Market equilibrium and the environmental effect of tax adjustments in China's automobile industry

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Abstract

This paper explores the effects of consumption and fuel tax regime adjustments on China's auto industry. Applying the model and simulation method of Berry, Levinson, and Pakes (1995), we conduct a comparative static analysis of equilibrium prices and sales, fuel consumption, and social welfare before and after tax adjustments. Further, for the first time, we compare the progressivity of both taxes. Our empirical findings suggest that fuel tax lowers vehicle consumption and consumer surplus more than consumption tax does, but our conclusion about the environmental effects of both taxes depends on the assumption of the fuel efficiency of outside fleets.

Keywords: China auto industry, welfare analysis, environmental effect, BLP model, tax progressivity

I. Introduction

China's automobile industry has developed rapidly in the last two decades. In 2009, China overtook the United States as the biggest auto market; the passenger car sales soared to 10.3 million, and the total vehicle sales were estimated at 13.6 million. However, a concomitant of this rapid development is the serious air pollution and carbon dioxide (CO_2) emission. With its annual CO_2 emission in 2007 accounting for 22.3% of the global total, China heads the list of sovereign states and territories on this score[1]. Meanwhile, emissions from motor vehicles have become the main source of air pollution in China's large- and medium-sized cities, according to the China Vehicle Emission Control Annual Report 2010 by the Ministry of Environmental Protection. This report shows that the volume of pollutants generated by motor vehicles across China in 2009 amounted to 51.4 million tons, with cars contributing most of it. Furthermore, Walsh (2000) also estimated that mobile sources contributed approximately 45–60% of the NOx emissions and about 85% of the CO emissions in major Chinese cities.

To reduce automobile emissions, China's Ministry of Finance and the State Administration of Taxation adjusted the consumption tax on vehicles twice, on Apr 1, 2006, and Sep. 1, 2008 (Table 1). In short, these policy adjustments raised the consumption tax rates on passenger vehicles with high displacements but lowered the rates on those with small engines[2]. Obviously, the purpose of this adjustment was to discourage high-emission cars and promote small ones, in an effort to reduce pollution and save energy. From the observed sale distribution changes over the years, as shown in Table 1, these tax adjustments raised the ratio of cars with engine size smaller than 2 liters, while shrinking the ratio of cars with larger displacement; thus, it would appear that the adjustments produced the intended effect. Meanwhile, other exogenous variables, such as gasoline price, product quality, and the number of car models, also changed, which may exaggerate or understate the effects of the taxation scheme changes on sale distribution. This calls for a formal investigation taking into account these exogenous changes.

This paper investigates the environmental effects of these tax scheme adjustments by conducting comparative static analysis on total fuel consumption and fleet average fuel efficiency[3]. We employ the model and simulation method of Berry, Levinson, and Pakes (1995; hereafter BLP) to obtain the equilibrium fuel consumption and fleet average fuel efficiency in a counterfactual tax scenario, and compare them to their actual counterparts. On the other hand, previous studies show that an effective emission-abatement policy is costly (Greene and Liu 1988, Crandall and Graham 1989, Kleit 1990, and Crandall 1992 for Corporate Average Fuel Economy [CAFE] and fuel tax, and White 1982 and Bresnahan and Yao 1985 for air-pollution standards of the Clean Air Act). Accordingly, we calculate the social welfare loss in new-car markets to measure the costs of tax changes[4]. To illustrate the effects of the consumption tax adjustments, we use a hypothetical fuel tax for comparison[5].

Our study shows that neither consumption tax nor fuel tax lowers the market-share-weighted average fleet fuel consumption significantly. However, fuel tax leads to a decrease in the total sale of new cars, which in turn leads to a decline in the total fuel consumption from new cars. It does not change the sale distribution over various fuel efficiency models. On the contrary, consumption tax adjustment skews the sale distribution toward more efficient new cars, and increases the total fuel consumption due to increased sales. The effects of these two taxes on environment depend on our assumption about the average fuel efficiency of outside goods. Further, the social welfare loss due to consumption tax is relatively less—in particular, the decrease in consumer surplus is less by an order of magnitude, in comparison to the fuel tax. Fuel tax actually transfers more welfare from private sector to the government.

The effectiveness of various emission-reduction policies has attracted attention from both policymakers and researchers for a long time. Most extant literature compares the tax policies such as fuel tax (Dahl 1979; Parry and Small 2005; Fullerton and Gan 2005; Feng, Fullerton, and Gan 2005; Bento et al. 2009), and other compulsory non-tax regulations such as CAFE (Crandall 1992; Sterner, Dahl, and Franzén 1992; Koopman 1995; Agras 1999; West 2004). Although ambiguous conclusions have been drawn on their effectiveness, most studies have found that fuel tax is more efficient in decreasing the Vehicle Miles Traveled (VMT), while CAFE is efficient in improving the average fuel economy of new cars[6]. However, few empirical studies to date have estimated the environmental and welfare effect of an excise tax on the car. China's automobile consumption tax is such an excise tax, with rates varying according to engine size. This tax is not as stringent as CAFE. Manufacturers do not need to restrict their average fuel efficiency; instead, they can choose to share some tax burdens to sustain their market shares. In this way, manufacturers partially internalize the marginal social cost of less fuel efficiency, rather than downsize the cars to satisfy the compulsory requirement[7]. Therefore, this tax may be a favorable policy to solve the safety issues due to CAFE. This paper is the first study to empirically investigate the efficiency and cost of this tax.

This paper differs from the previous studies in the following aspects. First, China's automobile consumption tax on displacement is unique[8], and this is the first paper to investigate the consequence of this tax and compare it to the fuel tax. This tax scheme sets progressive tax rates over displacement tiers, so tax payment is based on both displacement tiers and car values. Fullerton, Gan, and Hattori (2004) studied a similar annual automobile tax levied by the prefecture governments of Japan. Japanese automobile tax is a list of flat amounts over tiers of displacement, invariant to car value. China's tax scheme is more effective in reducing the sales of large cars than the lump-sum tax varying according to displacements, since car values are positively correlated with displacement. Besides, in terms of fairness, such a tax scheme is more progressive than the lump-sum tax scheme. This paper estimates the progressivity of the consumption tax, and compares it to that of the fuel tax.

Second, this paper simultaneously estimates the impacts of tax adjustment on both the demand and supply sides, while most empirical studies to date have focused on the demand side estimation (Greene and Liu 1988, Bento et al. 2009, West 2004). The BLP (1995) framework models the price competition among manufacturers, so it can be used to analyze the profit variation as well as consumer surplus changes due to exogenous tax changes, which makes this study capable of estimating the total social welfare changes rather than only consumer surplus changes.

Third, the empirical model in this study endogenizes the response of the equilibrium automobile prices to tax changes. The previous research usually ignores this while studying the effectiveness of emission-reduction policies (Fullerton, Gan, and Hattori 2004; West 2004). Since firms are heterogeneous in their costs, they may respond quite differently to a tax policy change. Firms with lower productivity have to pass on all the tax addition to consumers, while those with higher productivity can absorb some tax burden to sustain sales. Without considering the competition effect on car prices, the consumer welfare loss due to a tax change may be overestimated[9]. This paper investigates the tax incidence and finds that large-displacement car makers do share some tax burden to sustain their market share. Therefore, by incorporating this endogeneity, our estimates of welfare and environmental consequence add more precise evidence to the literature.

