A Review of Beijing's Vehicle Lottery

Short-Term Effects on Vehicle Growth, Congestion, and Fuel Consumption

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Abstract

Many cities worldwide have considered vehicle restriction policies to curb proliferating problems of traffic and pollution. At the beginning of 2011, Beijing became the first city to allocate vehicle license plates using a lottery. We provide background on Beijing's lottery, and analyze its short-term effects. We find that vehicle growth has been sharply curtailed, and congestion has been reduced. However, this policy may not reduce fuel consumption as much as expected.

Key Words: vehicle lottery, air pollution, traffic congestion, Beijing

Contents

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Introduction

China's economic development has propelled the issue of cars into the forefront of its current policy discussions. Although the wider availability of cars has improved the standard of living of China's residents, it has also exacerbated problems of air pollution, resulted in intense traffic congestion, and driven a rapid growth in the demand for energy.

At the beginning of 2011, Beijing restricted the purchase of automobiles by distributing new license plates via a publicly-held lottery. While the concept of restricting license plates is no longer new, Beijing is unique in restricting license plates via a lottery rather than using an auction system.

Singapore was the first country to implement license plate restrictions. Singaporeans participate in a monthly auction for the right to purchase a car. Revenues from these auctions are used in improving roads and public transport. Following Singapore's experience, Shanghai implemented a similar auction system in 1994. Chen and Zhao (2013) surveyed Shanghai residents and concluded that the public held a negative attitude toward the fairness of the policy and toward auctioning.

As of the writing of this paper, four Chinese cities have implemented license plate restrictions: Beijing, Shanghai, Guangzhou, and Guiyang. Guangzhou began restricting cars using a system with hybrid auction and lottery components. Many more cities in China are also considering restrictions. Internationally, many cities struggling with traffic are considering various models of restricting their automobiles.

In this paper, we provide an in-depth look at Beijing's experience with allocating vehicles through random assignment. We highlight three key differences between using a lottery and using an auction to allocate cars.

First, an auction raises revenue, while a lottery does not. Chen and Zhao (2013) document that 5 billion RMB were raised through the Shanghai lottery in 2011; Beijing's lottery does not raise any revenue. In Shanghai, these revenues were allocated to developing roads and building public transportation.

A second difference we found in Beijing is that not all those who received quotas after winning the lottery used them. Many of the lucky few who won the car lottery let their quotas expire without buying a car, with over 10% of lottery winners allowing their quotas to expire in some months. It is difficult to imagine auction entrants purchasing expensive permits and then allowing them to expire. As a result, vehicle ownership grows somewhat more slowly under the lottery system than under an auction system.

A third difference is that an auction system should result in those with the highest willingness-to-pay receiving cars. In a lottery system, the recipients of vehicles are a random subset of entrants. This has potential consequences that could be the subject of future research.

The primary purposes of this study are to present background on Beijing's lottery policy, and to provide analysis of its short-term impacts. We first provide a brief history of Beijing's vehicle regulation efforts. We then discuss how Beijing's lottery is implemented, and what intended and unintended consequences have resulted from its implementation.

Our paper is the first to study the impact of the car lottery on automobile trends in Beijing. We add to an extensive literature studying China's car market and projected demand for fuel. Because of China's size and growth rates, its automobile market is currently the largest and most important in the world, and has an outsized impact on global energy consumption patterns. The most directly comparable paper is Hao et al. (2011), who compared policies in Beijing and Shanghai to study their impact on fuel consumption. That paper did not study the substantial impacts of the lottery.

We find that, in the first few years after the policy, the growth of cars in Beijing has been sharply reduced. In combination with other traffic-easing policies, congestion has also improved significantly. Finally, we use a few simple calculations to provide rough estimates of the lottery's impact on fuel consumption, and conclude that it is unlikely to reduce fuel consumption as much as might be expected.

Why did Beijing Implement a Lottery?

The Need for Restrictions on Cars

China's rapid economic development is reflected in the rise in incomes of the residents of its capital Beijing. Beijing's GDP per capita has shot up in recent decades. In 2000, GDP per capita was $US 2,915. In 2010, it was $US 11,218, an annual growth rate of 14%.

Along with its growth in GDP per capita, Beijing's population has grown rapidly. Between 1990 and 2000, its population grew 26%, and between 2000 and 2010, its population grew a further 44%. In 2010, its population of permanent residents reached 19.6 million (Figure 1).

The municipality of Beijing officially occupies an area of 16,400 square kilometers, roughly the size of Connecticut. Most of Beijing's population and cars are concentrated in the central city area, which is enclosed by the concentric rings forming the primary highway system of the city. Its rapidly growing population and limited prime real estate have led to a densely packed downtown. Land area per capita within its core commercial area, enclosed by the 2nd Ring, is only 44 square meters per person.[1] About 84% of vehicles are distributed within the 6th Ring highway.

The rapid growth in population and per capita wealth has been reflected in the purchases of cars. Beijing waited 7 years to advance from 1 million cars to 2 million cars, but only 4 years to reach 3 million, and 3 years to reach 4 million. In 2005, it had 2.6 million cars. In 2010, it had 4.8 million vehicles, an annual growth rate of 13%.

The rapid increase in cars was accompanied by the rapid expansion of existing roads, and the construction of new road networks, yet the continuously increasing demand seemed to outpace the city's best efforts. Beijing has been named by numerous international organizations as one of the most congested cities in the world (see, for example, IBM 2010). The Beijing Transportation Annual Report stated that the average speeds of vehicles on arterial roads during morning rush hour decreased from 30 km/h in 2003 to 20 km/h in 2010, with even larger drops in vehicle speeds on secondary roads.

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[1] By comparison, the central city portion of the New York metropolitan area had a land area per capita of 97 square meters per person (Table 3 from Manville and Shoup 2005).

Beijing's automobile congestion has large and growing costs. Using data on vehicle flow rates and speeds, Xie et al. (2011) estimated that the costs of time delay, fuel consumption, and air pollution were between 5 and 25 billion RMB in 2008, about 0.5% to 2.5% of Beijing's GDP.

Moreover, Beijing's growing fleet of cars emits massive amounts of carbon monoxide (CO), nitrous oxide (NOx), and volatile organic compounds (VOCs); these contribute to Beijing's painfully poor air quality. According to data from the Beijing Municipal Environmental Protection Bureau, motor vehicle exhaust accounts for 40%-60% of suspended particulates, 80% of hydrocarbons, 70%-80% of NOx, and 23% of PM10. Liu et al. (2008) estimate that motor vehicles are the second largest source of PM2.5.

Other Attempts to Control Congestion

Beijing's government has been fully aware of the problems caused by too many cars. It has undertaken a series of administrative policies to relieve the stresses caused by congestion. These policies have taken a number of different forms, and we outline them in rough chronological order here.

As early as the 1990s, Beijing began taking measures to restrict the total number of motor vehicles. Beginning on March 1, 1998, Beijing imposed a parking certificate system on newly purchased motor vehicles in eight urban districts. This system required all motor vehicle owners applying for a license plate in the urban and inner suburban districts of Beijing to submit parking certificates checked by local public security and transportation administration authorities. This system was designed to restrict the number of vehicles in urban districts and to relieve congestion. However, the system was largely ineffective because of the slow registration and administration of parking certificates, the high costs of verification, and the arbitrary collection of fees. In addition, some parking certificates were faked. On January 1, 2004, the parking certificate system was officially cancelled.

At the beginning of 2004, the parking restriction system was replaced by a vehicle purchase tax, promulgated by the Interim Regulations of the People's Republic of China on Vehicle Purchase Taxes. A tax was levied on all organizations and individuals within the boundaries of China who purchased designated vehicles, including motor vehicles, motorcycles, tramcars, trailers, and agricultural trucks. Despite a tax of 10% on the purchase of cars, Beijing continued to experience high rates of motor vehicle growth.

Starting in 2005, Beijing sharply accelerated the amounts it invested in its fundamental transportation facilities (Figure 2). In 2010, 72 billion RMB were invested, over 5% of Beijing's

GDP. Of this amount, 7.7 billion RMB were invested in railways, 9.7 billion RMB in roads, and 41.1 billion RMB in urban public transport. Beijing's railway system has expanded rapidly. At the end of 2009, railway tracks spanned 228 kilometers. In 2010, 2011 and 2012, it expanded its tracks by 108 kilometers, 36 kilometers, and 70 kilometers, respectively.

In 2007, Beijing implemented a low-price public transport policy, which reduced subway fares and reduced all bus fares by 60%. The intention of this policy was to increase the attractiveness of buses and the subway system. As a result, the fares of most buses and the subway decreased to just 0.4 RMB and 2 RMB, respectively. However, this policy did not appear to have a substantial impact on travel habits. A survey conducted by the website People.net.com found that very few Beijing citizens actually changed their typical modes of transport despite the lower fares.

Because these market-based systems appeared to have only limited impact, Beijing has more recently relied on administrative means to restrict the growth in vehicles. During the Olympics in August 2008, Beijing implemented a license plate restriction, where cars could only drive on the road during certain days, according to whether they had an even- or odd-numbered plate.

Before the Olympics, the monthly congestion index consistently averaged above 7, reflecting "moderate" congestion.[2] The new restrictions had an immediate effect, sharply reducing congestion (Figure 3). In combination with other simultaneous reforms, large reductions in air pollution were observed.

Following the Olympics, Beijing implemented an ongoing license plate restriction, where cars could not drive on Beijing roads for one weekday each week, depending on the last digit of the license plate number. Congestion remained improved in the early months of 2008, and stayed below 6 for most months of 2009. However, the rapid increase in new vehicle ownership in Beijing during 2009 and 2010 gradually caused traffic to worsen until, by the end of 2010, the congestion index was at the same level as before the license plate restriction was implemented.

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[2] The Beijing Municipal Commission of Transport classifies traffic congestion into five levels according to a 10 point congestion index (Figure 3). According to this index, congestion is qualitatively described as "smooth," "basically smooth," "slightly congested," "moderately congested," and "seriously congested."

