

**Automobile Regulations in China Examined from a Behavioral Perspective**

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## **Abstract**

Automobile growth has created severe problems such as traffic congestion, air pollution, and carbon emission worldwide. To address these problems, Chinese local governments implemented a series of automobile regulations to slow down auto growth. They set up a yearly quota of license plates and require potential car buyers to obtain a license plate before buying an automobile. Local governments end up with three modes of allocating the scarce license plates: only lotteries, only auctions, and a mix of lotteries and auctions. The main debate is the tradeoff between the efficiency represented by auctions and the equity represented by lotteries. By drawing on two survey results in Beijing and Guangzhou, this thesis analyzes the automobile regulations with respect to the normative aspect, the empirical aspect and the behavioral aspect of the debate. I structure this thesis in three separate essays.

The first essay focuses on the normative aspect. It provides different ways of interpreting fairness, which is a guiding principle of the lottery-based allocation scheme adopted in Beijing. The essay builds up a three-layer framework to evaluate the fairness of the lottery-based allocation scheme. I conclude that the lottery is superficially fair because it only narrowly conforms to the equality rule, which generates a positive public view. The findings suggest that fairness is an extraordinary broad concept, and thus any policy can at most only conform to certain aspects of fairness, as in the Beijing case.

The second essay focuses on the empirical aspect. It analyzes how people chose between lotteries, auctions, and non-participation in Guangzhou, where a mixed mode of lotteries and auctions is adopted. This essay focuses on the marginal effects of socio-demographics, especially income, on choice. It turns out that high-income people chose both lotteries and auctions, in contrast to the common belief that lotteries benefitted the poor and auctions benefitted the rich. In fact, people responded strongly to the fluctuation of the number of participants and winning rates of lotteries and auctions. People speculated in both lotteries and auctions, instead of making decisions based on their needs or economic status.

The third essay focuses on the in-depth behavioral aspect. I analyzed the impact of risk biases on the choice between lotteries, auctions and non-participation under three different policy scenarios. Consistent with theories, people over-estimated the winning rates of lotteries and under-estimated the winning rates of auctions. When faced with a choice between only lotteries and non-participation or between only auctions and non-participation, the risk biases dominated the decision-making process. On the contrary, the cognitive biases did not influence decisions much if people were faced with lotteries, auctions, and non-participation, as in the Guangzhou case.

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## **Preface**

A version of chapter 2 has been submitted as Zhao, J. and Wang, S. (2016) Superficial Fairness of Transport Policies: Beijing's License Plate Lottery. Transportation Research Part A: Policy and Practice.

A version of chapter 3 has been submitted as Wang, S. and Zhao, J. (2017) Choosing between Lotteries and Auctions—Distributional Effects of License Plate Regulations in Guangzhou. Transportation Research Part A: Policy and Practice.

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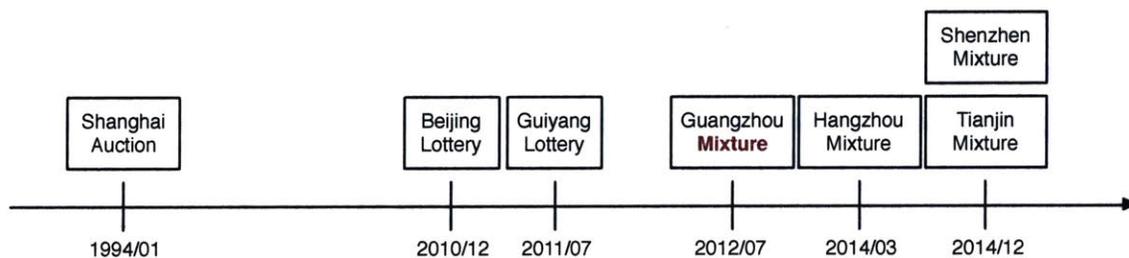
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## Chapter 1 Introduction

The transitional economy in China has significantly increased the number of individuals purchasing personal automobiles. Between 2000 and 2014, the total number of passenger car owners in China grew from 16.1 to 146.0 million (National Bureau of Statistics of China, 2013). This rapid growth has led to severe problems including air pollution, congestion, and energy consumption. Motor vehicles consume about 50% of the total oil annually consumed in China (Davis, Diegel, & Boundy, 2008; Ma, Fu, Li, & Liu, 2012). To mitigate this unprecedented growth, Chinese local governments, including those of Beijing, Shanghai, Guangzhou, and four other major cities, have implemented a series of license plate regulations. As shown in Figure 1, Shanghai was the first to limit license plates registration in 1994. After 16 years, Beijing implemented its own license plate regulation. The two policies are similar as both restrict automobile ownership growth; however, they differ in that Shanghai holds auctions to allocate license plates, while Beijing conducts lotteries. In 2012, Guangzhou introduced its policy, which is characterized by its mixed allocation scheme. Guangzhou residents need to choose between lotteries and auctions every month to obtain a license plate before buying an automobile. After Guangzhou, other cities adopted the similar mixed allocation rule as Guangzhou. The evolution of the series of license plate regulations, as shown in Figure 1, has shown that 1) the allocation scheme is the most controversial element of the series of license plate regulations; and 2) the mixed mode is becoming increasingly influential because several cities adopted this mode after Guangzhou.

**Figure 1 Evolution of license plate regulations in China**



The allocation schemes, lotteries or auctions, are controversial in many public policies because it involves the tradeoff between equity and efficiency. Both the scholars and the public believe that lotteries represent equity and auctions represent efficiency. This tradeoff renders the task of allocating license plates difficult, and naturally, the mix of lotteries and auctions is seen as incorporating the benefits of both equity and efficiency. However, the past research about this issue is far from complete. Past studies didn't answer

what fairness or efficiency gains were exactly in the lottery-based or the auction-based allocation scheme. Past studies didn't answer how people behaved in any of the allocation schemes, partially because no individual-level data are available. Beyond the application to license plate regulations, lotteries and auctions are generic ways to allocate limited public resources. Scholars believe that lotteries benefit the poor, while auctions benefit the rich (Sandel, 2010). However, empirical evidence is not adequate because lotteries and auctions are rarely simultaneously applied to the same group of residents. The series of license plate regulations provide a rare opportunity to illustrate the tradeoff between lotteries and auctions.

This thesis addresses this debate in three essays. The first essay analyzes how to interpret fairness concept differently and how to apply a framework of fairness to evaluate the lottery-based allocation scheme in Beijing. This study focuses on the normative aspect. The second essay analyzes how people behaved under the mixed allocation scheme in Guangzhou; in particular, whether people chose lotteries or auctions based on their mobility needs or economic status. This study focuses on the empirical aspect. The third essay analyzes how risk biases influenced behaviors under three different policy scenarios. This essay focuses on the micro-level behavioral aspect.

“Fairness,” though commonly invoked as an evaluative metric in transportation policy, remains an ambiguous concept. Chapter 2 provides a three-layer framework for assessing the fairness of transportation policies. The first layer differentiates substantive, perceived, and procedural fairness; the second layer concerns the concrete rules of assessing these three aspects; the third layer concerns the categorization of people. The framework also identifies four challenges, including frame of reference for comparison, scope of analysis, measurement difficulties, and conflicting fairness concepts. This chapter applies the framework to assess Beijing's vehicle license lottery policy, through a review of policy documents and a survey of public perception (n=1505). Assessed from the standpoint of substantive fairness, the policy mainly conforms to the equality rule, and dismisses the rules of equity and need. Regarding perceived fairness, the policy appeals to the general public, though three disadvantaged groups are less satisfied. Assessed for procedural fairness, although the policy has adopted reasonably complete procedures, the public does not perceive the procedures as fair. I conclude that the policy is superficially fair in three senses: 1) It only conforms to a narrowly conceived equality rule; 2) The government leverages the equality rule to improve public views without improving fairness substantively; and 3) the policy only creates weak connections between procedural and substantive fairness, and between procedural and perceived fairness.

Chapter 3 is an empirical study about Guangzhou. In 2012, Guangzhou introduced a vehicle license regulation, which controls the monthly quota of local automobile growth. Residents who want a license are required to choose between the lottery and auction method to obtain one. Since then, there have been heated debates about the distributional effects of lotteries and auctions; however, none of these debates has been grounded in empirical studies. We conducted a survey in January 2016 (n =1,000 people \* 12 months), and used random-effect mixed logit models to analyze how socioeconomic status, including income and automobile ownership, determined people's choices among lottery, auction, and non-participation alternatives. We find that income increased participation, but did not influence non-car owners' choice between lotteries and auctions, contrasting the common notion that lotteries benefit the poor. Further, the positive impact of car ownership on participation indicates a car-dependent trajectory of automobile growth. The significant socioeconomic differentiators between lotteries and auctions were age, gender, and education. Proxies of mobility needs are overall insignificant. The program attributes had a much larger impact in that people were more likely to choose lotteries with higher winning rates and more participants, and more likely to choose auctions with higher prices and more participants. We concluded that for those who participated, the choice between lotteries or auctions did not really depend on their income or mobility needs, but rather, the probability of winning plates and the opportunities for speculations.