The rest of the paper is organized as follows. Section II briefly introduces the automobile industry and the consumption tax system in China. Section III lays out the empirical model and estimation method. Section IV describes the data and summary statistics. Section V presents the empirical results of the model estimation and counterfactual experiments. Finally, section VI presents a summary.

II. Description of the automobile industry and tax adjustments

China's automobile industry

Over the last two decades, China's automobile industry has witnessed a rapid development. With new car sales of 13.6 million in 2009 and a vehicle population of 62 million at the end of the year, China became the largest auto market in the world[10]. The development of this industry is asymmetric; in particular, the market share of passenger vehicles has increased from 8.3% in 1990 to 75.7% in 2009, while the market share of trucks declined from 52.8% to 16.5%, reflecting a switch in this industry to private cars[11].

The automobile industry of China is highly competitive due to the entrance of new manufacturers and further deregulation required by the WTO agreement (Deng and

Ma 2010). There are 171 manufacturers in this market, and the total market share of the five largest firms accounted for 66.1% of sales in 2008 (see Table 2 for details). Among the top ten manufacturers, eight are joint ventures with foreign car makers: Volkswagen, BMW, Mercedes Benz, General Motors, Hyundai, Nissan, Honda, and Toyota. Local brands accounted for only 25.92% of the market in 2008. Figure 1 displays the joint-ownership structure of China's automobile market. The complex market structure and the nature of multi-ownership for the top manufacturers make it difficult for them to collude with each other[12]. Therefore, we choose a strategic competition framework to model this market.

Our empirical analysis focuses on the light-duty passenger vehicle market, consisting of the sedan, MPV, and SUV. This market accounts for 75.3% of the total vehicle production in China. Most of the production is for domestic consumption. In 2008, the export of light-duty passenger vehicles was 0.24 million, which is less than 4.8% of the total production[13]. The import was about 0.15 million, which is negligible.

The consumption tax system and fuel tax

In China, a car attracts three categories of taxes: the consumption tax, the value-added tax (VAT), and the vehicle purchase tax, paid by the manufacturers, retailers, and consumers, respectively, although almost all taxes will be transferred to the consumers finally. The consumption tax came into being in 1994 targeting high-value or high-resource-consuming goods. For car sales, the tax rates vary with the displacement tiers (Table 1). VAT has been fixed at 17% since 1993 for the entire retailing sector. Vehicle purchase tax has also been fixed at 10% since 2001 for all passenger vehicles as of 2010. The calculation formula for these three taxes is given below:

$$p^m(1+t^c)\times(1+t^r)=p$$
$$Vpt=p^m(1+t^c)\times t^v$$

where, t^c, t^v, and t^r are the rates for consumption tax, vehicle purchase tax, and VAT, respectively, p^m is the wholesale price to dealers, p is the list price to consumers, and Vpt is the vehicle purchase tax that consumers pay on top of the VAT-deducted list price. Since vehicle purchase and VAT rates do not vary with different car models and stay unchanged over time, we ignore their impact in our study.

The fuel tax took effect in January 2009, 15 years after the debate on the tax started in 1994[14]. Since air pollution has become a significant concern in China, the government finally decided to implement the fuel tax to facilitate energy saving and emission cuts as well as economic structural adjustments. Based on the price for 93# gasoline in the mass market, the tax rate is close to 30%.

III. Empirical model and estimation method

Empirical framework

Consumers are assumed to choose a car from *N* models to maximize their utilities.

The indirect utility function for consumer *i* purchasing product *j* is as follows:

$$u_j^i = const + (\beta_{ge} + \alpha_{ge} v_{ge}^i) GE_j + (\beta_{pw} + \alpha_{pw} v_{pw}^i) POWER_j + (\beta_{wg} + \alpha_{wg} v_{wg}^i) WEIGHT_j$$
$$+ (\beta_p + \alpha_p v_p^i + \eta_{ge} inc^i) PRICE_j + \beta_{br} BR\_DUM_j + \xi_j + \varepsilon_j^i$$

This indirect utility function assumes that consumers will compare the characteristics of the cars in their choice set. Some key car features, such as horsepower (POWER), weight, price, fuel efficiency, and the place of origin of their brands (BR_DUM) are observable, while other features are not. Therefore, we use ξ_j to indicate those features consumers will consider while making their purchase decision, but are not observable in our data, and assume it follows a distribution with mean zero. Given the fact that consumers usually evaluate fuel efficiency in the same way as expenditures on gas, it is assumed that their utility depends on gas expenditure (GE), which is the product of fuel consumption and gas price measured in Chinese currency RMB yuan/liter, rather than fuel efficiency. By its construct, GE records consumers' expenditure on gas for a 100-km drive. If the average driven distance for a representative consumer is standardized to 100 km per year, GE actually measures the total expenditure of a representative consumer on gasoline per year. Since consumers are heterogeneous in their driving patterns, we take into account this difference using variable v_{ge}^i, which is the ratio of an individual's idiosyncratic driven distance to the mean level. Similarly, individuals have idiosyncratic tastes on the other product characteristics; we denote these taste variations on power, weight, and price using v_{pw}^i, v_{wg}^i, and v_p^i, respectively. Model parameters $\phi = (\alpha, \beta, \eta)$ describe the consumer's preference on the car characteristics. Finally, we assume that the idiosyncratic consumer taste ε_j^i follows a traditional type I extreme value distribution; therefore, the probability for consumer *i* to choose product *j* is given as

$$S_{ij}\left(x_j, \theta \middle| v^i, inc^i\right) = \frac{e^{u_j^i}}{\sum_{k=0}^{N} e^{u_k^i}}$$, where x_j is a vector of all product characteristics.

The market share for product *j* is given as

$$S_j\left(x_j,\theta\right)=\int_B S_{ij}\left(x_j,\theta\middle|v^i,inc^i\right)dP(v)dP(inc) \qquad (1)$$

where B is the set of consumers whose idiosyncratic tastes and income drive them to purchase product j.

On the supply side, manufacturers conduct differentiated Bertrand competition, so the profit maximization problem for manufacturer f producing J_f models can be formalized as

$$\max_p \prod_f = \sum_{j\in J_f}\left(\frac{p_j}{\left(1+t_j\right)}-mc_j\right)MS_j\left(x_j,\theta\right)$$

Here, market size M is constant. Since car models with different displacements are exposed to different tax rate t_j, the net income for manufacturers is $\frac{p_j}{\left(1+t_j\right)}$. The marginal cost mc_j does not change in output, but it varies across different car models; therefore, it is a function of product characteristics w_j:

$$\ln(mc_j)=w_j\gamma+\omega_j$$

Since this function is in the log-linear form, the parameters γ indicate the percentage change of marginal costs due to a particular car characteristic change.

The first-order condition of the profit maximization problem gives the following equation:

$$\ln\left(\frac{p_j}{(1+t_j)}-\varpi_j(x,\theta,t)\right)=\ln mc_j=w_j\gamma+\omega_j \qquad (2)$$

where, $\varpi_j(x,\theta,t)$ is the markup of product j, and it should be a function of demand side variables, parameters, and taxes for all car models. Equations (1) and (2) give rise to the equilibrium conditions in the market.