In some ways, Beijing's experience with license plate restrictions mirrored that of Mexico City. Many citizens in Mexico City circumvented the policy by purchasing another car, causing second-hand vehicle sales to soar in the market. Until the year 1995, 22% of the drivers bought second vehicles (Eskeland and Feyzioglu 1997), resulting in increased traffic congestion. Davis (2008) found that the policy restriction did not improve air quality in Mexico City; instead, air pollution worsened during weekends and at off-peak periods during working days.

Similarly, in Beijing, drivers gradually found ways to circumvent the license plate restrictions. Drivers took detours and avoided restricted periods. In some cases, drivers purchased multiple cars with different license plate numbers to avoid restrictions on their driving times. Each of these measures eroded the usefulness of the license plate restrictions.

In summary, prior to the lottery, each of Beijing's attempts to control its congestion was either ineffective or only temporarily effective. Market-based reforms such as increasing the price of parking or taxing the sales of cars were inadequate to dent the enormous demand generated by Beijing's growth. Even restrictions on driving days seemed to only delay the overwhelming problems of dense traffic.

Implementation of the Beijing Lottery

Beijing's decision to impose restrictions on the number of cars sold each year was perhaps precipitated by a pair of embarrassing incidents. On September 14, 2010, construction work on roads between Beijing and neighboring Zhangjiakou triggered a paralyzing traffic jam stretching over 100 kilometers on the highway just outside of Beijing. For three days, traffic came to a standstill, with those affected progressing as little as a third of a mile per day. Then, on September 17, 2010, a traffic jam triggered by heavy rain affected the entire city. The congestion index remained at 10 for three consecutive hours, and 4,321 roads were seriously congested during the evening peak period. The jam lasted until 1:00 a.m. the next day.

There is no announcement or report documenting the official reasons why Beijing chose a lottery to restrict vehicle growth, rather than an auction. For years before Beijing's policy, both Singapore and Shanghai had successfully restricted cars with auctions. However, as a result of our interviews with administrators within Beijing's transportation agencies, we suggest two reasons.

First, a lottery system is seen as more equitable. A resident of average income would have a higher chance of obtaining a license plate through a lottery than he might if plates were sold through an auction. Income equality has become an increasingly important issue in China,

particularly to its urban residents. Car ownership is not seen as a luxury for the rich, but rather a symbol of entering the middle class. Second, Beijing had used a lottery in the past to allocate affordable housing. This policy was seen as successful, and may have inspired its use in allocating vehicles.

On December 13, 2010, Beijing first issued a plan to its residents that hinted at the upcoming cap on vehicle registrations. The plan also raised parking fees, expanded public transportation options, and announced the construction of new roads.

Starting on December 24, 2010, new registrations were frozen. Before purchasing a license plate, individuals and corporations were required to win a publicly-held lottery administered by the Beijing Municipal Commission of Transport. The lottery is held on the 26th day of each month, with 20,000 new car registrations to be selected each month from the pools of eligible applicants.

Individual applicants compete for 17,600 license plates each month. They register on a government website to be entered into the lottery, with no monetary cost. The application consists of ten questions, including the applicant's registration number, address, and contact information. Applicants are screened to make sure they are qualified to enter the lottery. Only those with a Beijing registration or residents who have paid taxes in Beijing for 5 years are allowed to enter the lottery. In addition, individuals who already have vehicles may not enter the lottery. However, a second driver in a household that has a car may enter the lottery; that person may win the right to buy a second car for the household.

Businesses can also win vehicle license plates, entering a separate lottery with 2,000 winners per month.[3] Government-sponsored institutions, social organizations, and other organizations are also able to apply for a license plate each year. Enterprises that pay VAT and sales taxes amounting to at least 50,000 RMB can also apply for a license plate each year, and can add a license plate with every 500,000 RMB of taxes paid. However, they cannot purchase more than 8 vehicles per year.

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[3] Commercial cars such as rental cars and taxis were also allocated 400 license plates each month. In sum, with individuals competing for 17,600 plates, businesses competing for 2,000 plates, and commercial cars competing for 400 plates, there are 20,000 new vehicle licenses available each month.

The license-plate lottery begins with six applicant representatives, members of the Beijing Municipal People's Congress, and members of the Beijing Municipal Committee of the Chinese People's Political Consultative Conference. Each lottery participant draws a number to generate a six-digit random seed. Under the supervision of notaries and the staff of the Discipline Inspection and Supervision Commission, the lottery numbers are sealed, and a technician inputs the sealed numbers into a computer. The computer determines the starting point in relation to the 6-digit seed, and then produces license-plate numbers on the spot. The technician inputs all the chosen numbers onto a disc, and the notary office, the Beijing Municipal Bureau of Supervision, and the Beijing Municipal Car Quota Control and Administration Office keep a copy of the disc. The chosen numbers are published on the license-plate lottery system website.

Winners of the lottery receive a "quota," a downloadable certificate functioning as a permit allowing the lottery winner the right to purchase a new or used car. Once the lottery has been won, the quota is free. Quota holders may purchase a license plate costing 125 RMB. Quotas are non-transferrable and cannot be sold. Winners have 6 months to purchase a car before their permit expires. If the lottery winner does not purchase a car during this interval, the permit goes back to expand the pool of quotas available in the next lottery.

Existing car owners do not have to win the lottery in order to retain their car registration. If they have their car destroyed, or sell their car to a used car dealer, they retain their license plates and can purchase a new car.

Enforcement of the lottery plate system is severe. Only cars with Beijing plates are permitted to drive in downtown Beijing during the weekday rush hours of 7:00 a.m. to 9:00 a.m., and 5:00 p.m. to 8:00 p.m. Cars with outside plates found driving during rush hour are fined 100RMB for each violation.

Effects of the Lottery System

Impacts on the Demand for License Plates

Residents reacted to Beijing's mid-December announcement of the lottery restriction by moving forward vehicle purchase decisions. There were two weeks between the initial announcement and a complete freeze on new vehicle registrations. In that interval, new vehicle registrations rose more than 50% (Figure 4). News articles at the time reported that customers would go into dealerships and purchase vehicles without bargaining and without having the opportunity to select their cars.

Over time, the lottery pool saw dramatic increases in the number of entries, and commensurate decreases in the probability of success (Figure 5). While those who participated in the first lottery in January 2011 had a 9% chance of winning, that probability decreased to less than 2% by August 2012.

The lottery's setup is likely to have artificially swelled the number of entries. Qualified applicants can enter the lottery by filling out a short online application and do not have to pay a fee. This structure led all members of the family to enter the lottery in many cases. In addition, households without an immediate need for a car entered the lottery, hoping that they would need a car by the time they won it.

As a result, many people who won the lottery did not purchase a vehicle within the allotted six months. This invalidated their quota. In June 2012, 10.9% of individual lottery winners did not purchase vehicles within the specified period. Even among corporate entrants, 22.8% of winners failed to purchase a vehicle.

The difficulty of winning the lottery suggests that many entrants with a high willingness-to-pay for a vehicle were unable to buy a car. At the same time, many quotas held by those who won the lottery expired without being used.

The high rate of quota expirations is fully rational under Beijing's lottery system. Entering the lottery is free for qualified applicants and requires only filling out a short online form. If the lottery is won, the applicant then has the option to purchase a vehicle, with no financial cost if the quota expires. If a lottery winner's quota expires, she can just enter the lottery again with no additional cost. The system is set up so that the act of entering the lottery generates positive value for the entrant, in the form of a chance to win an option to purchase a car.

Beijing revised its policy in January 2012 to address this problem. The validity period for applications was limited: those who wanted to participate in the license-plate lottery were required to use the lottery website to confirm their interest in obtaining a vehicle every three months; otherwise, their applications would be removed. Despite the relatively low bar now imposed, this change led to thousands of expired applications beginning in April 2012; we see dramatic fluctuations in the number of active lottery applications starting from this date.

A vigorous black market sprung up temporarily to service the shortage in available license plates. An illegal trade called "license plate renting" emerged. In this trade, an individual needing a car purchases a vehicle in the name of a lottery winner, paying the winner for this service. Once the individual needing a car obtains his own quota by winning the lottery himself,

he transfers the vehicle purchased from the original lottery winner to his own name. A second, related practice involved car dealerships. Many of these enterprising dealerships purchased hundreds of additional license plates before the restriction on license plates was implemented. An individual needing a car would purchase a vehicle designated by the dealer, paying several thousand additional RMB for the privilege of using the dealer's license plate. The arrangement is made with the understanding that the purchaser will return the rented license plate to the dealer when the purchaser has won the lottery himself.

Consequently, the People's Government of Beijing Municipality sternly declared that no special quotas or quota trading were permitted, with quotas to be recalled in serious cases. Those caught breaking the law would be held legally liable. It is believed that these new regulations are generally obeyed; media reports of black market license plates have diminished in recent months.

Effects on the Quantity of Motor Vehicles

The license plate lottery dramatically curbed increases in motor vehicles (Figure 4). New car registrations were cut over 75% between 2010 and 2011. Similarly, the growth in the number of total cars was dramatically slowed (Table 1).

Total sales of new vehicles in Beijing dropped commensurately. Sales of new automobiles dropped from 920,000 in 2010 to 400,000 in 2011, a decrease of 57%. Retail sales in Beijing decreased from 155.7 billion RMB to 86.8 billion RMB, a decrease of 44%. The second-hand automobile market also suffered from the new policy: sales of second-hand automobiles dropped from 520,000 in 2010 to 400,000 in 2011.[4]

Although the motor vehicle market clearly suffered from the policy, the overall economy of the Beijing municipality did not seem to suffer ill effects. Beijing's gross regional product grew from 1.41 trillion RMB in 2010 to 1.60 trillion RMB in 2011, a growth rate of 13.4%.

