Comparison of policies on vehicle ownership and use between Beijing and Shanghai and their impacts on fuel consumption by passenger vehicles

Han Hao a,b, Hewu Wang a,b,, Minggao Ouyang a,b

a State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China
b China Automotive Energy Research Center (CAERC), Beijing 100084, China

A R T I C L E   I N F O
Article history:
Received 2 June 2010
Accepted 22 November 2010
Available online 9 December 2010
Keywords:
Transport modeling
Vehicle policy
Vehicle ownership and use

A B S T R A C T
The fast growth of vehicle population in China has caused problems such as traffic congestion and excessive fuel consumption. There have been demands for policy control on growth in private vehicle travel demand. Beijing and Shanghai are China’s first two cities to implement policies on vehicle ownership and use. In this paper, we compared policies in the two cities and estimated their impacts on fuel consumption by passenger vehicles. The limitation of vehicle use in Beijing provides limited but immediate reduction in fuel consumption. The limitation of vehicle ownership in Shanghai provides large potential of fuel conservation in a longer term. Under current policy, fuel consumptions by passenger vehicles in Beijing and Shanghai in 2020 were estimated to reach 7.5 and 3.9 billion liters, respectively. The experiences of Beijing and Shanghai are highly relevant for cities in China and abroad that are facing the same problems.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Vehicle population in China has been growing dramatically over the last 10 years from 16.1 million in 2000 to 62.9 million in 2009 (Ministry of Public Security PRC, 2009). Vehicle ownerships in Beijing and Shanghai have reached 212 and 77 vehicles per 1000 capita in 2009. The fast growth of vehicle ownership has caused concerns over traffic congestion, air pollution and increasing fuel demand, especially in large cities. In other countries, there are some examples of interposing in the increase of private vehicle travel demand through administrative means (Chin and Smith, 1997; Chu, 2002; Koh, 2003). In China, Beijing and Shanghai are the first two cities to implement policies on vehicle ownership and use. The two cities are similar in many aspects such as developed economy, high population density, huge metro system being built, etc. However, due to different priorities of the policies implemented, vehicle ownership and use in the two cities are quite different. A detailed comparison of the two cities is presented in Table 1. In this study, we compared policies in the two cities and estimated their impacts on fuel consumption by passenger vehicles, with the purpose of indicating applicable vehicle policies for cities in China and abroad that are facing the same problems.

2. Policies on vehicle ownership and use

2.1. Policies on vehicle ownership

2.1.1. Nationwide policies on vehicle ownership

Since the beginning of this century, China has been promoting the growth of domestic vehicle market. At the beginning of 2009, the China state council announced the “auto industry revitalization planning”, which is part of the top 10 industrial revitalization planning (State Council PRC, 2009). The auto industry revitalization planning includes a series of measures promoting the growth of vehicle market, as listed below.

(1) From January 20, 2009 to December 31, 2009, for passenger vehicles with displacement of 1.6 L or less, the vehicle purchase tax is lowered to 5% which is only half of the normal purchase tax (10% of retail price). This measure was extended to the end of 2010 afterwards with the purchase tax of 7.5%.

(2) From March 1, 2009 to December 31, 2009, in rural areas, peasants buying minibuses with displacement of 1.3 L or less can receive subsidies amounting to 10% of the vehicle price. Peasants replacing tri-wheel vehicles and lower-speed vehicles with light duty trucks can receive subsidies of ¥2000 and ¥3000, respectively. The Chinese central government invested five billion Yuan in this subsidy program.

(3) The total amount of subsidies for scrappage of aging vehicles is raised from 0.6 billion Yuan in 2008 to 1 billion Yuan in 2009.
These measures significantly boomed China’s vehicle market. China’s vehicle sales increased from 9.38 million in 2008 to 13.5 million in 2009, as presented in Fig. 1.

2.1.2. Shanghai’s policies on vehicle ownership
Shanghai is the first city in China that limits the growth of private vehicle ownership. As early as in 1994, the Shanghai government began to control the total population of private vehicles by controlling the issue of license plates. The number of new private vehicle license plates issued per month is restricted to a certain number (normally under 10,000). Since 2000, the new private vehicle license plates have been issued by public auction (People’s Congress of Shanghai, 2000). From 2000 to 2007, a total number of 396,000 license plates were auctioned. As presented in Fig. 2, the bid price of a license plate has increased over time, with average price of ¥35,000 in 2008 (Chinese License Plates Net, 2009).