Chapter 4 focuses on how risk biases influenced how people made choices in the series of license plate regulations. While past studies have mainly focused on normative assessment, this study explores what determined public choices among non-participation, lottery, and auction alternatives, with a specific focus on the influence of risk biases. We implemented a questionnaire survey in January 2016 using a stratified sampling scheme. By using stated preference data and comparing three logit models that simulated the policy conditions in Guangzhou, Shanghai, and Beijing, this study yields two major findings. First, people overestimated the low probabilities of winning lotteries and underestimated the high probabilities of winning auctions. Second, risk biases influenced public choices. When choosing between non-participation and lotteries, or non-participation and auctions, people with more risk biases were more likely to choose lotteries and auctions. However, when people were choosing between lotteries, auctions, and non-participation, risk biases did not influence choices. Policy makers need to be aware of risk biases, understand how they change behavior, and potentially leverage it to achieve ideal policy outcomes.

## **Chapter 2 Superficial Fairness of Transport Policies: Beijing's License Plate Lottery**

### **Introduction**

Fairness, a guiding principle in many transportation policies, is a concept lacking wide agreement about its meaning. Although broadly understood as a principle of resource allocation, the substantial meanings governing this allocation vary, including strict egalitarianism, the difference principle, equality of opportunity, and welfare-based principles. Although there have been some discussions about fairness in transportation policies (May & Sumalee, 2005; Rosenbloom, 2009; TRBNA, 2011), much recent work focuses on improving practical measures of fairness (T. Bills, 2013; Litman, 2007; Ramjerdi, 2006), and only a limited number of studies focus on the connection between fairness theories and practical frameworks (B. Taylor & Norton, 2009). No study has fully applied an evaluative framework to a concrete case. In practice, fairness concerns often yield to efficiency concerns, and scholars have called for further research into applying this principle to concrete transportation policies (Rosenbloom, 2009). To address these concerns, this study aims to 1) integrate past studies to provide a framework to assess the fairness of transportation policies; and 2) apply this framework to assess the license plate lottery policy in Beijing to illustrate the dynamics of the fairness concepts.<sup>1</sup>

The framework consists of three layers. The first layer differentiates three aspects of fairness: substantive, perceived, and procedural fairness. The second layer concerns the concrete rules to evaluate the three aspects. The rules of assessing substantive fairness include equity, need, and equality. The rule of assessing perceived fairness is to investigate into public views. The rules of procedural fairness adopted in this study are information disclosure and transparency. The third layer concerns the categorization of people. Methods of social categorization are the lenses to understand the heterogeneity within substantive fairness and perceived fairness. The framework also identifies four common challenges, including specifying the frame of reference for comparison, defining the scope of analysis, defining the appropriate measurement, and reconciling conflicting fairness concepts. This framework, though still not comprehensive, is sufficiently coherent and operational to assess the fairness of transportation policies in practice.

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<sup>1</sup> “Fairness concepts” incorporate the rules of assessing fairness. Fairness concepts broadly refer to all the concepts relevant to fairness assessment used in this paper, including substantive, perceived, and procedural fairness; equality, equity, and need; transparency and information disclosure; public views; and assessment based on different categories of people.

We apply this framework to assess the license plate regulation in Beijing, where a lottery has been used to allocate license plates to residents. In January 2011, the Beijing government initiated a license plate regulation to mitigate traffic congestion (Beijing Traffic Management Bureau, 2010a; IBM, 2010). The government allocates the licenses by lotteries, with a monthly quota of 20,000 license plates during the first year. No entry payment is required for Beijing residents, though the policy does not apply to car owners, who already have licenses, and excludes migrants from participation. Every entrant has an equal chance to win a license, and lottery winners must register the license to a vehicle within six months. Unsuccessful entrants are automatically transferred into the next month's drawing.<sup>2</sup> In this lottery policy, fairness is a dominant principle: the policy document explicitly proclaims that "license plates should be distributed based on the principle of fairness" (Beijing Traffic Management Bureau, 2010b). Moreover, the fairness of the lottery policy has been a matter of constant and intense public dispute, full of conflicting views (B. Li & Li, 2012; F. Li, 2011). Therefore, the lottery policy serves as a test case to reflect the diverse fairness concepts of the assessment framework.

This paper unfolds as follows. The literature review synthesizes past studies to construct a three-layer framework and identify the four challenges of assessment. After discussing data and methods, we will successively assess the substantive, perceived, and procedural fairness of the Beijing license policy. To understand substantive and procedural fairness, we analyze policy documents and government-published data. To understand the heterogeneity of perceived fairness, we use ordered logit and probit models to analyze two surveys conducted in 2012 and 2013. This study yields three main findings. First, the lottery policy primarily follows the equality rule and dismisses the rules of equity and need. Second, the equality rule effectively results in a high level of perceived fairness in the general public, although this rule is narrowly applied to a limited socioeconomic group of Beijing residents. Third, the connections between procedural and substantive fairness, and between procedural and perceived fairness are weak. Survey respondents dismiss the reasonably complete procedure of the lottery policy. The procedure also contrasts with our primarily negative assessment from the perspective of substantive fairness. The findings reveal the peculiar context of Chinese cities, where the procedural tradition is weak and thus equality is used to signal fairness. The empirical findings from the case can inform the general policy conversation about how to balance substantive, perceived, and procedural fairness.

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<sup>2</sup> For more details of the policy, please see Appendix I.

## **Three-Layer Framework of Assessing Fairness**

This section synthesizes the past studies and provides a framework to assess the fairness of transportation policies. The framework has three layers: 1) three aspects of fairness: substantive, perceived, and procedural fairness, 2) the concrete rules to assess them, and 3) the categories of people. We will introduce substantive, perceived, and procedural fairness in order, and within each, we will discuss the assessment rules and categories of people. In the end, we will discuss four generic challenges of assessing fairness.

### **Substantive Fairness**

Substantive fairness focuses on the distribution of benefits and costs under a transportation policy, a topic extensively discussed by transportation policy makers and scholars. Schweitzer (2009) concludes that poor people benefitted from the Stockholm cordon toll because the revenue from the toll improved the public transit. Brown (1998) argues that the suburban residents can benefit if municipalities build commuter-oriented transit services. Rosenbloom (2009) argues that within a transit system, transit riders in central cities are thought to subsidize suburban riders, especially under flat-fare policies. These studies are similar to the traditional economic analysis, such as assessing the fairness of a tax by calculating its burden on households. Many scholars have assessed transportation policies from the substantive fairness perspective (T. Bills, 2013; T. S. Bills, Sall, & Walker, 2012; Delbosc & Currie, 2011; Garrett & Taylor, 1999; Giuliano, 1994; Levinson, 2002; Litman, 2007).

Substantive fairness includes three rules: equity, need, and equality. Equity implies that all receivers should share the same ratio of benefits to costs (Adams, 1965; Deutsch, 1975). Need implies that the least advantaged group should receive benefits (Rawls, 1971). Equality implies that people obtain equal chances or equal shares of benefits and costs (Ackerman & Alstott, 1999; Crocker, 1977; Deutsch, 1975). This equity rule has synthesized benefits-received, return-to-source, and costs-imposed fairness, proposed in the report of the TRBNA (2011). The equity rule indicates that the people who benefit should pay or that the people who bear cost should obtain compensation. The equity rule can also broadly include the three types of equity defined in B. Taylor and Norton (2009), including market, opportunity, and outcome equities, which are differentiated based on inputs, outputs, and consumption. The need rule has two related implications: advantaged groups should pay, which is similar to the ability-to-pay principle, or disadvantaged groups should gain compensation (Rosenbloom, 2009).

In practice, policy makers most widely apply the rules of equity and need. When people who use roads pay more in use fees, it follows the equity rule. When higher income people pay disproportionately more taxes to fund a transportation project, it follows the need rule (TRBNA, 2011). If license plate quotas follow the rule of equity, people with the highest marginal utility should obtain the license plates and pay the corresponding costs commensurate with their utility gain. An ideal auction can efficiently achieve this goal. The need rule would instead dictate that the most disadvantaged people should obtain the license plates, though how to identify disadvantaged people is contentious, varying with the ways to categorize people.

While transportation policy makers have adopted the rules of equity and need in numerous policies, they often neglect the equality rule. The rule of equality implies that all potential users should have equal shares of resources, specifically in this case, equal chances of obtaining a license plate. The equality rule is an oversimplified rule that scholars can easily challenge its legitimacy, and we speculate that this is the reason why the equality rule has been neglected in the past transportation studies. However, the rule of equality accurately captures the piece of substantive fairness of the lottery policy.

Categories of people are critical for assessing the substantive fairness of a policy. The rule of equity needs to compare the distribution of benefits and costs across different groups of people, and the rule of need requires a criterion to specify the disadvantaged group. We consider the categories of people to matter in two ways. The categories determine the frame in which how policy makers conceptualize a problem, and the chosen category determines the perspectives with which researchers evaluate a policy.