Effects on Congestion

Traffic congestion improved immediately in 2011 after the advent of the license plate lottery. Figure 6 compares congestion in 2010 and 2011. For each month in 2011, congestion is noticeably lower, suggesting that the set of policies enacted during this time had a significant

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[4] Because used cars can be sold in adjacent provinces, second-hand car sales did not drop as much.

effect. According to the 2011 Beijing Transport Annual Report, average driving speeds rose from 22.6 km/h in 2010 to 25.3 km/h in 2011.

Although the absolute number of vehicles on the road did not decrease (Table 1), the growth of the number of vehicles slowed dramatically with the lottery policy. Along with restricting vehicles, Beijing continued to reinforce its policies targeted at controlling congestion, including upgrades to road capacity, increases in parking fees, and the construction of more bus lanes. Although these measures had been ongoing in the years before the Beijing lottery, congestion continued to swell (see Figure 3.) While vehicle restrictions in isolation did not reduce vehicle numbers, they did reduce the growth in automobiles and allow these other measures to take effect. In other words, lottery restrictions reduced the growth in demand for roads, allowing the growth in the supply of roads and transportation alternatives to finally reduce congestion.

It is too early to judge whether reduced congestion will continue into the medium and long term. The post-Olympics policy restricting the weekdays that each car was able to drive on the road was effective in the short run, but lost its effectiveness after about two years. While part of this loss of effectiveness was undoubtedly due to the increased number of cars, part of it had to be attributed to driver adaptations to the car restrictions.

Effects on the Composition of Motor Vehicles Purchased

Statistics from the Beijing Municipal Office of State Administration of Taxation show that the average unit price of automobiles grew 28% between 2010 and 2011. Between 2003 and 2010, the average unit price of automobiles increased by a combined 14% (Figure 7).

There are many possible reasons for this increase in unit sales price, such as increased incomes and increased numbers of very wealthy residents in Beijing. One additional reason is the lottery policy. Because families have to win the lottery before purchasing a new car, they tend to concentrate their investment in transportation into a single car. As a result, when a vehicle is purchased, a single high-end car is purchased, rather than two low-end cars.

Evidence on the distribution of sales by brand supports this interpretation (Figure 8.) This figure shows that the total sales of vehicles declined sharply. While many mid-market firms took punishing double digit drops in sales, the steepest drops were suffered by domestic Chinese firms, which have more limited brand reputations. Luxury imported brands, like Mercedes-Benz and BMW, actually expanded their sales.

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The Effect of the Lottery on Fuel Use

In this portion of our study, we perform simple estimates of the impacts of Beijing's lottery policy on the sales of its cars and the total consumption of fuel.

The total amount of fuel consumed is calculated using Equation 1:

Fuel Used = Number of Vehicles * Vehicle Distance Travelled * Average Fuel Consumption Rate (1)

We must estimate each of the items on the right-hand side of Equation 1 between the years 2011 and 2020. In each section, we estimate these items under both the lottery policy and under the no-policy scenario (NPS).

Effects of the Policy on Vehicle Growth

The lottery restricted new license plates in Beijing to only 240,000 per year; contrast this with the net increase of 803,000 vehicles in 2010. We plot the actual number of vehicles in Beijing, and the number expected under the lottery policy, in Figure 9.[5]

To estimate the counterfactual sales of cars in Beijing under the no-policy scenario, we rely on estimates of the elasticity of demand for cars with respect to Beijing's gross regional product. Figure 9 offers visual evidence that the demand for cars and Beijing's gross regional product grew in tandem until 2010, when the announcement of the lottery prompted a surge in car sales (Figure 4).

First, we project Beijing's gross regional product. Growth averaged 16.1% between 2001 and 2010, falling no lower than 9.3% in any year. Given the impossibility of growing at those rates forever, we assume that growth in 2011 will be 16.1%, and then fall linearly until it reaches 3% in 2020. Although this implies a drastic slowdown from recent growth rates, it still implies that Beijing's gross regional product will grow almost 150% over the next 10 years.

Then, we estimate the elasticity of car growth with respect to GRP growth between 2003 and 2010, the years for which we have vehicle data. This elasticity averaged 1.12, with a low of 0.52. We remove 2010 from our estimate, because that year had a surge in demand that would

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[5] Note that car owners can replace their existing cars without having to win the lottery. Hence, the 240,000 cars that are added each year under the lottery policy represent a net increase in vehicles.

not have occurred had the lottery not been enacted. We assume that the elasticity of car demand will be 1.12 in 2010, and that it will fall linearly until it reaches 0.4 under our no policy scenario.

The results of our estimates are diagrammed in Figure 9. The gap between counterfactual growth in vehicle sales and the projected growth under the lottery policy is immediately visible in 2011, and remains large and significant over the next 10 years.

Effects on Fuel Use

Effects on Vehicle Distance Travelled

We now turn to estimating the second term in Equation 1, the average vehicle distance travelled (VDT). A few prior studies have also examined this problem in China. He et al. (2005) estimated that the overall annual VDT of cars decreased from 27,200 km in 1997 to 26,000 km in 2002, a very small fall. A more useful analysis for us is Hao et al. (2011), which used some data from Beijing, and projected a much sharper drop based on the aging of the car fleet and shifts in vehicle composition.

We use part of the analysis of Hao et al. (2011) to project vehicle distance travelled in Beijing. Using data between 2003 and 2008, they note that declines in VDT have linearly tracked rates of private car ownership. We analyzed 2005 to 2010 vehicle distance travelled data from the Beijing Transport Development Annual Report, and confirmed this relationship (Figure 10).

Our strategy is to assume that this linear relationship will continue to hold. We then use the estimated relationship to project vehicle distance travelled based on simple calculations of vehicle ownership rates.

We first calculate private car ownership rates. We assume that Beijing's population will continue to grow at its 10-year average of 2.8% per year. Then we use vehicle growth estimates to estimate private car ownership rates under both the lottery policy and the NPS. Using these projected vehicle density rates and the linear relationship calculated above, we derive rough estimates of vehicle distance travelled; results are presented in Figure 11.

Under the NPS scenario, we expect vehicle miles travelled to continue the recent trend of sharp decline for the next five years. Gradually, the vehicle miles travelled should flatten out. Under the lottery policy, vehicle density rates do not grow as quickly as they would under the NPS. As a result, vehicle distance travelled continues to decrease, but at a much slower rate.

There are intuitive reasons why vehicle distance travelled may be related to vehicle density rates; explanation of these reasons may shed light on our projection that the lottery policy

will result in a slower fall in VDT. First, congestion decreases the vehicle distance travelled; cars drive less when driving is less efficient. Because the lottery may result in improved congestion, we might expect VDT to increase. Second, lower overall vehicle ownership rates will result in fewer cars per household; as a result, those cars may be driven more intensively. The lottery limits the ability of households to expand from one car to two cars, because household members who already hold car registrations cannot enter the lottery.

Effects on the Average Fuel Consumption Rate (AFCR)

As documented above, one effect of the lottery policy was a shift in the composition of motor vehicles purchased. Beijing car buyers moved upmarket, purchasing imported cars and luxury cars at a much higher frequency. Because these cars tend to be larger and heavier, they also tend to be less fuel efficient.

To illustrate this point, Mercedes-Benz, Volvo, BMW, Toyota, and Audi are 5 of the 6 least fuel efficient brands of vehicles. After bouncing up and down between 2008 and 2010, their collective market share grew by 80% in 2011 and held steady in 2012. It is likely that the advent of the lottery shifted buyers toward these brands.

Using 2008-2012 data on sales by brand and AFCR by brand from the China Association of Automobile Manufacturers, we estimate the AFCR of each year's mix of cars sold in Figure 12. Based on the shift in sales toward cars with higher AFCR, we calculate that the AFCR of cars sold in Beijing increased by 3.3% between 2010 and 2011.

We assume that the AFCR under the no policy scenario will hold at 11 liters per 100 km; this is the AFCR we calculated for sales between 2008 and 2010. To estimate the AFCR under the lottery policy, we assume that Beijing will add 400,000 new cars with a higher AFCR mix to its car fleet each year.[6] Using our estimates of the total number of passenger vehicles from earlier in this section, we then calculate what fraction of this fleet will be composed of the older mix of cars, which we assume to have an AFCR of 11 liters per 100 km travelled, and what fraction will be composed of the newer mix of cars, which have an AFCR of 11.4 liters per 100 km travelled. The result of our estimate is that the AFCR of the overall car fleet increases in an approximately linear fashion from 11 to 11.2 liters per 100 km between 2010 and 2020 under the lottery policy.

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[6] In 2011, the first year of the lottery, 400,000 vehicles were sold in Beijing.

Effects on Total Fuel Use

Using Equation 1, and our estimates from earlier in this section, we calculate three scenarios. First, we calculate the fuel used under the NPS. Second, we calculate the fuel used under the lottery policy.

We also calculate, as a third scenario, the lottery policy without other adjustments. In this scenario, we calculate the fuel used when the number of vehicles has been restricted by the lottery, but use the VDT and the AFCR estimated from the no policy scenario.

The results of these simple calculations are displayed in Figure 13. Consider first the fuel used under the no policy scenario and under the lottery policy scenario with no adjustments. The wide gap between these two lines reflects the effect of restricting the number of cars sold through the lottery policy. The total fuel consumed is expected to decline in the years immediately following the lottery policy, reflecting the continuation of the sharp downward trend in vehicle distance travelled.

Now consider the fuel used under our primary estimate of the lottery policy. Although the amount of fuel consumed in Beijing by passenger vehicles is lower than it would be with no lottery policy in place, this line is far closer to the no policy scenario than it is to the lottery policy scenario with no adjustments. In 2020, the total number of vehicles under the lottery policy is 20% lower than the number under the NPS. However, total fuel consumed is only 3% lower.

There are two reasons for this disparity. First, we anticipate that vehicle distance travelled will fall less sharply under the lottery policy. Second, the lottery policy has encouraged consumers to concentrate their purchases on more expensive cars, resulting in a gradual shift in the vehicle mix toward less fuel-efficient vehicles. These factors have the combined of effect of mitigating the fuel savings that would be expected from cutting the number of vehicles by means of the lottery policy.