Estimation issues

We apply the GMM estimation method proposed by BLP (1995) to estimate the parameters in equations (1) and (2) simultaneously. In short, we use the observed market share to recover the mean utility in equation (1), which is a function of consumers' mean preference β, the observed product characteristics, and unobserved product characteristics ξ_j. Then, our moment condition is $E\left(\begin{bmatrix}\xi(\beta,\alpha,\eta)\\ \omega(\gamma)\end{bmatrix}\middle| Z\right)=0$, where Z is a set of instrumental variables described below. For the details of this method, readers can refer to BLP (1995). We will only discuss relevant issues involved in the estimation process.

One important issue of this method is the computation of aggregate market shares. Following Nevo (2001), we make *ns* random draws from standard normal distribution to simulate the idiosyncratic consumer tastes, and make the same amount of random draws for a vector of household income and annual driven distance based on survey data. These random values are used to calculate the conditional choice probability for each individual, and then the unconditional market shares are derived using the average of the individual market shares given by $S_j\left(x_j,\theta\right)=\frac{1}{ns}\sum_{i=1}^{ns}S_{ij}\left(x_j,\theta\middle|v^i,inc^i\right)$.

Another issue is the choice of instrumental variables for the price endogeneity problem. In this study, we use three sets of instrumental variables: the product characteristics, the sum of corresponding characteristics over all the firms' other models, and sum of product characteristics over other firms' car models in a market. Nevo (2001) shows that these are valid instrumental variables that are independent of the unobservable characteristic terms but correlated with prices.

Finally, given the estimates of structural parameters, we use compensating variation (CV) to calculate consumer surplus changes due to tax changes. For a logit discrete choice model on the demand side, Nevo (2000) shows that CV can be calculated as follows:

$$CV = \frac{M}{ns}\sum_{i=1}^{ns}\frac{\ln\{\sum_{j=0}^{N}\exp u_{j,post}^{i}\} - \ln\{\sum_{j=0}^{N}\exp u_{j,pre}^{i}\}}{(\beta_p + \alpha_p v_p^i + \eta_{ge} inc^i)}$$

IV. Data and summary statistics

This section describes three main sources of data used in this paper: (1) monthly car model sales from China Association of Automobile Manufacturers (CAAM); (2) product attributes collected from *Car Market Guide*; and (3) consumer demographic characteristics from a survey conducted among vehicle owners in Beijing by Guanghua School of Management at Beijing University of China in 2005. The summary statistics are listed in Tables 3 and 4.

Monthly sale and price data from January 2004 through December 2008 are available from CAAM. Since the car feature data for 2006 are missing, we have to drop the sales data for 2006 in our estimation. The total sale of car models for 2008 in our sample is 5.49 million, which accounts for 81.3% of the total passenger vehicle sales in the China market. To derive the market share for each car model, we set the market size at the number of city households who owned a house with more than three rooms, published in the Fifth National Population Census (2000) by the National Bureau of Statistics of China. This number is 17,963,399[15].

A stylized fact is that most entry and exit of car models occurred in January or some month in the second half year. In other words, the competition structure over half-year intervals is quite stable. Therefore, we aggregate the data into half-year levels and use the average monthly prices and sales for each half year to measure their sales and price. In this way, we can include the truncated data and make a comparison across 1297 car models. Large variations in both sales and prices are observed. The most popular car model has a monthly sale of over 19,000 units, while the minimum sale is only 12 units per month. The standard deviation in price is 123311.7, which is high relative to the average price of RMB 168454.8.

Product features are reported in the *Car Market Guide*. We define a car model by the product characteristics, including brand and the following model features. Horsepower is measured by kilowatts. $WEIGHT_j$ is the logarithm of the car weight measured in kilograms. Fuel consumption is a ratio given in liters/100 km, which is used to construct the gas expenditure variable as described in the model section. Place-of-origin dummy variables for brands show that European, Japanese, and American cars are most popular in China.

Household income is reported as categorical data in interval scales as listed in Table 5. We use the average of each interval to represent the income of consumers falling into that interval. For the first and last interval, we choose RMB 1,000 and 100,000, respectively. In this way, the average household income corresponding to the mean statistics in Table 3 amounts to RMB 8,300 per month[16]. The average distance traveled per year by Beijing car owners is about 22,000 km, and 60% of the drivers traveled less[17]. This supports our intuition that the main purpose of purchasing a car is for daily commute in China. Therefore, the driving pattern is relatively inelastic to some exogenous shocks such as fuel price changes. These survey data are used to simulate the consumers in the China auto market. Considering the computation burden, we finally randomly draw a thousand vectors of these two variables to represent individuals' demographic information.

V. Empirical results

In this section, we will first present the estimation results; then, we will report the empirical results for a counterfactual experiment to illustrate the impact of both consumption and fuel tax.

A. Estimation results

Estimates of the model parameters are listed in Table 6. All estimates for the mean utility function are significant with expected sign. Consumers prefer more powerful and larger size but less-fuel-consuming cars. These findings coincide with most of the previous research (Bresnahan 1987, Greene and Liu 1988, BLP 1995, Deng and Ma 2010). In particular, the statistic on driving distance shows that VMT is relatively inelastic in China; hence, it is assumed unchanged with vehicle choice and other exogenous factors such as fuel price. Therefore, the variation in fuel expenditure on different car models reflects the physical difference in cars' fuel efficiency. The negative coefficient of fuel expenditure shows that efficient cars are more favorable.

On the cost side, all estimates are significant. Unlike the demand side, fuel consumption rather than fuel expenditure is incorporated into the marginal cost function. This is because cost per se only depends on the car features and production technology, but not on fuel prices. A negative sign indicates that a more-fuel-consuming car costs less than a fuel-efficient car. Coefficients of brand dummies are also positive and significant. This may imply that foreign brands invest more than local brands on characteristics other than those included in our analysis.

Almost all the estimates for the idiosyncratic tastes and household demographic variation are insignificant, implying consumers are not so different in the car features in our study. However, consumers do show variation in their sensitivity to price, although the estimate for the standard deviation on the tastes for price (-0.1105) is less than one-third of that for price in the mean utility (-0.3894). Estimation results also show that households with higher income are less sensitive to price changes, but this effect is not significant.

B. Counterfactual experiments

While studying the effectiveness and welfare effect of tax changes, it is necessary to control for the market structure changes and keep technical surface unchanged before and after tax changes. However, associated with tax changes, new entry of car models is observed. To disentangle the tax effect on the equilibrium prices and market shares from changes in competition environment, we conduct a counterfactual experiment using the data for September to December 2008, during which period there were 252 car models in the market. We assume that the market structure is unchanged and that the tax scheme is set as it was before the tax adjustment in April 2006; we then solve the equilibrium prices and market shares. Similarly, we also solve the equilibrium set for a scenario in which gasoline is subject to a 30% fuel tax, while assuming the consumption tax scheme remained unchanged.

a). Equilibrium price analysis

Figure 2 displays the simulated tax-inclusive price changes before and after tax adjustments. Apparently, the price of most fuel-efficient cars declines after the consumption tax adjustment, while the price of high-fuel-consuming cars increases dramatically. However, a similar trend is not observed for fuel tax. On the contrary, manufacturers of fuel-consuming cars either undercut their prices or keep them unchanged to compete with efficient cars after fuel tax.

