upon is that on mixed oligopoly. A mixed oligopoly is defined as an oligopolistic market structure with a relatively small number of firms for which the objective of at least one firm differs from that of other firms (De Fraja and Delbono, 1990), as opposed to a private oligopoly in which all firms have the objective of profit maximization. Usually in a mixed oligopoly there is a public firm competing with a multitude of profit-maximizing firms (Poyago-Theotoky, 2001).

De Fraja and Delbona (1989) study a situation in which private and public firms compete both using only market instruments. When talking about public and private firms, they think of firms which pursue different objectives. They find that nationalization is always socially better than Stackelberg leadership, which is in turn socially better than Cournot-Nash behavior. If there is no way of avoiding competition with a public firm, private entrepreneurs would prefer the public firm to behave as a Stackelberg leader.

De Fraja and Delbona (1990) examine a case of mixed oligopoly which is particularly interesting from the point of view of economic and industrial policy: a market in which at least one publicly owned firm cohabits which at least one private firm. A market where there are both private and public firms is then a mixed oligopoly because the firms owned by private agents aim to maximize profits, whereas the publicly owned firms are interested in optimizing social targets. There are two broad results which emerge from the models considered in this survey. First, the public authority can fruitfully use the public firms as an instrument towards the achievement of its goals, namely the increase of social welfare. Second, in general, it does not seem to be optimal for the public authority to instruct the public firms to take decisions which result in equality between price and marginal cost, either because of a budget constraint, or because the maximum social welfare is reached when price is higher than public marginal cost.

Since previous articles on mixed oligopoly did not include foreign private firms, Fjell and Pal (1996) consider a mixed oligopoly model in which a state-owned public firm competes with both domestic and foreign private firms. The effect on the equilibrium involves a lower price and a different allocation of production. They also discuss issues such as the effects of an open door policy allowing foreign firms to enter and the effects of foreign acquisition of domestic firms.

White (1996) examines the use of output subsidies in the presence of a mixed oligopoly. He finds that if subsidies are used in a simultaneous-moves oligopoly and the industry is subsequently privatized, there is a reduction in social welfare. Moreover, both in the private oligopoly and in the mixed oligopoly, the optimal output subsidy is identical.

Poyago-Theotoky (2001) provide a much stronger "irrelevance" result with respect to firms' moves and market structure in the presence of output subsidization. In addition to a private oligopoly and a mixed oligopoly where all firms make their output decisions simultaneously, they consider the case of the public firms acting as a Stackelberg leader. They show that the optimal output subsidy is identical and profits, output and social welfare are also identical irrespective of whether (i) the public firm moves simultaneously with the private firms or (ii) the public firm acts as Stackelberg leader or (iii) all firms behave as profit-maximizers.

De Fraja (2009) argues that whether a taxpayer financed subsidy to some suppliers (typically the public ones) is tantamount to "unfair" competition should be assessed with the understanding of the nature of the objective function of the providers: behavior which would be deemed anti-competitive for a profit maximizing oligopolist, may be in line with the objective function of a public, welfare-maximizing supplier. On the other hand, where the presence of public suppliers bestows a positive externality on the private suppliers, then a taxpayer financed subsidy distributed asymmetrically to the players in the sector according to their ownership may benefit all suppliers, private and public alike.

In Lutz and Pezzino's (2010) setting, a private and a public firm face fixed quality-dependent costs of production and compete first in quality and then either in prices or in quantities. In the long run the public firm targets welfare maximization whereas the private firm maximizes profits. In the short run both firms compete in prices or quantities to maximize profits. They conclude that mixed competition is always socially desirable compared to a private duopoly regardless of the type of competition in the short run and the equilibrium quality ranking. In addition, mixed competition seems to be a more efficient regulatory instrument than the adoption of a minimum quality standard.

Bennett and La Manna (2012) also consider a mixed oligopoly with free entry by private firms, assuming that a public firm maximizes an increasing function of output, subject to a break-even constraint. An irrelevance result is obtained: whenever a mixed oligopoly is viable, then aggregate output, aggregate costs and welfare are the same with and without the public firm. However, replacing a viable mixed oligopoly with a public monopoly yields higher net welfare.

Haraguchi and Matsumura (2016) revisit the classic discussion comparing price and quantity competition, but in a mixed oligopoly in which one state-owned public firm competes against private firms. It has been shown that in a mixed duopoly, price competition yields a larger profit for the private firm. They adopt a standard differentiated oligopoly with a linear demand and find that regardless of the number of firms, price competition yields higher welfare, however, the profit ranking depends on the number of private firms. They also endogenize the price-quantity choice and find that Bertrand competition can fail to be an equilibrium, unless there is only one private firm.

A related literature is that on the objectives of state-owned firms. Ghandi and Lin (2012) model the dynamically optimal oil production on Iran's offshore Soroosh and Nowrooz fields, which have been developed by Shell Exploration through a buy-back service contract. In particular, they examine the National Iranian Oil Company's (NIOC) actual and contractual oil production behavior and compare it to the production profile that would have been optimal under the conditions of the contract. They find that the contract's production profile is different from optimal production profile for most discount rates, and that the NIOC's actual behavior is inefficient- its production rates have not maximized profits. Because the NIOC's objective is purported to be maximizing cumulative production instead of the present discounted value of the entire stream of profits, they also compare the NIOC's behavior to the production profile that would maximize cumulative production. They find that even though what the contract dictates comes close to maximizing cumulative production, the NIOC has not been achieving its own objective of maximizing cumulative production.

4. Econometric Model

4.1. Demand

Our structural econometric model improves upon conventional econometric analysis using traditional logit models. A traditional logit model of vehicle demand assumes the independence of irrelevant alternatives, and can therefore generate unrealistic substitution patterns. In a logit model, if you take away a car model from the choice set, then consumers of that car will buy other cars according to their market shares. However, in reality, if you remove, say, a luxury car, the consumers of that luxury car are probably more likely to buy another luxury car than a random consumer would, even if luxury cars have low market share.

In contrast, the random coefficients demand model of vehicle demand we use addresses this problem by allowing for interactions between unobserved consumer characteristics and observed product characteristics, thus allowing different consumers to vary in how much they like different car characteristics.

Our research builds on the work of Berry, Levinsohn and Pakes (1995), who develop a model for empirically analyzing demand and supply in differentiated products markets and then apply these techniques to analyze the equilibrium in the U.S. automobile industry. Their framework enables one to obtain estimates of demand and cost parameters for a class of oligopolistic differentiated products markets. Unlike traditional logit demand models, their random coefficients model allows for interactions between consumer and product characteristics, thus generating reasonable substitution patterns. Estimates from their framework can be obtained using only widely available product-level and aggregate consumer-level data, and they are consistent with a structural model of equilibrium in an oligopolistic industry. They apply their techniques to the U.S. automobile market, and obtain cost and demand parameters for (essentially) all models marketed over a twenty-year period. On the cost side, they estimate cost as a function of product characteristics. On the demand side, they estimate own- and cross-price elasticities as well as elasticities of demand with respect to vehicle attributes (such as weight or fuel efficiency).

Our research innovates upon the Berry et al. (1995) work by developing a model of the Chinese automobile market; by including alternative vehicles so that in addition to cost and demand parameters relating to gasoline-fueled vehicles, cost and demand parameters relating to alternative vehicles can be estimated; and by modeling the behavior of not only private automobile companies but also the state-owned automobile companies in China.

Let $x_j = \{x_{jk}\}_k$ denote a vector of observable vehicle characteristics *k* for vehicle model $j \in \{1,...,J\}$, ξ_j denote a vector of unobservable vehicle characteristics for vehicle model *j*, p_j denote the price of vehicle model *j*, β_k denote the mean taste parameter for vehicle characteristic *k*, ζ_{ik} denote a characteristic of consumer *i* that affects *i's* taste for vehicle characteristic *k*, and y_i denote consumer *i*'s income. The random coefficients specification for the utility of consumer *i* for vehicle model *j* is given by:

$$u_{ij} = \delta_j + \nu_{ij},$$

where δ_j is the common component of the utility for vehicle model *j* and is given by:

$$\delta_j = x_j \beta - \alpha p_j + \xi_j,$$

and where the first two terms in the idiosyncratic component ν_{ij} interact consumer and product characteristics:

$$\nu_{ij} = \sum_k x_{jk} \sigma_k \zeta_{ik} - \frac{1}{y_i} p_j + \varepsilon_{ij} ,$$

where ε_{ij} is distributed type I extreme value. We assume ζ_{ik} has a standard normal distribution so that the mean and variance of the marginal utilities associated with characteristic *k* are β_k and $\sigma_k^{\ 2}$, respectively. We assume income y_i is log normally distributed.

In addition to income, consumer unobservable that our model accounts for that may affect their preferences for car characteristics include age, education, gender, family size, occupation, commute distance, risk aversion, whether they like to be environmentally friendly, whether they like fast cars, whether they like safe cars, whether they like large cars, whether they live in a rural or urban area, whether they drive to remote outdoor areas (where a rugged truck/SUV might be preferred), local protectionism, local car dealers, local promotions, what types of cars their neighbors purchase, and anything else that may affect how much they like different car characteristics.

We normalize the deterministic components of the utility for the outside option $j=0$ of not purchasing a vehicle to 0, so that utility of consumer *i* for the outside option $j=0$ is given by:

$$u_{i0} = \varepsilon_{i0},$$

where ε_{i0} is distributed type I extreme value.

The share s_j of consumers who purchase vehicle model *j* is therefore given by:

$$s_j = E\left[\frac{\exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right)}{1+\sum_{j'=1}^{J}\exp\left(\delta_{j'} + \sum_k x_{j'k}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_{j'}\right)}\right],$$

where the expectation is taken over the distribution of the individual characteristics ζ_{ik} and income y_i.

Traditional logit and probit models commonly assume that there are no terms in the idiosyncratic component ν_{ij} that interact consumer and product characteristics (i.e., $\nu_{ij} = \varepsilon_{ij}$) and therefore that the variation in consumer tastes enters only through the additive error term ε_{ij}, which is assumed to be identically and independently distributed across consumers and choices. However, this strong assumption places very strong restrictions on the pattern of cross-price elasticities from the estimated model. All properties of market demand, including market shares and elasticities, are determined solely by the common component of utility δ_j. In the automobile market, for example, this property implies that any pair of cars with the same pair of market shares will have the same cross-price elasticity with any given third product.

In contrast, in a random coefficients demand model, owing to the interaction between consumer preferences and product characteristics in ν_{ij}, consumers who have a preference for size will tend to attach a high utility to all large cars, and this will induce large substitution effects between large cars.

The estimation equation on the demand side is the calculated common component of utility δ_j, which is given by the inverse market share function:

$$\delta_j(s_j) = x_j\beta - \alpha p_j + \xi_j,$$

where s_j is the share of consumers who purchase vehicle model *j*. To derive the inverse market share function $\delta_j(s_j)$, we first compute the expected market share function as a function of the common components of utility δ_j, where the expectation is taken over the distribution of consumer characteristics, and then invert the expected market share function to derive the common component of utility δ_j as a function of market share s_j via a contracting mapping algorithm. Following Li (2015), we employ Newton's method to increase the speed of convergence.

4.2. Supply

On the supply side, we make innovate upon the literature by allowing state-owned automobile companies to have different objectives from private automobile companies.

We assume a Bertrand (Nash-in-prices) equilibrium among multiproduct firms.

We assume private firms have as their objective that of maximizing profits. Their objective function is therefore profits $\pi(\cdot)$, which are given by:

$$\pi(\cdot) = \sum_{j \in J_f} (p_j - c_j(\cdot)) M s_j(\cdot),$$

where M is the total number of consumers and c_j is the marginal cost for vehicle *j*.

The estimation equation on the supply side for private firms is given by the following pricing equation for vehicle *j*:

$$p - \Delta^{-1} s = c,$$

where *p* is a vector of vehicle prices, one for each vehicle *j*; Δ is a matrix in which $\Delta_{jk} = -\frac{\partial s_k}{\partial p_j}$ if *j* and *k* are produced by the same firm and $\Delta_{jk} = 0$ otherwise; *s* is the vector of vehicle market shares; and *c* is the vector of vehicle marginal costs.

Unlike private firms, state-owned firms may have objectives other than profit maximization alone. We assume the objective function (utility function) for state-owned firms is given by the following weighted sum of profits $\pi(\cdot)$, consumer surplus $CS(\cdot)$, the squared difference $TAR(\cdot)$ between the number of alternative vehicles produced by that firm and a target number of alternative vehicles, and $ALT(\cdot)$ is the number of alternative vehicles produced by that firm:

$$U(\cdot) = \rho_1 \pi(\cdot) + \rho_2 CS(\cdot) + \rho_3 TAR(\cdot) + \left(1 - \rho_1 - \rho_2 - \rho_3\right) ALT(\cdot).$$

Consumer surplus $CS(\cdot)$ is the sum over the utilities of all the consumers in the market in that year, assuming each consumer chooses the one good *j* (which may be the outside option of not buying a car) that maximizes his/her utility:

$$\begin{aligned} CS(\cdot) &= M \cdot E_{y_i}\left[\ln\left(\sum_j \exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right)\right)\right] \\ &= M\int \ln\left(\sum_j \exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right)\right) f(y_i)dy_i \end{aligned}$$

The expectation is taken over the distribution of income y_i. In other words, consumer surplus is defined as:

$$CS(\cdot) = \sum_i \max_j u_{ij} = M \cdot E_{y_i}\left[E_\varepsilon[\max_j u_{ij}]\right]$$

The utility consumer i gets from vehicle j is given by:

$$u_{ij} = \delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j + \varepsilon_{ij}$$

When ε_{ij} is i.i.d. extreme value, then the expected utility consumer *i* gets from choose the one good *j* that maximizes her/her utility is:

$$E_\varepsilon\left[\max_j u_{ij}\right] = \ln\left(\sum_j \exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right) + 1\right)$$

where the outside good is included as exp(0)=1.

Thus,

$$CS(\cdot) = M \cdot E_{y_i}\left[\ln\left(\sum_j \exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right) + 1\right)\right].$$

$TAR(\cdot)$ is the squared difference between the number of alternative vehicles produced by that firm and a target number of alternative vehicles:

$$TAR(\cdot) = \left(\left(\sum_{j\in J_f;\, j\in hybrid} q_j\right) - \underline{h}\right)^2 = \left(\left(\sum_{j\in J_f;\, j\in hybrid} Ms_j\right) - \underline{h}\right)^2,$$

where the alternative vehicles target is $\underline{h}$, which we assume is the same for all the state-owned firms for now.

$ALT(\cdot)$ is the number of alternative vehicles produced by that firm:

$$ALT(\cdot) = \sum_{j\in J_f;\, j\in alt} q_j = \sum_{j\in J_f;\, j\in alt} Ms_j$$

The ρ's are weights put on each of the possible terms in the state-owned company's utility function.

Thus, the pricing equation for the state-owned firms is given by:

$$p - (\Delta)^{-1}\left[s - \frac{\rho_2}{\rho_1}e + \frac{1}{\rho_1}\left((2\rho_3\cdot(M\sum_l s_l) - \underline{h}) + (1-\rho_1-\rho_2-\rho_3)\right)\Delta^l\cdot 1_n\right] = c,$$

where Δ is defined the same as before; Δ^l is a matrix in which $\Delta^l{}_{jl} = \dfrac{\partial s_l}{\partial p_j}$ if $l\in J_f \wedge l\in hybrid$

and Δ_{jl}=0 otherwise; and e is a vector whose j^{th} element is given by:

$$E_{y_i} = \left[\frac{exp\left(\delta_j + \sum_k x_{jk}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j\right)\left(\alpha - \frac{1}{y_i}\right)}{\sum_{j'}\left[exp\left(\delta_{j'} + \sum_k x_{j'k}\sigma_k\zeta_{ik} - \frac{1}{y_i}p_j{}'\right)\right] + 1} \right].$$

For our specification of marginal costs c_j, to examine whether forming joint ventures with international firms would help improve the technology development of the domestic manufacturers, we include interactions between a "Has international joint venture" (HIJV) dummy with some of the technology-related car characteristics in our specification for marginal cost c_j. The HIJV dummy equals 1 if the Chinese car company forms a joint venture with any international car company and 0 otherwise. The technology-related car characteristics we chosen are: "the dummy for the car j being alternative vehicle", "fuel efficiency" and "horsepower".

Furthermore, to examine whether forming a joint venture with international companies located in different countries will have different effects on helping domestic firms' technology improvement, we also include interactions between an "international joint venture country" (IJVC) dummy and technology-related vehicle characteristics in our specification for marginal cost c_j. The IJVC dummy is equal to 1 if the Chinese car company forms a joint venture with an international car company headquartered in the country and 0 otherwise. There are six international joint venture countries: Japan, Germany, Britain, US, South Korea, Sweden, France and Italy. The technology-related characteristics chosen are "the dummy for the car *j* being alternative vehicle", "fuel efficiency" and "horsepower".

In 2012, the Corporate Average Fuel Consumption (CAFC) target went into effect, which might affect firms' competing strategies. We want to see if a firm that is required to meet the

CAFC target experiences a higher marginal cost from producing a car with worse fuel economy than the target corporate average. We therefore include three fuel economy interaction terms $fuel_{interaction}$ in the marginal cost c_j. The first term is the dummy variable for Phase 3 CAFC standard. The second is phase 3 national fuel economy standard limit less fuel efficiency and the last one is the interaction term between phase 3 fuel economy CAFC dummy and the difference between the phase 3 CAFC standard and fuel efficiency.

Marginal cost c_j for car *j* is therefore given by:

$$c_j = x_j\gamma + w\Gamma + \eta q_j + tech_{int} \cdot \psi_1 + techIJVC_{int} \cdot \psi_2 + fuel_{int} \cdot \psi_3 + \omega_j$$

where w is a joint venture dummy vector, for which the f^{th} element equals one if the maker that produces good j forms a joint venture with company f; $tech_{int}$ are the HIJV interaction terms, including the HIJV dummy interacted with the alternative vehicle dummy, fuel efficiency, and horsepower; $techIJVC_{int}$ are the three technology-related characteristics interacting with each of the IJVC dummies; $fuel_{int}$ are the fuel economy policy interaction terms; and ω_j are the unobservable cost variables.

4.3.Econometric Estimation

The parameters to be estimated include the means β of the marginal utility associated with each particular characteristic, the parameter α in the marginal disutility of price, the cost parameters γ, the coefficient Γ associated with joint venture companies, the coefficient η on quantity in marginal cost, the standard deviations σ of the marginal utility associated with each particular characteristic, the ρ's for the weights on different objective terms of state-owned firms and $\underline{h}$ for target number of alternative vehicle production, and finally the ψ_1 on the international joint venture dummy interaction terms, ψ_2 on the international joint venture country interaction terms, and ψ_3 on fuel economy interaction terms in marginal cost.

Because the observed equilibrium prices and quantities are simultaneously determined in the supply-and-demand system, instrumental variables are needed to address the endogeneity problem (Goldberger, 1991; Manski, 1995; Angrist et al., 2000; Lin, 2011). Since price and the market share variables are endogenous in demand and supply, we use instruments for the endogenous price and market share variables.

The instrumental variables we use in our estimation build on the work of Berry et al. (1995). We construct two different types of instrumental variables based on each car characteristic: the number of cars with similar values of the characteristic, and the value of the characteristic for the car *k* closest to car *j* in the value of the characteristic. More specifically, for each characteristic r, the first instrumental variable we create is the number of cars that has similar value of attribute r to car j. Two cars *j* and *k* are "similar" in characteristic r if the squared difference in their values of that characteristic is less than or equal to one tenth of the squared difference between the maximum and minimum values of that characteristic among all cars: $(x_{jr} - x_{kr})^2 \leq \frac{1}{10}\left(\max(x_r) - \min(x_r)\right)^2$. For the car capacity in terms of number of seats, we use a cutoff value of 2 instead of $\frac{1}{10}\left(\max(x_r) - \min(x_r)\right)^2$. A second instrumental variable we create for each characteristic r is the value of characteristic *r* for the car *k* closest to car *j* in the value of the characteristic.

The number of cars with similar values of the characteristic, and the value of the characteristic for the car k closest to car j in the value of the characteristic are good instruments for price in the demand equation because characteristics of other cars k of other firms are independent of the utility for a particular car j, and because they are correlated with price via the markup in the supply-side first-order conditions. Characteristics of other cars k of other firms also serve as good instruments for the market share of car j in the supply-side pricing equation.