Discussion and Conclusion

We have analyzed a policy that is unique in the world: the use of a lottery to allocate vehicle license plates. To conclude, we would like to highlight three key findings from this study.

First, the lottery policy did have a significant effect on both vehicles sold and congestion. With this policy put in place alongside other policies aimed at improving transportation, Beijing

experienced a sharp drop in the number of vehicles sold and immediate improvements in congestion. Increases in average driving speeds were also reported.

Second, the lottery policy might not decrease fuel consumption as much as might be expected. Our projections suggest that, while the total number of vehicles in Beijing will be decreased 20% by 2020, the annual consumption of fuel will decrease only 3%. This disparity results because the lottery blunts expected increases in vehicle density rates, causing vehicle distance travelled to fall less rapidly than expected. In addition, the lottery has caused Beijing customers to buy less fuel-efficient cars.

Finally, the lottery had the unintended consequence of allocating vehicles to people who clearly did not have the highest willingness-to-pay. The number of entries in Beijing rapidly dwarfed the number of license plates available until the chance of winning was only 2% in August 2012. Because each resident can enter the lottery only once each month, even a resident with very high willingness-to-pay may not be able to purchase a license plate under these circumstances. At the same time, a large number of lottery winners failed to buy vehicles. Winning the lottery is similar to receiving the option to purchase a car; this has positive value because the financial cost of entering the lottery is zero.

In summary, the Beijing Government has adopted a battery of market and non-market policy instruments (e.g., driving restrictions, lottery, expansion of the subway system, parking fees, fuel taxes, high-speed transit facilities, etc.) in an attempt to reduce the negative transport externalities so apparent in the city. Compared to non-market mechanisms, market-based mechanisms have often been advocated by economists as a better approach to allocating scarce public resources, on grounds of economic efficiency and revenue generation. For example, fuel taxes offer a second-best and administratively simple policy to deal with multiple externalities from automobile use (Parry et al. 2007). Our analysis suggests that it is not enough to simply prefer market to non-market mechanisms, but that it is also important to look closely at the operation of specific policies, individually and in combination. In the future, evaluation of possible unintended consequences of each policy, or comparisons of different policies such as lottery versus auction, or auction versus gasoline tax, is needed.

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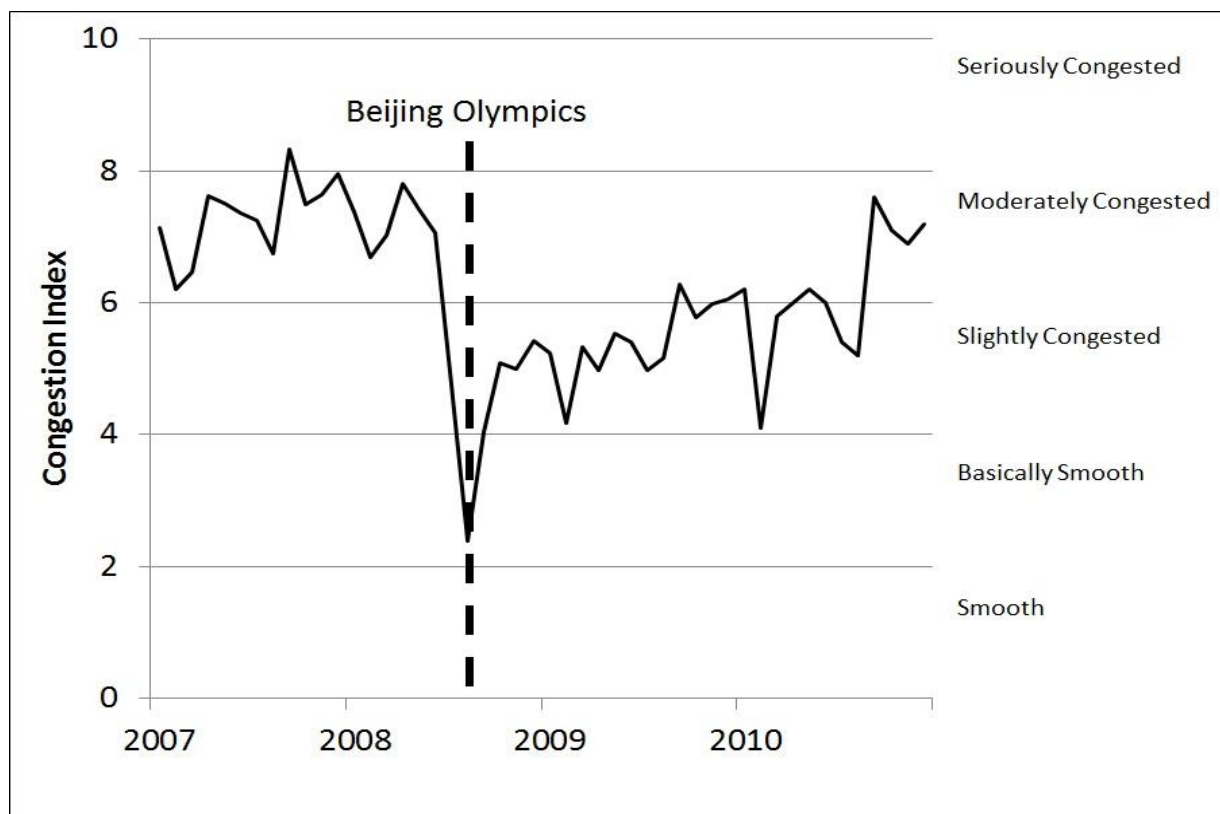
Figures and Table

Figure 1. Population Growth and Vehicle Growth in Beijing
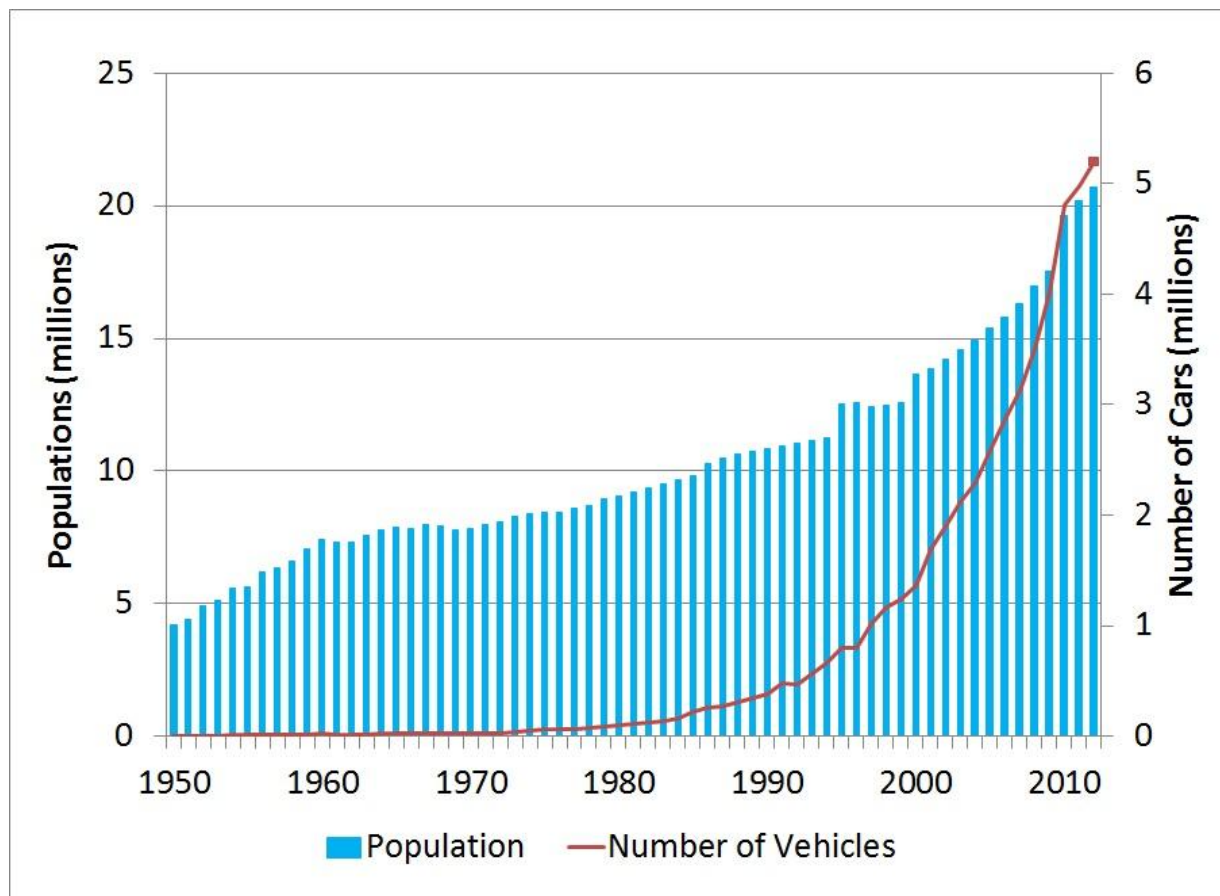
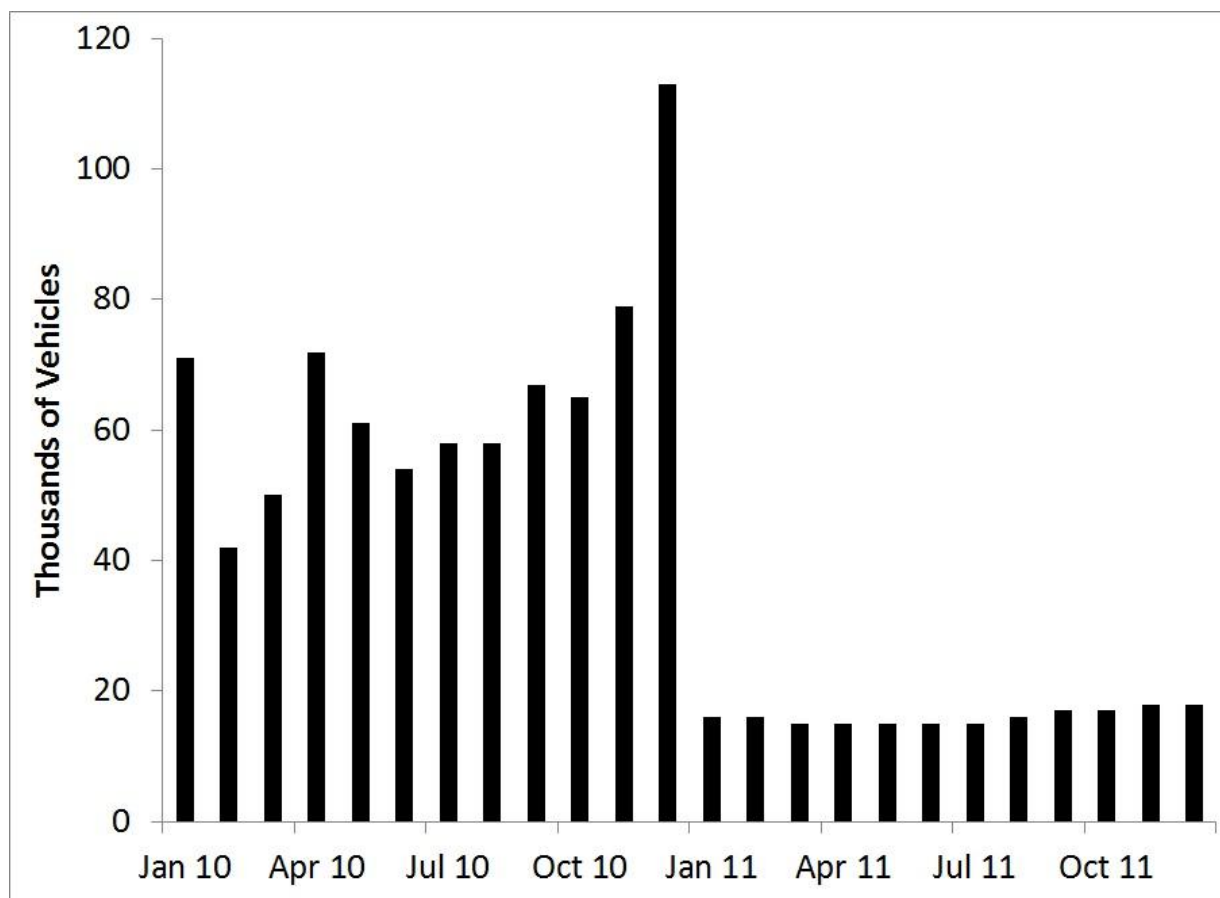Source: Beijing Transportation Research Center