Geographic location, economic status, generational condition, socio-demographic characteristics, and travel information are five common ways to categorize people (Litman, 2007). Geographic fairness is an overriding fairness concern for politicians since they represent certain jurisdictions (TRBNA, 2011). Levinson (2005) argues that the transit price is unfair because urban transit riders cross-subsidize suburban transit users. Economic fairness compares the burden of costs between the rich and the poor. The transit fares that do not vary by distance cause higher fares per mile for low-income passengers because they tend to make shorter transit trips (Bates & Anderson, 1982). Generational fairness compares across generations. The use of debt to fund transportation transfers funding responsibility to future generations, yielding generational unfairness (TRBNA, 2011). Other socio-demographic characteristics involve gender, age, race, or ethnicity. Studies compare benefits and costs based on travel information. Rosenbloom (2009) argues that bus and rail passengers obtain different number of subsidies, generating unfairness across travel modes.

### **Perceived fairness**

While scholars emphasize substantive fairness, practical challenges often lie in perceived fairness. The negative public perception of transportation policies, often not based on empirical evidence, hinders implementation (TRBNA, 2011). B. Taylor and Kalauskas (2010) argue that road-pricing proposals often fail because the public perceives road-pricing as unfair. The public sees high occupancy/toll (HOT) lanes as “Lexus lanes,” portrayed by the media that wealthy cars roaring past congested poor cars (May & Sumalee, 2005). As a result, politicians and voters prefer alternative approaches to tackle congestion, such as building new lanes, although the effect of the alternatives has been proven limited (B. Taylor & Kalauskas, 2010).

Previous studies have observed a conflict between substantive and perceived fairness. Policy instruments that conform to perceived fairness can violate substantive fairness. For example, to deal with troubled transportation finances, municipalities choose to raise sales taxes rather than gas taxes (Altshuler, 2010; Wachs, 2005). Citizens tend to perceive a small proportional increase in sales tax as fair, while perceiving a larger proportional increase in gas tax, which generates the same revenue, as unfair (Altshuler, 2010; Wachs, 2005). However, assessed from the perspective of substantive fairness, Wachs (2009) argues that a gas tax is fairer because it can distinguish the people who travel longer or shorter distances, while sales tax is blind to it.

In the case of road pricing policies, people in different social positions perceive fairness differently. While the public believes that low-income people think road pricing is unfair, Mitchell (2009) suggests that only 2 out of 21 cases show that low-income people are strongly against road pricing. In fact, the group affected by a policy frequently perceives fairness differently than unaffected groups. Moreover, the general public and experts often perceive fairness differently. The public assesses a policy from the standpoint of their own benefits, while experts calculate social benefits (Schaller, 2010).

### **Procedural fairness**

Procedural fairness emphasizes the process used to achieve a result, as opposed to substantive fairness, which emphasizes the distributional effects of a policy (Deutsch, 1975; Leventhal, 1980). “Treating everybody equally” concerns processes, and “making everybody equal” concerns results (Hayek, 1948). Results and processes can be closely related, but contain no necessary connection (Lind & Tyler, 1988; Thibaut & Walker, 1975). In this study, we only assess procedural fairness through information provision

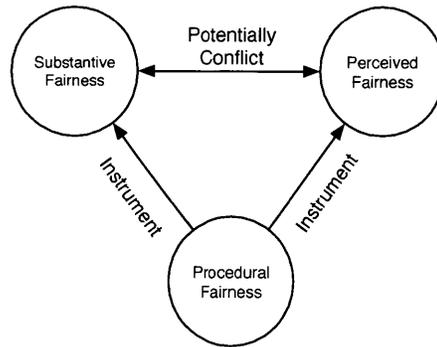
and transparency, though it can broadly include consistency, bias-suppression, accuracy, correctability, and representativeness in public policies (Leventhal, 1980).

Procedural fairness can improve substantive and perceived fairness, and reconcile the conflict between them. B. Taylor and Kalauskas (2010) suggest that transportation policy makers should incorporate more public participation in the planning stage to improve substantive fairness. Public participation in Chicago changed a policy decision made by Chicago Transit Authority, so that the Brown Line could serve minority communities during the reconstruction of other lines (TRBNA, 2011). To improve perceived fairness, B. Taylor and Kalauskas (2010) suggest municipalities establish trust between elected officials and transportation agencies, and enlist the supports of influential constituencies before announcing a policy. Figure 1 illustrates the relationship of substantive, perceived, and procedural fairness.

#### **Four challenges of assessing fairness**

Any study that aims to assess fairness faces the following four challenges: its choice of reference policies, its scope of analysis, measurement difficulty, and conflicting fairness concepts. First, fairness is relative to some baseline. No study can claim a policy as fair or unfair without comparison to another policy (Rosenbloom, 2009). User fees can have a regressive impact, but are less regressive than sales taxes. The challenge is how to find an appropriate reference policy for comparison. Second, assessment varies with the scope of analysis. In a temporal dimension, it is more difficult to analyze the long-run impacts of a transportation project than the short-run impacts. The scope can include benefits, costs, or both. It is also more difficult to compute both benefits and costs than to compute only benefits or costs (TRBNA, 2011). The scope may include revenue transfer. How the revenue from road pricing is used changes the assessment of fairness (TRBNA, 2011). Third, measurements influence assessment. The performance of transport system can be measured by vehicle miles traveled, passenger miles traveled, or passenger trips (Litman, 2007). Income can be measured by either life-cycle average income or current income (West, 2011). Lastly, fairness concepts conflict at multiple levels. Road pricing may be substantively fair but is perceived as unfair (B. Taylor & Kalauskas, 2010). The equity rule requires road users to bear the costs of their transport services, whereas the need rule requires subsidies for disadvantaged road users; the equality rule requires that people receive uniform public resources, whereas the need rule requires that the distribution of resources favors the poor. Litman (2007) points out that it is difficult to answer whether a transportation policy should benefit a low-income but physically able person or a medium-income but disabled person. Given this challenge, no policy can satisfy all fairness concepts. Policymakers must consider how to prioritize the divergent fairness concepts in a specific policy, or how a specific policy reflects a particular relationship of substantive, perceived, and procedural fairness.

**Figure 2: relationship of three aspects of fairness in the past studies**



### **Methods: Analyzing Policy Documents, Official Data, and Questionnaire Survey**

Our application of this assessment framework to the Beijing license lottery relies on three sources of data: policy documents, official data, and questionnaire surveys that we conducted in 2012 and 2013. The policy documents include the “Temporary Provision on Number Control of Small Passenger Cars” and its three versions of implementation specifics. We compared the differences of these documents to understand the evolution that the local government intended to lead. We analyzed the official monthly data of entrants and quotas to see the change patterns in the past years, and explored the surveys to measure people’s perception and preferences. Other information, such as newspaper reports and court rulings, is specifically used to support our argument about the activities after people obtain licenses. Please see the lottery policy details and the official data in Appendix I.

Our research team hired Shanghai Online Market Research Corporation Ltd. (OMRC), which operates the online survey platform [www.51poll.com](http://www.51poll.com), to conduct the questionnaire survey. Samples were selected from a database of 120,000 individuals living in Beijing. Potential respondents were offered incentives of 6 CNY (US\$1) for completing the questionnaire. The questionnaire was first tested in a pilot survey among 73 respondents (they are not included in the final dataset) and revised accordingly in May 2012. The main survey was conducted in two waves. The first wave was in June 2012, for which OMRC sent invitations to 8,365 randomly selected individuals. 1,557 individuals clicked the questionnaire link, and 1,085 completed the questionnaire (69.7%). Due to the disproportionately high prevalence of car owners among the respondents in the first wave, a booster wave focused on non-car owners was conducted to bring sample characteristics closer to the population. The second wave was conducted in January 2013, for which OMRC sent invitations to 7,638 randomly selected individuals. 3,055 clicked the link, and 600

completed the questionnaire (19%). After combining the two waves, removing incomplete responses, and examining the validity of each questionnaire, we use 1,505 valid responses in this study.

To analyze perceived fairness, we regress the scores of perceived fairness on socio-demographic information by using ordered logit and probit models. Independent variables are demographic and socioeconomic information, location, vehicle ownership, and travel behavior. Dependent variables are the perception of the lottery policy, the perception relative to Shanghai auction, and the preference between lottery and auction. Most attitudinal questions were presented as statements on a 5-level Likert scale. Specific questions are reported in Table 2.