A summary of price changes is listed in Table 7. Cars are categorized into various groups by fuel consumptions; then, we calculate the average price changes due to tax adjustments for each group. Consumption tax adjustment is embodied in the auto prices: the average price for efficient cars is lowered since the consumption tax rate for this section is lowered, while the average price for fuel consuming cars increases due to a higher consumption tax rate. Although manufacturers have already shared some tax burden (we will show the tax incidence below in detail), they have no capability to absorb all the tax, so the final prices for inefficient cars increases by a notable scale. Fuel tax causes an adverse pattern in price changes. The reason is that fuel tax affects fuel expenditures on different car models disproportionally. It raises the fuel cost on inefficient cars much more than on the efficient models. To sustain their market share, the manufacturers of fuel-consuming cars have to lower their prices. On the other hand, the efficient cars obtain advantage after fuel tax, so they can charge higher prices.

b). Tax incidence

Before investigating the welfare effect of tax adjustments, we analyze the tax incidence first since this will give a rough picture about welfare transfer between consumers and manufacturers.

Since the tier of tax rates is set by displacement levels, we plot the percentage change of tax-inclusive prices versus car displacement in Figure 3. For cars with displacement lower than 1.5 liters, their effective tax rate is lower after adjustment. Consequently, we observe a negative change in price for most car models in this category. For cars with displacement between 1.5 and 2.5 liters, their tax-inclusive prices are not supposed to change since they are exposed to barely changed tax rates. However, the intensive competition in this category drove the prices of most models down more or less. Therefore, actually manufacturers in this segment shared some tax burdens. For cars falling into the category of 2.5–3, 3–4, and above 4 liters, we expect their tax-inclusive price to increase by 4%, 16%, and 30%, respectively, if manufacturers do not share any tax burden. Figure 3 shows that most manufacturers for cars below 4 liters just passed on the tax burden to consumers directly. Only those producing large cars shared moderate taxes to sustain their market shares. Therefore, we expect to see consumers lose more than the producers from tax rate increases.

c). Impact on fuel consumption and welfare analysis

The environmental effects of these two tax adjustments are expected to be different. Since the tax-inclusive prices benefit efficient cars in their market shares under consumption tax adjustment, the market share-weighted average fuel consumption is expected to decrease for this case. However, it is ambiguous as regards fuel tax since the price changes reversely to the fuel expenditure. We summarize the share-weighted average fuel consumption in the first column in Table 8.

Our results show that neither fuel tax nor consumption tax has a significant effect on fuel efficiency[18]. However, the average fuel consumption decreased by 0.2% after consumption tax adjustment, while the average fuel consumption increased by 0.5% after fuel tax adjustment.

An interesting finding is that the total consumption of fuel under various scenarios displays completely opposite trends (column 2)[19]. Fuel tax reduces total consumption of fuel by 16 billion liters, while consumption tax leads to an increase by 0.16 billion liters. How should the result on fleet average fuel consumption be reconciled with that on the total fuel consumption? To answer this question, we need to look into the definition of these two measurements. The fleet average fuel consumption is a sale-weighted average fuel consumption conditional on purchase; therefore, when the realized total sale decreases on a relatively larger scale than the average fuel consumption does, then the conditional average increases. In the case of fuel tax, consumptions on all fuel efficiency levels have dropped after tax since the expenditure on gas go beyond consumers' budgets, leading to sharp decline of total sale of cars, while the sale distribution over fleet average fuel consumption does not change much (column 6 in Table 7). In the case of consumption tax, however, the decreased tax rate for the small-displacement cars attracted more sales, leading to an increase of total sales, while the sale distribution skewed to efficient cars (column 5 in

Table 7). Therefore, we observe a decrease in the total consumption of fuel due to the decline of fleet size and an increase of average fuel consumption due to the drop in marginal consumers under fuel tax, but observe completely opposite trends under consumption tax.

A natural question arises: Which measurement should we use to make a judgment on the policies? The answer to this question depends on the assumption of the outside goods. When a consumer chooses not to purchase a car in our dataset, he may choose not to purchase, in which case his fuel consumption is zero, or to purchase a used car or any car outside of our data, in which case his fuel consumption may be even higher. Given the unavailability of used-car data, we calculate the thresholds of fleet average fuel consumption for the outside goods, which makes the total consumption of fuel under the scenario of both tax adjustments indifferent to each other, using the following equation:

$$TFC_n^f + AMT_o * AFCO * (1 - \sum_j S_j^f) * M = TFC_n^c + AMT_o * AFCO * (1 - \sum_j S_j^c) * M$$

where, TFC_n^f and TFC_n^c are the total fuel consumption for new cars subject to fuel tax and sale tax, respectively (as shown in column 3), AMT is the average distance traveled, $AFCO$ is the average fuel consumption of outside goods, $(1 - \sum_j S_j^f)$ and $(1 - \sum_j S_j^c)$ are the market shares of outside goods under fuel and consumption taxes, respectively. Since AMT is available from our demographic data sample, $AFCO$ can be solved from the above equation. Similarly, we solve the threshold of average fuel consumption for consumption tax to reduce total consumption of fuel relative to the no-tax case.

Figure 4 illustrates the savings in total consumption of fuel under both taxes. Our results show that when the average fuel consumption for the outside goods is above 3.30 liters/100 km, consumption tax is effective to lower the total consumption of fuel, compared to the case without tax; when it is below 6.62 liters/100 km, fuel tax can save total consumption of fuel. When the average fuel consumption of the outside goods is below 6.55 liters/100 km, fuel tax works better than consumption tax in lowering total consumption of fuel. Intuitively, if consumers who choose the outside options are more likely to purchase an inefficient car, then policy leading to less total sale of new cars will become worse even if it saves the consumption of fuel on new cars. For instance, assuming the average fuel consumption for used cars is 10 liters/100 km, then only if the chance for an outside-goods consumer to choose a used car is below 65.5% will fuel tax become more efficient than consumption tax.

On the other side, both taxes lead to consumer welfare loss, but they are quite different in magnitude and welfare re-distribution (columns 3–6). The welfare loss due to consumption tax adjustment (4 million) is about four orders of magnitude less than that caused by fuel tax (13.1 billion). More importantly, fuel tax leads to a consumer welfare loss (8.07 billion) in an order of magnitude more than the loss from consumption tax (199 million). The same pattern is observed in the manufacturers' profit, while the government's tax income increases by 562 million from fuel consumption, even using the number of fuel tax for one year. In other words, both taxes result in welfare re-distribution among economic principals, but fuel tax transfers welfare from the private sector to the government in a much larger magnitude.

d). Tax progressivity

Policy makers are usually concerned about the distributional effect of a tax. Most economists and policy makers support a progressive tax system, since “it is not very unreasonable that the rich should contribute to the public expense, not only in proportion to their revenue but something more”[20]. To measure the progressivity, we construct the Lorenz curves proposed in Suits (1977). Figure 5 illustrates the distributional effect of both taxes over household incomes. It shows that the percentage of tax burden borne by the lowest income groups is higher than their share of total income for both taxes, so the curves arch above the diagonal equity line, which is similar to the sales and excise taxes in the states shown in Suites (1977).

Our findings coincide with those of West (2004) in that both consumption tax and fuel tax are regressive[21]. However, West (2004) finds that gas or miles taxes are significantly less regressive than size taxes, but our findings suggest that consumption tax based on the size of displacement is less regressive than fuel tax for the lower income group but the effect is the opposite for the higher income group.