We compute the demand-side unobservable ξ as the residual in the common component of the demand-side utility estimation equation. We compute the cost-side unobservable ω as the residual in the supply-side marginal cost estimation equation, where the marginal cost is given by the pricing equation. We then interact the instruments with the computed demand- and cost-side unobservables to form the moment conditions.

The demand and supply side equations are jointly estimated using instruments for the endogenous price and market share variables via generalized method of moments. One challenge is determining whether the model has converged at a global or local minimum (Knittel and Metaxoglou, 2014). We experimented with several combinations of starting values to initialize the parameters to be estimated in order to find the set of parameters that minimized the weighted sum of squared moments.

Standard errors are formed by a nonparametric bootstrap. Model-displacement-style-years are randomly drawn from the data set with replacement to generate 100 independent pseudo-samples of size equal to the actual sample size. The structural econometric model is run on each of the new pseudo-samples. The standard error is then formed by taking the standard deviation of the estimates from each of the random samples.

5. Data

The annual data set we have collected includes all the models marketed from the year 2004 to year 2013 in the Chinese automobile industry. Within each model, we have collected information of price and quantity sales of each displacement of that model. Furthermore, for each model displacement, we also gathered information on vehicles characteristics for each style within that model. Since models both appear and exit over the entire time period, we have an unbalanced panel. We treat each style of a model-displacement-year as a single observation. Throughout the paper, each model-displacement-style-year is treated as different observations as long as they differ in any vehicle characteristics.

The quantity sales data from year 2004 to year 2013 of each model displacement was collected from the *China Auto Market Almanac*, which includes the quantity sales of all vehicles sold by car manufactures in China, both indigenous firms and joint ventures. We have collected two sets of price data, both in units of 10,000 RMB. The first price variable was collected from *China Automotive Industry Year book* for each model displacement. The other price variable was grabbed from *www.autohome.com.cn*, which is one of the largest vehicle websites in China. (Other famous and widely used car websites are: *http://auto.sohu.com*, *http://auto.163.com*, *http://auto.sina.com.cn*, *http://auto.qq.com*). The price is listed as nominal manufacturer's suggested retail price (MSRP). It is better to get real transaction price. However, that is usually not easy to find.

After merging the price and quantity sales from the three sources mentioned above, our data set consists of 1601 model-displacement-year observations, representing 531 model displacements. The information about vehicle characteristics was obtained from *www.autohome.com.cn.* For more information about the vehicle characteristics in our data set, see Chen, Lin Lawell and Wang (2017).

One unique feature of the Chinese automobile industry is that some of the car manufacturers are state owned. Among the 64 car makers in our sample, 49 of them are state owned. As long as the name of the car manufacturers are different in *www.autohome.com.cn*, we treated those manufacturers as different makers. Since the majority of car companies in China are operated under shareholding system, there are few car companies that are 100% state owned. However, governments do hold a majority of the stocks of some of the companies. Throughout the paper, a stated owned firm is defined as a car manufacturer for which a majority of stock of its parent company (greater than 50%) is held by governments (either central government or local government), although some of its stock might be held by foreign companies, including those with which the firm forms an international joint venture. Information about the ownership of the car companies are referred from *baike.baidu.com* which is used to track back their parent companies, and from *China Industry Business Performance Data of year 2013* as well.

In addition, we have collected data on the adult population (age 15-64) from year 2000 to 2014 from *World Development Indicators* to proxy the automobile market size. Information about urban income across all provinces of year 2010 to 2013 are gathered from *China Statistical Year Book*.

Table 1 presents summary statistics of the vehicle characteristics we have chosen to focus on in our structural econometric model: fuel efficiency, length, weight, passenger capacity (in terms of the number of seats), and horsepower. Unlike in the U.S., where the measurement of fuel efficiency is mileage per gallon, China uses a fuel consumption measurement of liters per 100 kilometers to evaluate the energy density (the smaller the value is, the better in terms of energy efficiency). Therefore, we use a reciprocal of that measurement, which is 100 kilometers per liter of gas to evaluate energy intensity. The mean is 0.131 100km/L, with a standard deviation of 0.02, minimum of 0.752 100km/L and maximum of 0.233 100km/L. The average length is 4456.209 mm, with a minimum of 3400 mm and maximum of 6870 mm. Its standard deviation is 359.680. The average weight is 1345.930 kg, the median is 1324 kg, 95% of the vehicles in our sample has a weight below 1800 kg. The average passenger capacity is 5 seats. The minimum is 2 seats and maximum is 5 seats. Average horsepower is 130.226 PS, and the minimum and maximum are 970 PS and 4700 PS, respectively.

Regarding alternative fuel vehicles, there are 28 model-displacement-style-year observations in our data set that are powered by alternative fuel sources. These alternative fuel vehicles include hybrid cars powered on both gasoline and electricity, purely electric cars, plug in hybrid cars, and extended range electric vehicles. Of these, 21 model-displacement-style-years were produced after 2010. In the year 2010, the Chinese government established a project called "Energy Saving Projects", using a fiscal subsidy to encourage energy saving. Some autos with small displacement (less than 1.6L) will receive a subsidy (directly to the car makers) such that the market price is the price after subsidized. We will evaluate the effects of this policy on supply and demand. It is possible that this policy encourages the production of vehicles with small displacement.

6. Results

6.1. Parameter estimates

The results of structural econometric model of supply and demand are reported in Table 3. Specifications (2) and (3) include dummies for having international joint venture with a particular country interacted with technology-related vehicle characteristics; Specification (3) also includes dummies for having international joint venture with a particular car company from US and Japan interacted with technology-related vehicle characteristics

We discuss the results on the demand side first. In Specification (1) the means and standard deviations of the marginal utilities of all the chosen car characteristics are positive and significant. In Specification (2), the standard deviations of the marginal utility of all the chosen vehicle characteristics except length are positive and significant. The mean of the marginal utility of capacity is significant and negative, and its standard deviation is significant and positive, which suggests that on average people might prefer a smaller car but there is a distribution of consumers' preferences over car capacity. The marginal disutility of price is a little higher in Specification (2) than that in Specification (1). The means and standard deviations of the marginal utilities of all the chosen car characteristics in Specification (3) are quite similar to those in Specification (2), except that the standard deviation of the marginal utility of length, which was insignificant in Specification (2), becomes significant in Specification (3).

On the cost side, all the coefficients in the marginal cost on the chosen car characteristics are positive and significant in both Specifications (1) and (2). The coefficient on quantity is smaller in (2) than that in (1). The coefficients on joint ventures with various international car companies have different signs in (1) and (2), indicating that forming joint ventures with international car companies have mixed effects on the marginal cost. All of the coefficients on international joint venture and technology interactions are negatively significant in Specification (1). However, one interesting finding is that the coefficient on the interaction between having a joint venture and the dummy for whether or not the car is an alternative car is negative and significant in Specification (2). As mentioned earlier, in Specification (2) we add in the terms that interact the country dummy where the headquarters of the international car company forming joint ventures with particular Chinese car companies are located with the technology related variables. For both the U.S. and Japan, the coefficients on these interaction terms are all negative and significant in both Specifications (2) and (3), which suggests that forming joint ventures with car companies from these two countries will help decrease the marginal cost of technology-related vehicle characteristics on net, especially the cost of making an alternative car. On the other hand, forming joint ventures from other counties will actually increase the cost of technology-related car characteristics on net. The coefficients on fuel economy policy variables are quite similar in these three specifications. They are all positive and significant. That implies the established fuel economy policy would increase the marginal cost.

Finally, in terms of the weights put on different terms in state-owned firms utility, results in both (1) and (2) suggest that the majority of the weight is put on profit, with some weight put on consumer surplus, and a little bit weight put on squared deviation from target number of alternative vehicles. However, in Specification (3), the weight on squared deviation from target number of alternative vehicles are not significicant. For all of the three specifications, the target number of alternative vehicles are estimated to be 150.

In Specification (2) and (3), we discover that the coefficients on the interactions between the dummies for forming international joint ventures with car companies from the U.S. and Japan and the technology-related variables are all negative. We want to examine in detail the effects of the international car companies in these two countries on the marginal costs of the technology-related vehicle features. Thus in Specification (3), we add interactions between dummies for international joint ventures with each U.S. and Japan car company interacted with the technology-related car characteristics.

We examine the net effects of forming joint ventures with each U.S. and Japan company on the marginal cost of each of the three chosen technology-related vehicle characteristics. The net effects and their corresponding standard errors are summarized in Table 4. There are three notable patterns in the results. First, all the net effects are negative, which means that forming joint ventures with car companies in the US and Japan decreases the marginal cost of technology-related vehicle characteristics on net. Second, for fuel efficiency, the net effects appear more negative for Japanese firms than for US firms, which suggests that joint ventures with Japanese firms may decrease the marginal costs of fuel efficiency more than joint ventures with US firms. Third, for horsepower, the opposite appears to be the case: in general, with the exception of Honda, the net effects appear more negative for US firms than for Japanese firms, which suggests that joint ventures with US firms may decrease the marginal costs of horsepower more than joint ventures with Japanese firms. These results may reflect a possible relative preference for horsepower in the US, and a possible relative preference for fuel efficiency in Japan.

6.2. Welfare

In Table 5, we present the welfare statistics calculated using the parameter estimates from Specification (2) of Table 3 and actual data on prices, market shares, and vehicle characteristics. The welfare statistics we calculate include consumer surplus; total firm profits for private firms; average firm profits for private firms; total firm utility for state-owned firms, average firm utility for state-owned firms. Our welfare calculations show that although the total utility of state-owned firms has been increasing since 2010, the average utility of state-owned firms decreases in 2012 and climbs back in 2013.

To assess how well our model does in predicting the actual data, we calculate actual and simulated statistics for costs and welfare for the base case in year 2013 using the parameter estimates from Specification (2) of Table 3. The cost statistics we calculate include: average costs of alternative vehicles; average costs for each quartile of fuel efficiency; average costs for all cars. The welfare statistics we calculate include: consumer surplus; total firm profits for private firms; average firm profits for private firms; total firm utility for state-owned firms, average firm utility for state-owned firms.

The actual statistics are calculated using actual data prices, market shares, and vehicle characteristics for year 2013. The simulated statistics for the base case are calculated by solving for a fixed point, since market shares are a function of price and prices are a function of market shares. With the simulated market shares and prices and the actual vehicle characteristics, we are able to calculate the costs and welfare. We bootstrap the standard errors.

The actual and simulated statistics for cost are presented in Table 6a; the actual and simulated statistics for welfare are presented in Table 6b. As seen in these tables, our model does a fairly good job simulating the actual data.

6.3. Elasticities

We calculate the own- and cross- price elasticities using the parameter estimates from Specifications (1) and (2) in Table 3. We select 20 different car model displacements including basic passenger vehicles, MPVs, and SUVs. As seen in the own price elasticities in Table 7a, the demand for each of the chosen 20 model displacements are highly elastic. The demand for SUVs and MPVs is more elastic than that for basic passenger vehicles in general, while there are variations within the demand for SUV and MPV themselves. Across both specifications, the absolute value of price elasticities for Honda CR-V 2.4L, Tiguan 1.8, and ix 35 2.0L, which are produced by joint ventures, are much larger than those for basic passenger vehicles and the other SUV H6 1.5T, which is produced by an indigenous car maker. Although the price elasticities for MPVs is in general larger, that of MPV Succe 1.5L is similar in magnitude to those of basic passenger vehicles.

Table 7b summarizes the cross elasticities of the demand of the chosen 20 model-displacement with respect to the price of a selected alternative vehicle model: the Buick E-assist 2.4L. The cross elasticities of all model displacement selected across both specifications are all zero, which suggests that all of the chosen model displacements are not substitutes with Buick E-assist 2.4L.

7. Simulations

One advantage of estimate a structural econometric model is that we can use the estimate parameters to simulate demand, supply, and welfare under counterfactual scenarios. We use the parameters estimated from our structural model to run counterfactual simulations to analyze the effects on demand, cost, and welfare of adding a new alternative vehicle and of different counterfactual government policies.

For each counterfactual scenario, we calculate statistics for market shares, costs, and welfare in 2013. The market shares statistics we calculate include: market shares for each alternative vehicle; total market shares for all alternative vehicles; and market share for each quartile of fuel efficiency. The cost statistics we calculate include: average costs of alternative vehicles; average costs for each quartile of fuel efficiency; average costs for all cars. The welfare statistics we calculate include: consumer surplus; total firm profits for private firms; average firm profits for private firms; total firm utility for state-owned firms, average firm utility for state-owned firms. The simulated statistics are calculated by solving for a fixed point, since market shares are a function of price and prices are a function of market shares. We bootstrap the standard errors.

The first series of counterfactual simulations we run is to simulate the effects of introducing new vehicles, including new alternative vehicles. We define ten different alternative vehicles to be introduced and run the simulation after the introduction of each of these vehicles. For each of the simulated statistics, we conduct a two-sample t-test to compare the statistic from the simulation with the respective statistics from the base-case simulation of the status quo. The results are reported in Table 8.

7.1. New car simulations

In new car simulation 1 in Table 8a, the new car introduced is like the Buick E-assist 2.4L hybrid, but with fuel efficiency 1.25 times more efficient. After introducing the new vehicle, the market share for low fuel efficiency vehicle decreases. And the average costs for each quartile of fuel efficiency increase. The total firm profit for private firms increases, so does the average firm profit for private firms.

In new car simulation 2 in Table 8b, the new car introduced is like the Buick E-assist 2.4L hybridm but with fuel efficiency 1.25 times longer. After introducing the new vehicle, the market share for low fuel efficiency vehicle decreases. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms increases, so does the average firm profit for private firms.

In new car simulation 3 in Table 8c, the new car introduced is like the Buick E-assist 2.4L hybridm but with weight 1.25 times heavier. After introducing the new vehicle, the market share for vehicles with both low and high fuel efficiency decreases. And the average costs for all quartiles of fuel efficiency increase.

In new car simulation 4 in Table 8d, the new car introduced is like the Buick E-assist 2.4L hybrid, but with weight 1.25 times lighter. After introducing the new vehicle, the market share for vehicles with both low and high fuel efficiency decreases. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms and the average firm profit for private firms increase.

In new car simulation 5 in Table 8e, the new car introduced is like the Buick E-assist 2.4L hybrid, but with one more seat. After introducing the new vehicle, the market shares for vehicles in the 1st, 2nd, and 4th quartile decrease. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms and the average firm profit for private firms increase.

In new car simulation 6 in Table 8f, the new car introduced is like the Buick E-assist 2.4L hybrid, but with horsepower 1.25 times higher. After introducing the new vehicle, the market shares for vehicles with lower and higher fuel efficiency decrease. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms and the average firm profit for private firms increase.

In new car simulation 7 in Table 8g, the new car introduced is like the Buick E-assist 2.4L hybrid, but with horsepower 1.25 times lower. After introducing the new vehicle, the market shares for vehicles with lower and higher fuel efficiency decrease. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms and the average firm profit for private firms increase.

In new car simulation 8 in Table 8h, the new car is like the Buick E-assist 2.4L hybrid, but is produced by a private company that does not form international joint ventures, instead of a state-owned company that forms international joint ventures. After introducing the new vehicle, the market shares for vehicles with lower and higher fuel efficiency decrease. And the average costs for all quartiles of fuel efficiency increase.

In new car simulation 9 in Table 8i, the new car introduced is like the Buick E-assist 2.4L hybrid, but firm does not form a joint venture with any international companies. After introducing the new vehicle, the market shares for vehicles with higher fuel efficiency decrease. And the average costs for all quartiles of fuel efficiency increase. The total firm profit for private firms and the average firm profit for private firms increase.

In new car simulation 10 in Table 8j, the new car introduced is like the Buick E-assist 2.4L hybrid, but is produced by a private company that forms joint ventures with international companies. After introducing the new vehicle, the market shares for vehicles with both lower and higher fuel efficiency decrease. And the average costs for all quartiles of fuel efficiency increase.

7.2. Policy simulations

We also simulate the effects of various counterfactual government policies on demand, cost, and welfare. For each of the simulation, we conduct a two-sample t-test to compare the statistic from the simulation with the respective statistics from the base-case simulation of the the status quo. The results are reported in Table 9.

In Table 9a, the new policy we simulated is privation, in which we make all state-owned firms private. The simulated total market share for all vehicles decreases, compared with the base case scenario. The market share for each quartile of fuel efficiency decreases. Average costs of alternative vehicles, so does the average cost for low fuel efficiency. The average costs for high fuel efficiency increase. In terms of welfare, consumer surplus, total firm profit for private firms increases, however average firm profit for private firms decreases when all the firms are private.

In Table 9b, the new policy is to ban all international joint ventures. The simulated total market share for all alternative vehicles increases compared with the base case simulation. All of the market share for each quartile of fuel efficiency decreases. Except for the average costs of vehicles with the median of fuel efficiency, all of the average costs for vehicles of other quartiles of fuel efficiency increases. Consumer surplus decreases, but total firm profit for private firms and average firm profit for private firms increase.

In Table 9c, the new policy is getting rid of the Fuel Economy Phase II or III standards. Under that scenario, the simulated total market share for all alternative vehicles decreases, so does the market share for each quartile of fuel efficiency. The average costs of vehicles with low fuel efficiency decreases and that of vehicles with high fuel efficiency increases. Consumer surplus increases. Total firm profit for private firms and average firm profit for private firms decreases. The total profit for private firms and average firm profit for private firms decreases.

In Table 9d, we simulate the scenario that there were no Corporate Average Fuel Consumption (CAFC). The total market share for all alternative vehicles increases. The market shares for vehicles of all quartile of fuel efficiency decrease. The average cost for vehicles with low fuel efficiency decreases and that of vehicles with high fuel efficiency increases. The average costs for all cars increase. All of the welfare statistics increases including consumer surplus, utility for state-owned firms and profit for private firms.

In Table 9e, we simulate under the new policy scenario that there are no fuel economy standards at all. The total market share for all alternative vehicles increases. The market share for vehicles within each quartile of fuel efficiency decreases. The average costs for vehicles with low fuel efficiency decreases and those for vehicles with high fuel efficiency increase, so does the average costs for all cars. The welfare statistics all get larger.

In Table 9f, the new policy is that the Corporate Average Fuel Consumption (CAFC) standard applies to all cars. Under that scenario, the total market share for each quartile of fuel efficiency decreases compared with the base case simulation. The average costs for vehicles with low fuel efficiency decreases. The average costs for vehicles with high fuel efficiency increase. The consumer surplus increases.

In Table 9g, the new policy is to raise fuel economy Phase II III target by 5%. The simulated total market share for all alternative vehicles decreases, so does the market share for each quartile of fuel efficiency. The average costs for vehicles with low fuel efficiency decrease and those for vehicles with high fuel efficiency increase. The average costs for all cars increase. The total firm profit and average profit for private firms increases. In Table 9h, the fuel economy Phase II III target has been raised by 10%. The total market share for all alternative vehicles and the average costs for all vehicles now become insignificant. And the total and average firm profit for private firms decrease. In Table 9i, the fuel economy Phase II III target has been raised by 15%. The simulated total market share for all alternative vehicles decreases. The total market share for each quartile of fuel efficiency decreases. Same as before, the average costs for vehicles with low fuel efficiency decreases, but those of vehicles with high fuel efficiency increases. However in this policy scenario, consumer surplus increases.

In Table 9j, the new policy we simulate is to raise Corporate Average Fuel Consumption (CAFC) target by 5%. The total market share for all alternative vehicles and the total market share for each quartile of fuel efficiency decreases compared with the base case simulation. The average costs for vehicles with low fuel efficiency decreases and those for vehicles with high fuel efficiency increase. The average costs for all cars decreases. In terms of welfare, consumer surplus increases, and the firm profit for private firms and firm utility for state-owned firms decreases. In Table 9k, the CAFC target is raised by 10%, under which the average costs for all cars becomes insignificant, so does firm utility for state-owned firms. In Table 9l, we simulate the new policy that the CAFC target is raised by 15%. Unlike the previous two scenarios, the total market share for all alternative vehicles becomes positive and all of the welfare statistics including consumer surplus, firm profit and utility increase.