**Table 1 Perceived fairness of Beijing’s car license lottery and preference for lottery or auction (weighted)**

Preference for lottery or auction	Lottery	Auction	
Different from Beijing's lottery policy, Shanghai has used a license auction to regulate car ownership. If you were asked to plan transportation policies in Beijing, which car ownership policy would you choose, considering both effectiveness and public acceptance?	76.9%	23.1%	
Assessment the overall fairness of the policy	Agree <sup>3</sup>	Neutral	Disagree
The policy is fair since all people are treated the same and everyone has the same chance of winning.	66.5%	22.7%	10.8%
The vehicle license lottery policy in Beijing is fairer than Shanghai's auction policy, since you can enter the lottery and have a chance of winning a license regardless of your financial ability.	69.5%	23.9%	6.6%
Prior v. New car owners			
The lottery policy is not fair to new car purchasers since drivers who owned cars before the policy don't need to go through this process	52.6%	31.0%	16.4%
Local v. Migrant			
The requirement for registration is too strict since people holding a temporary residence need to pay income tax continuously for 5 years	61.2%	19.4%	19.4%
The registration requirement is unfair to migrants since they have to hold a working residence permit or temporary residence permit but have paid social security and tax continuously for 5 years.	60.5%	20.3%	19.2%
Transparency			
It is not possible for the draw procedure to be transparent since only the first few drawings could be watched in real time.	74.9%	20.8%	4.3%
Although lottery registrants can get the results via internet and telephone, they cannot obtain detailed information on the draw procedure.	77.8%	18.8%	3.4%
There are “black-box operations” in the lottery procedure	70.2%	25.8%	4.0%
Information Provision			

<sup>3</sup> Respondents indicated their agreement with these statements on a five-level Likert scale: strongly agree, partially agree, neutral, partially disagree and strongly disagree. “Agree” includes both “strongly agree” and “partially agree,” and “disagree” includes “partially disagree” and “strongly disagree”

I cannot update my knowledge of the changes made in the policy.	74.0%	16.4%	9.6%
Lottery registrants often realize the policy changes when it is too late.	67.2%	23.7%	9.1%

We validated the representativeness of the sample using three techniques. First, by comparing the un-weighted sample and population distribution, Table 7 in Appendix shows that the sample fairly matches the population for most of the socio-demographic dimensions. Second, we have used iterative proportional fitting (IPF) to weight the sample in six dimensions: age, gender, education, household location, hukou status, and household car ownership against the Sixth National Population Census of the People's Republic of China (National Bureau of Statistics of China, 2013). IPF can ensure that the statistics calculated in the sample represents Beijing citizens. Third, the ordered logit and probit models can achieve consistency without weighting, as long as sampling is not an endogenous sampling scheme. However, we admit that the sampling may involve some biases; for example, those who are more satisfied or dissatisfied with the lottery policy are more likely to respond, and this bias cannot be captured by controlling variables. The representativeness of the data can be inadequate.

### **Assessing Substantive, Perceived, and Procedural Fairness**

The three major findings are 1) the lottery policy largely conforms to the rule of equality; 2) the intention of following the equality rule improves perceived fairness; 3) there are weak connections between procedural and perceived fairness, and between procedural and perceived fairness. Before moving to these concrete findings, we will make four assumptions of assessment.

#### **Assumptions before assessing the fairness of the lottery policy**

Given the four challenges of assessing fairness, we will clarify four assumptions. The assumptions are expedients rather than objective decisions. We make them partially to simplify the analysis and partially to obviate the difficulty of collecting comprehensive data.

First, since fairness is relative, we choose the most relevant policy, the auction policy in Shanghai, as a reference case. In 1994, Shanghai first adopted a similar license plate regulation, and distributed the license plates by auction, which guarantees that the highest bidders can gain the license plate. G. Xue (2004) criticizes Shanghai's distributional mechanism, claiming the rich benefited to the detriment of the poor, while Chen and Zhao (2013) offer a more moderate assessment of the auction policy, arguing the revenue transfer invested into public transit benefits socially disadvantaged people. Since the contention between the lottery and the auction concentrates on fairness, this study uses Shanghai as the reference

policy. Second, the scope of this study covers the distribution right after the lottery, as well as revenue transfer, which is generated in the auction in Shanghai. This study will not assess long-run effects, such as land-use changes caused by the change of automobile ownerships. Third, to measure benefits, this study focuses on resource allocation, rather than the utilities obtained from resources. It does not attempt to assess different individual valuation because of data limitations. Fourth, while we have clarified the multi-faceted fairness concepts, we are not prioritizing certain fairness concepts over others for assessment. The question we explore is how the lottery policy prioritizes some fairness concepts, and what the dynamics of the fairness concepts is in this particular policy. This study uses five population categories, including high vs. low income, local vs. migrants, prior vs. new car owners, car owners vs. non-car owners, and spatially advantaged vs. spatially disadvantaged. While these five categories are by no means exhaustive, they can capture the main social groups relevant to this policy.

### **Assessing substantive fairness through equity, need, and equality**

Our analysis illustrates that, regarding immediate effects and without the comparison to the auction policy, the lottery policy mainly follows the equality rule, but it abandons the rules of equity and need. Moreover, the lottery policy deviates from equality if we consider the activities after people obtain licenses. With the auction policy as a reference point, the lottery policy conforms to equity and need rules even less.

The lottery policy largely conforms to the rule of equality, but the equality rule fails in the categories of local vs. migrant, and prior vs. new car owners. The lottery policy prioritizes the even distribution of license plates. Policy specifics, such as no-cost lottery participation, attempt to lower barriers to participation and avoid economic exclusion. Besides the no-fee entry, all individual entrants share the same odds of winning, regardless of geographic location or income. But the lottery policy conforms to the equality rule only to a limited extent. Although a resident holding a Beijing hukou has no difficulty entering the lottery, migrants either are not eligible to join the lottery or face very restrictive barriers. Furthermore, by the time of the policy implementation in January 2011, there were already 3.9 million private cars on Beijing's streets. Those vehicle license owners were grandfathered into the policy: they were exempted from participating in the lottery and continued enjoying the privilege of using their vehicles.

The lottery policy does not conform to the rules of equity and need, even regarding only the immediate effects. The lack of a corresponding payment for the license plate by lottery winners contravenes the rule of equity, which requires that people should bear costs commensurate to the benefits they receive (Yi et

al., 2013). Many argue that if the Beijing government had implemented the policy based on people's mobility demands, the car license policy could have led to a "fairer" result because people who have a higher willingness to pay can acquire a license with reasonable costs (Fan, 2013; Jiang, 2013). The policy does not extend preferential treatment to those who are socially, economically, or spatially disadvantaged, disregarding any need-based rules of distribution.

The lottery policy deviates from the rule of equality if the activities after people obtain licenses are taken into account. Since license plates are often allocated to people with little need due to the random lottery process, illegal leasing markets have formed to transfer the licenses to residents with a high willingness to pay but no success in the lottery process (B. Li & Li, 2012; F. Li, 2011). Many prior owners who have no need for a license instead sell or rent licenses at a black market price.<sup>4</sup> Another conduit of transfer is fake lawsuits in which a seller's vehicle is used to "pay off the debt" to a buyer, thus achieving a legal transfer of the vehicle (Beijing Times, 2012). Although these mechanisms are defined as illegal and rigorously restricted by the local government, they enable the people with greater willingness-to-pay to obtain a license plate by paying certain amount of money.

Using the auction policy as a reference, we conclude that the lottery policy violates the rules of equity and need to a greater extent. The auction policy orders license allocation by the urgency with which entrants seek to acquire a vehicle. The auction also makes the winners pay the amount of money commensurate with the benefits they obtain. Taking into account revenue transfer, the auction policy leads to more public transit investment, providing redistributive benefits to the non-car owners and the poor<sup>5</sup> (SFB, 2015). In contrast, Beijing's lottery raises no revenue and forgoes the opportunity of cross-subsidizing the disadvantaged groups. Nie (2013) suggests that the lottery policy represents a fiscal loss to the Beijing government of approximately CNY 26.4 billion, 6% of the Beijing government's annual revenue.

### **Assessing perceived fairness through public opinion**

Overall, survey respondents view the lottery as fair. As shown in Table 2, 66.5% of the public believes the lottery policy is fair, 22.7% neutral, and only 10.8% believes that it is unfair. Comparing Beijing's lottery to Shanghai's auction makes this view even more pronounced: only 6.6% disagree that the Beijing

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<sup>4</sup> No official data on the actual black market price. Various newspapers report the black market price of the license to range between CNY30,000 and 200,000.

<sup>5</sup> Shanghai's public auction has important fairness impacts for the city. Auction revenues are used to redistribute resources from car owners to public transit users. Calculated based on the allocated quota and average bidding price for each month, the license auction in Shanghai generated CNY 6.7 billion in 2014 alone. This revenue was spent on buying more buses (28%), subsidies for transit transfer (23%), senior passes (14%), transit construction and maintenance (18%), MRT construction (13%), and miscellaneous uses (SFB, 2015).

policy is fairer than Shanghai. To avoid ambiguity in the reported policy attitude, we asked the participants to explicitly choose between Beijing's lottery and Shanghai's auction. An overwhelming majority (76.9%) of the respondents prefer the lottery to the auction.