VI. Conclusion

We found that fuel tax is more costly than sales tax in increasing the fuel efficiency level because consumption tax leverages tax payment on different displacement types of automobiles: subsidizing small-displacement cars with tax income from large cars, while fuel tax equates the marginal costs of reducing fuel consumption across all uses (Crandall 1992). Therefore, the consumption tax is more efficient to induce consumers to choose fuel-efficient cars, making the sale distribution skewed toward efficient cars; the sale distribution over fuel efficiency remains unchanged in the case of fuel tax adjustment. However, fuel tax decreases the total sale of new cars, while consumption tax adjustment actually enlarges the total sale a little bit. Therefore, they have the opposite effect on the total consumption of fuel. Their total effects on the environment, however, depend on the average fuel efficiency of the outside goods. As long as the proportion of outside-goods consumers who finally purchase a high-fuel-consuming car is not large, the fuel tax works better in lowering the total consumption of fuel.

Our fairness study shows that consumption tax is less regressive than the fuel tax for low-income consumers. Moreover, it does not reduce consumer surplus as much as fuel tax does. Nevertheless, considering the externality of savings in fuel consumption, the welfare loss due to fuel tax should be much lower.

However, our conclusion relies on one assumption: we assume the driving pattern will not change even when consumers are exposed to a 30% fuel tax. Considering the fact that the main purpose of driving in China is business transportation, this assumption is reasonable. Kahn (1996) finds that "emissions reduction has occurred even though total vehicle miles travelled has more than doubled," and his explanation about this phenomenon is that emissions fall when new-car emissions regulation becomes more stringent. This also supports our assumption about travel pattern, since his finding proved that regulation on fuel efficiency is more efficient than policies affecting driving patterns in reducing emissions.

References

Agras, Jean. 1999. "The Kyoto Protocol, CAFE Standards, and Gasoline Taxes." *Contemporary Economic Policy*. 17(3): 296-308.

Bento, Antonio M., Lawrence H. Goulder, Mark R. Jacobsen, and Roger H. von Haefen. 2009. "Distributional and Efficiency Impacts of Increased US Gasoline Taxes." *American Economic Review*, 99(3): 667–99.

Berry, Steven, James Levinsohn and Ariel Pakes. 1995. "Automobile Prices in Market Equilibrium." *Econometrica*, 63(4): 841-890.

Bresnahan, Timothy. 1987. "Competition and collusion in the American automobile market: the 1955 price war." Journal of Industrial Economics, 35(4): 457-482.

Bresnahan, Timothy and Dennis A. Yao. 1985. "The Nonpecuniary Costs of Automobile Emissions Standards." *RAND Journal of Economics*, 16: 437-455.

Crandall, R. 1992. "Policy Watch: Corporate Average Fuel Economy Standards." *The Journal of Economic Perspectives*, 6(2): 171-180.

Crandall, Robert W., and John D. Graham. 1989. "The Effect of Fuel Economy Standards on Automobile Safety." *Journal of Law and Economics*, 32: 97-118.

Dahl, Carol A, 1979. "Consumer Adjustment to a Gasoline Tax." *The Review of Economics and Statistics*, 61(3): 427-32.

Deng, Haiyan and Alyson Ma. 2010. "Market Structure and Pricing Strategy of China's Automobile Industry", *The Journal of Industrial Economics*, 58(4): 818-845.

Feng, Ye, Don Fullerton and Li Gan. 2005. "Vehicle Choices, Miles Driven And

Pollution Policies.” National Bureau of Economic Research Working Paper 11553.

Fullerton, Don and Li Gan. 2005. "Cost-Effective Policies to Reduce Vehicle Emissions." *American Economic Review,* 95(2): 300–304.

Fullerton, Don, Li Gan, and Miwa Hattori. 2004. “A Model to Evaluate Vehicle Emission Incentives Policies in Japan.” *working paper.*

Greene, David L. and Jin-Tan Liu. 1988. "Automobile Fuel Economy Improvements and Consumer Surplus," *Transportation Research*, 22(A): 203-218.

Harrington, Winston. 1997. “Fuel Economy and Motor Vehicle Emissions.” *Journal of Environmental Economics and Management*. 33(3): 240-252

Hu, Weimin, Junji Xiao, and Xiaolan Zhou. 2011. “An Analysis on the Competition Structure of China Automobile Industry.” Working Paper.

Kahn, M. 1996. “New Evidence on Trends in Vehicle Emissions.” *The RAND Journal of Economics*, 27(1): 183-196

Kleit, Andrew N. 1990. "The Effect of Annual Changes in Automobile Fuel Economy Standards.” *Journal of Regulatory Economics*, 2(2): 151-172.

Koopman, Gert Jan. 1995. “Policies to Reduce CO_2 Emissions from Cars in Europe: A Partial Equilibrium Analysis.” *Journal of Transport Economics and Policy*, 29(1): 53-70

Nevo, Aviv. 2000. “Mergers with Differentiated Products: The Case of the Ready-to-Eat Cereal Industry.” *The RAND Journal of Economics*, 31(3): 395-421.

Nevo, Aviv. 2001. “Measuring Market Power in the Ready-to-Eat Cereal Industry.” *Econometrica*, 69(2): 307-342.

Parry, Ian W. H., and Kenneth A. Small. 2005. "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review*, 95(4): 1276–1289.

Petrin, Amil. 2002. “Quantifying the Benefits of New Products: The Case of the Minivan." *Journal of Political Economy*, 110:705-729, 2002.

Research department of industrial economy under the Development Research Center of the State Council and the Society of Automotive Engineers of China, Volkswagen Group China 2009, *Annual report on automotive industry in China*, Social Science Academic Press (China).

Sterner, Thomas, Carol Dahl and Mikael Franzén. 1992. “Gasoline Tax Policy, Carbon Emissions and the Global Environment.” *Journal of Transport Economics and Policy*, 26(2): 109-119

Suits, DB, 1977. “Measurement of Tax Progressivity.” *The American Economic Review*. 67(4): 747-752.

Walsh, M.P., 2000. “Transportation and the environment in China.” China Environment Series, Washington, DC.

West, Sarah. 2004. “Distributional effects of alternative vehicle pollution control policies.” *Journal of Public Economics*, 88: 735– 757

White, L.J. 1982. “The Regulation of Air Pollutant Emissions from Motor Vehicles.” Washington, D.C.: American Enterprise Institute.