In Table 9m to Table 9o, we simulate the new policies by increasing the target number of alternative vehicles for state-owned firms by 10, 25 and 50 respectively. When the target number of alternative vehicles for state-owned firms was increased by 10, the total market share for all alternative vehicles decreases compared with the base case simulation. The market share for each quartile of fuel efficiency decreases. The average costs for vehicles with low fuel efficiency decreases, and those for vehicles with high fuel efficiency increases. The average costs for all cars decreases. The consumer surplus increases and the total firm and average firm profit for private firms decreases. When the target number of alternative vehicles for state-owned firms has been increased by 25 in Table 9n, unlike the previous scenario, the total market share for all alternative vehicles are greater than the base case simulation. In addition, although the consumer surplus becomes insignificant, the total and average firm profit for private firms and the total and average firm utility for state-owned firms increases. When the target number of alternative vehicles for state-owned firms has been increased by 50 in Table 9o, total market share for all alternative vehicles increases compared with the base case simulation. All of the market share for each quartile of fuel efficiency decreases. The average costs for vehicles with low fuel efficiency decreases and those for vehicles with high fuel efficiency increases. The average costs for all cars increases. The total and average firm profit for private firms and total and average firm utility for state-owned firms increase.

8. Conclusions

According to our results, the standard deviations of the marginal utility of chosen vehicle characteristics are statistically significant in all of the models specified, suggesting that it is important to allow for consumers to vary in how much they like different car characteristics. We also find that state-owned car companies may have different objectives from private car companies. However, although state-owned car companies care about other objectives such as consumer surplus and alternative vehicle production, their primary objective is to make profits.

One unique feature of Chinese automobile industry is that a number of domestic car companies form joint ventures with international car companies. Our results show that the effects of forming joint ventures with international car companies are mixed, with some decreasing the marginal costs and others actually impose costs on production. Our results also show evidence suggesting that forming joint ventures with any of the international car company would help domestic technology improvement in terms of making cars more powerful and fuel efficient. After incorporating the international joint venture country dummy and technology-related variables interactions, we find that forming joint ventures with international car companies located in Japan and US decreases the marginal cost of equipping cars with better technology. However, forming joint ventures in general would not actually help alternative fuel technology improvement.

In analyzing the effect of vehicle fuel economy regulations, we find that both phase III fuel economy standard limits and Corporate Average Fuel Consumption (CAFC) regulation would increase production cost. Moreover, it costs producers more to comply with the CAFC target.

Our research is significant for industry, government, society, academia, and NGOs. Our model of the demand and cost in the Chinese automobile market will be significant for industry, particularly car manufacturers interested in better targeting cars, including alternative vehicles, for the Chinese market. Our estimates of the factors that affect demand and supply in the Chinese automobile market is significant for policy-makers interested in developing incentive policies to increase market penetration of alternative vehicles with potential environmental and climate benefits.

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Table 1. Summary statistics, 2010-2013

Variable	# Obs	Mean	Std. Dev.	Min	Max
Price (1,000 Yuan)	2215	158.401	119.8673	28.800	899.600
Quantity	2215	51,986.65	53,832.95	1	263,410
Alternative vehicle (dummy)	2215	0.030	0.171	0.000	1.000
Fuel efficiency (100km/L)	2215	0.134	0.021	0.078	0.233
Length (mm)	2215	4500.094	319.829	3400.000	5175.000
Weight (kg)	2215	1373.050	235.891	815.000	2310.000
Capacity (number of seats)	2215	5.093	0.432	4.000	7.000
Horsepower (PS)	2215	137.327	41.225	46.000	310.000

Table 2a. First-stage F-statistics: Fuel economy standard model with "has international joint venture dummy" interactions

Endogenous variables	Instruments Chosen	First-Stage F-Statistic
Alternative Fuel Vehicle	Number of cars with similar values of: - Fuel efficiency - Length	7.63
Fuel Efficiency	- Weight - Capacity - Horsepower	220.86
Length	Value for the closest car of: - Fuel efficiency - Length	226.95
Weight	- Weight - Horsepower	1105.38
Capacity	Value for the closest car with a different model-year-displacement of: - Fuel efficiency - Weight	1129.10
Horsepower	Fraction of other cars that year that are alternative vehicles	394.14
Price	Has international joint venture dummy interacted with: - Fraction of other cars that year that are alternative vehicles - Number of cars with similar values of fuel efficiency - Number of cars with similar values of horsepower	258.88
Quantity	Difference between fuel economy target and the number of cars with similar values of fuel efficiency Different between Corporate Average Fuel Consumption (CAFC) target and the number of cars with similar values of fuel efficiency, interacted with dummy for being required to meet CAFC target	13.33

Table 2b. First-stage F-statistics: Fuel economy standard model with "international joint venture country" dummy interactions

<table>
<tr><th>Endogenous variables</th><th>Instruments Chosen</th><th>First-Stage F-Statistic</th></tr>
<tr><td>Alternative Fuel Vehicle</td><td rowspan="8">Number of cars with similar values of:
- Fuel efficiency
- Length
- Weight
- Capacity
- Horsepower

Value for the closest car of:
- Fuel efficiency
- Length
- Weight
- Horsepower

Value for the closest car with a different model-year-displacement of:
- Fuel efficiency
- Length
- Weight

Fraction of other cars that year that are alternative vehicles

Has international joint venture dummy interacted with:
- Fraction of other cars that year that are alternative vehicles
- Number of cars with similar values of fuel efficiency
- Number of cars with similar values of horsepower

Dummy for joint venture with company in:
- Japan
- Germany
- Great Britain
- U.S.
- South Korea
- Sweden
- France
- Italy
interacted with:
- Fraction of other cars that year that are alternative vehicles</td><td>10.11</td></tr>
<tr><td>Fuel Efficiency</td><td>24.39</td></tr>
<tr><td>Length</td><td>46.36</td></tr>
<tr><td>Weight</td><td>39.77</td></tr>
<tr><td>Capacity</td><td>474.88</td></tr>
<tr><td>Horsepower</td><td>56.09</td></tr>
<tr><td>Price</td><td>47.90</td></tr>
<tr><td>Quantity</td><td>8.12</td></tr>
</table>

- Number of cars with similar values of fuel efficiency
- Number of cars with similar values of horsepower

Difference between fuel economy target and the number of cars with similar values of fuel efficiency

Different between Corporate Average Fuel Consumption (CAFC) target and the number of cars with similar values of fuel efficiency, interacted with dummy for being required to meet CAFC target

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Table 3. Results of structural econometric model of supply and demand, 2010-2013

	(1)	(2)	(3)
Mean β of marginal utility of:			
Alternative vehicle (dummy)	0.210***	0.106***	0.106***
	(0.006)	(0.001)	(0.012)
Fuel efficiency (100km/L)	0.211***	0.235***	0.235***
	(0.007)	(0.002)	(0.003)
Length (m)	0.017***	0.294***	0.294***
	(0.002)	(0.004)	(0.006)
Weight (metric ton)	0.220***	0.281***	0.281***
	(0.001)	(0.001)	(0.002)
Capacity (number of seats)	0.005***	-0.133***	-0.133***
	(0.001)	(0.002)	(0.004)
Horsepower (PS)	0.070***	0.168***	0.168***
	(0.003)	(0.005)	(0.009)
Constant	0.118***	0.333***	0.333***
	(0.003)	(0.000)	(0.003)
Standard deviation σ of marginal utility of:			
Alternative vehicle (dummy)	0.107***	0.163***	0.163***
	(0.006)	(0.003)	(0.002)
Fuel efficiency (100km/L)	0.133***	0.112***	0.112***
	(0.000)	(0.001)	(0.004)
Length (m)	0.078***	-0.009	-0.009**
	(0.004)	(0.007)	(0.003)
Weight (metric ton)	0.187***	0.347***	0.347***
	(0.002)	(0.004)	(0.005)
Capacity (number of seats)	0.065***	0.105***	0.105***
	(0.002)	(0.000)	(0.007)
Horsepower (0.01PS)	0.046***	0.029***	0.029***
	(0.007)	(0.001)	(0.008)
Constant	0.207***	0.210***	0.210***
	(0.001)	(0.002)	(0.004)
Parameter α in marginal disutility of price (1,000 Yuan)	0.348***	0.420***	0.420***
	(0.001)	(0.000)	(0.000)

Coefficient γ in marginal cost on:			
Alternative vehicle (dummy)	0.241***	0.139***	0.139***
	(0.008)	(0.003)	(0.002)
Fuel efficiency (100km/L)	0.093***	0.060***	0.060***
	(0.007)	(0.000)	(0.005)
Length (m)	0.113***	0.126***	0.126***
	(0.004)	(0.003)	(0.010)
Weight (metric ton)	0.121***	0.101***	0.101***
	(0.005)	(0.003)	(0.004)
Capacity (number of seats)	0.230***	0.156***	0.156***
	(0.006)	(0.002)	(0.003)
Horsepower (0.01PS)	0.157***	0.113***	0.113***
	(0.003)	(0.003)	(0.010)
State-owned (dummy)	0.177***	0.111***	0.111***
	(0.002)	(0.005)	(0.002)
Constant	0.191***	0.245***	0.245***
	(0.002)	(0.006)	(0.003)
Coefficient η on quantity in marginal cost	0.014***	0.007***	0.007***
	(0.001)	(0.000)	(0.001)
Coefficient Γ in marginal cost on joint venture with:			
Mazda	0.105***	0.158***	0.158***
	(0.005)	(0.000)	(0.003)
Honda	-0.085***	-0.064***	-0.064***
	(0.002)	(0.006)	(0.003)
Kaihatsu	0.181***	0.054***	0.054***
	(0.003)	(0.004)	(0.001)
Toyota	0.134***	0.219***	0.219***
	(0.001)	(0.004)	(0.007)
Suzuki	0.012***	-0.028***	-0.028**
	(0.001)	(0.005)	(0.010)
Nissan	0.029***	0.033***	0.033***
	(0.001)	(0.000)	(0.002)
Mitsubishi	0.012***	0.185***	0.185***
	(0.001)	(0.000)	(0.001)

Isuzu	-0.092***	-0.110***	-0.110***
	(0.003)	(0.007)	(0.007)
Daimler	-0.237***	-0.224***	-0.224***
	(0.003)	(0.002)	(0.003)
BMW	-0.081***	-0.059***	-0.059***
	(0.004)	(0.001)	(0.004)
Volkswagen	0.033***	0.035***	0.035***
	(0.001)	(0.000)	(0.006)
Audi	0.151***	0.092***	0.092***
	(0.004)	(0.007)	(0.004)
Lotus	-0.245***	-0.253***	-0.253***
	(0.002)	(0.004)	(0.005)
GM	-0.225***	-0.189***	-0.189***
	(0.001)	(0.005)	(0.006)
Ford	-0.051***	0.029***	0.029***
	(0.010)	(0.003)	(0.005)
Chrysler	-0.037***	-0.135***	-0.135***
	(0.008)	(0.006)	(0.005)
Hyundai	-0.024***	0.003	0.003
	(0.001)	(0.008)	(0.006)
Kia	-0.159***	-0.115***	-0.115***
	(0.004)	(0.001)	(0.011)
Volvo	0.025***	0.134***	0.134***
	(0.001)	(0.001)	(0.005)
Saab	0.122***	0.193***	0.193***
	(0.001)	(0.001)	(0.005)
PSA	-0.219***	-0.31***	-0.31***
	(0.001)	(0.001)	(0.000)
Fiat	-0.149***	-0.382***	-0.382***
	(0.006)	(0.000)	(0.004)
Coefficient in marginal cost on international joint venture-technology interactions:			
Has international joint venture * alternative vehicle	-0.070***	0.144***	0.144***
	（0.000）	(0.001)	(0.008)
Has international joint venture * fuel efficiency	-0.230***	-0.160***	-0.160***
	(0.000)	(0.005)	(0.005)

Has international joint venture * horsepower	-0.170***	-0.073***	-0.073***
	(0.000)	(0.003)	(0.008)
Coefficient in marginal cost on having international joint venture with a particular country interacted with technology:			
Japan * alternative vehicle		-0.420***	-0.420***
		(0.003)	(0.003)
Japan * fuel efficiency		-0.713***	-0.713***
		(0.003)	(0.004)
Japan * horsepower		-0.851***	-0.851***
		(0.002)	(0.004)
Germany * alternative vehicle		0.118***	0.118***
		(0.001)	(0.005)
Germany * fuel efficiency		0.708***	0.708***
		(0.002)	(0.003)
Germany * horsepower		0.774***	0.774***
		(0.005)	(0.001)
Britain * alternative vehicle		1.005***	1.005***
		(0.002)	(0.004)
Britain * fuel efficiency		0.213***	0.213***
		(0.003)	(0.004)
Britain * horsepower		0.615***	0.615***
		(0.003)	(0.003)
US * alternative vehicle		-0.203***	-0.203***
		(0.002)	(0.004)
US * fuel efficiency		-0.149***	-0.149***
		(0.009)	(0.004)
US * horsepower		-0.662***	-0.662***
		(0.002)	(0.002)
South Korea * alternative vehicle		0.445***	0.445***
		(0.002)	(0.002)

South Korea * fuel efficiency	0.678***	0.678***
	(0.002)	(0.004)
South Korea * horsepower	0.361***	0.361***
	(0.001)	(0.010)
Sweden * alternative vehicle	0.981***	0.981***
	(0.004)	(0.004)
Sweden * fuel efficiency	0.748***	0.748***
	(0.002)	(0.004)
Sweden * horsepower	0.912***	0.912***
	(0.001)	(0.001)
France * alternative vehicle	0.268***	0.268***
	(0.010)	(0.007)
France * fuel efficiency	0.437***	0.437***
	(0.002)	(0.007)
France * horsepower	0.203***	0.203***
	(0.000)	(0.003)
Italy * alternative vehicle	0.098***	0.098***
	(0.002)	(0.002)
Italy * fuel efficiency	0.336***	0.336***
	(0.002)	(0.003)
Italy * horsepower	1.042***	1.042***
	(0.000)	(0.004)
Coefficient in marginal cost on having international joint venture with a particular car company from Japan or US interacted with technology:		
Mazda * fuel efficiency		-0.182***
		(0.006)
Mazda * horsepower		-0.264***
		(0.003)
Mazda * alternative vehicle		-0.146***
		(0.004)

Honda * fuel efficiency	-0.136***
	(0.006)
Honda * horsepower	-0.869***
	(0.001)
Honda * alternative vehicle	-0.580***
	(0.003)
Daihatsu * fuel efficiency	-0.550***
	(0.002)
Daihatsu * horsepower	-0.145***
	(0.004)
Daihatsu * alternative vehicle	-0.853***
	(0.003)
Toyota * fuel efficiency	-0.622***
	(0.003)
Toyota * horsepower	-0.351***
	(0.003)
Toyota * alternative vehicle	-0.513***
	(0.001)
Suzuki * fuel efficiency	-0.402***
	(0.008)
Suzuki * horsepower	-0.076***
	(0.008)
Suzuki * alternative vehicle	-0.240***
	(0.002)
Nissan * fuel efficiency	-0.123***
	(0.007)
Nissan * horsepower	-0.184***
	(0.006)
Nissan * alternative vehicle	-0.240***
	(0.004)
Mitsubishi * fuel efficiency	-0.417***
	(0.005)
Mitsubishi * horsepower	-0.050***

			(0.009)
Mitsubishi * alternative vehicle			-0.903***
			(0.002)
Isuzu * fuel efficiency			-0.945***
			(0.007)
Isuzu * horsepower			-0.491***
			(0.004)
Isuzu * alternative vehicle			-0.489***
			(0.003)
GM * fuel efficiency			-0.338***
			(0.008)
GM * horsepower			-0.900***
			(0.003)
GM * alternative vehicle			-0.369***
			(0.001)
Ford * fuel efficiency			-0.111***
			(0.005)
Ford * horsepower			-0.780***
			(0.006)
Ford * alternative vehicle			-0.390***
			(0.003)
Chrysler * fuel efficiency			-0.242***
			(0.003)
Chrysler * horsepower			-0.404***
			(0.005)
Chrysler * alternative vehicle			-0.096***
			(0.005)
Coefficient in marginal cost on fuel economy policy variables:			
Difference between fuel economy target and actual fuel efficiency (100km/L)	0.547***	0.547***	0.547***
	(0.000)	(0.004)	(0.007)
Firm needs to meet Corporate Average Fuel Consumption (CAFC) target (dummy)	0.279***	0.279***	0.279***

	(0.000)	(0.003)	(0.002)
Difference between Corporate Average Fuel Consumption (CAFC) target and actual fuel efficiency (100km/L) * Firm needs to meet Corporate Average Fuel Consumption (CAFC) target (dummy)	0.958***	0.958***	0.958***
	(0.000)	(0.006)	(0.003)
Estimated parameters in state-owned firms' utility on different objectives			
ρ_1 weight on profit	0.786***	0.920***	0.920***
	(0.001)	(0.002)	(0.005)
ρ_2 weight on consumer surplus	0.090***	0.060***	0.060***
	(0.004)	(0.054)	(0.002)
ρ_3 weight on squared deviation from target number of alternative vehicles	0.010***	0.001***	0.001
	(0.001)	(0.000)	(0.001)
$(1-\rho_1-\rho_2-\rho_3)$ weight on number of alternative vehicles	0.114***	0.019	0.019***
	(0.004)	(0.054)	(0.005)
$\underline{h}$ target number of alternative vehicles	150***	150***	150***
	(0.000)	(0.000)	(0.000)
# Observations	2215	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; **

Table 4: Net effects of forming joint ventures with each U.S. and Japan car company on the marginal cost of the technology-related vehicle characteristics

	Alternative Vehicle	Fuel Efficiency	Horsepower
Japanese firms			
Mazda	-0.422***	-1.055***	-1.188***
	(0.009)	(0.009)	(0.010)
Honda	-0.856***	-1.009***	-1.793***
	(0.009)	(0.009)	(0.009)
Daihatsu	-1.129***	-1.423***	-1.069***
	(0.009)	(0.007)	(0.009)
Toyota	-0.789***	-1.495***	-1.275***
	(0.009)	(0.007)	(0.009)
Suzuki	-0.516***	-1.275***	-1.000***
	(0.009)	(0.010)	(0.012)
Nissan	-0.460***	-0.996***	-1.108***
	(0.009)	(0.009)	(0.011)
Mitsubishi	-1.179***	-1.290***	-1.108***
	(0.009)	(0.008)	(0.013)
Isuzu	-0.765***	-1.818***	-1.415***
	(0.009)	(0.009)	(0.010)
US firms			
GM	-0.428***	-0.647***	-1.635***
	(0.009)	(0.010)	(0.009)
Ford	-0.449***	-0.420***	-1.515***
	(0.009)	(0.008)	(0.011)
Chrysler	-0.155***	-0.551***	-1.139***
	(0.010)	(0.007)	(0.010)

Notes: Standard errors are reported in parentheses. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 5. Welfare

	2010	2011	2012	2013
Consumer surplus (1,000 Yuan)	13,916.00***	7,203.50***	818.77***	2,631.90***
	(591.99)	(255.83)	(40.37)	(107.12)
Total firm profit for private firms	862.82***	613.69***	787.00***	1,944.60***
	(0.14)	(0.09)	(0.77)	(0.22)
Average firm profit for private firms	86.28***	61.37***	87.45***	216.07***
	(0.01)	(0.01)	(0.01)	(0.03)
Total firm utility for state-owned firms	1,993.10***	2,902.40***	3,036.40***	4,156.60***
	(5.47)	(7.90)	(8.08)	(11.22)
Average firm utility for state-owned firms	76.66***	100.08***	97.95***	115.46***
	(0.21)	(0.27)	(0.26)	(0.31)

Notes: Welfare is calculated using parameter estimates from Specification (2) of Table 3. Consumer surplus is in 1,000 Yuan; all other values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 6a. Actual and simulated costs, 2013

	Actual statistics	Simulated statistics
Average costs (1000 Yuan) of alternative vehicles	1653.80 ***	1510.90 ***
	(193.45)	(205.59)
Average costs (1000 Yuan)for each quartile of fuel efficiency		
1st quartile	269.46 ***	314.82 ***
	(0.14)	(41.23)
median	135.29 ***	132.83 ***
	(0.13)	(17.77)
3rd quartile	680.61 ***	578.41 ***
	(80.19)	(123.17)
4th quartile	39.83 ***	34.70 ***
	(0.10)	(7.34)
Average costs (1,000 Yuan) for all cars	213.32 ***	212.26 ***
	(7.64)	(38.47)

Notes: Costs calculated using parameter estimates from Specification (2) of Table 3. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 6b. Actual and simulated welfare, 2013

	Actual	Simulated
Consumer surplus (1000 Yuan)	2631.90***	2402.80***
	(107.12)	(236.57)
Total firm profit for private firms	1944.60***	2119.10***
	(0.22)	(189.05)
Average firm profit for private firms	216.07***	235.46***
	(0.03)	(21.01)
Total firm utility for state-owned firms	4156.60***	4159.60***
	(11.22)	(589.79)
Average firm utility for state-owned firms	115.46***	115.54***
	(0.31)	(16.38)

Notes: Welfare is calculated using parameter estimates from Specification (2) of Table 3. Consumer surplus is in 1,000 Yuan; all other values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 7a: Own price elasticities for state-owned models

Model displacement	(1)	(2)
Focus 1.8L	-44.347	-52.666
C-Quatre 1.6L	-50.225	-50.341
Eado 1.6L	-34.757	-38.229
Gran Lavida 1.6L	-58.593	-75.436
Jetta 1.6L	-35.135	-40.909
Buick Excellegt 1.5L	-41.243	-46.862
Bora 1.6L	-46.717	-52.098
Langdong 1.6L	-53.845	-66.084
Verna 1.4L	-35.068	-39.212
Cruz 1.6L	-55.975	-63.260
Corolla Ex 1.6L	-39.423	-44.728
Corolla	-57.530	-58.988
Octavia 1.6L	-54.133	-60.071
Lotus L5	-48.211	-54.566
H6 1.5T	-46.692	-52.277
Honda CR-V 2.4L	-98.997	-118.980
Tiguan 1.8T	-86.887	-99.631
ix35 2.0L	-71.108	-81.194
Touran 1.4T	-63.464	-72.159
Succe1.5L	-27.606	-30.919

Note: Specifications (1) and (2) correspond to Specifications (1) and (2) in Table 3.