2.1.3. Beijing’s policies on vehicle ownership
Beijing has not taken any actions to control the vehicle ownership. However as announced by City Planning Commission of Beijing recently, the Beijing government is establishing a package of transportation plans to address the severe traffic condition. The measure of limiting vehicle population is seriously discussed. However, according to the Traffic Commission of Beijing, Beijing will not take Shanghai’s measures of limiting license plates by bidding.

2.2. Policies on vehicle use

2.2.1. Beijing’s policies on vehicle use
To relieve the traffic pressure, Beijing focused on the limitation of vehicle use through administrative means. During the 2008 Beijing Olympics and Paralympics Games, Beijing issued the first regulation on limitation of vehicle use. In 2008, 2009 and 2010, Beijing issued the second, third and fourth regulations. The current regulation will be in effect through April 2012 (Beijing Government, 2008a, 2008b, 2009, 2010). Table 2 summarizes major measures of the regulations.

Besides, Guangzhou has announced to implement regulation on limitation of vehicle use during the Asian games in 2010. The regulation to be implemented in Guangzhou is quite similar with that of Beijing during the Olympics.

Table 1
Comparison between Beijing and Shanghai.

<table>
<thead>
<tr>
<th></th>
<th>By the end of 2009</th>
<th>Beijing</th>
<th>Shanghai</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>16,808</td>
<td>6,341</td>
<td></td>
</tr>
<tr>
<td>Population (million)</td>
<td>17.55</td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td>GDP (¥ billion)</td>
<td>1,187</td>
<td>1,490</td>
<td></td>
</tr>
<tr>
<td>Per capita GDP (¥1000)</td>
<td>67.6</td>
<td>77.6</td>
<td></td>
</tr>
<tr>
<td>Vehicle population (million)</td>
<td>3.72</td>
<td>1.47</td>
<td></td>
</tr>
<tr>
<td>Vehicle ownership (vehicles/1000 capita)</td>
<td>212.0</td>
<td>76.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 2
Regulations on limitation of vehicle use implemented by the Beijing government.

<table>
<thead>
<tr>
<th>Regulation document</th>
<th>Start</th>
<th>End</th>
<th>Major measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>The announcement on temporary traffic management measures for motor vehicles in Beijing during the Olympics and Paralympics Games</td>
<td>July 1, 2008</td>
<td>September 20, 2008</td>
<td>On odd (even) days, only vehicles with odd (even) plate tail numbers are allowed to be used (special purpose vehicles, transit buses and taxis are not included).</td>
</tr>
<tr>
<td>The announcement on the implementation of traffic management measures in Beijing</td>
<td>October 11, 2008</td>
<td>April 10, 2009</td>
<td>(1) 30% of government vehicles are forbidden to be used.</td>
</tr>
<tr>
<td>(2) Vehicles are forbidden to be used for one certain weekday per week, depending on the plate tail numbers. The relationship between vehicle plate tail numbers and the forbidden weekdays are changed approximately monthly and the new rule is announced by the government ahead of implementation. For the first round, vehicles with tail numbers of 1 and 6 are forbidden to be used on Monday, 2 and 7 on Tuesday, 3 and 8 on Wednesday, 4 and 9 on Thursday and 5 and 0 on Friday (special purpose vehicles, transit buses and taxis are not included).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The announcement on continuing the implementation of traffic management measures in Beijing</td>
<td>April 11, 2009</td>
<td>April 10, 2010</td>
<td>Same as the previous regulation except for that the correspondence rule between vehicle tail number and forbidden weekday is changed every 13 weeks.</td>
</tr>
<tr>
<td>The announcement on the implementation of traffic management measures during the peak hours of weekdays in Beijing</td>
<td>April 11, 2010</td>
<td>April 10, 2012</td>
<td>Same as the previous regulation.</td>
</tr>
</tbody>
</table>
2.2. Shanghai’s policies on vehicle use

During the 2010 Shanghai Expo, the Shanghai government implemented the traffic support program for the 2010 Shanghai Expo. According to this program, parts of the government vehicles are forbidden to be used during the 2010 Shanghai Expo. The measure of limiting private vehicle use by their plate tail numbers was prepared as alternative measure but not implemented during the 2010 Shanghai Expo.