Table 1 Adjustments of consumption tax rates on vehicles and sale distribution over displacements in China

Effective since		**Displacement (L)**						
		≤1.0	1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0	3.0–4.0	>4.0
1994 (%)		3	5	5	5–8	8	8	8
Apr. 1, 2006 (%)		3	3	5	9	12	15	20
Sale distribution (%)	***2006***	*18.67*	*47.85*	*20.89*	*10.31*	*2.13*	*0.12*	*0.03*
	2007	*12.10*	*48.29*	*25.58*	*12.08*	*1.71*	*0.23*	*0.01*
Sep. 1, 2008 (%)		1	3	5	9	12	25	40
Sale distribution (%)	***2008***	*10.50*	*51.73*	*24.60*	*11.34*	*1.43*	*0.38*	*0.01*
	2009	*12.33*	*57.32*	*19.38*	*9.37*	*1.35*	*0.22*	*0.03*

Source: Tax rates—China State Administration of Taxation; Sale distribution—China Auto Industry Development Annual Report 2010

Table 2 The market shares for top 10 manufactures in China auto industry

Rank	Manufacturers	Market Share (%)
1	SAIC (Shanghai Auto Industry Cooperation)	18.3
2	FAW	16.3
3	DFM (Dongfeng Motor Cooperation)	14.1
4	CHANA (Changan Automobile)	9.2
5	BAW (Beijing Automobile Works Co.,Ltd)	8.2
6	GAIG (Guangzhou Auto Industry Cooperation)	5.6
7	Cherry	3.8
8	Brilliance Auto	3.0
9	Hafei Automobile Group	2.4
10	Geely Holding Group	2.4

Source: China Auto Industry Development Annual Report 2010

Table 3 Summary statistics for households' income and annual vehicle miles traveled

Variable	Obs	Mean	Std.	Min	Max
Household income (RMB yuan)	7809	6.65	2.37	1	12
Annual mileage (km)	7809	22096.02	13717.84	2880	105000

Table 4 Summary statistics for key product characteristics and sale

Variable	Obs	Mean	Std.	Min	Max
Horsepower (kW)	1297	92.19	33.44	26.50	257.00
Displacement (liters)	1297	1.90	0.62	0.80	4.70
Weight (kg)	1297	1342.23	297.34	645.00	2590.00
Fuel Consumption (liters/100 km)	1297	6.94	1.96	3.60	21.70
American	1297	0.12	0.32	0.00	1.00
Japanese	1297	0.24	0.43	0.00	1.00

Korean	1297	0.08	0.27	0.00	1.00
European	1297	0.26	0.44	0.00	1.00
Sale	1297	2335.30	2751.26	12.00	19185.40
Price (yuan)	1297	168454.80	123311.70	28800.00	856300.00

Table 5 Interval scales for household income

M1 What is your monthly household income before tax? (RMB)	
1. 2,000 or below	2. 2,001-3,000
3. 3,001-4,000	4. 4,001-5,000
5. 5,001-6,000	6. 6,001-8,000
7. 8,001-10,000	8. 10,001-15,000
9. 15,001-20,000	10. 20,001-50,000
11. 50,001-80,000	12. 80,000 or above

Table 6 Estimates of the full model

Variables	Utility function (β, α, η)	Marginal cost function (γ)
Mean	β	
Constant	-23.3938**	-15.6213**
	(3.9116)	(3.6280)
Power	0.0263**	0.0075**
	(0.0063)	(0.0009)
Weight	2.5476**	2.4769**
	(0.6906)	(0.5055)
Gas expenditure	-1.0251**	
	(0.2701)	
Fuel consumption		-0.3561**
		(0.0890)
Price	-0.3894**	
	(0.0895)	
American	1.2617**	0.4462**
	(0.1678)	(0.0813)
Japanese	1.3903**	0.5110**
	(0.1718)	(0.0779)
Korean	0.4670*	0.3976**

	(0.2246)	(0.0770)
European	1.5093**	0.7267**
	(0.1979)	(0.1056)
Standard deviation of idiosyncratic tastes	α	
Power	0.0010	
	(0.0100)	
Weight	0.0015	
	(0.1216)	
Gas expenditure	0.0011	
	(0.1349)	
Price	-0.1105**	
	(0.0306)	
Interactions with household income	η	
Price	0.0013	
	(0.0014)	

Note: * and ** indicate the 5% and 1% level of significance, respectively. Within parentheses are the standard errors.

Table 7 Summary of price changes due to tax adjustments

Fuel consumption category (liters/100 km)	**# of car models**	**Price changes due to (%)**		**Total sale changes due to (%)**	
		Consumption tax	Fuel tax	Consumption tax	Fuel tax
(0, 5)	18	-0.6192	0.3272	0.98	-22.68
(5, 6)	57	-0.4657	0.1983	1.18	-21.92
(6, 7)	74	-0.2341	0.1225	0.44	-21.51
(7, 8)	54	0.0212	-0.1297	-0.14	-20.48
(8, max)	49	1.8531	-0.2305	-1.19	-18.31

Table 8 Impacts of consumption and fuel tax

(FT, CT)[a]	**Mean fuel consumption** (liters/100 km)	**Total fuel consumption** (10 billion liters)	**Firm profit**	**Consumer surplus**	**Consumption Tax**	**Fuel tax**	**Social welfare**[c]
			(unit: RMB 10 billions)				
(1, 0)[b]	6.6612	5.9563	1.8612	3.4204	0.3163	.1310	5.5979
(0, 0)	6.6264	7.5581	2.2891	4.2274	0.3911	--	6.9076
(0, 1)	6.6071	7.5744	2.2791	4.2075	0.4206	--	6.9072

Note: a. FT – fuel tax, CT – consumption tax; b. the binary variable indicates whether a tax is imposed: 1 yes, 0 no.

c. Since the fuel tax is a transfer from consumers to government, it is not included in social welfare.

Figure 1 The joint-venture structure for the major auto manufacturers

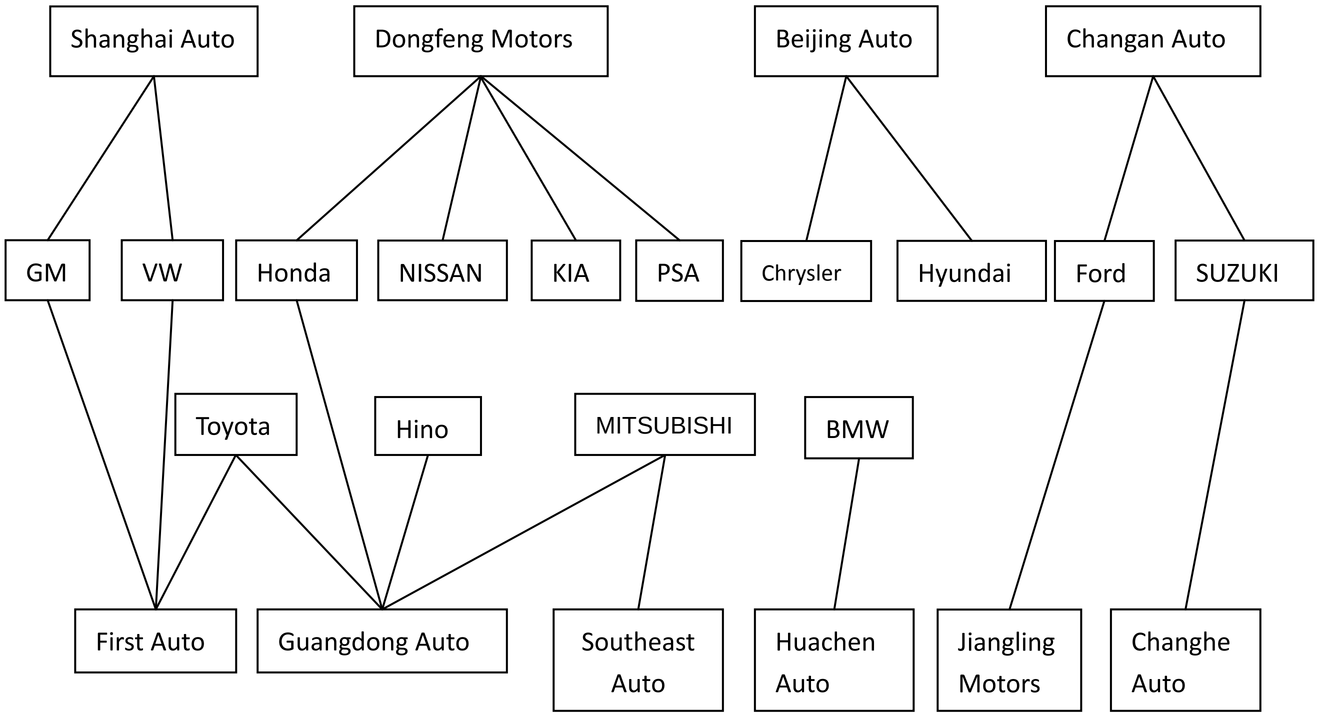


Figure 2(a) Percentage price changes due to consumption tax adjustment by fuel consumption levels