Table 7b: Cross price elasticities for state-owned model

Model displacement	(1)	(2)
Focus 1.8L	0.000	0.000
C-Quatre 1.6L	0.000	0.000
Eado 1.6L	0.000	0.000
Gran Lavida 1.6L	0.000	0.000
Jetta 1.6L	0.000	0.000
Buick Excellegt 1.5L	0.000	0.000
Bora 1.6L	0.000	0.000
Langdong 1.6L	0.000	0.000
Verna 1.4L	0.000	0.000
Cruz 1.6L	0.000	0.000
Corolla Ex 1.6L	0.000	0.000
Corolla	0.000	0.000
Octavia 1.6L	0.000	0.000
Lotus L5	0.000	0.000
H6 1.5T	0.000	0.000
Honda CR-V 2.4L	0.000	0.000
Tiguan 1.8T	0.000	0.000
ix35 2.0L	0.000	0.000
Touran 1.4T	0.000	0.000
Succe1.5L	0.000	0.000

Notes: The hybrid vehicle picked here is "*Buick E-assist 2.4L hybrid*". Specifications (1) and (2) correspond to Specifications (1) and (2) in Table 3.

Table 8a. New car simulation 1: New car is like "Buick E-assist 2.4L hybrid" but with fuel efficiency 1.25 times more efficient

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001207	0.000017
	(0.042711)	(0.004271)
Market share for each quartile of fuel efficiency		
1st quartile	0.042203***	-0.001531**
	(0.004093)	(0.000460)
median	0.011085***	0.000074
	(0.001049)	(0.000107)
3rd quartile	0.073918***	0.000051
	(0.007033)	(0.000712)
4th quartile	0.001050***	-0.000014
	(0.000100)	(0.000011)
Average costs of alternative vehicles	1578.76	95.50
	(10351.70)	(1035.41)
Average costs for each quartile of fuel efficiency		
1st quartile	311.40***	16.10**
	(33.50)	(5.55)
median	129.61***	14.66***
	(13.44)	(2.31)
3rd quartile	563.19***	48.39**
	(111.46)	(16.74)
4th quartile	32.63***	5.67***
	(5.99)	(0.98)
Average costs for all cars	208.09	33.22
	(409.74)	(41.17)
Consumer surplus (1000 Yuan)	2446.06	-9.70
	(59461669.03)	(5950000.00)
Total firm profit for private firms	2019.43***	51.40*
	(146.34)	(24.94)
Average firm profit for private firms	224.38***	5.71*
	(16.26)	(2.77)
Total firm utility for state-owned firms	4074.54	296.10
	(33308113.46)	(3330000.00)
Average firm utility for state-owned firms	113.18	8.22
	(925225.37)	(92500.00)
The utility of the firm producing the new car	388.49	15.12
	(33308033.22)	(3330000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 8b. New car simulation 2: New car is like "Buick E-assist 2.4L hybrid" but with length 1.25 times longer

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001319 (0.053894)	0.000130 (0.005389
Market share for each quartile of fuel efficiency		
1st quartile	0.042667*** (0.004035)	-0.001067* (4552.000000)
Median	0.011096*** (0.001067)	0.000085 (0.000109)
3rd quartile	0.073144*** (0.007101)	-0.000723 (0.000719)
4th quartile	0.001021*** (0.000098)	-0.000043*** (0.000010)
Average costs of alternative vehicles	1605.67 (13482.13)	122.40 (1348.36)
Average costs for each quartile of fuel efficiency		
1st quartile	345.85*** (41.94)	50.55*** (6.10)
Median	142.86*** (17.50)	27.91*** (2.57)
3rd quartile	602.11*** (132.20)	87.31*** (18.19)
4th quartile	36.38*** (7.66)	9.41*** (1.09)
Average costs for all cars	234.81*** (525.57)	59.94 (52.71)
Consumer surplus (1,000 Yuan)	2289.48 (77821609.91)	-166.30 (7780000.00)
Total firm profit for private firms	2182.79*** (182.85)	214.80*** (27.24)
Average firm profit for private firms	242.53*** (20.32)	23.86*** (3.03)
Total firm utility for state-owned firms	4346.19 (8113747.75)	567.80 (811000.00)
Average firm utility for state-owned firms	120.73 (225381.88)	15.77 (22500.00)
The utility of the firm producing the new car	390.53 (8113563.85)	17.16 (811000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 8c. New car simulation 3: New car is like "Buick E-assist 2.4L hybrid" but with weight 1.25 times heavier

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001377 (0.048249)	0.000187 (0.004825)
Market share for each quartile of fuel efficiency		
1st quartile	0.041540*** (0.004001)	-0.002194*** (0.000452)
Median	0.010992*** (0.001063)	-0.000019 (0.000109)
3rd quartile	0.072944*** (0.006961)	-0.000923 (0.000705)
4th quartile	0.001032*** (0.000098)	-0.000032* (0.000010)
Average costs of alternative vehicles	1619.51 (12259.81)	136.20 (1226.17)
Average costs for each quartile of fuel efficiency		
1st quartile	346.80*** (37.11)	51.50*** (5.78)
Median	146.82*** (15.45)	31.87*** (2.43)
3rd quartile	620.85*** (121.24)	106.05*** (17.41)
4th quartile	40.38*** (6.72)	13.41*** (1.02)
Average costs for all cars	246.88 (480.46)	72.01 (48.22)
Consumer surplus (1,000 Yuan)	2390.61 (68208985.62)	-65.20 (6820000.00)
Total firm profit for private firms	2267.29*** (158.17)	299.30*** (25.65)
Average firm profit for private firms	251.92*** (17.57)	33.25*** (2.85)
Total firm utility for state-owned firms	4473.21 (16417294.51)	694.80 (1640000.00)
Average firm utility for state-owned firms	124.26 (456035.96)	19.30 (45600.00)
The utility of the firm producing the new car	402.31 (16417140.45)	28.94 (1640000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 8d. New car simulation 4: New car is like "Buick E-assist 2.4L hybrid" but with weight 1.25 times lighter

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001279 (0.039759)	0.000089 (0.003976)
Market share for each quartile of fuel efficiency		
1st quartile	0.044954*** (0.003995)	0.001220** (0.000452)
median	0.010973*** (0.001029)	-0.000038 (0.000105)
3rd quartile	0.072894*** (0.006914)	-0.000973 (0.000700)
4th quartile	0.001030*** (0.000098)	-0.000034** (0.000010)
Average costs of alternative vehicles	1595.88 (9373.03)	112.60 (937.53)
Average costs for each quartile of fuel efficiency		
1st quartile	358.49 (33.86)	63.19*** (5.57)
median	135.69 (13.34)	20.74*** (2.31)
3rd quartile	582.18 (108.86)	67.38*** (16.57)
4th quartile	34.78 (6.14)	7.81*** (0.99)
Average costs for all cars	224.59 (367.93)	49.72 (37.02)
Consumer surplus (1,000 Yuan)	2467.58 (54839246.43)	11.80 (5480000.00)
Total firm profit for private firms	2205.67*** (151.67)	237.70*** (25.25)
Average firm profit for private firms	245.07*** (16.85)	26.40*** (2.81)
Total firm utility for state-owned firms	4235.65 (36851485.26)	457.20 (3690000.00)
Average firm utility for state-owned firms	117.66 (1023652.37)	12.70 (102000.00)
The utility of the firm producing the new car	393.52 (36851425.50)	20.15 (3690000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 8e. New car simulation 5: New car is like "Buick E-assist 2.4L hybrid" but with one more seat

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001362 (0.040752)	0.000172 (0.004075)
Market share for each quartile of fuel efficiency		
1st quartile	0.040783*** (0.004049)	-0.002951*** (0.000456)
median	0.010788*** (0.001050)	-0.000223* (0.000107)
3rd quartile	0.072859*** (0.007034)	-0.001008 (0.000712)
4th quartile	0.001041*** (0.000099)	-0.000023* (0.000011)
Average costs of alternative vehicles	1615.79 (9565.90)	132.50 (956.81)
Average costs for each quartile of fuel efficiency		
1st quartile	316.26*** (33.48)	20.96** (5.55)
median	133.12*** (13.05)	18.17*** (2.29)
3rd quartile	584.39*** (108.55)	69.59*** (16.55)
4th quartile	36.23*** (5.82)	9.26*** (0.97)
Average costs for all cars	226.08 (377.49)	51.21 (37.97)
Consumer surplus (1,000 Yuan)	2339.95 (56796217.24)	-115.80 (5680000.00)
Total firm profit for private firms	2147.57*** (149.65)	179.60*** (25.13)
Average firm profit for private firms	238.62*** (16.63)	19.95*** (2.79)
Total firm utility for state-owned firms	4255.47 (38231291.98)	477.10 (3820000.00)
Average firm utility for state-owned firms	118.21 (1061980.33)	13.25 (106000.00)
The utility of the firm producing the new car	387.23 (38231231.49)	13.86 (3820000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 8f. New car simulation 6: New car is like "Buick E-assist 2.4L hybrid" but with horsepower 1.25 times higher

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001407	0.000217
	(0.050134)	(0.005013)
Market share for each quartile of fuel efficiency		
1st quartile	0.042727***	-0.001007*
	(0.004064)	(0.000458)
median	0.010927***	-0.000084
	(0.001045)	(0.000107)
3rd quartile	0.072862***	-0.001005
	(0.007108)	(0.000720)
4th quartile	0.001035***	-0.000029**
	(0.000098)	(0.000010)
Average costs of alternative vehicles	1626.69	143.40
	(12670.89)	(1267.27)
Average costs for each quartile of fuel efficiency		
1st quartile	366.05***	70.75***
	(39.77)	(5.95)
median	148.24***	33.29***
	(16.30)	(2.49)
3rd quartile	629.40***	114.60***
	(125.68)	(17.72)
4th quartile	42.03***	15.06***
	(7.33)	(1.06)
Average costs for all cars	252.34	77.47
	(493.03)	(49.47)
Consumer surplus (1,000 Yuan)	2430.15	-25.60
	(70721006.82)	(7070000.00)
Total firm profit for private firms	2315.89***	347.90***
	(172.07)	(26.53)
Average firm profit for private firms	257.32***	38.65***
	(19.12)	(2.95)
Total firm utility for state-owned firms	4517.29	738.90
	(12210843.50)	(1220000.00)
Average firm utility for state-owned firms	125.48	20.52
	(339190.10)	(33900.00)
The utility of the firm producing the new car	408.46	35.09
	(12210685.05)	(1220000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 8g. New car simulation 7: New car is like "Buick E-assist 2.4L hybrid" but with horsepower 1.25 times lower

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001287	0.000097
	(0.040607)	(0.004061)
Market share for each quartile of fuel efficiency		
1st quartile	0.040054***	-0.003680***
	(0.003911)	(0.000444)
median	0.011042***	0.000031
	(0.001062)	(0.000108)
3rd quartile	0.074226***	0.000359
	(0.006981)	(0.000707)
4th quartile	0.001035***	-0.000029**
	(0.000099)	(0.000011)
Average costs of alternative vehicles	1597.97	114.70
	(9308.00)	(931.03)
Average costs for each quartile of fuel efficiency		
1st quartile	311.36***	16.06**
	(33.40)	(5.54)
median	138.93***	23.98***
	(13.95)	(2.34)
3rd quartile	602.02***	87.22***
	(110.81)	(16.70)
4th quartile	36.30***	9.33***
	(6.14)	(0.99)
Average costs for all cars	228.75	53.88
	(367.18)	(36.94)
Consumer surplus (1,000 Yuan)	2581.09	125.30
	(53645483.33)	(5360000.00)
Total firm profit for private firms	2124.26***	156.30***
	(149.70)	(25.14)
Average firm profit for private firms	236.03***	17.36***
	(16.63)	(2.79)
Total firm utility for state-owned firms	4293.66	515.30
	(34671505.89)	(3470000.00)
Average firm utility for state-owned firms	119.27	14.31
	(963097.39)	(96300.00)
The utility of the firm producing the new car	405.26	31.89
	(34671426.21)	(3470000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 8h. New car simulation 8: New car is like "Buick E-assist 2.4L hybrid" but is produced by a private company

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001249	0.000059
	(0.032819)	(0.003282)
Market share for each quartile of fuel efficiency		
1st quartile	0.042713***	-0.001021*
	(0.003897)	(0.000443)
median	0.010982***	-0.000029
	(0.001021)	(0.000105)
3rd quartile	0.073462***	-0.000405
	(0.006816)	(0.000691)
4th quartile	0.001035***	-0.000029**
	(0.000095)	(0.000010)
Average costs of alternative vehicles	1588.88	105.60
	(7543.08)	(754.59)
Average costs for each quartile of fuel efficiency		
1st quartile	316.63***	21.33***
	(33.46)	(5.55)
median	127.90***	12.95***
	(13.25)	(2.30)
3rd quartile	559.19***	44.39*
	(109.07)	(16.58)
4th quartile	31.27***	4.30***
	(5.85)	(0.97)
Average costs for all cars	208.17	33.30
	(297.79)	(30.05)
Consumer surplus (1,000 Yuan)	2409.46	-46.30
	(43630465.59)	(4360000.00)
Total firm profit for private firms	2069.98	102.00
	(74048.89)	(7404.93)
Average firm profit for private firms	207.00	-11.67
	(7404.89)	(740.49)
Total firm utility for state-owned firms	4073.46	295.10
	(30109974.51)	(3010000.00)
Average firm utility for state-owned firms	113.15	8.19
	(836388.18)	(83600.00)
The profit of the firm producing the new car	382.05	8.68
	(30094642.21)	(3010000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 8i. New car simulation 9: New car is like "Buick E-assist 2.4L hybrid" but firm does not form a joint venture with any international companies

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001234	0.000044
	(0.031783)	(0.003178)
Market share for each quartile of fuel efficiency		
1st quartile	0.043777***	0.000043
	(0.003902)	(0.000444)
median	0.010901***	-0.000110
	(0.001022)	(0.000105)
3rd quartile	0.073801***	-0.000066
	(0.006815)	(0.000691)
4th quartile	0.001034***	-0.000030**
	(0.000095)	(0.000010)
Average costs of alternative vehicles	1585.19	101.90
	(7340.63)	(734.35)
Average costs for each quartile of fuel efficiency		
1st quartile	331.39***	36.09***
	(34.93)	(5.64)
median	128.21***	13.26***
	(13.83)	(2.33)
3rd quartile	568.38***	53.58**
	(109.79)	(16.63)
4th quartile	32.07***	5.10***
	(6.10)	(0.98)
Average costs for all cars	211.70	36.83
	(288.77)	(29.16)
Consumer surplus (1,000 Yuan)	2599.37	143.60
	(40765452.88)	(4080000.00)
Total firm profit for private firms	2094.21***	126.20***
	(154.11)	(25.40)
Average firm profit for private firms	232.69***	14.02***
	(17.12)	(2.82)
Total firm utility for state-owned firms	4117.68	339.30
	(28204660.63)	(2820000.00)
Average firm utility for state-owned firms	114.38	9.42
	(783462.80)	(78300.00)
The utility of the firm producing the new car	395.19	21.82
	(28204579.88)	(2820000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 8j. New car simulation 10: New car is like "Buick E-assist 2.4L hybrid" but is produced by a private company that forms joint ventures with international companies

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001344	0.000154
	(0.042754)	(0.004275)
Market share for each quartile of fuel efficiency		
1st quartile	0.042612***	-0.001122*
	(0.003875)	(0.000441)
median	0.011007***	-0.000004
	(0.001059)	(0.000108)
3rd quartile	0.073030***	-0.000837
	(0.006987)	(0.000708)
4th quartile	0.001033***	-0.000031**
	(0.000099)	(0.000011)
Average costs of alternative vehicles	1611.51	128.20
	(10402.55)	(1040.50)
Average costs for each quartile of fuel efficiency		
1st quartile	345.07***	49.77***
	(32.00)	(5.46)
median	141.17***	26.22***
	(13.25)	(2.30)
3rd quartile	600.71***	85.91***
	(111.71)	(16.76)
4th quartile	37.49***	10.52***
	(5.94)	(0.97)
Average costs for all cars	234.64	59.77
	(409.92)	(41.19)
Consumer surplus (1,000 Yuan)	2480.77	25.00
	(58842813.69)	(5880000.00)
Total firm profit for private firms	2211.67	243.70
	(133551.79)	(13400.02)
Average firm profit for private firms	221.17	2.50
	(13355.18)	(1335.50)
Total firm utility for state-owned firms	4349.47	571.10
	(33567422.94)	(3360000.00)
Average firm utility for state-owned firms	120.82	15.86
	(932428.42)	(93200.00)
The utility of the firm producing the new car	399.42	26.05
	(33572522.04)	(3360000.00)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9a. New Policy Simulation 1: Privatization

	Simulated statistics	**Difference from base case**
Total market share for all alternative vehicles	0.001257 (9.879600)	-0.000044* (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001700 (0.869530)	-0.039796*** (0.000296)
median	0.000459* (2.113000)	-0.010538*** (0.000030)
3rd quartile	0.003034* (2.711800)	-0.070703*** (0.000160)
4th quartile	0.000041 (1.180000)	-0.001006*** (0.000005)
Average costs of alternative vehicles	1499.80*** (7.31)	-11.08 (29.04)
Average costs for each quartile of fuel efficiency		
1st quartile	269.37*** (6.17)	-45.45*** (6.01)
median	135.18*** (7.00)	2.35 (2.63)
3rd quartile	680.50*** (5.45)	102.09*** (17.54)
4th quartile	39.83*** (5.33)	5.13*** (1.05)
Average costs for all cars	218.98*** (5.42)	6.72 (5.58)
Consumer surplus (1,000 Yuan)	2571.80*** (9.54)	169.03*** (35.87)
Total firm profit for private firms	6540.10*** (10.32)	4420.98*** (66.12)
Average firm profit for private firms	145.34*** (10.32)	-90.12*** (2.53)
Total firm utility for state-owned firms		-3989.87*** (65.12)
Average firm utility for state-owned firms		

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 9b. New Policy Simulation 2: **Ban all international joint ventures**