Figure 2. Investment in Fundamental Transport Facilities in Beijing from 2001 to 2010
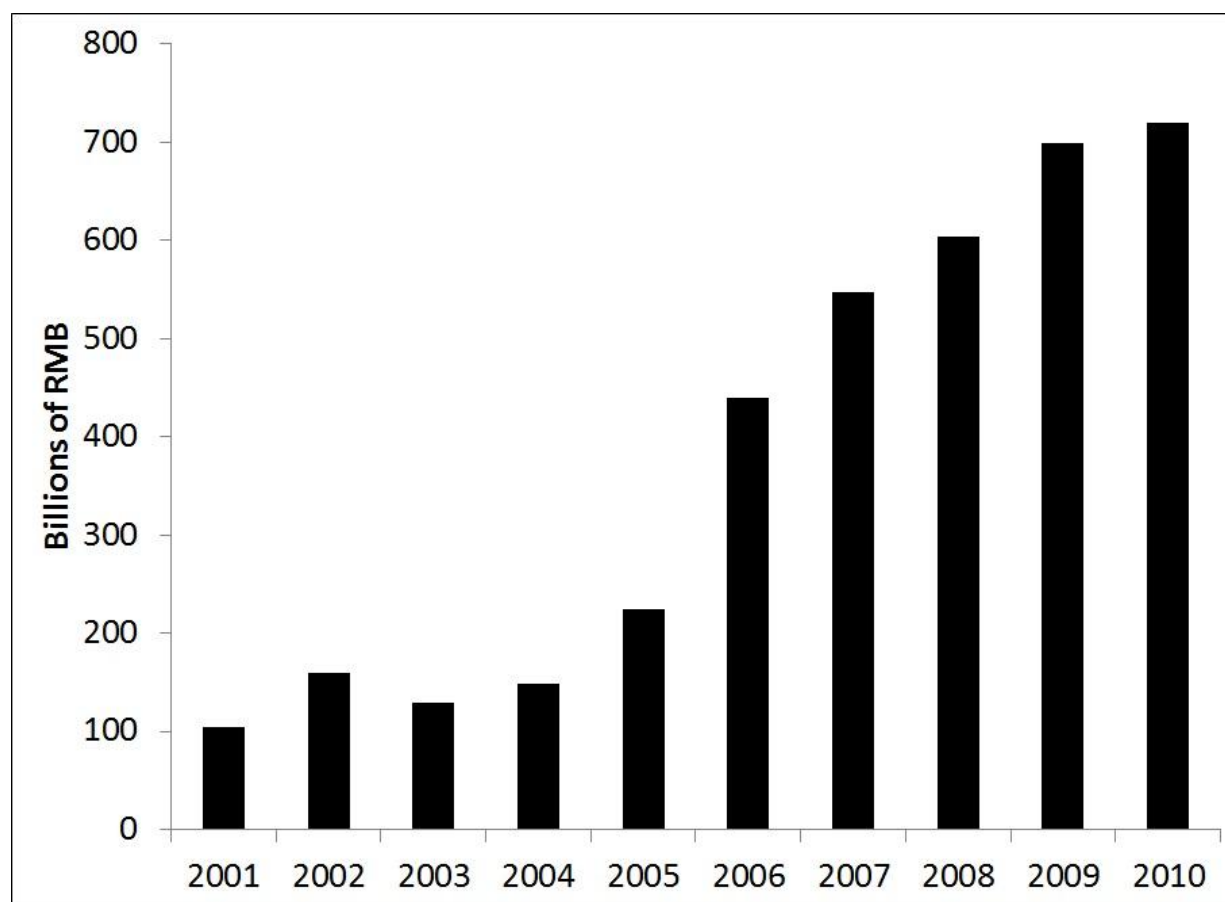
Source: Beijing Transportation Research Center

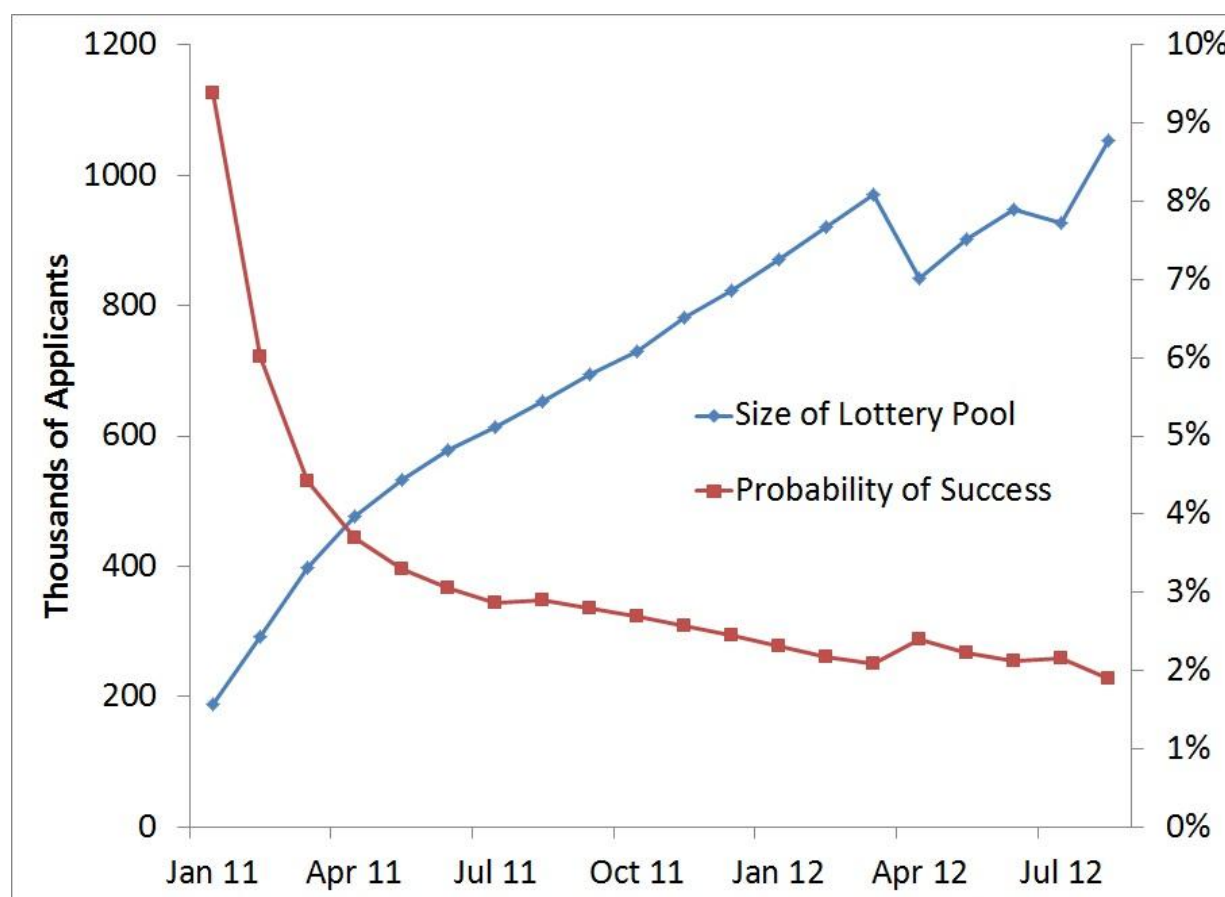**Figure 3. Congestion Index for Beijing (2007-2010)**