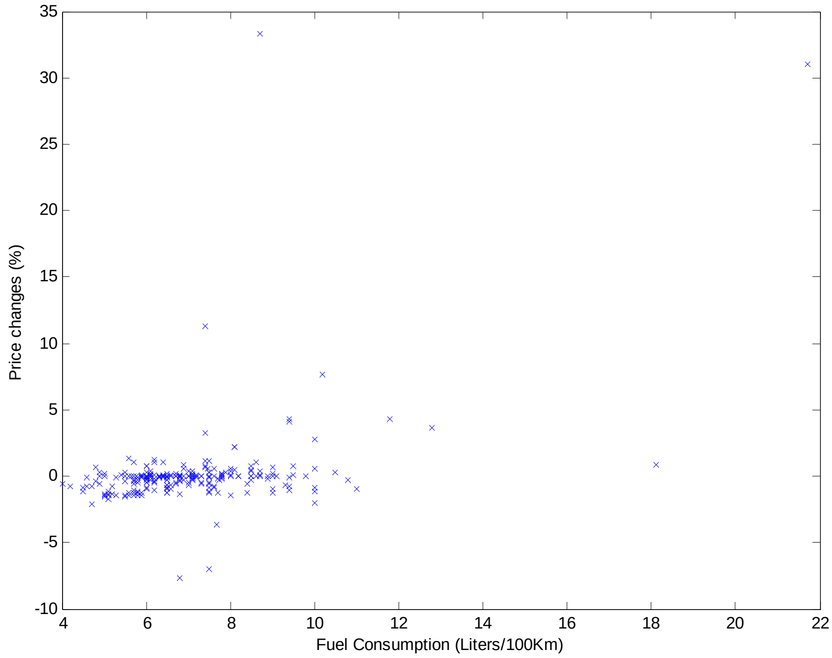


Figure 2(b) Percentage price changes due to fuel tax adjustment by fuel consumption levels