	Simulated statistics	**Difference from base case**
Total market share for all alternative vehicles	0.003211** (0.000339)	0.001910*** (0.000036)
Market share for each quartile of fuel efficiency		
1st quartile	0.003020 (0.005135)	-0.038476*** (0.000560)
median	0.000548 (0.000294)	-0.010449*** (0.000036)
3rd quartile	0.003597* (0.001580)	-0.070140*** (0.000195)
4th quartile	0.000042 (0.000037)	-0.001005*** (0.000005)
Average costs of alternative vehicles	1982.80*** (215.64)	471.94*** (29.79)
Average costs for each quartile of fuel efficiency		
1st quartile	269.06** (85.24)	-45.76*** (9.47)
median	135.13*** (22.50)	2.30 (2.87)
3rd quartile	680.22*** (131.01)	101.81*** (17.98)
4th quartile	39.83*** (7.94)	5.13*** (1.08)
Average costs for all cars	250.67*** (43.11)	38.41*** (5.78)
Consumer surplus (1,000 Yuan)	1900.70*** (170.40)	-502.15*** (29.16)
Total firm profit for private firms	4313.80*** (439.28)	2194.71*** (47.82)
Average firm profit for private firms	479.31*** (48.81)	243.85*** (5.31)
Total firm utility for state-owned firms	4155.80*** (540.99)	-3.81 (80.03)
Average firm utility for state-owned firms	115.44*** (15.03)	-0.10 (2.22)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; ***$p<0.001$

Table 9c. New Policy Simulation 3: No Fuel Economy Phase II or III standards

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001247*** (0.000128)	-0.000054*** (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001691 (0.002136)	-0.039800*** (0.000308)
median	0.000438 (0.000225)	-0.010559*** (0.000031)
3rd quartile	0.002917* (0.001204)	-0.070820*** (0.000166)
4th quartile	0.000041 (0.000038)	-0.001006*** (0.000005)
Average costs of alternative vehicles	1497.60*** (206.69)	-13.29 (29.15)
Average costs for each quartile of fuel efficiency		
1st quartile	269.47*** (43.17)	-45.35*** (5.97)
median	135.31*** (18.35)	2.48 (2.55)
3rd quartile	680.63*** (124.67)	102.22*** (17.53)
4th quartile	39.86*** (7.42)	5.16*** (1.04)
Average costs for all cars	210.22*** (39.79)	-2.04 (5.53)
Consumer surplus (1,000 Yuan)	2473.80*** (223.93)	70.97* (32.57)
Total firm profit for private firms	2054.60*** (195.97)	-64.48* (27.23)
Average firm profit for private firms	228.29*** (21.77)	-7.17* (3.03)
Total firm utility for state-owned firms	4161.30*** (604.80)	1.66 (84.48)
Average firm utility for state-owned firms	115.59*** (16.80)	0.05 (2.35)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9d. New Policy Simulation 4: No Corporate Average Fuel Consumption (CAFC) Standards

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001473*** (0.000131)	0.000172*** (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001917 (0.002233)	-0.039579*** (0.000315)
median	0.000507* (0.000234)	-0.010490*** (0.000032)
3rd quartile	0.003376*** (0.001159)	-0.070361*** (0.000163)
4th quartile	0.000048 (0.000038)	-0.000999*** (0.000005)
Average costs of alternative vehicles	1553.30*** (205.74)	42.37 (29.09)
Average costs for each quartile of fuel efficiency		
1st quartile	269.18*** (48.72)	-45.64*** (6.38)
median	135.01*** (20.17)	2.18 (2.69)
3rd quartile	680.34*** (127.91)	101.93*** (17.76)
4th quartile	39.57*** (8.03)	4.87*** (1.09)
Average costs for all cars	268.78*** (42.26)	56.52*** (5.71)
Consumer surplus (1,000 Yuan)	2661.80*** (286.35)	259.03*** (37.14)
Total firm profit for private firms	2365.70*** (212.80)	246.58*** (28.46)
Average firm profit for private firms	262.85*** (23.64)	27.39*** (3.16)
Total firm utility for state-owned firms	4753.90*** (687.16)	594.29*** (90.56)
Average firm utility for state-owned firms	132.05*** (19.09)	16.51*** (2.52)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9e. New Policy Simulation 5: No Fuel Economy Standards at All

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001363*** (0.000146)	0.000062** (0.000019)
Market share for each quartile of fuel efficiency		
1st quartile	0.001897 (0.002247)	-0.039599*** (0.000316)
median	0.000477* (0.000229)	-0.010520*** (0.000031)
3rd quartile	0.003191* (0.001125)	-0.070546*** (0.000161)
4th quartile	0.000045 (0.000037)	-0.001002*** (0.000005)
Average costs of alternative vehicles	1526.00*** (206.85)	15.05 (29.16)
Average costs for each quartile of fuel efficiency		
1st quartile	269.19*** (51.80)	-45.63*** (6.62)
median	135.03*** (20.85)	2.20 (2.74)
3rd quartile	680.37*** (131.07)	101.96*** (17.99)
4th quartile	39.60*** (8.58)	4.90*** (1.13)
Average costs for all cars	240.98*** (45.11)	28.72*** (5.93)
Consumer surplus (1,000 Yuan)	2740.40*** (266.84)	337.62*** (35.66)
Total firm profit for private firms	2285.60*** (232.40)	166.47*** (29.96)
Average firm profit for private firms	253.95*** (25.82)	18.49*** (3.33)
Total firm utility for state-owned firms	4474.40*** (701.27)	314.83*** (91.63)
Average firm utility for state-owned firms	124.29*** (19.48)	8.75*** (2.55)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9f. New Policy Simulation 6: Corporate Average Fuel Consumption (CAFC) Standard applies to all cars

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001292* (0.000129)	-0.000009 (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001788 (0.002411)	-0.039708*** (0.000328)
median	0.000453* (0.000218)	-0.010544*** (0.000030)
3rd quartile	0.003007* (0.001199)	-0.070730*** (0.000166)
4th quartile	0.000043 (0.000037)	-0.001004*** (0.000005)
Average costs of alternative vehicles	1508.50* (205.01)	-2.38 (29.03)
Average costs for each quartile of fuel efficiency		
1st quartile	269.46* (46.10)	-45.36*** (6.18)
median	135.29* (18.01)	2.46 (2.53)
3rd quartile	680.61* (121.29)	102.20*** (17.29)
4th quartile	39.83* (7.71)	5.13*** (1.06)
Average costs for all cars	220.08* (39.35)	7.82 (5.50)
Consumer surplus (1,000 Yuan)	2597.60* (264.33)	194.76*** (35.47)
Total firm profit for private firms	2145.50* (207.94)	26.35 (28.10)
Average firm profit for private firms	238.38* (23.10)	2.92 (3.12)
Total firm utility for state-owned firms	4262.40* (594.78)	102.77 (83.76)
Average firm utility for state-owned firms	118.40* (16.52)	2.86 (2.33)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 9g. New Policy Simulation 7a: Raise Fuel Economy Phase II-III target by 5%

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001261*** (0.000126)	-0.000040* (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001830 (0.002245)	-0.039666*** (0.000316)
median	0.000459* (0.000213)	-0.010538*** (0.000030)
3rd quartile	0.003026* (0.001173)	-0.070712*** (0.000164)
4th quartile	0.000043 (0.000037)	-0.001004*** (0.000005)
Average costs of alternative vehicles	1501.00*** (205.60)	-9.85 (29.08)
Average costs for each quartile of fuel efficiency		
1st quartile	269.46*** (44.80)	-45.36*** (6.09)
median	135.30*** (18.31)	2.47 (2.55)
3rd quartile	680.61*** (123.43)	102.20*** (17.44)
4th quartile	39.83*** (7.65)	5.13*** (1.06)
Average costs for all cars	223.98*** (39.88)	11.72 (5.54)
Consumer surplus (1,000 Yuan)	2437.90*** (248.22)	35.13 (34.29)
Total firm profit for private firms	2220.70*** (201.84)	101.56*** (27.65)
Average firm profit for private firms	246.74*** (22.43)	11.28*** (3.07)
Total firm utility for state-owned firms	4282.70*** (603.42)	123.11 (84.38
Average firm utility for state-owned firms	118.96*** (16.76)	3.42 (2.34)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; ***$p<0.001$

Table 9h. New Policy Simulation 7b: Raise Fuel Economy Phase II-III target by 10%

	Simulated statistics	**Difference from base case**
Total market share for all alternative vehicles	0.001287*** (0.000122)	-0.000014 (0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001618 (0.002139)	-0.039878*** (0.000309)
median	0.000434 (0.000225)	-0.010563*** (0.000031)
3rd quartile	0.002917* (0.001173)	-0.070820*** (0.000164)
4th quartile	0.000041 (0.000038)	-0.001006*** (0.000005)
Average costs of alternative vehicles	1507.40*** (205.96)	-3.45 (29.10)
Average costs for each quartile of fuel efficiency		
1st quartile	269.47*** (42.37)	-45.35*** (5.91)
median	135.30*** (18.56)	2.47 (2.57)
3rd quartile	680.61*** (126.22)	102.20*** (17.64)
4th quartile	39.83*** (7.73)	5.13*** (1.07)
Average costs for all cars	205.63*** (40.35)	-6.63 (5.57)
Consumer surplus (1,000 Yuan)	2428.70*** (266.84)	25.91 (35.66)
Total firm profit for private firms	2062.70*** (195.66)	-56.43* (27.21)
Average firm profit for private firms	229.19*** (21.74)	-6.27* (3.02)
Total firm utility for state-owned firms	4108.80*** (638.81)	-50.81 (86.94)
Average firm utility for state-owned firms	114.13*** (17.75)	-1.41 (2.41)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9i. New Policy Simulation 7c: Raise Fuel Economy Phase II-III target by 15%

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001260*** (0.000125)	-0.000041* (0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001560 (0.002493)	-0.039936*** (0.000334)
median	0.000437 (0.000223)	-0.010560*** (0.000031)
3rd quartile	0.002885** (0.001115)	-0.070852*** (0.000160)
4th quartile	0.000041 (0.000038)	-0.001006*** (0.000005)
Average costs of alternative vehicles	1500.60*** (204.70)	-10.28 (29.01)
Average costs for each quartile of fuel efficiency		
1st quartile	269.47*** (45.96)	-45.35*** (6.17)
median	135.30*** (17.78)	2.47 (2.51)
3rd quartile	680.62*** (121.88)	102.21*** (17.33)
4th quartile	39.84*** (7.46)	5.14*** (1.05)
Average costs for all cars	203.56*** (38.85)	-8.70 (5.47)
Consumer surplus (1,000 Yuan)	2458.10*** (218.24)	55.31* (32.19)
Total firm profit for private firms	1971.80*** (204.00)	-147.29*** (27.81)
Average firm profit for private firms	219.09*** (22.67)	-16.37*** (3.09)
Total firm utility for state-owned firms	4096.80*** (568.15)	-62.79 (81.89)
Average firm utility for state-owned firms	113.80*** (15.78)	-1.74 (2.27)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9j. New Policy Simulation 8a: Raise Corporate Average Fuel Consumption (CAFC) target by 5%

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001259*** (0.000127)	-0.000042* (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001601 (0.002220)	-0.039895*** (0.000314)
median	0.000420* (0.000213)	-0.010577*** (0.000030)
3rd quartile	0.002819* (0.001220)	-0.070918*** (0.000167)
4th quartile	0.000040 (0.000037)	-0.001007*** (0.000005)
Average costs of alternative vehicles	1500.40*** (203.89)	-10.47 (28.95)
Average costs for each quartile of fuel efficiency		
1st quartile	269.47*** (41.16)	-45.35*** (5.83)
median	135.30*** (17.80)	2.47 (2.52)
3rd quartile	680.61*** (118.71)	102.20*** (17.11)
4th quartile	39.84*** (7.67)	5.13*** (1.06)
Average costs for all cars	195.05*** (38.03)	-17.21*** (5.41)
Consumer surplus (1,000 Yuan)	2510.30*** (254.11)	107.48*** (34.72)
Total firm profit for private firms	2014.90*** (192.83)	-104.22*** (27.00)
Average firm profit for private firms	223.88*** (21.43)	-11.58*** (3.00)
Total firm utility for state-owned firms	3998.60*** (558.67)	-161.02* (81.24)
Average firm utility for state-owned firms	111.07*** (15.52)	-4.47* (2.26)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 9k. New Policy Simulation 8b: Raise Corporate Average Fuel Consumption (CAFC) target by 10%

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001242*** (0.000132)	-0.000059** (0.000018)
Market share for each quartile of fuel efficiency		
1st quartile	0.001607 (0.002293)	-0.039889*** (0.000319)
median	0.000449* (0.000227)	-0.010548*** (0.000031)
3rd quartile	0.002994** (0.001102)	-0.070743*** (0.000159)
4th quartile	0.000043 (0.000036)	-0.001004*** (0.000005)
Average costs of alternative vehicles	1496.30*** (205.94)	-14.64 (29.10)
Average costs for each quartile of fuel efficiency		
1st quartile	269.47*** (46.54)	-45.35*** (6.22)
median	135.31*** (17.81)	2.48 (2.52)
3rd quartile	680.62*** (123.34)	102.21*** (17.43)
4th quartile	39.84*** (7.66)	5.14*** (1.06)
Average costs for all cars	215.36*** (39.95)	3.10 (5.55)
Consumer surplus (1,000 Yuan)	2324.70*** (230.38)	-78.11* (33.02)
Total firm profit for private firms	2057.30*** (216.99)	-61.85* (28.78)
Average firm profit for private firms	228.58*** (24.11)	-6.88* (3.20)
Total firm utility for state-owned firms	4203.60*** (590.44)	43.95 (83.46)
Average firm utility for state-owned firms	116.77*** (16.40)	1.23 (2.32)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9l. New Policy Simulation 8c: Raise Corporate Average Fuel Consumption (CAFC) target by 15%

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001349***	0.000048**
	(0.000121)	(0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001786	-0.039710***
	(0.002349)	(0.000323)
median	0.000470	-0.010527***
	(0.000225)	(0.000031)
3rd quartile	0.003106**	-0.070632***
	(0.001160)	(0.000163)
4th quartile	0.000043	-0.001004***
	(0.000035)	(0.000005)
Average costs of alternative vehicles	1522.70***	11.75
	(204.22)	(28.98)
Average costs for each quartile of fuel efficiency		
1st quartile	269.48***	-45.34***
	(42.76)	(5.94)
median	135.31***	2.48
	(16.99)	(2.46)
3rd quartile	680.63***	102.22***
	(117.13)	(17.00)
4th quartile	39.85***	5.15***
	(7.23)	(1.03)
Average costs for all cars	235.32***	23.06***
	(36.62)	(5.31)
Consumer surplus (1,000 Yuan)	2483.00***	80.16*
	(226.43)	(32.75)
Total firm profit for private firms	2205.50***	86.40***
	(188.77)	(26.72)
Average firm profit for private firms	245.06***	9.60***
	(20.98)	(2.97)
Total firm utility for state-owned firms	4424.90***	265.34***
	(544.68)	(80.28)
Average firm utility for state-owned firms	122.91***	7.37***
	(15.13)	(2.23)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 9m. New Policy Simulation 9a: Increase the target number of alternative vehicles for state-owned firms by 10

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001205*** (0.000123)	-0.000096*** (0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001662 (0.002379)	-0.039834*** (0.000326)
median	0.000423 (0.000227)	-0.010574*** (0.000031)
3rd quartile	0.002850* (0.001207)	-0.070887*** (0.000167)
4th quartile	0.000040 (0.000038)	-0.001007*** (0.000005)
Average costs of alternative vehicles	1487.10*** (204.82)	-23.82 (29.02)
Average costs for each quartile of fuel efficiency		
1st quartile	269.46*** (44.36)	-45.36*** (6.06)
median	135.29*** (18.04)	2.46 (2.53)
3rd quartile	680.61*** (122.40)	102.20*** (17.36)
4th quartile	39.83*** (7.27)	5.13*** (1.03)
Average costs for all cars	195.65*** (38.71)	-16.61*** (5.46)
Consumer surplus (1,000 Yuan)	2601.10*** (263.38)	198.29*** (35.40)
Total firm profit for private firms	2032.90*** (195.10)	-86.25*** (27.17)
Average firm profit for private firms	225.87*** (21.68)	-9.59*** (3.02)
Total firm utility for state-owned firms	4016.00*** (602.85)	-143.59 (84.34)
Average firm utility for state-owned firms	111.56*** (16.75)	-3.98 (2.34)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table 9n. New Policy Simulation 9b: Increase the target number of alternative vehicles for state-owned firms by 25

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001362*** (0.000116)	0.000061*** (0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001810 (0.002350)	-0.039686*** (0.000323)
median	0.000466* (0.000237)	-0.010531*** (0.000032)
3rd quartile	0.003063** (0.001218)	-0.070674*** (0.000167)
4th quartile	0.000043 (0.000036)	-0.001004*** (0.000005)
Average costs of alternative vehicles	1525.90*** (205.04)	15.02 (29.04)
Average costs for each quartile of fuel efficiency		
1st quartile	269.46*** (43.97)	-45.36*** (6.03)
median	135.29*** (17.83)	2.46 (2.52)
3rd quartile	680.61*** (122.10)	102.20*** (17.34)
4th quartile	39.83*** (7.42)	5.13*** (1.04)
Average costs for all cars	229.00*** (38.46)	16.74*** (5.44)
Consumer surplus (1,000 Yuan)	2451.10*** (240.68)	48.29 (33.75)
Total firm profit for private firms	2220.00*** (195.42)	100.87*** (27.19)
Average firm profit for private firms	246.66*** (21.71)	11.20*** (3.02)
Total firm utility for state-owned firms	4352.10*** (585.10)	192.47* (83.08)
Average firm utility for state-owned firms	120.89*** (16.25)	5.35* (2.31)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

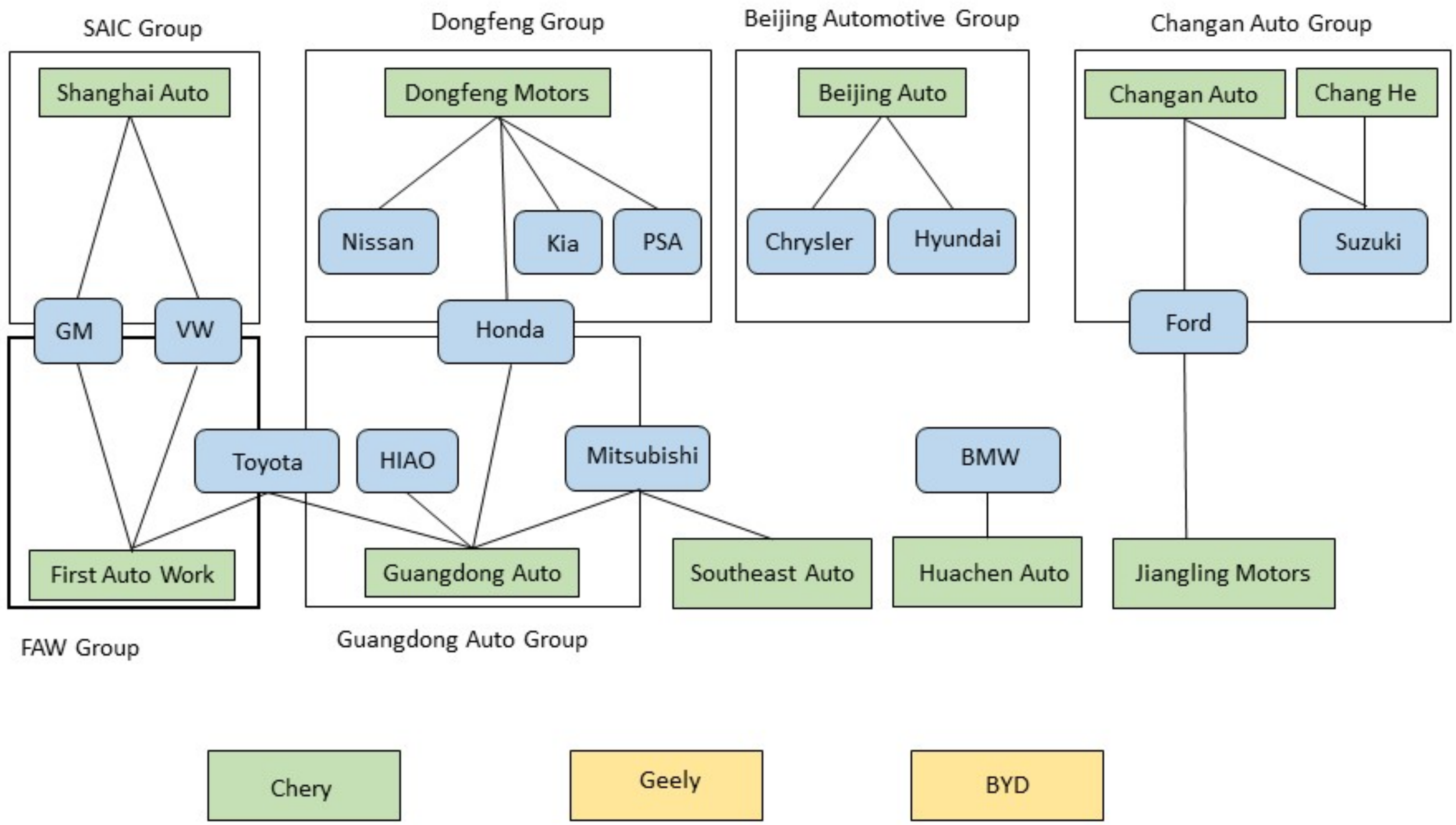
Table 9o. New Policy Simulation 9c: Increase the target number of alternative vehicles for state-owned firms by 50