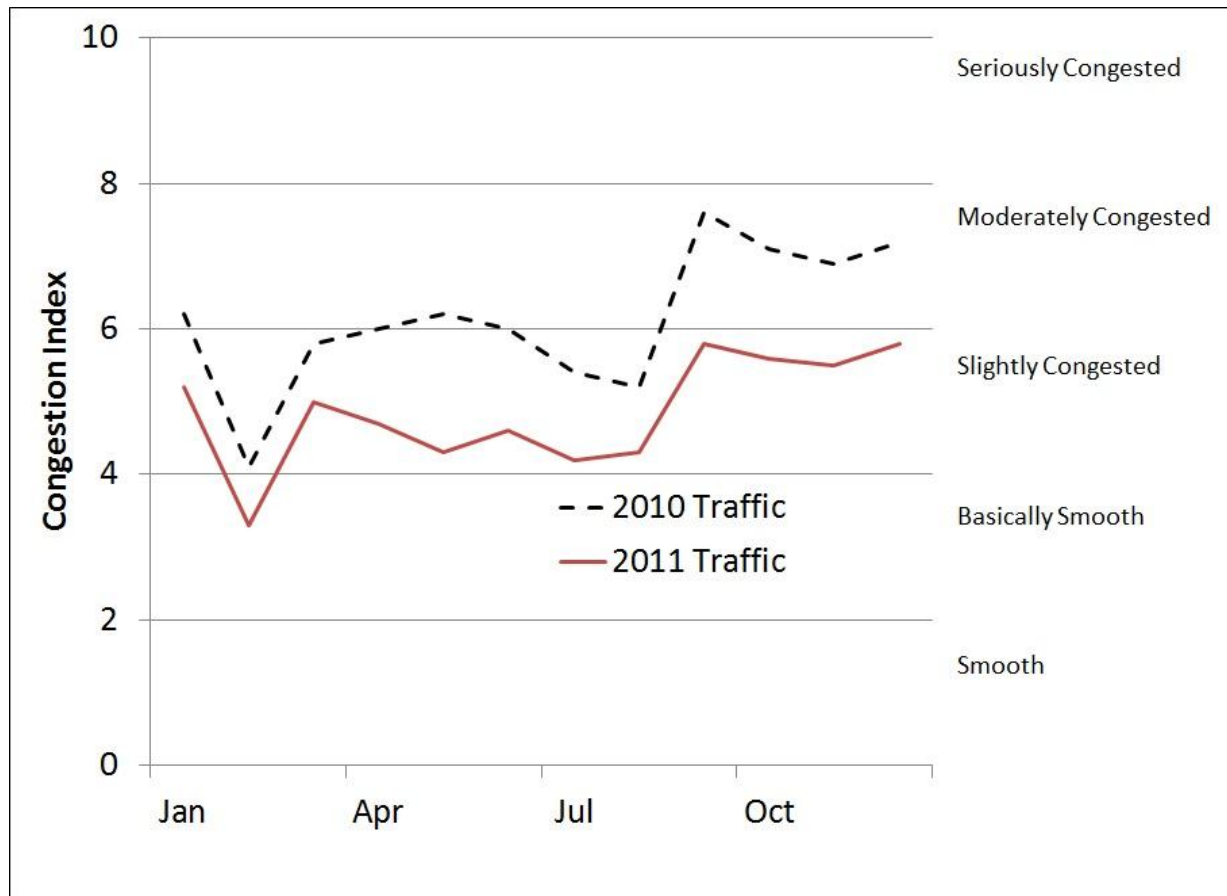Source: Beijing Transportation Research Center

Figure 2. Monthly Changes in New Cars in Beijing, 2010 and 2011


Source: Beijing Municipal Traffic Management Bureau

Figure 5. The Growing Number of Applicants to the Car Lottery, and the Diminishing Chance of Success

Source: "Work Report of Thoughts and Measures on Controlling the Total Quantity of Motor Vehicles in the Face of International Cities," Beijing Municipal Transport Commission and Beijing Transportation Research Center (November 2012).

**Figure 6. Congestion Index Levels, before and after the Advent of the Beijing Car Lottery**

Source: Beijing Transportation Research Center

**Figure 7. Average Sales Price of Vehicles in Beijing**
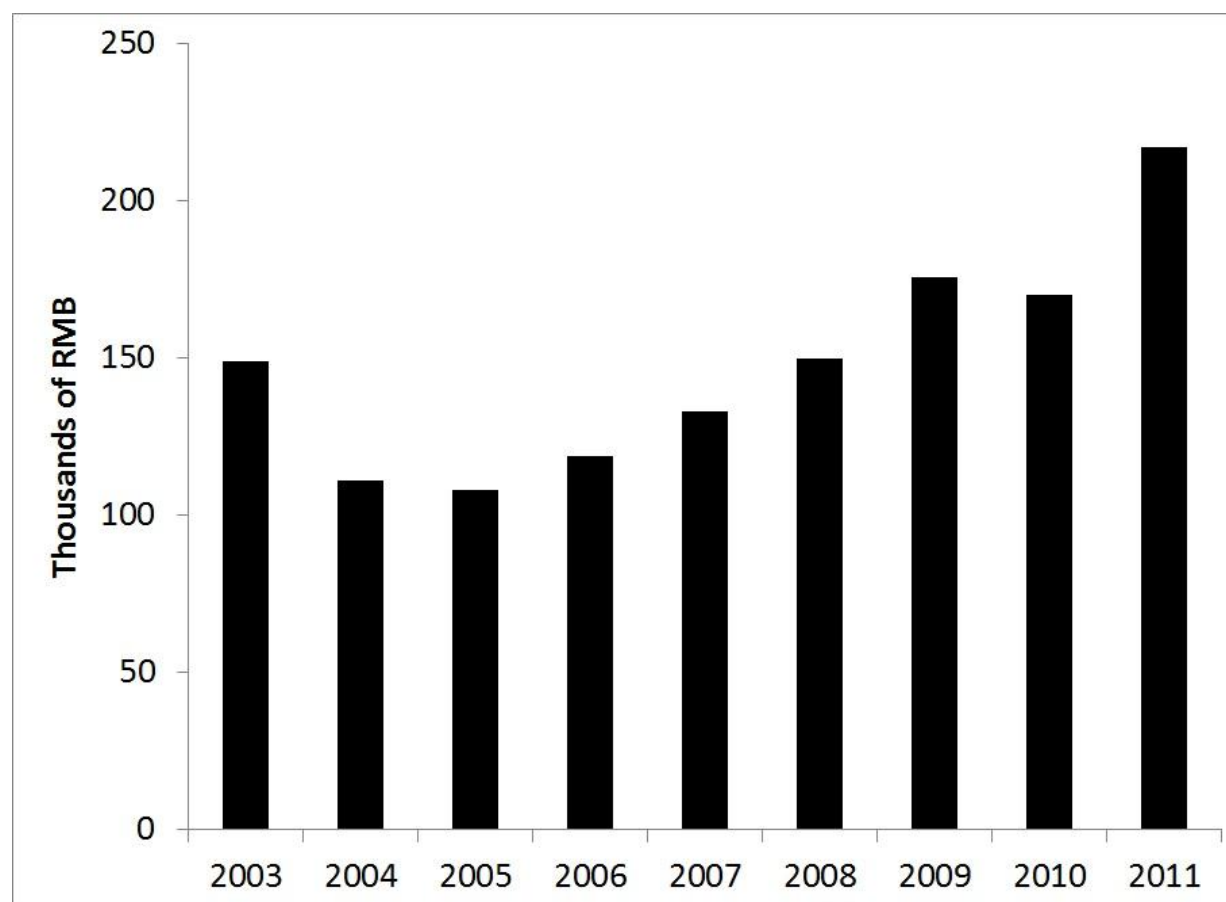
Source: Beijing Municipal Office of State Administration of Taxation