This positive public view suggests that the public understanding of fairness follows the equality rule. People believe that the policy is fair because "everybody has the same chance of winning," which is exactly the equality rule (Table 2, Row 4). Since the lottery policy's substantive fairness conforms only to equality, the equality rule is the only option to explain the positive public perception. This is consistent with B. Taylor and Kalauska (2010) finding that the public computes the benefits and costs in an intuitive way, rather than adopting complex computation, which is often used in the equity rule. The equality rule, which is not emphasized in previous academic analysis, appeals to the public for its simplicity. The assessment of substantive fairness has demonstrated that the lottery policy deviates from the rules of equity and need further when compared to the auction. But the public believes that the lottery policy becomes fairer when comparing it to the auction. This also suggests that the public adopts the simple equality rule, instead of more complex equity and need rules, to assess the fairness of the lottery policy.

There are divergent views about specific policy aspects, although the public perceives the policy as fair overall. About 52.6% of respondents think it is unfair that prior car owners are exempt from the lottery; 61.2% agree that the hukou-based eligibility is unfair for migrants; about 60% feel the specific requirement for temporary residents to pay income tax continuously for five years is unfair.

Beyond the overall positive attitudes, we investigate the heterogeneity of the public views across five socioeconomic dimensions (Table 3). To ensure a robust result, we have tested three dependent variables in three groups of models. The three dependent variables are the score of perceived fairness, the score of perceived fairness relative to auction, and the public preference between lottery and auction. The first and second groups include ordered probit and ordered logit model. The last group is a binary logit choice model. The five socioeconomic variables are prior car owners, new car owners (non car owners are used as the reference case), hukou, geographical location, and income. Except for income, the variables are discrete dummies.

### **Table 3 Models of analyzing the heterogeneity of public opinion**

VARIABLES	Model 1 Perceived Fairness Ordered Probit	Model 2 Perceived Fairness Ordered Logit	Model 3 Perceived Fairness Relative to Auction Ordered Probit	Model 4 Perceived Fairness Relative to Auction Ordered Logit	Model 5 Lottery vs. Auction Choice Binary Logit (Base: Lottery)
Income	1.24 (3.77)	6.29 (6.39)	-0.67 (3.67)	0.54 (6.18)	-10.4 (9.23)
Prior Car Owners	0.238*** (0.059)	0.358*** (0.102)	0.055 (0.060)	0.085 (0.105)	0.148 (0.143)
New Car Owners	0.414*** (0.093)	0.668*** (0.160)	0.301*** (0.096)	0.486*** (0.171)	-0.0755 (0.235)
Hukou (Migrants)	-0.181*** (0.059)	-0.351*** (0.103)	-0.230*** (0.060)	-0.410*** (0.104)	0.882*** (0.139)
Location (Middle)	-0.093 (0.068)	-0.112 (0.118)	-0.123* (0.069)	-0.221* (0.120)	-0.118 (0.164)
Location (Periphery)	-0.152* (0.082)	-0.201 (0.145)	-0.158* (0.081)	-0.235* (0.139)	-0.0528 (0.187)
Constant cut1	-1.865*** (0.102)	-3.340*** (0.199)	-2.178*** (0.108)	-4.050*** (0.224)	
Constant cut2	-1.319*** (0.093)	-2.208*** (0.167)	-1.721*** (0.097)	-3.023*** (0.180)	
Constant cut3	-0.125 (0.091)	-0.151 (0.155)	-0.635*** (0.089)	-1.034*** (0.154)	
Constant cut4	0.937*** (0.095)	1.613*** (0.166)	0.621*** (0.090)	1.021*** (0.155)	
Constant					-1.672*** (0.212)
Observations	1,497	1,497	1,497	1,497	1,497
Final Log Likelihood	-1973	-1974	-1854	-1854	-724.7
AIC	3965.82	3967.67	3727.49	3728.21	1463.40
BIC	4018.94	4020.79	3780.60	3781.32	1500.58

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

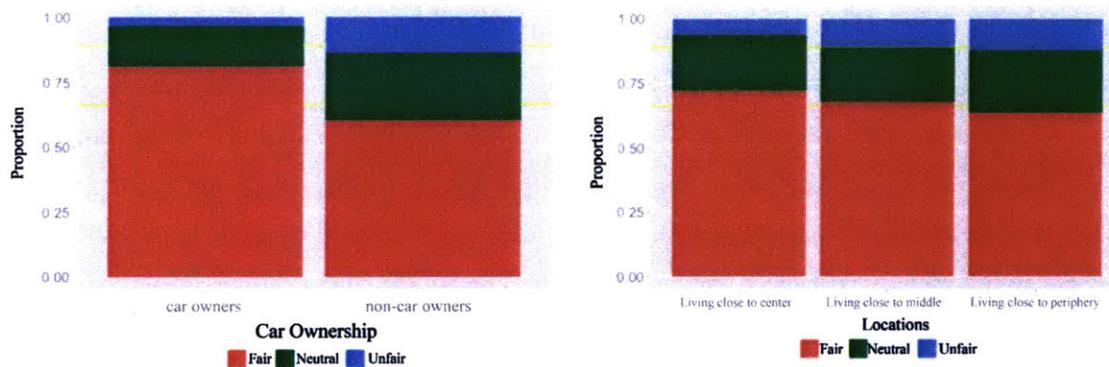
The coefficients of the probit and logit models are not comparable directly because there is a conversion ratio between them. The ratios of the coefficients between ordered probit and ordered logit models are similar.

AIC: Akaike information criterion; BIC: Bayesian information criterion

The five models show robust and consistent results: non-car owners, migrants, and geographically disadvantaged groups are less satisfied with the lottery policy. Income is insignificant in all the five models, implying that the perceived fairness does not vary with income. This is consistent with the past

literature where authors argue that income does not have an impact on the perceived fairness though people usually believe so. Prior car owners and new car owners are more likely to perceive the lottery policy as fair. New car owners won the lotteries due to good luck, and this could lead to the positive perception of the policy. Compared to locals, migrants are more likely to perceive the policy as unfair and more likely to choose the auction. This is consistent with the fact that there are barriers for migrants to participate in the policy. Geographical location is also significant: the people living close to the periphery are more likely to perceive the lottery policy as unfair. This result reflects the weakness of the equality rule. While local residents have the same opportunity to win a license plate, those living far from the city center urgently need a car. As a result, they are unsatisfied with the lottery policy. Figure 2 visualizes the result by comparing perceived fairness scores across car ownership and location.

**Figure 2 Perceived fairness by car ownership and home location**



### Assessing procedural fairness through information disclosure and transparency

The archival data suggests that this policy has a reasonably complete procedure, according to the rules of transparency and information disclosure. Documented regulations for the Beijing lottery require transparency and the disclosure of implementation details to citizens.<sup>6</sup> The Beijing Municipal Commission of Transport (BMCT) has undertaken to satisfy the procedural requirements by launching a website<sup>7</sup> and instigating local agencies to announce policy details. Following the requirement of transparency, the BMCT specifies the details to legitimate the lottery process. For each lottery, the quota of license plates and the composition of the quota are announced in advance.<sup>8</sup> A variety of people can

<sup>6</sup> Article 3 of the implementation specifics of Beijing’s car license regulation claims: “Car licenses should be distributed based on the principles of openness and fairness”. Openness indicates transparency and accuracy of information disclosure to everybody

<sup>7</sup> Known as the “Beijing vehicles quota management and information system”; <http://www.bjhjyd.gov.cn/>

<sup>8</sup> The composition means the quota assigned to the pools of individuals, organizations, and new-energy vehicles, which are

attend the lottery in person including representatives randomly selected from the applicant pool and media personnel. Notaries and regulatory personnel supervise the lottery process. Twenty-five minutes after a drawing, people can either use the website or call a phone service to check the result. Details about the people who acquired licenses and which organizations won the lottery are also announced on the website. The BMCT also requires information to be made available to residents. At the beginning of each year, it announces the yearly quota, monthly quota, and quota calculation methods. The information subject to mandatory disclosure also includes the planned growth rate of automobiles per year, the lottery procedures and results, the process to enter the lottery, and the list of eligible applicants and the reason why certain applicants are ineligible. The BMCT announces the information on both the official website and local agencies of transportation management.

However, public views disclose that the public distrusts the procedural endeavors made by the government. In Table 2, 74.9% of the respondents think that the drawing procedure cannot be transparent because only a few drawings can be watched in real time. This is in contrast to the fact that they can always watch the process in real time. About 70% of the respondents believe that there are “black-box” operations in the lottery process. People show discontent with the process of information provision. About 67.2% of respondents say that lottery registrants often did not realize policy changes until it is already too late, and 74.0% claim they cannot update their knowledge of policy changes, despite the fact that the government does have a website which announces comprehensive and detailed information to the public in a mostly timely manner.

Instead of serving as an effective instrument to improve substantive and perceived fairness, the procedural approach is weakly related to substantive and perceived fairness in the lottery policy. Although the archival data suggest that the government has basically fully disclosed the information and made the process transparent, the public does not have the sense of the procedural endeavors made by the government. People even believe that it is simply impossible to address the fairness issue by procedure. Similarly, while the procedure is reasonably complete, the assessment from substantive fairness perspective is mostly negative. These discrepancies suggest a gap between procedural and perceived fairness and between procedural and substantive fairness. We believe that this reflects the peculiar context of Chinese cities, where the public participation is relatively weak due to historical and conventional reasons. The public tends to see procedural fairness as a bureaucratic ritual instead of achieving substantive goals.