3. Policy effectiveness analysis

3.1. Policy effectiveness analysis on vehicle ownership

As introduced above, Shanghai has been controlling the total population of private vehicles by limiting the issue of license plates while Beijing has not begun to limit the vehicle population. As a result of the different policies in the two cities, vehicle population growth in Shanghai has been much slower than in Beijing. Over the last 10 years, Beijing’s vehicle population has risen from 1.04 to 3.72 million (Beijing Statistics Bureau, 2009) and that of Shanghai from 0.49 to 1.47 million (Shanghai Statistics Bureau, 2009). Fig. 3 plots the vehicle ownerships versus per capita GDP for all provincial regions in China mainland. Vehicle ownerships of all the provinces are increasing as a function of per capita GDP with different rates. Beijing’s vehicle ownership has risen more quickly than Shanghai. Between per capita GDP of ¥20,000 and ¥60,000, vehicle ownership of Beijing rose steeply from about 40 to 185 vehicles per 1000 people, with elasticity of 3.6 (elasticity was approximately calculated as vehicle ownership increment divided by per capita GDP increment). Shanghai’s vehicle ownership rose slowly from about 20 to 60 vehicles per 1000 people, with elasticity of about 1. Elasticity of other provinces is generally between Beijing and Shanghai.

The limitation of private vehicle ownership in Shanghai has also caused difference in vehicle type structure between the two cities. Fig. 4 presents the compositions of registered vehicles of Beijing and Shanghai in 2008. The proportion of passenger vehicles in Shanghai is significantly lower than in Beijing. The reason for this difference is that the majority of private vehicles are passenger vehicles. The limitation of private vehicle ownership in Shanghai mainly constrained the growth of passenger vehicle population.

Private vehicle license plates in Shanghai were issued by auction, implying that people with higher incomes have more chances to get the limited number of license plates. Economically, people with higher incomes tend to buy cars with higher prices. The result is that the market share of high-price vehicles in Shanghai is higher than that in Beijing.

3.2. Policy effectiveness analysis on vehicle use

As introduced above, Beijing has implemented four phases of regulations to limit vehicle use. During the Olympics, vehicle use was limited according to odd/even license plate tail numbers. It was estimated that vehicle flow was reduced by 21% and average fleet speed was increased by 27% after the implementation (The Ministry of Communications, 2008). The Beijing Transportation Research Center conducted an investigation to evaluate the effectiveness of the limitation from October 2008 to April 2009 (Beijing Transportation Research Center, 2009). It was demonstrated that vehicle use had been effectively reduced. In spite of the fact that 0.45 million new vehicles joined the vehicle fleet in Beijing during the period of limitation, the vehicle flows in the main streets were reduced by 4.1% and on the ring roads by 2.8%. The duration of congestion on weekdays was significantly reduced from 7 to 2.5 h. Some travel demands once satisfied by vehicles has been diverted to public transport. The passenger flow volume of public transport increased by 20.8% during the limitation.

However the limitation of vehicle use according to plate number also intends to increase the vehicle ownership. Some people owning one car choose to own another car with a different plate number so that
they can drive everyday by alternate use of the two cars. It was investigated that about 30% of car sales in Beijing was to satisfy the need of the second car and the major intention of owning the second car is to avoid the limitation of vehicle use. The rebound effect of vehicle ownership increase partly offsets policy's effects on reduction of total vehicle use.

4. Policy impacts on fuel consumption by passenger vehicles

One of the primary goals of implementing policies on vehicle ownership and use in Beijing and Shanghai is to limit the excessive growth of vehicle fuel consumption. In this study, we estimated the fuel consumptions by passenger vehicles in Beijing and Shanghai under current policy scenario (CPS) and no policy scenario (NPS) and evaluated policy impacts on fuel consumption by passenger vehicles through comparison of the two scenarios. We employed the bottom-up approach to model the growth of fuel consumption by passenger vehicles, as described by Eq. (1) (He et al., 2005).

\[
FC_i = VP_i \cdot AFC_i \cdot VDT_i
\]

where \(FC_i\) is the fuel consumption by passenger vehicles in year \(i\), \(VP_i\) is the vehicle population of passenger vehicles in year \(i\), \(AFC_i\) is the average fuel consumption rate (AFCR) of passenger vehicles in year \(i\) and \(VDT_i\) is the average vehicle distance traveled (VDT) in year \(i\).