Figure 8. Changes in Sales of Cars between 2010 and 2011 in Beijing, by Brand of Car
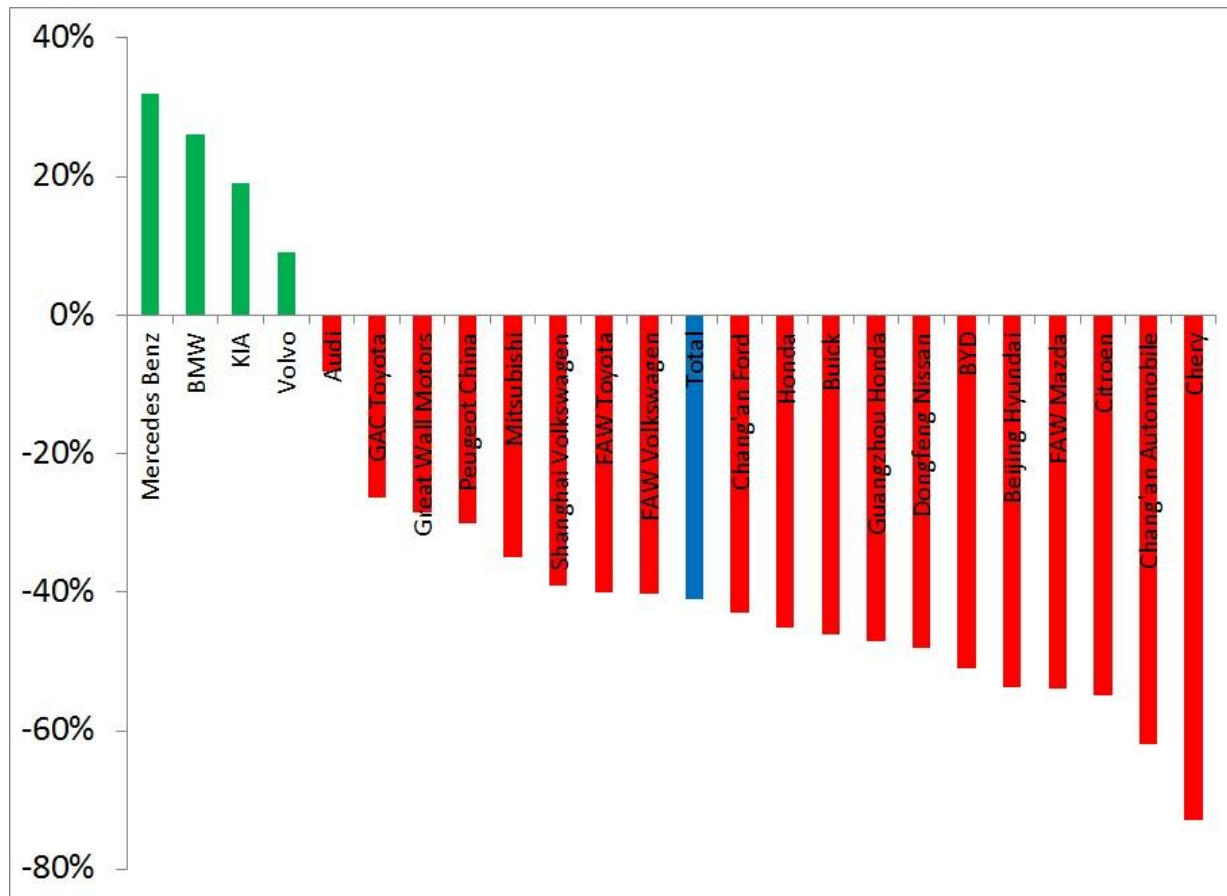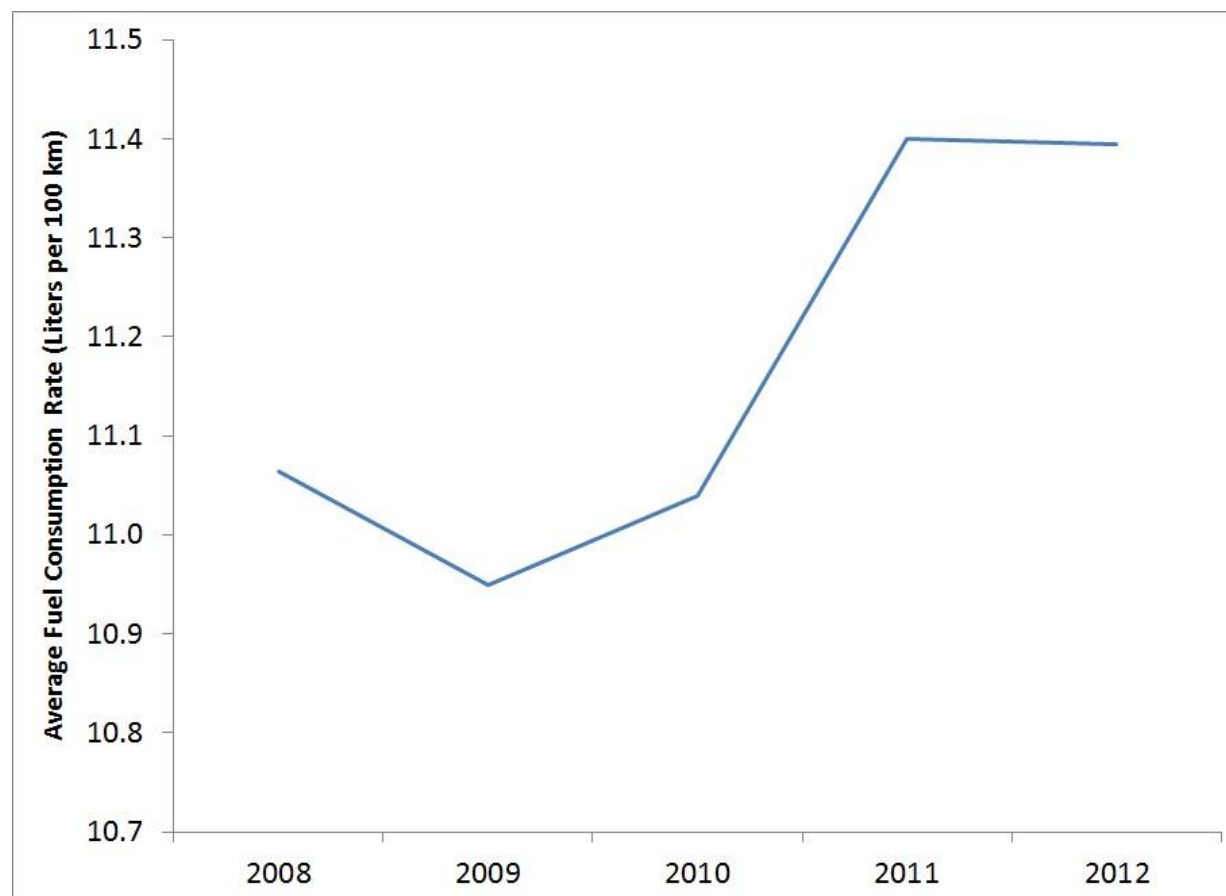