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illustrated in Appendix I.

## **Limitations of analysis**

Two major limitations are the incomplete contents of the framework and the caveats in survey and modeling. First, the framework is by no means exhaustive. The rules of assessing substantive, perceived, and procedural fairness are not comprehensive. Similarly, the categories of people enumerated in this paper are not comprehensive. The critical category of people varies with contexts. Race is not an important category in Beijing, while it is very important in the US. Given the nature of conflicting fairness concepts, it is impossible to figure out a self-consistent structure in a generic way. Second, the sample may not be representative enough and the modeling is imperfect. The four assumptions made before assessing the lottery policy has shown that we adopt expedients due to the lack of complete data and for the sake of simplifying analysis. Since there is no long-term data, we cannot discuss the benefits and costs of the land-use changes caused by this policy. The sampling may have self-selection bias. People who are more satisfied or unsatisfied with the policy are more likely to respond. In the models, the non-car owners, migrants, and geographically disadvantaged groups are unsatisfied with the policy, but it is possible that they are simply unsatisfied with any policy due to their disadvantaged status. The models have low fit, which suggests that the variables can only capture a limited information about people's preferences. Moreover, a policy always aims to achieve multiple goals, such as efficiency, individual liberty, and social stability, far beyond fairness. We focus on fairness due to its ambiguity in practice. Future studies need to substantiate the framework and prioritize some fairness concepts in concrete cases. A panel regression can deal with some caveats in the sampling and the models. The analysis of Beijing's lottery policy is only an exemplary case.

## **Conclusions**

By synthesizing the fairness discussions in the past studies, this study provides a framework of assessing the fairness of transportation policies. By applying the three-layer framework, this study investigates the relationships of the fairness concepts in the automobile regulation policy in Beijing. We first specify the reference, a similar automobile regulation policy with auction as the distributive rule in Shanghai. For the sake of model simplicity, we only focus on the immediate effects on car ownership, using license plates *per se* as the measurement. Analysis shows that the lottery policy conforms to only the equality rule, and dismisses the rules of equity and need. The public in general perceives this policy as fair, though non-car owners, migrants, and geographically disadvantaged groups are more unsatisfied with the policy than the average. The fairness perceived by the public is consistent with the analysis based on equality, rather than equity and need. While the regulations for procedural fairness are reasonably complete, the public has a

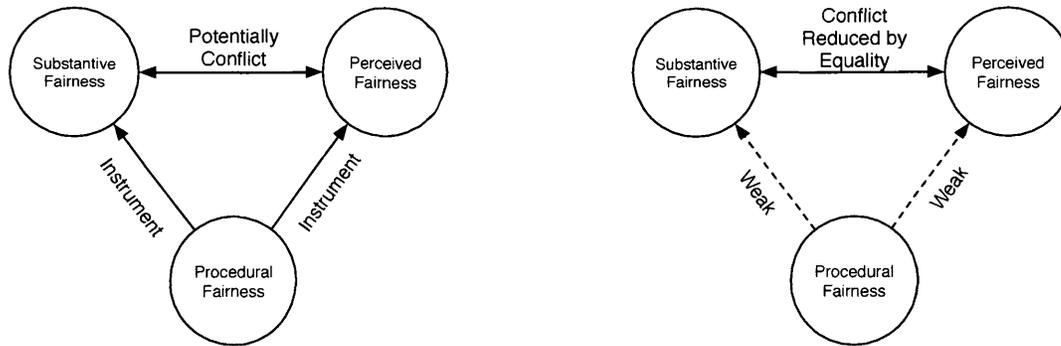
negative view about procedural integrity and transparency. This suggests that the procedural approach is weakly related to the substantive and perceived fairness in the license plate regulation. Among all these findings, we would like to stress three important points, which can forge a deeper understanding of the Chinese context illustrated through the generic analytical framework.

First, the lottery policy is superficially fair because it only conforms to the equality rule within a limited socioeconomic boundary. The eligible applicants share the same odds of winning the lottery. The policy is not substantively fair in terms of the equity and need rules. Using the auction policy as a reference and focusing on the activities after the initial distribution of licenses, we conclude that the policy further deviates from the rules of substantive fairness.

Second, equality as a rule of substantive fairness can effectively create a positive public view about a policy. Equality is the rule that the past studies have largely ignored. We speculate that this rule is so simple and so “superficial” that a comprehensive technical analysis is rarely conducted. The rule of equity has its root in the theories of market efficiency, and the rule of need has its root in the theories of social justice, while equality rule does not have much traction in an academic argument. However, this rule of equality, due to its simplicity and superficiality, appeals to public views.

Third, the procedural approach is weakly related to the substantive and the perceived fairness in the lottery policy. While Taylor and Kalauskas (2010) have suggested that a better process is the key to improve substantive and perceived fairness, the analysis of the lottery policy demonstrates that the public may perceive the procedures as only superficial rituals. Sometimes this problem makes a complete procedure even worse: the public may believe that it is just the governmental endeavor to obfuscate its own deeper interests. However, by arguing for the weak connections, we are not arguing that governments should disregard procedure, which could improve substantive and perceived fairness in general.

**Figure 3: relationship of three aspects of fairness in the past studies (left) and in the lottery policy (right)**



Actually the foregoing three points are correlated, and this correlation reflects the particular context of Chinese cities. While the procedural approach is generally the way to improve substantive and perceived fairness worldwide, Chinese cities cannot improve the perceived fairness of a policy through the procedural approach because respect for procedures is limited. It is also difficult to convey to residents a complex but fair policy, which often conforms to the rules of equity and need. As a result of these complexities, the Beijing lottery adopts a superficial fairness rule, which uses equality as the governing norm. It is a symbolic shortcut to change public views, and this approach is effective in Beijing since the public in general sees the policy as fair. Figure 3 illustrates the contrast of the three aspects of fairness between past studies and the lottery policy. However, we are not arguing a government ought to influence the public views by adopting the equality rule in public policies. Public engagement can improve substantive and perceived fairness in a fundamental way.

## **Chapter 3 Choosing between Lotteries and Auctions—Distributional Effects of License Plate Regulations in Guangzhou**

### **Introduction**

This chapter analyzes the distributional effects by surveying how people behaved under the mixed allocation rule in Guangzhou. In particular, we are interested in how socio-demographic variables, such as income and automobile ownership, determined the choices among lottery, auction, and non-participation alternatives. Although the distributional effects of lotteries and auctions have been debated extensively in China, none of the past studies has grounded its argument in solid empirical evidence. One critical reason is that there is no publicly available dataset that provides individual-level information. However, this study draws on results from the survey we conducted in January 2016, which captures the behaviors and attitudes of 1,000 Guangzhou residents. The dataset at the individual level allows us to analyze exactly how each resident behaved when faced with the choice between lottery, auction, and non-participation alternatives. Our understanding of individual behaviors enables us to analyze the distributional effects of lotteries and auctions at an aggregate level.

In 2012, the Guangzhou government implemented a license plate regulation characterized by its mixed allocation mode. Of the total license plates allocated, 50% were through lotteries, 40% through auctions, and 10% were assigned to new-energy vehicles. This study is fueled by the discussions on distributional effects of lotteries and auctions, which have been heatedly debated by scholars and the public since the beginning of the regulations. For example, although being theoretically the most efficient way to allocate public resources, auctions have been opposed by many scholars. These scholars contend that auctions can harm the poor, because the poor do not have the economic power to win license plates in such stiff competition. On the contrary, some scholars argue that auctions respect different levels of mobility needs and can yield revenues, which are in turn invested in public transit to subsidize the poor.

We choose Guangzhou as an exemplary case of the series of license plate regulations in China. As the first city to use the mixed mode, Guangzhou deserves our close examination. In Guangzhou, each month, the residents can obtain a license plate, choosing between a lottery and an auction, but they cannot choose both. Individuals can re-enter the process every month or choose to drop out. Once a person wins a license plate, he/she needs to register an automobile with the license plate within six months. The public dataset shows that overall, people preferred lotteries to auctions. For example, in December 2015, the

quota of the plates auctioned was 3,550, while that allocated through lottery was 4,840. However, in the same month, there were 12,804 auction participants and 415,644 lottery participants. Given the low winning rates of lotteries, auctions are a quick means of obtaining a license plate<sup>9</sup>. To elicit the individual behaviors of local residents, we asked survey respondents to report their choices among lottery, auction, and non-participation alternatives in each month between January and December 2015. The survey included questions related to residents' income, socio-demographics, and travel information, which are the potential determinants of residents' choices among lottery, auction, and non-participation alternatives.

The following section reviews the existing discussion on lotteries and auctions in general and in this particular case. Section III introduces the survey we based our analysis on, as well as key statistics. Section IV compares the coefficients and fits of a multinomial logit model and a mixed logit model, and discusses their limits. Section V concludes our findings.