	Simulated statistics	Difference from base case
Total market share for all alternative vehicles	0.001349*** (0.000119)	0.000048** (0.000017)
Market share for each quartile of fuel efficiency		
1st quartile	0.001780 (0.002183)	-0.039716*** (0.000312)
median	0.000465* (0.000224)	-0.010532*** (0.000031)
3rd quartile	0.003096** (0.001129)	-0.070641*** (0.000161)
4th quartile	0.000043 (0.000036)	-0.001004*** (0.000005)
Average costs of alternative vehicles	1522.70*** (203.29)	11.79 (28.91)
Average costs for each quartile of fuel efficiency		
1st quartile	269.46*** (40.84)	-45.36*** (5.80)
median	135.29*** (17.33)	2.46 (2.48)
3rd quartile	680.61*** (118.23)	102.20*** (17.07)
4th quartile	39.83*** (7.33)	5.13*** (1.04)
Average costs for all cars	233.98*** (36.87)	21.72*** (5.33)
Consumer surplus (1,000 Yuan)	2483.10*** (232.65)	80.26* (33.18)
Total firm profit for private firms	2222.00*** (185.36)	102.90*** (26.48)
Average firm profit for private firms	246.89*** (20.60)	11.43*** (2.94)
Total firm utility for state-owned firms	4417.20*** (549.89)	257.58*** (80.64)
Average firm utility for state-owned firms	122.70*** (15.28)	7.16*** (2.24)

Notes: Costs and consumer surplus are in 1,000 Yuan. Profit, and firm utility are in billion Yuan. Standard errors are reported in parentheses. Significance stars following the difference from base case indicated the significance of a two-sample t-test of the difference between the statistic in the counterfactual simulation and that in the base-case simulation. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Appendix A

Figure A1: Market Structure of Chinese Automobile Industry



Notes: Chinese firms that are at least partially state-owned are in green. Private Chinese firms are in yellow. Interactional car companies are in blue. Lines connecting firms indicate joint ventures between firms.
Source: Hu, Xiao and Zhou (2014)

Figure A2: Geographical location of Chinese automobile companies

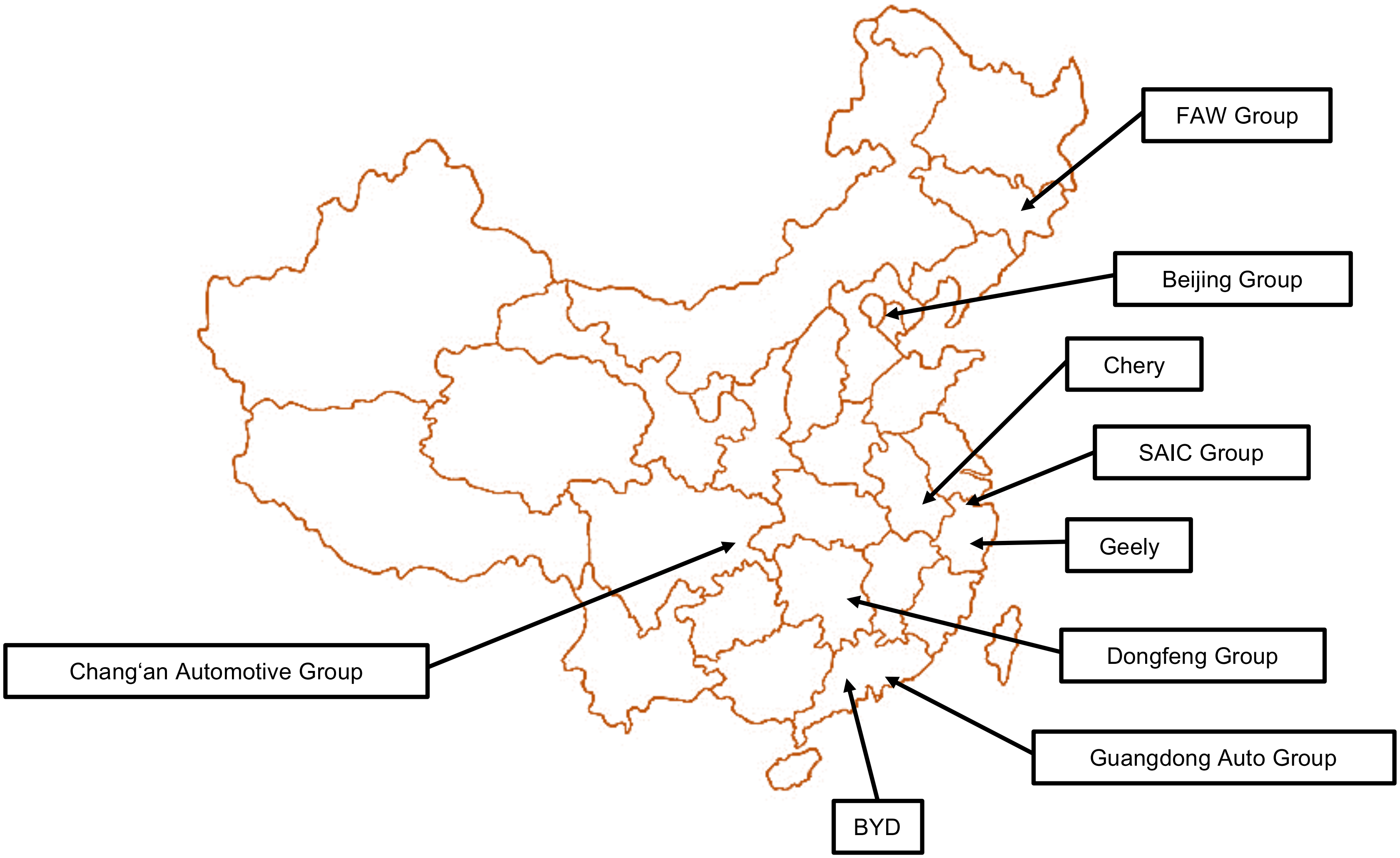


Table A1. First-stage F-statistics: Different objectives for state-owned model with "has international joint venture dummy" interactions

Endogenous variables	Instruments Chosen	First-Stage F-Statistic
Alternative Fuel Vehicle	Number of cars with similar values of:	8.810
	- Fuel efficiency	
	- Length	
Fuel Efficiency	- Weight	49.500
	- Capacity	
	- Horsepower	
Length		112.340
	Value for the closest car of:	
Weight	- Fuel efficiency	95.140
	- Length	
	- Weight	
Capacity	- Horsepower	1224.520
	Value for the closest car with a different model-year-displacement of:	
Horsepower	- Fuel efficiency	131.090
	- Weight	
Price		99.350
	Fraction of other cars that year that are alternative vehicles	
	Has international joint venture dummy interacted with:	
	- Fraction of other cars that year that are alternative vehicles	
Quantity	- Number of cars with similar values of fuel efficiency	10.770
	- Number of cars with similar values of horsepower	

Table A2. First-stage F-statistics: Different objectives for state-owned model with "international joint venture country" dummy interactions

<table>
<tr><th>Endogenous variables</th><th>Instruments Chosen</th><th>First-Stage F-Statistic</th></tr>
<tr><td>Alternative Fuel Vehicle</td><td rowspan="8">Number of cars with similar values of:
- Fuel efficiency
- Length
- Weight
- Capacity
- Horsepower

Value for the closest car of:
- Fuel efficiency
- Length
- Weight
- Horsepower

Value for the closest car with a different model-year-displacement of:
- Fuel efficiency
- Length
- Weight

Fraction of other cars that year that are alternative vehicles

Has international joint venture dummy interacted with:
- Fraction of other cars that year that are alternative vehicles
- Number of cars with similar values of fuel efficiency
- Number of cars with similar values of horsepower

Dummy for joint venture with company in:
- Japan
- Germany
- Great Britain
- U.S.
- South Korea
- Sweden
- France
- Italy
interacted with:
- Fraction of other cars that year that are alternative vehicles
- Number of cars with similar values of fuel efficiency
Number of cars with similar values of horsepower</td><td>10.11</td></tr>
<tr><td>Fuel Efficiency</td><td>24.39</td></tr>
<tr><td>Length</td><td>46.36</td></tr>
<tr><td>Weight</td><td>39.77</td></tr>
<tr><td>Capacity</td><td>474.88</td></tr>
<tr><td>Horsepower</td><td>56.09</td></tr>
<tr><td>Price</td><td>47.90</td></tr>
<tr><td>Quantity</td><td>6.43</td></tr>
</table>

Appendix B

Table B1. Results of model with interactions between consumer preferences and price, 2010-2013

	(1)	(2)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.480***	0.390***
	(0.054)	(0.087)
Fuel efficiency (100km/L)	0.490***	0.450***
	(0.049)	(0.074)
Length (mm)	0.360***	0.330***
	(0.081)	(0.060)
Weight (kg)	0.460***	0.430***
	(0.069)	(0.082)
Capacity (number of seats)	0.200**	0.190***
	(0.075)	(0.047)
Horsepower (PS)	0.020	0.020
	(0.067)	(0.078)
Constant	0.510***	0.430***
	(0.060))	(0.055)
Parameter α in marginal disutility of price (1,000 Yuan)	0.300***	0.230**
	(0.054)	(0.073)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.300***	0.300***
	(0.063)	(0.057)
Fuel efficiency (100km/L)	0.050	0.020
	(0.066)	(0.073)
Length (mm)	0.460***	0.390***
	(0.050)	(0.077)
Weight (kg)	0.460***	0.500***
	(0.050)	(0.051)
Capacity (number of seats)	0.450***	0.440***
	(0.051)	(0.054)
Horsepower (PS)	0.700***	0.600***
	(0.058)	(0.072)
State-owned (dummy)		0.480***
		(0.078)
Constant	0.700***	0.600***
	(0.050)	(0.073)
Coefficient η on quantity in marginal cost	0.008	0.003
	(0.033)	(0.023)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001.

Table B2. Results of model with full set of interactions between consumer preferences and product characteristics, 2010-2013

	(1)	(2)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.190***	0.700***
	(0.025)	(0.004)
Fuel efficiency (100km/L)	0.050*	0.600***
	(0.021)	(0.012)
Length (m)	0.160***	0.150***
	(0.033)	(0.007)
Weight (metric ton)	0.170***	0.380***
	(0.032)	(0.006)
Capacity (number of seats)	0.040	-0.130***
	(0.029)	(0.004)
Horsepower (PS)	0.210***	0.370***
	(0.023)	(0.003)
Constant	0.080*	0.150***
	(0.032)	(0.001)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.160***	0.200***
	(0.042)	(0.004)
Fuel efficiency (100km/L)	0.450***	0.420 ***
	(0.055)	(0.005)
Length (m)	0.510***	0.020***
	(0.054)	(0.004)
Weight (metric ton)	0.230***	0.250***
	(0.028)	(0.005)
Capacity (number of seats)	0.030	0.480***
	(0.021)	(0.010)
Horsepower (0.01PS)	0.350***	0.330***
	(0.044)	(0.007)
Constant	0.080***	0.400***
	(0.027)	(0.005)
Parameter α in marginal disutility of price (10,000 yuan)	0.480***	0.330***
	(0.057)	(0.005)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.230***	0.450***
	(0.027)	(0.003)
Fuel efficiency (100km/L)	0.290***	0.280***
	(0.046)	(0.002)
Length (m)	0.070***	0.190***
	(0.019)	(0.006)
Weight (metric ton)	0.170***	0.020***

	(0.034)	(0.004)
Capacity (number of seats)	0.360***	0.700***
	(0.041)	(0.004)
Horsepower (0.01PS)	0.600***	0.150***
	(0.061)	(0.006)
State-owned (dummy)		0.110***
		(0.012)
Constant	0.160***	0.130***
	(0.026)	(0.006)
Coefficient η on quantity in marginal cost	0.010***	0.001**
	(0.002)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001.

Table B3. Model with international joint venture dummies, possibly allowing stated-owned firms to have different objectives, 2010-2013

	(1)	(2)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.054***	0.075***
	(0.000)	(0.010)
Fuel efficiency (100km/L)	0.067***	0.137**
	(0.000)	(0.047)
Length (m)	0.181***	0.154***
	(0.000)	(0.011)
Weight (metric ton)	0.015***	0.059***
	(0.000)	(0.018)
Capacity (number of seats)	0.415***	0.131***
	(0.000)	(0.018)
Horsepower (PS)	1.200***	0.022
	(0.000)	(0.012)
Constant	0.133	0.056*
	(0.000)	(0.025)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.120***	0.033**
	(0.000)	(0.014)
Fuel efficiency (100km/L)	0.651***	0.154***
	(0.000)	(0.017)
Length (m)	0.283***	0.132***
	(0.000)	(0.010)
Weight (metric ton)	0.473***	0.008
	(0.000)	(0.010)
Capacity (number of seats)	0.078***	0.038***
	(0.000)	(0.009)
Horsepower (0.01PS)	0.014***	0.170***
	(0.000)	(0.008)
Constant	0.001***	0.021
	(0.000)	(0.015)
Parameter α in marginal disutility of price (1,000 Yuan)	0.258***	0.271***
	(0.000)	(0.013)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.738***	0.056*
	(0.000)	(0.022)
Fuel efficiency (100km/L)	0.466***	0.071**
	(0.000)	(0.022)
Length (m)	0.778***	0.125***
	(0.000)	(0.009)

Weight (metric ton)	0.042***	0.039
	(0.000)	(0.044)
Capacity (number of seats)	0.197***	0.180***
	(0.000)	(0.041)
Horsepower (0.01PS)	0.126***	0.099***
	(0.000)	(0.017)
State-owned (dummy)	0.022***	0.132***
	(0.000)	(0.009)
Constant	0.628***	0.094***
	(0.026)	(0.005)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	-0.144***	0.083***
	(0.000)	(0.016)
Honda	-0.002***	-0.177***
	(0.000)	(0.009)
Daihatsu	-0.526***	0.001
	(0.000)	(0.022)
Toyota	-0.209***	-0.169***
	(0.000)	(0.023)
Suzuki	-0.081***	-0.047***
	(0.000)	(0.010)
Nissan	0.011***	0.185***
	(0.000)	(0.034)
Mitsubishi	-0.077***	0.135***
	(0.000)	(0.008)
Isuzu	0.875***	0.328***
	(0.000)	(0.033)
Daimler	-0.077***	0.058***
	(0.000)	(0.017)
BMW	0.247***	-0.060***
	(0.000)	(0.011)
Volkswagen	0.011***	0.138***
	(0.000)	(0.031)
Audi	0.006***	-0.181***
	(0.000)	(0.005)
Lotus	0.089***	0.009
	(0.000)	(0.008)
GM	-0.04***	-0.100**
	(0.000)	(0.036)
Ford	-0.784***	-0.034
	(0.000)	(0.031)
Chrysler	0.733***	0.156***
	(0.000)	(0.017)
Hyundai	-0.214***	-0.116**
	(0.000)	(0.029)
Kia	0.831***	-0.063***
	(0.000)	(0.016)
Volvo	0.843***	0.122***

	(0.000)	(0.01)
Saab	0.269***	0.115***
	(0.000)	(0.011)
PSA	-0.035***	0.136***
	(0.000)	(0.009)
Fiat	-0.158***	0.120***
	(0.000)	(0.026)
Coefficient η *on quantity in marginal cost*	0.003***	0.002
	(0.000)	(0.003)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit		0.754***
		(0.038)
ρ_2 weight on consumer surplus		0.011
		(0.009)
ρ_3 weight on squared deviation from target number of alternative vehicles		0.006
		(0.004)
$\underline{h}$ target number of alternative vehicles		1050***
		(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001.

Table B4. Model include interaction with "has international joint venture" dummy, possibly allowing stated-owned firms to have different objectives, 2010-2013

	(1)	(2)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.054***	0.210***
	(0.000)	(0.003)
Fuel efficiency (100km/L)	0.067***	0.211***
	(0.000)	(0.002)
Length (m)	0.181***	0.017***
	(0.000)	(0.002)
Weight (metric ton)	0.015***	0.220***
	(0.000)	(0.001)
Capacity (number of seats)	0.415***	0.005***
	(0.000)	(0.001)
Horsepower (PS)	1.200***	0.079***
	(0.000)	(0.004)
Constant	0.133***	0.118***
	(0.000)	(0.006)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.120***	0.107***
	(0.000)	(0.005)
Fuel efficiency (100km/L)	0.651***	0.133***
	(0.000)	(0.005)
Length (m)	0.283***	0.078***
	(0.000)	(0.002)
Weight (metric ton)	0.473***	0.187***
	(0.000)	(0.001)
Capacity (number of seats)	0.078***	0.065***
	(0.000)	(0.005)
Horsepower (0.01PS)	0.014***	0.046***
	(0.000)	(0.007)
Constant	0.001***	0.207***
	(0.000)	(0.005)
Parameter α in marginal disutility of price (1,000 Yuan)	0.258***	0.348***
	(0.000)	(0.001)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.738***	0.241***
	(0.000)	(0.006)
Fuel efficiency (100km/L)	0.466***	0.093***
	(0.000)	(0.000)
Length (m)	0.778***	0.113***
	(0.000)	(0.003)
Weight (metric ton)	0.042***	0.121***

	(0.000)	(0.003)
Capacity (number of seats)	0.197***	0.230***
	(0.000)	(0.005)
Horsepower (0.01PS)	0.126***	0.157***
	(0.000)	(0.009)
State-owned (dummy)	0.022***	0.177***
	(0.000)	(0.003)
Constant	0.628***	0.191***
	(0.000)	(0.003)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	-0.144***	0.105***
	(0.000)	(0.003)
Honda	-0.002***	0.085***
	(0.000)	(0.003)
Daihatsu	-0.526***	-0.181***
	(0.000)	(0.008)
Toyota	-0.209***	-0.134***
	(0.000)	(0.009)
Suzuki	-0.081***	0.012***
	(0.000)	(0.003)
Nissan	0.011***	-0.029***
	(0.000)	(0.005)
Mitsubishi	-0.077***	-0.012***
	(0.000)	(0.002)
Isuzu	0.875***	-0.092***
	(0.000)	(0.002)
Daimler	-0.077***	-0.237***
	(0.000)	(0.003)
BMW	0.247***	-0.081***
	(0.000)	(0.003)
Volkswagen	0.011***	-0.033***
	(0.000)	(0.004)
Audi	0.006***	-0.151***
	(0.000)	(0.001)
Lotus	0.089***	-0.245***
	(0.000)	(0.006)
GM	-0.040***	-0.225***
	(0.000)	(0.002)
Ford	-0.784***	-0.051***
	(0.000)	(0.007)
Chrysler	0.733***	-0.037***
	(0.000)	(0.001)
Hyundai	-0.214***	0.024**
	(0.000)	(0.009)
Kia	0.831***	0.159***
	(0.000)	(0.006)
Volvo	0.843***	0.025*
	(0.000)	(0.010)