Source: www.beiyacheshi.com

**Figure 9. Projections of the Number of Passenger Vehicles in Beijing.**
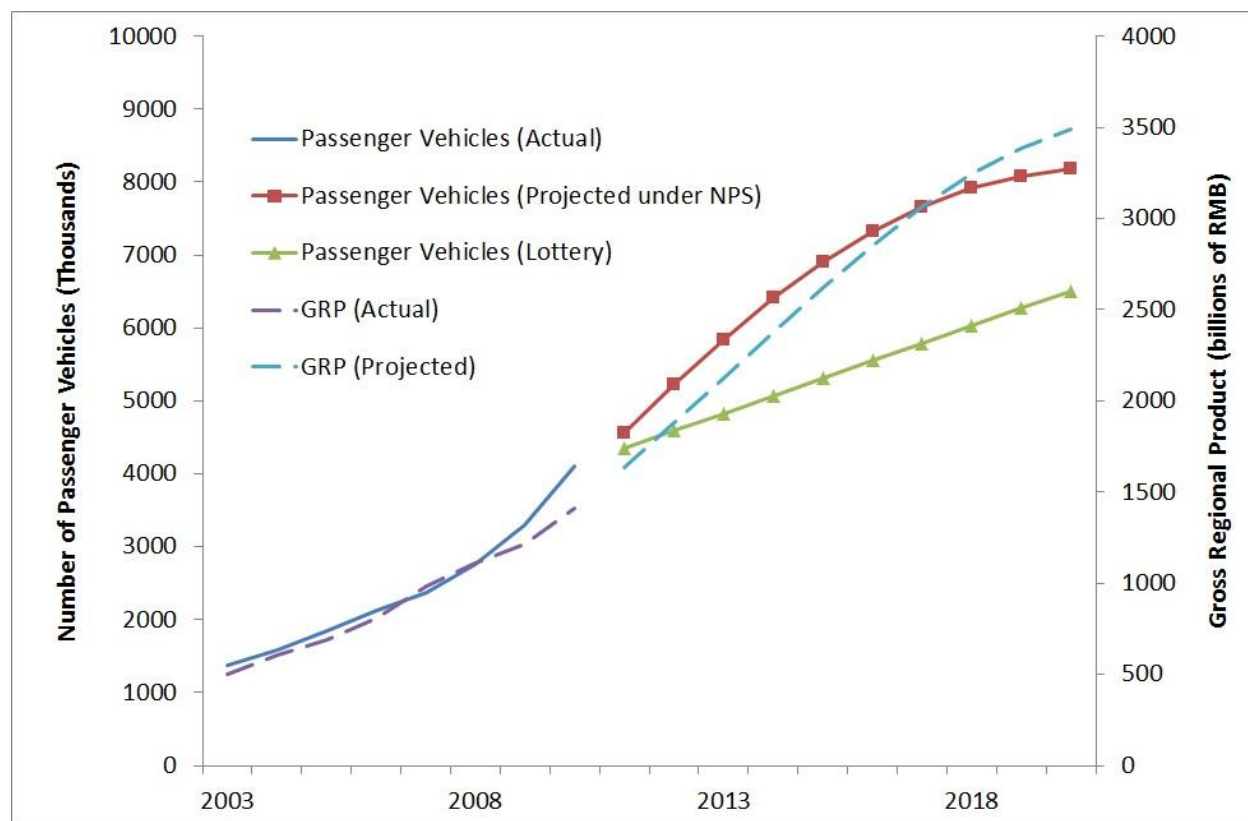
Figure 10. The Relationship between Vehicle Density and Average Distance Travelled in Beijing.
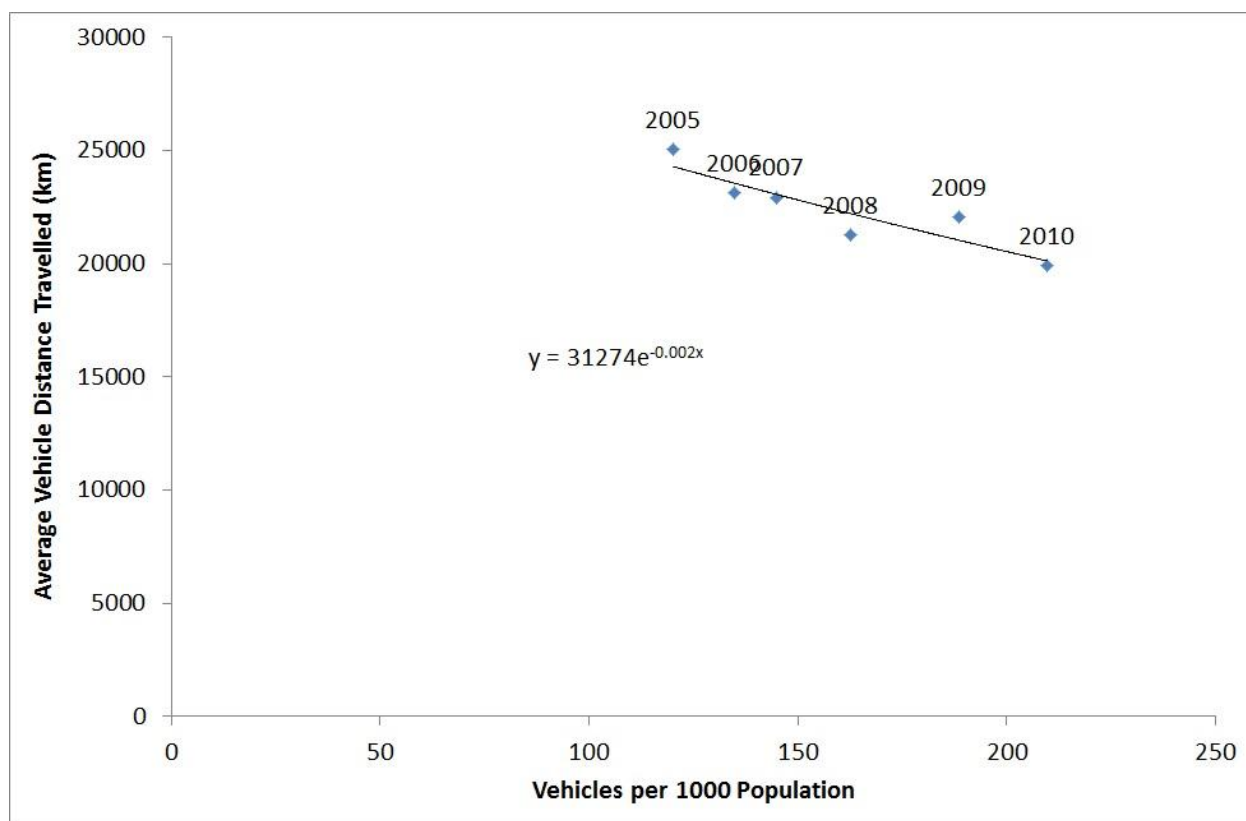
Figure 11. Projections of Vehicle Distance Travelled in Beijing
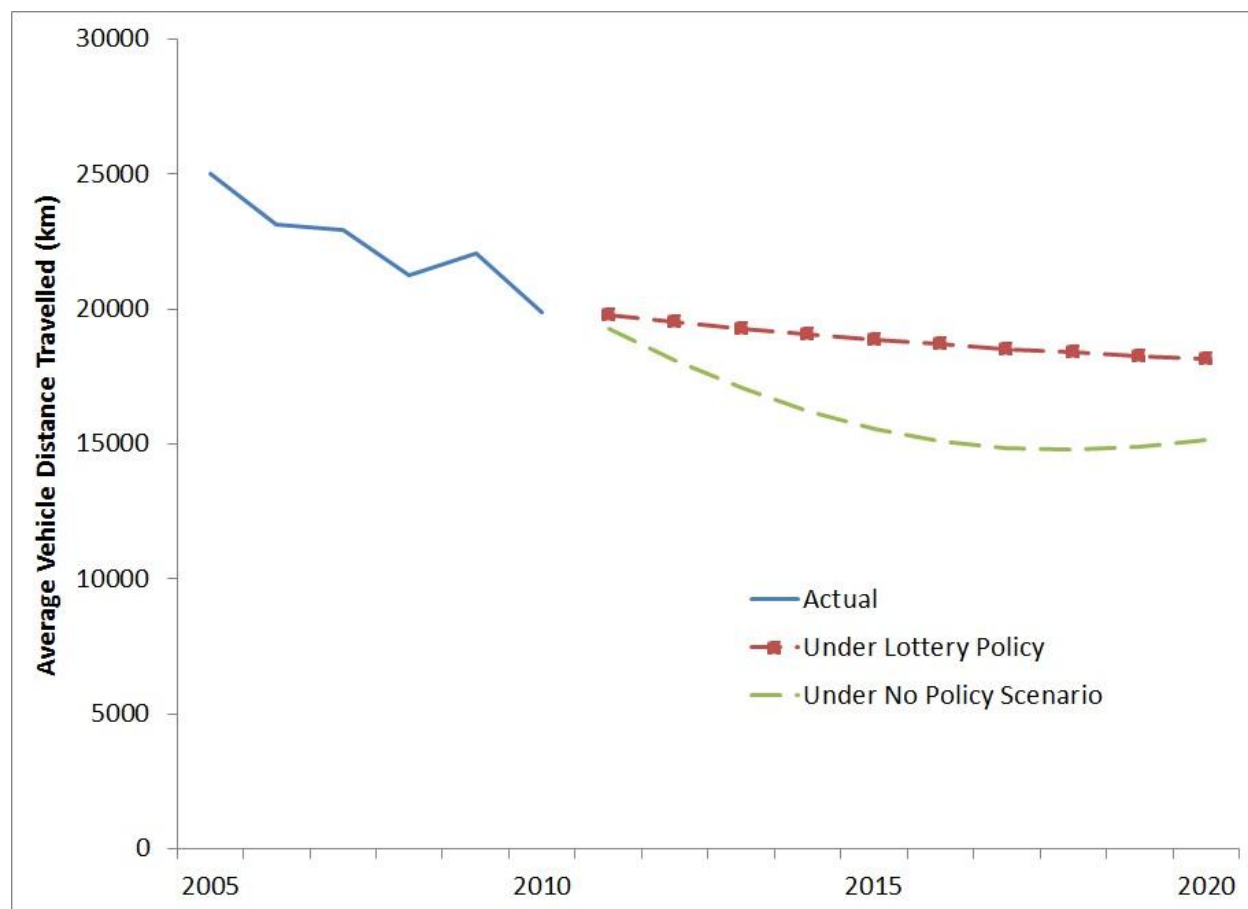
Figure 12. Calculation of Overall Average Fuel Consumption Rate in Beijing

Figure 13. Calculation of Overall Fuel Consumption Rate in Beijing
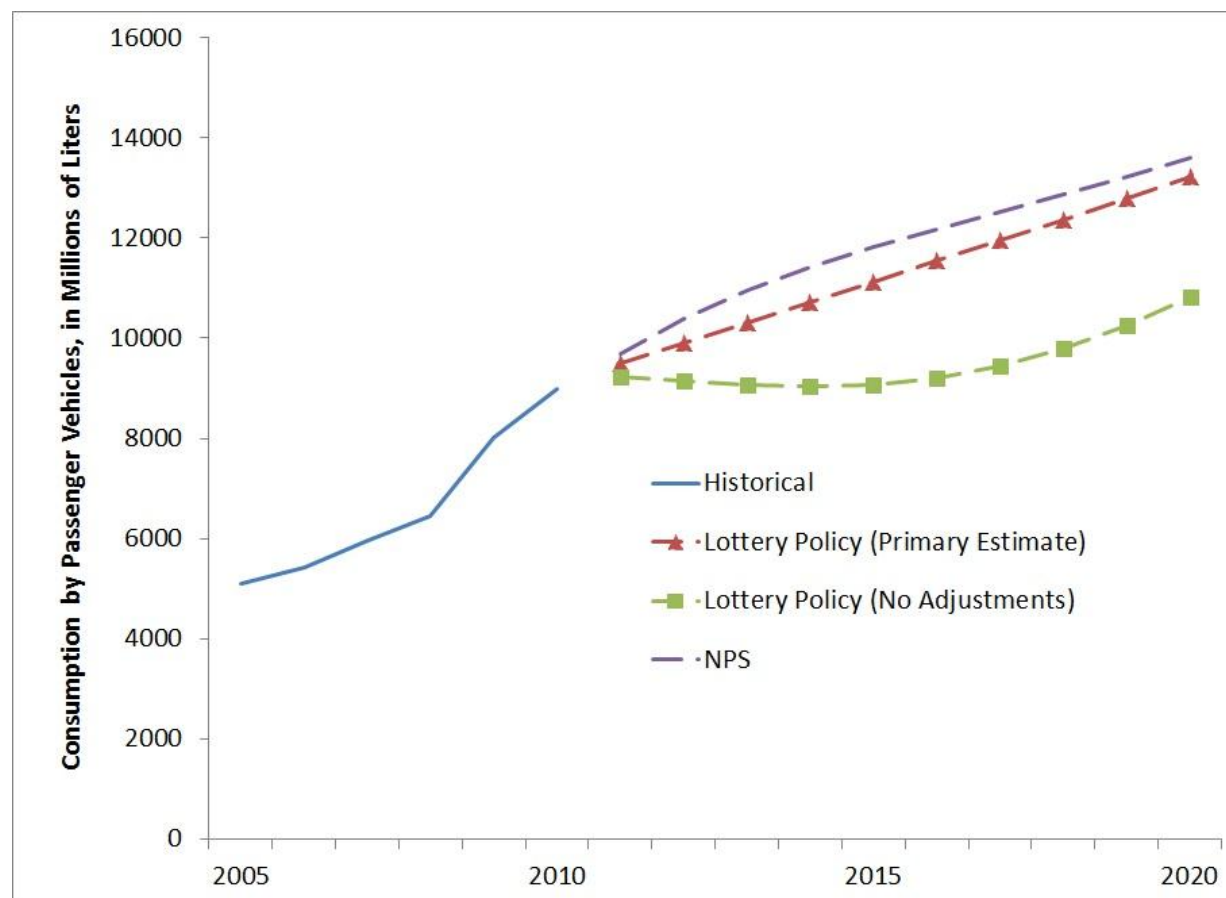
Table 1. Total Numbers of Motor Vehicles in Beijing, in Millions

Year	Motor Vehicles	Private Vehicles	Private Cars
2003	2.124	1.389	9.29
2004	2.296	1.547	1.107
2005	2.583	1.798	1.343
2006	2.876	2.065	1.612
2007	3.128	2.358	1.928
2008	3.504	2.693	2.289
2009	4.019	3.186	2.818
2010	4.809	3.909	3.566
2011	4.984	N/A	3.717

Source: Beijing Transport Annual Report (2003-2012)