## **Literature Review**

Lotteries and auctions are two common ways to allocate a number of public resources, such as health care, public housing, recreational opportunities, and many others. Lotteries are often seen as fair, while auctions are seen as efficient but unfair (Evans, Vossler, & Flores, 2009; Goodwin, 2013; Hofstee, 1990). G. A. Taylor, Tsui, and Zhu (2003) argue that a lottery is “usually employed to resolve allocation problems in order to reflect a spirit of fairness and equality, since everyone has an equal chance to win, regardless of whatever characteristics or qualities one may possess.” Sandel (2010) argues that it is fair, particularly between the rich and the poor, to conscript people into the army through lotteries; however, the option of buying out after the lottery renders the process unfair because the poor are destined to be conscripted into the army.

Proponents of auctions often ground their argument in social welfare or efficiency (Cheung, 1974; Evans et al., 2009). Competition does not disappear after any price or quantity control, but only takes different forms, such as waiting in queues, competing on the basis of friendship or physical violence, or using power in a black market (Cheung, 1974). Rationing by lotteries causes rent dissipation, which is a waste of social resources (Cheung, 1974). Similarly, Barzel (1974) suggests that rationing properties by lotteries is costly because competitors need to “bid” by waiting; however, the waiting time spent on queues is not transferable, leading to huge losses for society. Z. Xue (2012) makes an outright claim that rationing

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<sup>9</sup> For more detailed statistics about lotteries and auctions, please check Table 8 in Appendix.

public resources without a price is the most wasteful among all the allocation methods. However, although lotteries are generally believed to be less efficient than auctions, lotteries can be more efficient than other non-price rationing rules or even price-based auctions, depending on risk attitudes and consumers' time valuations (Kerr, 1995; G. A. Taylor et al., 2003).

In light of the pros and cons of lotteries and auctions, a mix of these two allocation mechanisms has been increasingly implemented by governments and discussed by scholars. Evans et al. (2009) provide an example in which the permits of passing through the Panama Canal are allocated by a mix of lotteries and auctions. In relation to immigration policies, auctions are proposed as a complement to the current lotteries to allocate Specialty Worker visas (Committee for Economic Development, 2001). Evans et al. (2009) discuss the theoretical impact of mixing lotteries and auctions. They conclude that auction bids can be systematically reduced, because lotteries impose an opportunity cost to auctions, and a mixed allocation mechanism does not compromise the efficiency of its auction component.

In similarity with the generic theoretical view, Chinese scholars primarily believe that lotteries are fair and auctions are unfair in license plate regulations. After auctions were implemented in Shanghai, scholars critiqued that the auctions only benefitted the rich, to the detriment of the poor (G. Xue, 2004; Y. Ye, 2007). This argument appears to be sound, given that the price of a license plate in Shanghai's auction was over USD 14,000 as at February 2013 (Chinese Car Plate Website, 2015). As a remedy to the unfairness of the auction in Shanghai, the lottery in Beijing upholds fairness as its main principle (Beijing Traffic Management Bureau, 2010b). Even under the pressure of extremely low winning rates of the lotteries in 2014, a government official said Beijing would never auction license plates because it aims to protect the interest of the poor (Tengxun Newspaper, 2014). Many scholars posit that the poor preferred lotteries because they were more likely to benefit from lotteries than auctions (D. Li, 2012; Z. Zhang, 2012). Some scholars support lotteries because they posit that owning an automobile is a necessity, and driving is a fundamental right (Jiang, 2013; G. Xue, 2004).

Further, studies mainly argue that unlike lotteries, auctions are efficient. Auction prices reveal the demand and the cost of resources, which the random allocation by lotteries cannot achieve (Nie, 2013). Many studies demonstrate that allocating license plates by auctions causes a smaller loss of total social welfare than lotteries (Hou, Peng, & Ma, 2013; Liu, 2008; Nie, 2013; L. Ye & Yin, 2013). The lottery was not efficient because it was blind to mobility needs (D. Li, 2012). In addition, it forwent the opportunity of raising governmental revenue. The costs of waiting time in the lottery were a waste of social resources, and the low winning rates made it difficult for people with urgent mobility needs to obtain a license plate

quickly (Jiang, 2013; Nie, 2013; Xuan, Ai, & Zhang, 2013). In contrast to the claim that owning an automobile is a necessity, D. Li (2012) argues that automobiles are luxury goods, which should be distributed based on market rules.

As a natural derivation of the previous views, scholars and the public generally believe that Guangzhou, where both lotteries and auctions are available, has incorporated both equity and efficiency concerns (Hou et al., 2013; Jiang, 2013; W. Zhang, 2012). Jiang (2013) argues that the mixed mode differentiated different levels of mobility needs. Some studies argue that the mixed mode is reasonable because people with urgent mobility needs could participate in the auction and the poor could enter the lottery with the hope of winning a license plate (D. Li, 2012).

Although the dominant view is that lotteries are fair and auctions are efficient, scholars sometimes challenge the fairness of lotteries and argue that in reality auctions are fair. Some scholars critique lotteries as unfair, stating that equal winning opportunities do not reflect mobility needs, which can only be approximated by the willingness to pay in auctions (Fan, 2013; Nie, 2013). Others critique that lotteries are unfair to new car owners and migrant residents (Jiang, 2013). Moreover, the revenue generated by auctions and invested in public transit has a positive impact on socially disadvantaged people (Chen & Zhao, 2013; Hou et al., 2013; D. Li, 2012). This argument is consistent with official data. In Shanghai, the CNY 6.7 billion revenue generated in 2014 was spent on buying more buses (28%), subsidies for transit transfer (23%), senior passes (14%), transit construction and maintenance (18%), MRT construction (13%), and miscellaneous uses (Shanghai Financial Bureau, 2015). This revenue transfer provided redistributive benefits to the poor and non-car owners (L. Ye & Yin, 2013).

Beyond the debate on the equity and efficiency of lotteries and auctions, this regulation can be approached from many other perspectives. For instance, Singapore adopted a similar Vehicle Quota Scheme (VQS) in 1990. Studies have discussed the factors leading to the vehicle quota controls, such as the elasticity of automobile ownership and the incentives of planners (Chin & Smith, 1997; Phang, 1993). Some studies analyze the details of the auction mechanism in Singapore, comparing transferable certificates of entitlements (COEs) to nontransferable ones, and comparing discriminatory to nondiscriminatory auctions (Koh & Lee, 1994). Concerning the license plate regulations in China, there have been many other perspectives as well, such as analyzing the impact on traffic speed, air pollution, the number of vehicles sold annually, fuel consumption, and the relationship between auto usage and ownership (Chin & Smith, 1997; Sun, Zheng, & Wang, 2014; Yang, Liu, Qin, & Liu, 2014). All the concerns above are valid perspectives. However, these discussions avoided the key tradeoff between

lotteries and auctions in the series of license plate regulations; they did not analyze the distributional effects of this policy based on individual behaviors.

In this study, we analyze the distributional effects of the mixed mode in Guangzhou, rather than answering whether this policy is equitable. We avoid the equity assessment due to the ambiguity of the concept of equity. We focus on direct outcomes, namely those who chose lottery, auction, and non-participation alternatives, rather than indirect outcomes, such as the impacts of revenue transfers. With numerous potential determinants of choices, we concentrate our analysis, but not exclusively, on socio-demographic variables, such as income and automobile ownership, because income is the most salient variable in any debate related to distributional effects, and automobiles are the target factor in car restriction policies.

Based on past studies, we conclude that income, automobile ownership, mobility needs, and other context-specific variables, should be used as explanatory variables in models. Income is largely important, such that it is related to all discussions about distributional effects. This policy targets automobiles; therefore, it is also a necessary explanatory variable. One contention is whether a hybrid of lotteries and auctions can differentiate people with different levels of mobility needs. However, mobility needs are ambiguous; they are not clearly specified. We use household size, number of children, one-way commuting travel time, and travel time to bus stops and rail stations to approximate mobility needs. Scholars and the public generally contend that lotteries benefit the poor and auctions benefit the rich<sup>10</sup>. However, this contention is also ambiguous and open to two possible interpretations. One is that lotteries benefitted the poorest and auctions benefitted the richest. The other is that auction participants had relatively higher income than lottery participants did, while neither of the two groups belonged to the poorest or the richest. By analyzing the effects of these variables on choice, we clarify and substantiate these ambiguous statements made by the past studies.

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<sup>10</sup> Our survey shows the public opinions are consistent with this contention. About 54.2% of people in the sample agree or strongly agree that the poor choose the lottery and the rich choose the auction, while only 9.4% of people disagree or strongly disagree with this statement. Similarly, about 53.5% of the people in our sample agree or strongly agree that the lottery benefits the poor and the auction benefits the rich, while only 18.0% of the people disagree or strongly disagree.

## Methods, survey design, and data collection

We worked with a professional survey company in China to collect information on Guangzhou residents<sup>11</sup>. Each respondent was paid CNY20 (3 USD) in the form of cash rewards or gift coupons for answering the survey. In total, 10,248 invitations were sent by emails, among which 3,074 people checked the emails. Finally, we collected 1,000 observations.