Saab	0.269***	0.122***
	(0.000)	(0.007)
PSA	-0.035***	0.219***
	(0.000)	(0.001)
Fiat	-0.158***	-0.149***
	(0.000)	(0.010)
Coefficient η on quantity in marginal cost	0.003***	0.014***
	(0.000)	(0.001)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit		0.786***
		(0.005)
ρ_2 weight on consumer surplus		0.090***
		(0.002)
ρ_3 weight on squared deviation from target number of hybrid vehicles		0.010***
		(0.001)
$\underline{h}$ target number of alternative vehicles		150.000***
		(0.000)
Estimated parameters in "Has international joint venture dummies" interaction terms		
ψ_1 on HIJV * alternative vehicle	-0.279***	-0.070***
	(0.000)	(0.007)
ψ_2 on HIJV * fuel efficiency	-0.547***	-0.230***
	(0.000)	(0.006)
ψ_3 on HIJV * horsepower	-0.958***	-0.170***
	(0.000)	(0.001)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table B5. Model include interaction with "international joint venture country" dummy, possibly allowing stated-owned firms to have different objectives, 2010-2013

	(1)	(2)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.312***	0.106***
	(0.000)	(0.000)
Fuel efficiency (100km/L)	0.199***	0.235***
	(0.000)	(0.000)
Length (m)	0.163***	0.294***
	(0.000)	(0.000)
Weight (metric ton)	0.236***	0.281***
	(0.000)	(0.000)
Capacity (number of seats)	0.148***	-0.133***
	(0.000)	(0.000)
Horsepower (PS)	0.067***	0.168***
	(0.000)	(0.000)
Constant	0.122***	0.333***
	(0.000)	(0.000)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.343***	0.163***
	(0.000)	(0.000)
Fuel efficiency (100km/L)	0.078***	0.112***
	(0.000)	(0.000)
Length (m)	0.046***	-0.009***
	(0.000)	(0.000)
Weight (metric ton)	0.261***	0.347***
	(0.000)	(0.000)
Capacity (number of seats)	0.100***	0.105***
	(0.000)	(0.000)
Horsepower (0.01PS)	0.004***	0.029***
	(0.000)	(0.000)
Constant	0.370***	0.210***
	(0.000)	(0.000)
Parameter α in marginal disutility of price (1,000 Yuan)	0.263***	0.420***
	(0.000)	(0.000)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.147***	0.139***
	(0.000)	(0.000)
Fuel efficiency (100km/L)	0.088***	0.060***
	(0.000)	(0.000)
Length (m)	0.226***	0.126***
	(0.000)	(0.000)

Weight (metric ton)	0.206***	0.101***
	(0.000)	(0.000)
Capacity (number of seats)	0.017***	0.156***
	(0.000)	(0.000)
Horsepower (0.01PS)	0.254***	0.113***
	(0.000)	(0.000)
State-owned (dummy)	0.131***	0.111***
	(0.000)	(0.000)
Constant	0.077***	0.245***
	(0.000)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	-0.228***	0.158***
	(0.000)	(0.000)
Honda	-0.182***	-0.064***
	(0.000)	(0.000)
Daihatsu	0.234***	0.054***
	(0.000)	(0.000)
Toyota	-0.136***	0.219***
	(0.000)	(0.000)
Suzuki	-0.037***	-0.028***
	(0.000)	(0.000)
Nissan	0.154***	0.033***
	(0.000)	(0.000)
Mitsubishi	0.210***	0.185***
	(0.000)	(0.000)
Isuzu	-0.160***	-0.110***
	(0.000)	(0.000)
Daimler	-0.240***	-0.224***
	(0.000)	(0.000)
BMW	-0.261***	-0.059***
	(0.000)	(0.000)
Volkswagen	0.262***	0.035***
	(0.000)	(0.000)
Audi	-0.160***	0.092***
	(0.000)	(0.000)
Lotus	-0.318***	-0.253***
	(0.000)	(0.000)
GM	-0.127***	-0.189***
	(0.000)	(0.000)
Ford	0.229***	0.029***
	(0.000)	(0.000)
Chrysler	0.345***	-0.135***
	(0.000)	(0.000)
Hyundai	-0.295***	0.003***
	(0.000)	(0.000)
Kia	-0.406***	-0.115***
	(0.000)	(0.000)

Volvo	-0.161***	0.134***
	(0.000)	(0.000)
Saab	-0.127***	0.193***
	(0.000)	(0.000)
PSA	0.183***	-0.310***
	(0.000)	(0.000)
Fiat	-0.188***	-0.382***
	(0.000)	(0.000)
Coefficient η on quantity in marginal cost	0.003***	0.007***
	(0.000)	(0.000)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit		0.920***
		(0.000)
ρ_2 weight on consumer surplus		0.060***
		(0.000)
ρ_3 weight on squared deviation from target number of hybrid vehicles		0.001***
		(0.000)
$\underline{h}$ target number of alternative vehicles		600.000***
		(0.000)
Estimated parameters ψ_1 in "Has international joint venture dummies" interaction terms		
HIJV * alternative vehicle	0.267***	0.144***
	（0.000）	(0.000)
HIJV * fuel efficiency	-0.215***	-0.160***
	(0.000)	(0.000)
HIJV * horsepower	-0.141***	-0.073***
	(0.000)	(0.000)
Estimated parameters ψ_2 in "International joint venture country" interaction terms		
Japan * fuel efficiency	-0.107***	-0.713***
	(0.000)	(0.000)
Japan * horsepower	-0.962***	-0.851***
	(0.000)	(0.000)
Japan * alternative vehicle	-0.005***	-0.420***
	(0.000)	(0.000)
Germany * fuel efficiency	0.775***	0.708***
	(0.000)	(0.000)
Germany * horsepower	0.817***	0.774***
	(0.000)	(0.000)
Germany * alternative vehicle	0.869***	0.118***
	(0.000)	(0.000)
Britain * fuel efficiency	0.084***	0.213***
	(0.000)	(0.000)
Britain * horsepower	0.400***	0.615***
	(0.000)	(0.000)
Britain * alternative vehicle	0.260***	1.005***

	(0.000)	(0.000)
US * fuel efficiency	-0.800***	-0.149***
	(0.000)	(0.000)
US * horsepower	-0.431***	-0.662***
	(0.000)	(0.000)
US * alternative vehicle	-0.911***	-0.203***
	(0.000)	(0.000)
South Korea * fuel efficiency	0.182***	0.678***
	(0.000)	(0.000)
South Korea * horsepower	0.264***	0.361***
	(0.000)	(0.000)
South Korea * alternative vehicle	0.146***	0.445***
	(0.000)	(0.000)
Sweden * fuel efficiency	0.136***	0.748***
	(0.000)	(0.000)
Sweden * horsepower	0.869***	0.912***
	(0.000)	(0.000)
Sweden * alternative vehicle	0.580***	0.981***
	(0.000)	(0.000)
France * fuel efficiency	0.550***	0.437***
	(0.000)	(0.000)
France * horsepower	0.145***	0.203***
	(0.000)	(0.000)
France * alternative vehicle	0.853***	0.268***
	(0.000)	(0.000)
Italy * fuel efficiency	0.622***	0.336***
	(0.000)	(0.000)
Italy * horsepower	0.351***	1.042***
	(0.000)	(0.000)
Italy * alternative vehicle	0.513***	0.098***
	(0.000)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table B6. Welfare for the model without "has international joint venture" interactions, possibly allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	1,717.00	941.41	303.96	459.07
	(2,549.20)	(1,508.20)	(839.45)	(915.82)
Total firm profit for private firms	865.99***	615.70***	788.84***	1,949.60***
	(2.15)	(1.37)	(1.19)	(3.40)
Average firm profit for private firms	86.60***	61.57***	87.650***	216.63***
	(2.15)	(0.14)	(0.13)	(0.38)
Total firm utility for state-owned firms	1,662.70***	2,405.60***	2,506.70***	3,432.10***
	(182.19)	(173.00)	(146.73)	(197.78)
Average firm utility for state-owned firms	63.95***	82.95***	80.86***	95.34***
	(700.71)	(5.97)	(4.73)	(5.49)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table B7. Welfare for the model with "has international joint venture" interactions, possibly allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	68.26***	33.51***	6,723.20**	15.09***
	(3.14)	(1.62)	(0.36)	(0.73)
Total firm profit for private firms	858.38***	610.87***	784.61***	1,937.60***
	(0.49)	(0.31)	(0.27)	(0.77)
Average firm profit for private firms	85.84***	61.09***	87.18***	215.29***
	(0.04)	(0.07)	(0.06)	(0.081)
Total firm utility for state-owned firms	1,701.70***	2,467.20***	2,582.60***	3,531.70***
	(10.38)	(14.24)	(15.17)	(20.34)
Average firm utility for state-owned firms	65.45***	85.08	83.31	98.10
	(0.400)	(0.49)	(0.49)	(0.57)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table B8. Welfare for the model with international joint venture country interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	13.43***	6.70***	0.80***	2.64***
	(0.51)	(0.23)	(0.03)	(0.10)
Total firm profit for private firms	858.38***	610.87***	784.61***	1,937.60***
	(0.00)	(0.00)	(0.00)	(0.00)
Average firm profit for private firms	85.84***	61.09***	87.18***	215.29***
	(0.22)	(0.14)	(0.13)	(0.38)
Total firm utility for state-owned firms	1,985.50***	2,884.90***	3,022.40*	4,132.50***
	(0.03)	(0.14)	(0.00)	(0.01)
Average firm utility for state-owned firms	76.37***	99.48***	97.50***	114.79***
	(0.00)	(0.00)	(0.00)	(0.00)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * $p<0.05$; ** $p<0.01$; ***$p<0.001$

Table B9. Welfare for the model with fuel economy standard interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	70.85***	34.84***	7.01***	15.89***
	(5.56)	(3.17)	(0.73)	(1.31)
Total firm profit for private firms	858.38***	610.87***	784.61***	1,937.60***
	(0.69)	(0.44)	(0.38)	(1.09)
Average firm profit for private firms	85.84***	61.09***	87.180***	215.29***
	(0.07)	(0.04)	(0.42)	(0.12)
Total firm utility for state-owned firms	1,701.90***	2,467.40***	2,582.60***	3,531.80***
	(3.93)	(5.72)	(4.980)	(7.51)
Average firm utility for state-owned firms	65.46***	85.08***	83.31***	98.105***
	(0.15)	(0.20)	(0.16)	(0.21)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table B10. Welfare for the the State-owned fuel economy model with "international joint venture country" dummy interactions including interactions between dummies for international joint ventures with each US and Japan car company interacted with the technology-related car characteristics

	2010	2011	2012	2013
Consumer surplus	13.92***	7.20***	0.82***	2.63***
	(1183.20)	(588.24)	(79.44)	(234.57)
Total firm profit for private firms	862.82***	613.69***	787.08***	1944.60***
	(0.60)	(0.38)	(0.33)	(0.94)
Average firm profit for private firms	86.28***	61.37***	87.45***	216.07***
	(0.06)	(0.04)	(0.04)	(0.10)
Total firm utility for state-owned firms	2165.50***	3154.30***	3300.40***	4517.90***
	(1.15)	(2.59)	(2.10)	(3.55)
Average firm utility for state-owned firms	83.29***	108.77***	106.47***	125.50***
	(0.04)	(0.09)	(0.07)	(0.10)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Appendix C

Table C1. Model with international joint venture dummies allowing stated-owned firms to have different objectives, 2010-2013

	(2)	(3)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.075***	0.163***
	(0.010)	(0.000)
Fuel efficiency (100km/L)	0.137**	0.195***
	(0.047)	(0.000)
Length (m)	0.154***	0.229***
	(0.011)	(0.000)
Weight (metric ton)	0.059***	0.163***
	(0.018)	(0.000)
Capacity (number of seats)	0.131***	0.221***
	(0.018)	(0.000)
Horsepower (PS)	0.022	0.145***
	(0.012)	(0.000)
Constant	0.056*	0.154***
	(0.025)	(0.000)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.033**	
	(0.014)	
Fuel efficiency (100km/L)	0.154***	
	(0.017)	
Length (m)	0.132***	
	(0.010)	
Weight (metric ton)	0.008	
	(0.010)	
Capacity (number of seats)	0.038***	
	(0.009)	
Horsepower (0.01PS)	0.170***	
	(0.008)	
Constant	0.021	
	(0.015)	
Parameter α in marginal disutility of price (1,000 Yuan)	0.271***	0.087***
	(0.013)	(0.001)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.056*	0.153***
	(0.022)	(0.000)
Fuel efficiency (100km/L)	0.071**	0.161***
	(0.022)	(0.000)
Length (m)	0.125***	0.188***
	(0.009)	(0.000)

Weight (metric ton)	0.039	0.146***
	(0.044)	(0.000)
Capacity (number of seats)	0.180***	0.214***
	(0.041)	(0.000)
Horsepower (0.01PS)	0.099***	0.177***
	(0.017)	(0.000)
State-owned (dummy)	0.132***	0.191***
	(0.009)	(0.000)
Constant	0.094***	0.172***
	(0.005)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	0.083***	0.311***
	(0.016)	(0.000)
Honda	-0.177***	-0.923***
	(0.009)	(0.000)
Daihatsu	0.001	0.430***
	(0.022)	(0.000)
Toyota	-0.169***	0.185***
	(0.023)	(0.000)
Suzuki	-0.047***	-0.905***
	(0.010)	(0.000)
Nissan	0.185***	-0.980***
	(0.034)	(0.000)
Mitsubishi	0.135***	-0.439***
	(0.008)	(0.000)
Isuzu	0.328***	0.111***
	(0.033)	(0.000)
Daimler	0.058***	-0.258***
	(0.017)	(0.000)
BMW	-0.060***	0.409***
	(0.011)	(0.000)
Volkswagen	0.138***	0.595***
	(0.031)	(0.000)
Audi	-0.181***	0.262***
	(0.005)	(0.000)
Lotus	0.009	0.603***
	(0.008)	(0.000)
GM	-0.100**	-0.711***
	(0.036)	(0.000)
Ford	-0.034	0.222***
	(0.031)	(0.000)
Chrysler	0.156***	-0.117***
	(0.017)	(0.000)
Hyundai	-0.116**	0.297***
	(0.029)	(0.000)
Kia	-0.063***	-0.319***
	(0.016)	(0.000)
Volvo	0.122***	0.424***

	(0.01)	(0.000)
Saab	0.115***	-0.508***
	(0.011)	(0.000)
PSA	0.136***	-0.086***
	(0.009)	(0.000)
Fiat	0.120***	-0.262***
	(0.026)	(0.000)
Coefficient η *on quantity in marginal cost*	0.002	0.002***
	(0.003)	(0.000)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit	0.754***	0.312***
	(0.038)	(0.021)
ρ_2 weight on consumer surplus	0.011	0.301***
	(0.009)	(0.000)
ρ_3 weight on squared deviation from target number of alternative vehicles	0.006	0.091***
	(0.004)	(0.000)
$\underline{h}$ target number of alternative vehicles	1050***	650.000***
	(0.000)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001. Specification (2) is the random coefficient model and specification (3) is the traditional logit model without any interaction between consumer characteristics and product characteristics.

Table C2. Model with international joint venture dummies allowing stated-owned firms to have different objectives, 2010-2013

	(2)	(3)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.075***	0.163***
	(0.010)	(0.000)
Fuel efficiency (100km/L)	0.137**	0.195***
	(0.047)	(0.000)
Length (m)	0.154***	0.229***
	(0.011)	(0.000)
Weight (metric ton)	0.059***	0.163***
	(0.018)	(0.000)
Capacity (number of seats)	0.131***	0.221***
	(0.018)	(0.000)
Horsepower (PS)	0.022	0.145***
	(0.012)	(0.000)
Constant	0.056*	0.154***
	(0.025)	(0.000)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.033**	
	(0.014)	
Fuel efficiency (100km/L)	0.154***	
	(0.017)	
Length (m)	0.132***	
	(0.010)	
Weight (metric ton)	0.008	
	(0.010)	
Capacity (number of seats)	0.038***	
	(0.009)	
Horsepower (0.01PS)	0.170***	
	(0.008)	
Constant	0.021	
	(0.015)	
Parameter α in marginal disutility of price (1,000 Yuan)	0.271***	0.087***
	(0.013)	(0.001)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.056*	0.153***
	(0.022)	(0.000)
Fuel efficiency (100km/L)	0.071**	0.161***
	(0.022)	(0.000)
Length (m)	0.125***	0.188***
	(0.009)	(0.000)

Weight (metric ton)	0.039	0.146***
	(0.044)	(0.000)
Capacity (number of seats)	0.180***	0.214***
	(0.041)	(0.000)
Horsepower (0.01PS)	0.099***	0.177***
	(0.017)	(0.000)
State-owned (dummy)	0.132***	0.191***
	(0.009)	(0.000)
Constant	0.094***	0.172***
	(0.005)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	0.083***	0.311***
	(0.016)	(0.000)
Honda	-0.177***	-0.923***
	(0.009)	(0.000)
Daihatsu	0.001	0.430***
	(0.022)	(0.000)
Toyota	-0.169***	0.185***
	(0.023)	(0.000)
Suzuki	-0.047***	-0.905***
	(0.010)	(0.000)
Nissan	0.185***	-0.980***
	(0.034)	(0.000)
Mitsubishi	0.135***	-0.439***
	(0.008)	(0.000)
Isuzu	0.328***	0.111***
	(0.033)	(0.000)
Daimler	0.058***	-0.258***
	(0.017)	(0.000)
BMW	-0.060***	0.409***
	(0.011)	(0.000)
Volkswagen	0.138***	0.595***
	(0.031)	(0.000)
Audi	-0.181***	0.262***
	(0.005)	(0.000)
Lotus	0.009	0.603***
	(0.008)	(0.000)
GM	-0.100**	-0.711***
	(0.036)	(0.000)
Ford	-0.034	0.222***
	(0.031)	(0.000)
Chrysler	0.156***	-0.117***
	(0.017)	(0.000)
Hyundai	-0.116**	0.297***
	(0.029)	(0.000)
Kia	-0.063***	-0.319***
	(0.016)	(0.000)
Volvo	0.122***	0.424***

	(0.01)	(0.000)
Saab	0.115***	-0.508***
	(0.011)	(0.000)
PSA	0.136***	-0.086***
	(0.009)	(0.000)
Fiat	0.120***	-0.262***
	(0.026)	(0.000)
Coefficient η *on quantity in marginal cost*	0.002	0.002***
	(0.003)	(0.000)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit	0.754***	0.312***
	(0.038)	(0.021)
ρ_2 weight on consumer surplus	0.011	0.301***
	(0.009)	(0.000)
ρ_3 weight on squared deviation from target number of alternative vehicles	0.006	0.091***
	(0.004)	(0.000)
$\underline{h}$ target number of alternative vehicles	1050***	650.000***
	(0.000)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001. Specification (2) is the random coefficient model and specification (3) is the traditional logit model without any interaction between consumer characteristics and product characteristics.