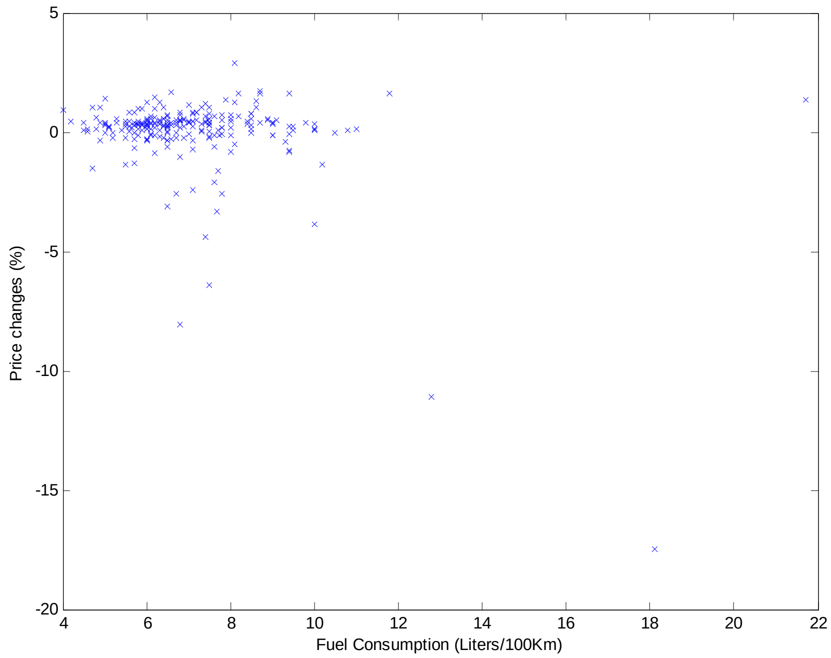


Figure 3 Tax-inclusive price changes due to consumption tax by displacement

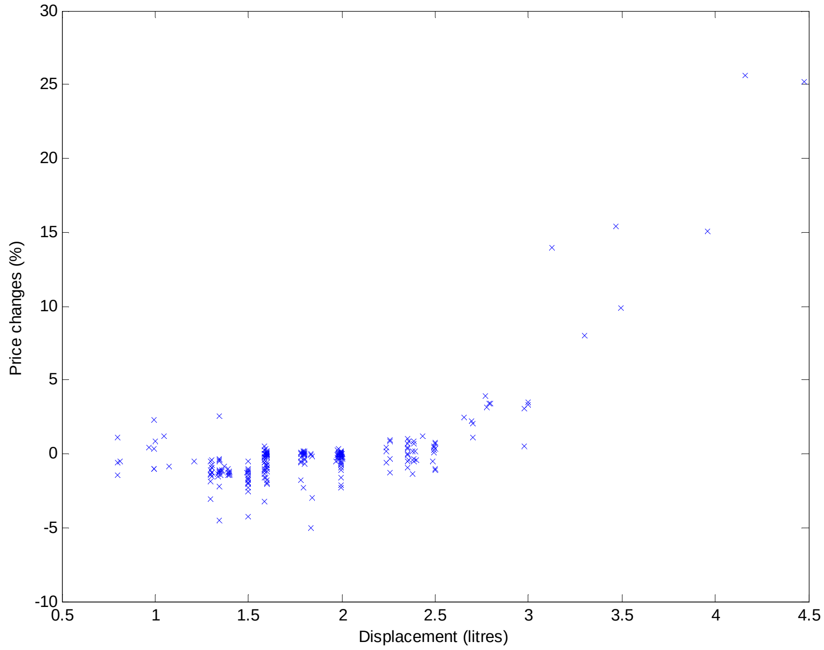


Figure 4 Savings of total consumption of fuel due to taxes

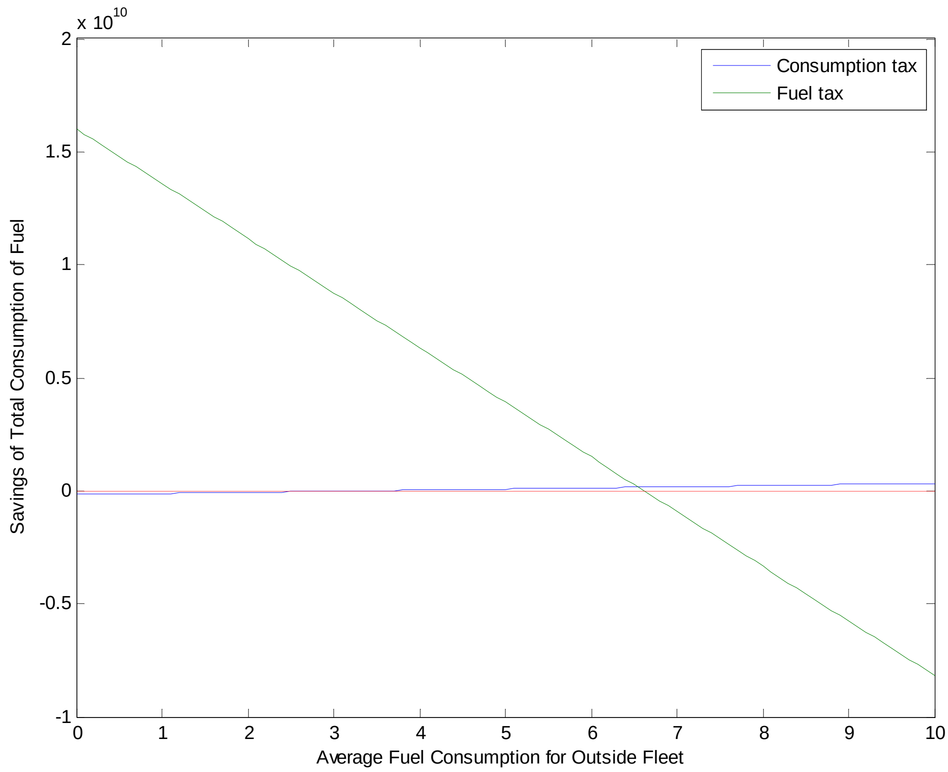
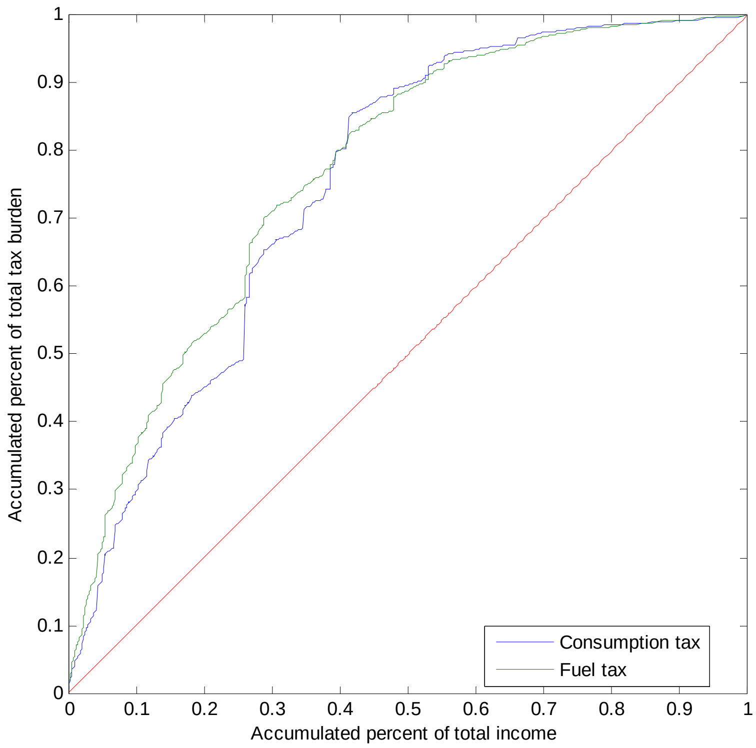


Figure 5 Lorenz curves for consumption tax and fuel tax



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[1] Data source: Carbon Dioxide Information Analysis Center of the US Department of Energy.

[2] The policy design is based on a roughly positive relationship between displacements and fuel consumption, henceforth car emissions. And, taxing directly on displacement, an observable car feature, is more implementable than taxing on emissions.

[3] Harrington (1997) showed that better fuel economy can strongly contribute to lower emissions of CO and hydrogen carbonate. Therefore, literature has widely applied the average fuel economy to measure the effectiveness of alternative emissions-abatement policies. This paper follows this measurement standard.

[4] Fullerton and Gan (2005) also used this measurement as costs for emission-abatement policies.

[5] Fuel tax adjustment was effective in January 2009, but our sample period ends in

December 2008, so such a fuel tax adjustment is hypothetical. Based on the price for 93# gasoline in the mass market, the tax rate is about 30%.

[6] Parry and Small (2005) also conclude that fuel tax causes greater shifts in fuel economy than VMT reduction.

[7] Downsizing may cause serious safety problem and results in higher costs for a regulation policy. Greene and Liu (1988) find that for a gallon fuel saving, the welfare loss is $0.3; Crandall and Graham (1989) estimate that welfare losses per gallon is $0.41~0.63 considering the safety issue caused by downsizing due to CAFE.

[8] Some European countries also levy vehicle excise duties or consumption tax based on the engine size. For example, the excise duty on motorcycles in Cyprus is also calculated based on the engine size, taking into account the age and mass of carbon dioxide emissions of the vehicle. Britain used to have a similar taxation scheme before Mar. 1st 2001. These excise duties or consumption taxes are paid by drivers rather than the manufacturers; and more importantly, the lump-sum tax based on the displacement is not subject to the car price. Therefore, it is recessive within a displacement interval.

[9] For example, Petrin (2002) estimates that gains from increased price competition due to the entry of Minivan may explain 43 percent of total consumer benefits.

[10] News release February 24th, 2011, National Development and Reform Commission of China.

[11] China Automotive Industry Yearbook 2010.

[12] A formal hypothesis test study on alternative non-nested competition models by Hu, Xiao and Zhou (2011) also supports our intuition.

[13] Annual report on automotive industry in China 2009.

[14] The delay of the enactment of fuel tax was mainly due to two reasons. In the 1990s,

National People's Congress rejected proposals to use fuel tax to replace the road toll, which is collected by local governments. Local governments were concerned that they would lose out financially. Since 2000, implementation of fuel tax has been delayed because of sharp rises in the international oil price, with policymakers expressing concern that the tax will increase inflation.

[15] This number is arbitrary. Setting the market size at different number will mainly change estimate of the constant coefficient on the demand side since that will change the relative market share of each car model to the outside goods; however, the ratios of market share between different car models will not change.

[16] The average household income is RMB4395 per month in Beijing 2005 (National Statistics Bureau of China). Given the fact that the survey targets on vehicle owners, this statistic is reasonable.

[17] Another survey conducted in Beijing, Shanghai, Guangzhou, Jinan and Hangzhou 2005 by Sinotrust, which is a leading consulting firm in China, shows that the 66.7% consumers mainly use car for business travel or daily commute from home to working place.

[18] The t-statistic for the difference in the mean of fuel consumption between the scenario pre and after consumption tax adjustment is .3.

[19] We use the randomly drawn annual vehicle miles driven in our demographic data part to calculate the market share weighted average total consumption of fuel for each car model and then sum them up to derive this number.

[20] Adam Smith, *The Wealth of Nations.*

[21] West (2004) concludes that fuel tax is progressive over the bottom half of the income distribution but regressive over the wealthiest half of the income distribution. Since our study is targeted on car owners, who belong to the wealthy group in China,

so our findings actually support his.