4.1. Estimation of passenger vehicle population

4.1.1. Under CPS

The past vehicle populations under CPS are the actual populations in history and can be extracted from China statistical yearbook. The only difference is that due to the limitation of vehicle ownership in Shanghai, quite a number of vehicles with nonlocal license plates are actually being used in Shanghai. These vehicles are not included in Shanghai's statistics. Taking this into account, we assumed that the actual passenger vehicle population of Shanghai was 1.1 times the statistical data.

For the projection of future trends of vehicle populations under CPS, it is assumed that the current policies on vehicle ownership and use will be in effect through 2020. We first projected Beijing's passenger vehicle population under NPS by GDP elasticity. GDP elasticity of passenger vehicle population is defined as the percentage change in the number of vehicles with a 1% change in GDP. In this study, we used an approximate formula as presented by Eq. (2) to define the elasticity. Vehicle population can be derived by Eq. (3).

\[
E_i = \frac{VP_i/VP_{i-1} - 1}{GDP_i/GDP_{i-1} - 1}
\]

\[
VP_i = (E_i \cdot GGR_i + 1)VP_{i-1}
\]

where \(E_i\) is the GDP elasticity of vehicle population in year \(i\), \(GDP_i\) is the gross domestic production in year \(i\) and \(GGR_i\) is the GDP growth rate in year \(i\). We calculated GDP elasticity of passenger vehicle population in Beijing from 2000 to 2008 according to Eq. (2). The elasticity varies between 1 and 2.5 and the average is 1.55. We assumed that elasticity will decrease linearly from 1.5 in 2010 to 1 in 2020. GDP growth rate was assumed to decrease linearly from 8% in 2010 to 5% in 2020. Based on the assumptions above, passenger vehicle population in Beijing under NPS can be derived by Eq. (3).

Under CPS, the limitation of vehicle use in Beijing promotes the growth of passenger vehicle ownership. We assumed that passenger vehicle population under CPS would be 10% higher than under NPS after the implementation of regulation limiting vehicle use. Shanghai's passenger vehicle population under CPS is controlled by the government and depends on the number of license plates issued. We assumed that the government will issue 150,000 new license plates for passenger vehicles per year after 2010. Together with passenger vehicles with nonlocal plates, a total number of 165,000 new passenger vehicles will join Shanghai's vehicle fleet every year.

4.1.2. Under NPS

Passenger vehicle populations under NPS are the same with populations under CPS before the implementation of policies. As mentioned above, Beijing and Shanghai began their policies in 2008 and 1994, respectively. Therefore, passenger vehicle populations of Beijing before 2008 and Shanghai before 1994 under NPS are the same with the populations under CPS. The growth of passenger vehicle populations afterwards is simulated by Eq. (3). We assumed that GDP elasticity of passenger vehicle population in Shanghai is the same with that in Beijing after 1994.

4.1.3. Estimation of passenger vehicle populations

Fig. 5 shows the estimation of passenger vehicle populations under CPS and NPS in Beijing and Shanghai. Passenger vehicle populations in the two cities are affected by policies in different levels. Under NPS, passenger vehicle populations in Beijing and Shanghai will reach about 7.1 and 7.9 million in 2020, respectively. Under CPS, the populations in Beijing and Shanghai will be 7.9 and 3.1 million, respectively. Beijing's passenger vehicle population under CPS is slightly higher than that under NPS because the limitation of vehicle use promotes the growth of vehicle ownership. Shanghai's passenger vehicle population under CPS is significantly lower than that under NPS with a gap of about 4.9 million in 2020.

4.2. Estimation of VDT

Numerous studies have been conducted on VDT in China. He et al. (2005) estimated that the annual VDT of cars decreased from 27,200 km in 1997 to 26,000 km in 2002. Huo et al. (2007) projected that annual VDT of cars would decrease to 13,000 km in 2030. The investigation of VDT in Beijing and Shanghai indicated that annual VDT of passenger vehicles in Shanghai was about 8% higher than that of Beijing (before the limitation of vehicle use; Tsinghua University, 2010).