Table C3. Model including interaction with "international joint venture country" dummy allowing stated-owned firms to have different objectives, 2010-2013

	(2)	(3)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.106***	0.105***
	(0.000)	(0.000)
Fuel efficiency (100km/L)	0.235***	0.234***
	(0.000)	(0.000)
Length (m)	0.294***	0.293***
	(0.000)	(0.005)
Weight (metric ton)	0.281***	0.28***
	(0.000)	(0.002)
Capacity (number of seats)	-0.133***	-0.134***
	(0.000)	(0.006)
Horsepower (PS)	0.168***	0.167***
	(0.000)	(0.002)
Constant	0.333***	0.332***
	(0.000)	(0.001)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.163***	
	(0.000)	
Fuel efficiency (100km/L)	0.112***	
	(0.000)	
Length (m)	-0.009***	
	(0.000)	
Weight (metric ton)	0.347***	
	(0.000)	
Capacity (number of seats)	0.105***	
	(0.000)	
Horsepower (0.01PS)	0.029***	
	(0.000)	
Constant	0.210***	
	(0.000)	
Parameter α in marginal disutility of price (1,000 Yuan)	0.420***	0.419***
	(0.000)	(0.168)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.139***	0.138***
	(0.000)	(0.000)
Fuel efficiency (100km/L)	0.060***	0.059***
	(0.000)	(0.000)
Length (m)	0.126***	0.125***
	(0.000)	(0.000)
Weight (metric ton)	0.101***	0.100***

	(0.000)	(0.000)
Capacity (number of seats)	0.156***	0.155***
	(0.000)	(0.000)
Horsepower (0.01PS)	0.113***	0.112***
	(0.000)	(0.000)
State-owned (dummy)	0.111***	0.110***
	(0.000)	(0.000)
Constant	0.245***	0.244***
	(0.000)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	0.158***	-0.311***
	(0.000)	(0.000)
Honda	-0.064***	0.923***
	(0.000)	(0.000)
Daihatsu	0.054***	0.43***
	(0.000)	(0.000)
Toyota	0.219***	0.185***
	(0.000)	(0.000)
Suzuki	-0.028***	-0.905***
	(0.000)	(0.000)
Nissan	0.033***	0.980***
	(0.000)	(0.000)
Mitsubishi	0.185***	-0.439***
	(0.000)	(0.000)
Isuzu	-0.110***	0.111***
	(0.000)	(0.000)
Daimler	-0.224***	-0.258***
	(0.000)	(0.000)
BMW	-0.059***	0.409***
	(0.000)	(0.000)
Volkswagen	0.035***	0.595***
	(0.000)	(0.000)
Audi	0.092***	0.262***
	(0.000)	(0.000)
Lotus	-0.253***	-0.603***
	(0.000)	(0.000)
GM	-0.189***	0.711***
	(0.000)	(0.000)
Ford	0.029***	0.222***
	(0.000)	(0.000)
Chrysler	-0.135***	-0.117***
	(0.000)	(0.000)
Hyundai	0.003***	-0.297***
	(0.000)	(0.000)
Kia	-0.115***	-0.319***
	(0.000)	(0.000)
Volvo	0.134***	-0.424***

	(0.000)	(0.000)
Saab	0.193***	0.508***
	(0.000)	(0.000)
PSA	-0.310***	-0.086***
	(0.000)	(0.000)
Fiat	-0.382***	-0.262***
	(0.000)	(0.000)
Coefficient η on quantity in marginal cost	0.007***	0.006***
	(0.000)	(0.003)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit	0.920***	0.600***
	(0.000)	(0.000)
ρ_2 weight on consumer surplus	0.060***	0.300***
	(0.000)	(0.000)
ρ_3 weight on squared deviation from target number of hybrid vehicles	0.001***	0.010***
	(0.000)	(0.005)
$\underline{h}$ target number of alternative vehicles	600.000***	600.000***
	(0.000)	(0.000)
Estimated parameters ψ_1 in "Has international joint venture dummies" interaction terms		
HIJV * alternative vehicle	0.144***	-0.490***
	(0.000)	(0.000)
HIJV * fuel efficiency	-0.160***	-0.339***
	(0.000)	(0.000)
HIJV * horsepower	-0.073***	-0.652***
	(0.000)	(0.000)
Estimated parameters ψ_2 in "International joint venture country" interaction terms		
Japan * fuel efficiency	-0.713***	-0.534***
	(0.000)	(0.000)
Japan * horsepower	-0.851***	0.090***
	(0.000)	(0.000)
Japan * alternative vehicle	-0.420***	0.112***
	(0.000)	(0.000)
Germany * fuel efficiency	0.708***	0.136***
	(0.000)	(0.000)
Germany * horsepower	0.774***	0.679***
	(0.000)	(0.000)
Germany * alternative vehicle	0.118***	-0.495***
	(0.000)	(0.000)
Britain * fuel efficiency	0.213***	0.190***
	(0.000)	(0.000)
Britain * horsepower	0.615***	-0.495***
	(0.000)	(0.000)
Britain * alternative vehicle	1.005***	-0.148***
	(0.000)	(0.000)

US * fuel efficiency	-0.149***	-0.055***
	(0.000)	(0.000)
US * horsepower	-0.662***	-0.851***
	(0.000)	(0.000)
US * alternative vehicle	-0.203***	-0.561***
	(0.000)	(0.000)
South Korea * fuel efficiency	0.678***	0.930***
	(0.000)	(0.000)
South Korea * horsepower	0.361***	-0.697***
	(0.000)	(0.000)
South Korea * alternative vehicle	0.445***	0.583***
	(0.000)	(0.000)
Sweden * fuel efficiency	0.748***	-0.815***
	(0.000)	(0.000)
Sweden * horsepower	0.912***	-0.879***
	(0.000)	(0.000)
Sweden * alternative vehicle	0.981***	0.989***
	(0.000)	(0.000)
France * fuel efficiency	0.437***	0.001***
	(0.000)	(0.000)
France * horsepower	0.203***	0.865***
	(0.000)	(0.000)
France * alternative vehicle	0.268***	-0.613***
	(0.000)	(0.000)
Italy * fuel efficiency	0.336***	-0.990***
	(0.000)	(0.000)
Italy * horsepower	1.042***	0.528***
	(0.000)	(0.000)
Italy * alternative vehicle	0.098***	-0.480***
	(0.000)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001. Specification (2) is the random coefficient model and specification (3) is the traditional logit model without any interaction between consumer characteristics and product characteristics.

Table C4. Model including interaction with fuel economy standard allowing stated-owned firms to have different objectives, 2010-2013

	(1)	(3)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.210***	0.210***
	(0.006)	(0.000)
Fuel efficiency (100km/L)	0.211***	0.211***
	(0.007)	(0.000)
Length (m)	0.017***	0.025***
	(0.002)	(0.000)
Weight (metric ton)	0.220***	0.222***
	(0.001)	(0.000)
Capacity (number of seats)	0.005***	0.014***
	(0.001)	(0.000)
Horsepower (PS)	0.070***	0.072***
	(0.003)	(0.000)
Constant	0.118***	0.120***
	(0.003)	(0.000)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.107***	
	(0.006)	
Fuel efficiency (100km/L)	0.133***	
	(0.000)	
Length (m)	0.078***	
	(0.004)	
Weight (metric ton)	0.187***	
	(0.002)	
Capacity (number of seats)	0.065***	
	(0.002)	
Horsepower (0.01PS)	0.046***	
	(0.007)	
Constant	0.207***	
	(0.001)	
Parameter α in marginal disutility of price (1,000 Yuan)	0.348***	0.073***
	(0.001)	(0.000)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.241***	0.241***
	(0.008)	(0.000)
Fuel efficiency (100km/L)	0.093***	0.093***
	(0.007)	(0.000)
Length (m)	0.113***	0.113***
	(0.004)	(0.000)
Weight (metric ton)	0.121***	0.121***
	(0.005)	(0.000)

Capacity (number of seats)	0.230***	0.230***
	(0.006)	(0.000)
Horsepower (0.01PS)	0.157***	0.157***
	(0.003)	(0.000)
State-owned (dummy)	0.177***	0.177***
	(0.002)	(0.000)
Constant	0.191***	0.191***
	(0.002)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	0.105***	0.618***
	(0.005)	(0.000)
Honda	-0.085***	0.859***
	(0.002)	(0.000)
Kaihatsu	0.181***	0.805***
	(0.003)	(0.000)
Toyota	0.134***	0.577***
	(0.001)	(0.000)
Suzuki	0.012***	-0.183***
	(0.001)	(0.000)
Nissan	0.029***	-0.240***
	(0.001)	(0.000)
Mitsubishi	0.012***	-0.887***
	(0.001)	(0.000)
Isuzu	-0.092***	0.029***
	(0.003)	(0.000)
Daimler	-0.237***	-0.490***
	(0.003)	(0.000)
BMW	-0.081***	-0.168***
	(0.004)	(0.000)
Volkswagen	0.033***	0.979***
	(0.001)	(0.000)
Audi	0.151***	-0.713***
	(0.004)	(0.000)
Lotus	-0.245***	0.500***
	(0.002)	(0.000)
GM	-0.225***	0.471***
	(0.001)	(0.000)
Ford	-0.051***	0.060***
	(0.010)	(0.000)
Chrysler	-0.037***	0.682***
	(0.008)	(0.000)
Hyundai	-0.024***	0.042***
	(0.001)	(0.000)
Kia	-0.159***	0.071***
	(0.004)	(0.000)
Volvo	0.025***	0.522***
	(0.001)	(0.000)
Saab	0.122***	0.097***

	(0.001)	(0.000)
PSA	-0.219***	-0.818***
	(0.001)	(0.000)
Fiat	-0.149***	-0.818***
	(0.006)	(0.000)
Coefficient η on quantity in marginal cost	0.014***	0.002
	(0.001)	(0.005)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit	0.786***	0.900***
	(0.001)	(0.000)
ρ_2 weight on consumer surplus	0.090***	0.090***
	(0.004)	(0.000)
ρ_3 weight on squared deviation from target number of hybrid vehicles	0.010***	0.010***
	(0.001)	(0.005)
$\underline{h}$ target number of alternative vehicles	150***	150.000*
	(0.000)	(0.000)
Estimated parameters ψ_1 in "Has international joint venture dummies" interaction terms on		
HIJV * alternative vehicle	-0.070***	-0.943***
	（0.000）	(0.000)
HIJV * fuel efficiency	-0.230***	0.418***
	(0.000)	(0.000)
HIJV * horsepower	-0.170***	-0.983***
	(0.000)	(0.000)
Phase_III_CAFC_dummy	0.279***	0.156***
	(0.000)	(0.000)
Phase_II_III_targetdiff	0.547***	0.856***
	(0.000)	(0.000)
Phase_IIICAFC_targetdiff* Phase_III_CAFC_dummy	0.958***	0.645***
	(0.000)	(0.000)

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001. Specification (1) is the random coefficient model and specification (3) is the traditional logit model without any interaction between consumer characteristics and product characteristics.

Table C5. Model include interaction with fuel economy standard and interaction with "international joint venture country" dummy, possibly allowing stated-owned firms to have different objectives, 2010-2013

	(2)	(3)
Mean β of marginal utility of:		
Alternative vehicle (dummy)	0.106***	0.105***
	(0.001)	(0.000)
Fuel efficiency (100km/L)	0.235***	0.234***
	(0.002)	(0.000)
Length (m)	0.294***	0.293***
	(0.004)	(0.000)
Weight (metric ton)	0.281***	0.280***
	(0.001)	(0.000)
Capacity (number of seats)	-0.133***	0.134***
	(0.002)	(0.000)
Horsepower (PS)	0.168***	0.167***
	(0.005)	(0.000)
Constant	0.333***	0.332***
	(0.000)	(0.000)
Standard deviation σ of marginal utility of:		
Alternative vehicle (dummy)	0.163***	
	(0.003)	
Fuel efficiency (100km/L)	0.112***	
	(0.001)	
Length (m)	-0.009	
	(0.007)	
Weight (metric ton)	0.347***	
	(0.004)	
Capacity (number of seats)	0.105***	
	(0.000)	
Horsepower (0.01PS)	0.029***	
	(0.001)	
Constant	0.210***	
	(0.002)	
Parameter α in marginal disutility of price (1,000 Yuan)	0.420***	0.419***
	(0.000)	(0.000)
Coefficient γ in marginal cost on:		
Alternative vehicle (dummy)	0.139***	0.138***
	(0.003)	(0.000)
Fuel efficiency (100km/L)	0.060***	0.059***
	(0.000)	(0.000)
Length (m)	0.126***	0.125***
	(0.003)	(0.000)

Weight (metric ton)	0.101***	0.100***
	(0.003)	(0.000)
Capacity (number of seats)	0.156***	0.155***
	(0.002)	(0.000)
Horsepower (0.01PS)	0.113***	0.112***
	(0.003)	(0.000)
State-owned (dummy)	0.111***	0.110***
	(0.005)	(0.000)
Constant	0.245***	0.244***
	(0.006)	(0.000)
Coefficient Γ in marginal cost on joint venture with:		
Mazda	0.158***	-0.311***
	(0.000)	(0.000)
Honda	-0.064***	0.923***
	(0.006)	(0.000)
Kaihatsu	0.054***	0.430***
	(0.004)	(0.000)
Toyota	0.219***	0.185***
	(0.004)	(0.000)
Suzuki	-0.028***	-0.905***
	(0.005)	(0.000)
Nissan	0.033***	0.980***
	(0.000)	(0.000)
Mitsubishi	0.185***	-0.439***
	(0.000)	(0.000)
Isuzu	-0.110***	0.111***
	(0.007)	(0.000)
Daimler	-0.224***	-0.258***
	(0.002)	(0.000)
BMW	-0.059***	0.409***
	(0.001)	(0.000)
Volkswagen	0.035***	0.595***
	(0.000)	(0.000)
Audi	0.092***	0.262***
	(0.007)	(0.000)
Lotus	-0.253***	-0.603***
	(0.004)	(0.000)
GM	-0.189***	0.711***
	(0.005)	(0.000)
Ford	0.029***	0.222***
	(0.003)	(0.000)
Chrysler	-0.135***	-0.117***
	(0.006)	(0.000)
Hyundai	0.003	-0.297***
	(0.008)	(0.000)
Kia	-0.115***	-0.319***
	(0.001)	(0.000)
Volvo	0.134***	-0.424***

	(0.001)	(0.000)
Saab	0.193***	0.508***
	(0.001)	(0.000)
PSA	-0.31***	-0.086***
	(0.001)	(0.000)
Fiat	-0.382***	-0.262***
	(0.000)	(0.000)
Coefficient η on quantity in marginal cost	0.007***	0.006**
	(0.000)	(0.002)
Estimated parameters in state-owned firms' utility on different objectives		
ρ_1 weight on profit	0.920***	0.600***
	(0.002)	(0.000)
ρ_2 weight on consumer surplus	0.060***	0.300***
	(0.054)	(0.000)
ρ_3 weight on squared deviation from target number of alternative vehicles	0.001***	0.010*
	(0.000)	(0.005)
$\underline{h}$ target number of alternative vehicles	150***	600.000
	(0.000)	(0.000)
Estimated parameters ψ_1 in "Has international joint venture dummies" interaction terms on		
HIJV * alternative vehicle	0.144***	-0.590***
	(0.001)	(0.000)
HIJV * fuel efficiency	-0.160***	-0.339***
	(0.005)	(0.000)
HIJV * horsepower	-0.073***	-0.650***
	(0.003)	(0.000)
Phase_III_CAFC_dummy	0.279***	0.333***
	(0.003)	(0.000)
Phase_II_III_targetdiff	0.547***	0.467***
	(0.004)	(0.000)
Phase_IIICAFC_targetdiff* Phase_III_CAFC_dummy	0.958***	0.648***
	(0.006)	(0.000)
Estimated parameters ψ_2 in "International joint venture country" interaction terms		
Japan * fuel efficiency	-0.713***	0.534***
	(0.003)	(0.000)
Japan * horsepower	-0.851***	0.090***
	(0.002)	(0.000)
Japan * alternative vehicle	-0.420***	0.112***
	(0.003)	(0.000)
Germany * fuel efficiency	0.708***	0.136***
	(0.002)	(0.000)
Germany * horsepower	0.774***	0.679***
	(0.005)	(0.000)
Germany * alternative vehicle	0.118***	-0.495***
	(0.001)	(0.000)

Britain * fuel efficiency	0.213***	0.190***
	(0.003)	(0.000)
Britain * horsepower	0.615***	-0.495***
	(0.003)	(0.000)
Britain * alternative vehicle	1.005***	-0.148***
	(0.002)	(0.000)
US * fuel efficiency	-0.149***	-0.055***
	(0.009)	(0.000)
US * horsepower	-0.662***	-0.851***
	(0.002)	(0.000)
US * alternative vehicle	-0.203***	-0.561***
	(0.002)	(0.000)
South Korea * fuel efficiency	0.678***	0.930***
	(0.002)	(0.000)
South Korea * horsepower	0.361***	-0.697***
	(0.001)	(0.000)
South Korea * alternative vehicle	0.445***	0.583***
	(0.002)	(0.000)
Sweden * fuel efficiency	0.748***	-0.815***
	(0.002)	(0.000)
Sweden * horsepower	0.912***	-0.879***
	(0.001)	(0.000)
Sweden * alternative vehicle	0.981***	0.989***
	(0.004)	(0.000)
France * fuel efficiency	0.437***	0.001***
	(0.002)	(0.000)
France * horsepower	0.203***	0.865***
	(0.000)	(0.000)
France * alternative vehicle	0.268***	-0.613***
	(0.010)	(0.000)
Italy * fuel efficiency	0.336***	-0.990***
	(0.002)	(0.000)
Italy * horsepower	1.042***	0.528***
	(0.000)	(0.000)
Italy * alternative vehicle	0.098***	-0.480***
	(0.002)	(0.000)
# Observations	2215	2215

Notes: Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001. Specification (1) is the random coefficient model and specification (3) is the traditional logit model without any interaction between consumer characteristics and product characteristics.

Table C6. Welfare for the traditional logit model without "has international joint venture" interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	3.02***	2.52***	2.30***	2.21***
	(0.04)	(0.04)	(0.04)	(0.05)
Total firm profit for private firms	866.08***	615.76***	788.88***	1949.80***
	(0.07)	(0.04)	(0.04)	(0.11)
Average firm profit for private firms	86.61***	61.58***	87.65***	216.64***
	(0.01)	(0.00)	(0.00)	(0.01)
Total firm utility for state-owned firms	37,291.00***	38,180.00***	38,109.00***	36,660.00***
	(175.61)	(198.24)	(200.77)	(219.24)
Average firm utility for state-owned firms	1,434.30***	1,316.60***	1,229.30***	1,018.30***
	(6.75)	(6.84)	(6.48)	(6.09)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table C7. Welfare for the traditional logit model with "has international joint venture" interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	2.49***	2.01***	1.82***	1.742***
	(0.00)	(0.00)	(0.00)	(0.00)
Total firm profit for private firms	865.99***	615.70***	788.84***	1,949.60***
	(3.05)	(1.93)	(1.69)	(4.82)
Average firm profit for private firms	86.60***	61.57***	87.65***	216.63***
	(0.31)	(0.19)	(0.19)	(0.54)
Total firm utility for state-owned firms	2,134.30***	3,044.60***	3,171.00***	4,232.10***
	(73.60)	(79.37)	(78.10)	(61.90)
Average firm utility for state-owned firms	82.09***	104.99***	102.29***	117.56***
	(2.83)	(2.74)	(2.52)	(1.72)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table C8. Welfare for the traditional logit model with international joint venture country interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	0.00	0.00	0.00	0.00
	(1.19)	(0.96)	(0.88)	(0.85)
Total firm profit for private firms	859.65***	611.68***	785.32***	1,939.60***
	(3.24)	(2.06)	(1.80)	(5.13)
Average firm profit for private firms	85.97***	61.17***	87.26***	215.51***
	(0.32)	(0.21)	(0.20)	(0.57)
Total firm utility for state-owned firms	4,707.60***	5,354.50***	5,432.10***	5,973.70***
	(1652.00)	(1677.70)	(1673.00)	(1580.00)
Average firm utility for state-owned firms	181.06***	184.64***	175.23***	165.94***
	(63.54)	(57.85)	(53.97)	(43.89)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table C9. Welfare for the traditional logit model with fuel economy standard interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	1.96***	1.52***	1.37***	1.31***
	(0.00)	(0.00)	(0.00)	(0.00)
Total firm profit for private firms	865.99***	615.70***	788.84***	1,949.60***
	(2.99)	(1.89)	(1.66)	(4.72)
Average firm profit for private firms	86.60***	61.57***	87.65***	216.63***
	(0.30)	(0.19)	(0.184)	(0.52)
Total firm utility for state-owned firms	2,134.20***	3,044.60***	3,171.00***	4,232.10***
	(91.34)	(100.40)	(98.19)	(80.03)
Average firm utility for state-owned firms	82.09***	104.99***	102.29***	117.56***
	(3.51)	(3.46)	(3.17)	(2.22)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001

Table C10. Welfare for the logit model with fuel economy standard interactions and international joint venture country interactions, allowing stated-owned firms to have different objectives, 2010-2013

	2010	2011	2012	2013
Consumer surplus	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Total firm profit for private firms	863.46***	614.09***	787.43***	1,945.60***
	(1.33)	(0.842)	(0.74)	(2.10)
Average firm profit for private firms	86.35***	61.41***	87.49***	216.18***
	(0.13)	(0.08)	(0.08)	(0.23)
Total firm utility for state-owned firms	4,712.00***	5,364.40***	5,440.10***	5,987.40***
	(1708.00)	(1735.90)	(1730.50)	(1635.90)
Average firm utility for state-owned firms	181.23***	184.98***	175.49***	166.32***
	(65.69)	(59.86)	(55.82)	(45.44)

Notes: All values are in units of billion Yuan. Standard errors are reported in parentheses. Significance codes: * p<0.05; ** p<0.01; ***p<0.001