In this study, we assumed that annual VDT of passenger vehicles in Beijing under NPS was 27,200, 26,400, 18,000 and 16,000 km in 1990, 2000, 2010 and 2020, respectively. Annual VDT of passenger vehicles in Shanghai under NPS was 8% higher than that of Beijing in the same time. For the CPS scenario, the annual VDT of passenger vehicles in Beijing was lowered to 85% of NPS scenario to reflect the effect of limitation of vehicle use in Beijing.
4.4. Estimation of policy impacts

Based on the assumptions above, we calculated the fuel consumptions by passenger vehicles under CPS and NPS in Beijing and Shanghai from 1990 to 2020. The results are shown in Fig. 6. Fuel consumptions under CPS are lower than under NPS after the implementation of vehicle policies for both Beijing and Shanghai. Under NPS, the fuel consumptions by passenger vehicles in Beijing and Shanghai will reach 8 and 9.6 million liters in 2020, respectively. Under CPS, fuel consumption in Shanghai in 2020 will be reduced by 59.4% and in Beijing by 5.7%. The limitation of vehicle ownership is more effective than the limitation of vehicle use on reducing fuel consumption. The response time of Beijing’s and Shanghai’s policies on fuel consumption is different. Fuel consumption by passenger vehicles in Beijing goes down immediately after the implementation of vehicle use limitation. In Shanghai, policy takes effect on fuel consumption gradually after the implementation of vehicle ownership limitation.

5. Discussion

The considerations of Beijing and Shanghai to implement policies on private vehicle ownership and use are almost the same to ease traffic congestion and to reduce vehicle fuel consumption. However, the measures adopted and the effects achieved are quite different. Beijing focuses on the limitation of vehicle use through administrative means. Under its policy configuration, vehicle use is limited while vehicle ownership is promoted. The benefit of Beijing’s policy is that local vehicle market is well promoted. The negative impact is that the rebound effect of vehicle ownership increase partly offsets policy’s effects on reduction of total vehicle use. As estimated in Section 4, only 5.7% reduction in passenger vehicle fuel consumption will be achieved in 2020 by implementing the current policy. Shanghai focuses on the limitation of vehicle ownership by controlling the total number of private vehicles. Policy implemented in Shanghai significantly reduced the fuel consumption by passenger vehicles. Fuel consumption by passenger vehicles under current policy in Shanghai will be only 59.4% of that without policy accommodation in 2020. Despite the significant reduction in energy consumption, it is argued that the issue of license plates through public auction is unfair for citizens with lower incomes because they are less likely to get the license plates through auction. Another fact is that the current policy in Shanghai leads to the increase in ACFR of passenger vehicles.

6. Conclusion remarks

In this study, we compared Beijing’s and Shanghai’s policies on private vehicle ownership and use and estimated their impacts on fuel consumption by passenger vehicles. The experiences of Beijing and Shanghai are highly relevant for cities in China and abroad that are also facing the problems of traffic congestion and excessive vehicle fuel consumption. The effects of vehicle policies are multifarious. There are advantages and disadvantages both in Beijing’s and Shanghai’s policies. To find the optimal policy for a city is to find the balance point between traffic condition, energy consumption, vehicle market and social equity.

Both policies implemented in Beijing and Shanghai reduced the fuel consumption by passenger vehicles. The limitation of vehicle use in Beijing provides limited but immediate reduction in fuel consumption. The limitation of vehicle ownership in Shanghai provides large potential of fuel conservation in a longer term. The policies in Beijing and Shanghai can be used as short-term and long-term solutions for energy conservation, respectively.

Acknowledgements

The project is supported by the CAERC program (Tsinghua/GM/SAIC-China). The authors would like to thank the reviewers, Benny Zhang of GM, Dr. Xunmin Ou of Tsinghua University and Dr. Hong Huo of Tsinghua University for their generous help.

References


Huo of Tsinghua University for their generous help.
Tsinghua University, 2010. Investigation of vehicle distance traveled in large cities of China, Beijing, China.