We adopted a quota sampling scheme to collect data (Singleton Jr, Straits, & Straits, 1993). This is because, in each month, only a small fraction of people chose lotteries, and an even smaller fraction chose auctions. To increase the efficiency of data analysis, the two categories with small proportions of participation, namely lottery and auction participants, were assigned higher quotas than their proportions in the population. While there were only about 10,000 auction participants and 400,000 lottery participants among 12 million Guangzhou citizens each month, we assigned the quota of 200 to auction participants, 400 to lottery participants, and 400 to non-participants.

The survey started with the choice between lottery, auction, and non-participation alternatives from January 2015 to December 2015, followed by questions related to socio-demographic variables, such as age, gender, *hukou* status, automobile ownership, and income. Since those who win plates are not allowed to enter an auction or a lottery again, we withdrew the observations occurring after they won. In the rest of the survey, the respondents answered questions about their travel behaviors, such as typical travel modes and travel times, as well as more detailed questions about socio-demographics, such as household size and number of children. In addition to the dataset we collected, we have also incorporated some official data, such as prices, winning rates, and numbers of entrants of lotteries and auctions.

Table 2 compares the age, *hukou*, gender, and household size distributions of our sample to those of the public dataset provided by the Guangzhou government. Overall, the sample nearly replicates the entire distribution of all the variables. However, we oversampled three-member households, and under-sampled older individuals. However, M. E. Ben-Akiva and Lerman (1985) point out that the stratified sampling scheme and the discrepancy between the sample and the population do not create inconsistency in the coefficients estimated in Logit models, except for the alternative-specific constant terms. Hence, we do

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<sup>11</sup> The company asked to remain anonymous

not need to weigh the sample to fit the population for the sake of estimating the coefficients of Logit models.

We employ two choice models to analyze behaviors. The dependent variables are the same across the two models, including revealed choices among auction, lottery, and non-participation alternatives. The first is a multinomial logit (MNL) model with clustered standard error. The clustered standard error allows correlation among individual respondents across twelve months. This MNL model requires an Independence of Irrelevant Alternative (IIA) assumption as well as homogenous error terms (M. E. Ben-Akiva & Lerman, 1985). However, we anticipate that neither IIA nor homogeneity applies, because lotteries and auctions are similar in relation to non-participation. To address this problem, a mixed logit (MXL) model is used. The alternative-specific terms of the MXL model are random. From a modeling perspective, the MXL model is more flexible than the MNL model.

Since the dataset covers twelve choices of each individual from January to December 2015, the MXL model needs to accommodate the correlation of error terms for each individual (Revelt & Train, 1998). Generally, there are two modeling schemes to deal with it: fixed effects (FE) and random effects (RE) mixed logit model (Greene, 2011). This study only uses an RE mixed logit model because its alternative, FE mixed logit model, cannot estimate the coefficients of time-invariant variables. However, the key variables of interest, such as income and automobile ownership, are time-invariant. To implement this RE mixed logit model, we used the package *mixlogit* in Stata.

In our study, we find that the MXL models can fit the dataset considerably better than the MNL model. The pseudo R square of the MNL model is around 10%, while the pseudo R squares of the MXL models are around 60% (See Table 3). This indicates that the random alternative-specific terms are very effective. The signs of the coefficients of the MNL model and the MXL model are approximately the same, although their magnitudes are different. This discrepancy suggests that heterogeneity exists in the error terms of the true choice model. Given that the MXL model has a better fit and is theoretically more accommodating, we primarily base our analysis on the MXL model but occasionally refer to the MNL model to discuss the stability of the coefficients. In the following results section, we will present some graphs first and subsequently move to choice models.

**Table 2 Socio-Demographics of the sample and the population**

	Sample Total	Sample Total	Population Total	Population Total
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	No.	%	No.	%
<b>Age Groups</b>				
20 - 24 Years Old	114	11.4	1,862,543	18.1
25 - 35 Years Old	589	58.9	2,688,113	26.2
35 - 45 Years Old	261	26.1	2,378,475	23.1
Older than 45 Years Old	36	3.6	3,346,027	32.6
Total	1000	100	10,275,158	100
<b>Hukou (Residence Status)</b>				
Local Citizens	701	70.1	8,077,303	62.5
Non-local Citizens with Residence Permits	147	14.7	4,849,497	37.5
Non-local Citizens without Residence Permits	141	14.1		
	11	1.1	NA	NA
Total	1000	100	12,926,800	100
<b>Gender</b>				
Male	520	52.0	6,639,745	52.3
Female	480	48.0	6,062,203	47.7
Total	1000	100	12,701,948	100
<b>Automobile numbers before participation</b>				
0	391	39.1	NA <sup>12</sup>	NA
1	599	59.9	NA	NA
2	10	1.0	NA	NA
Total	1000	100	NA	NA
<b>Household Income Groups (Month)</b>				
5,000 Yuan and Less	156	15.6	NA	NA
5,000 - 10,000 Yuan	161	16.1	NA	NA
10,000 - 20,000 Yuan	519	51.9	NA	NA
20,000 - 40,000 Yuan	134	13.4	NA	NA
More than 40,000 Yuan	30	3	NA	NA
Total	1000	100	NA	NA
<b>Household Size</b>				
1	46	4.6	979,690	12.0
2	111	11.1	1,807,830	22.2
3	611	61.1	2,904,603	35.6
4	109	10.9	2,032,616	24.9

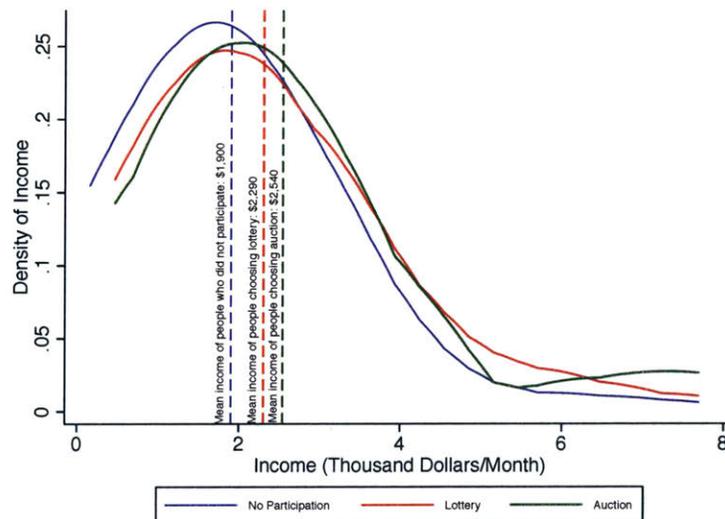
<sup>12</sup> We cannot obtain the distribution of income, automobile numbers, and the status of license plates simply because there is no publically available data

5	123	12.3	425,318	5.2
Total	1000	100	8,150,057	100

The income distributions of the three groups overlapped significantly (Figure 3). As regards average household incomes, people who chose lotteries were not the most disadvantaged. They had a medium-level income, CNY 14,500 (USD 2,230) per month, which was USD 390 higher than the average income of non-participants and USD 250 lower than that of auction participants. Approximately 60% of the people who chose lotteries or auctions had at least one automobile before they participated, while only about 40% of the non-participants had at least one automobile (

Figure 4). The data does not support the common notion that the poor chose the lottery and the rich chose the auction. They both were rich relative to the non-participants, which are the majority of the population.

**Figure 3 Comparison of income of those who chose auction, lottery, and the non-participation alternative**



**Figure 4 Comparison of auto ownership of those who chose auction, lottery, and the non-participation alternative**

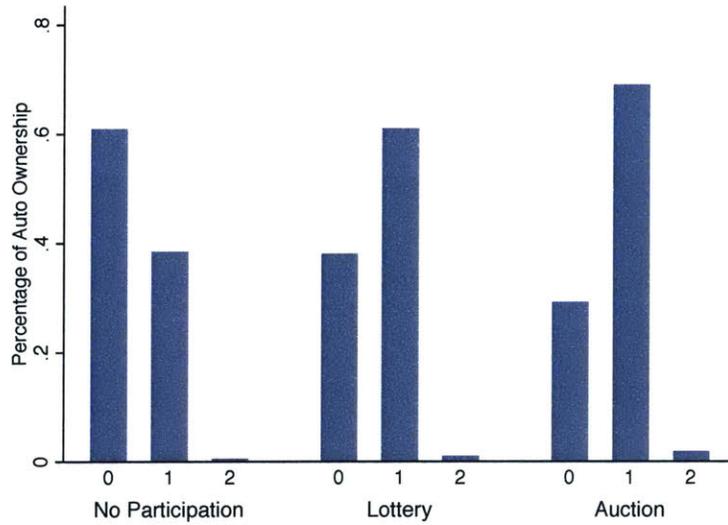


Table 3 shows the results of the two choice models. Both use the non-participation alternative as the base. The MXL model fits the dataset considerably better than the MNL model. The pseudo R square of the MNL model is 12.0%, while the pseudo R square of the MXL model is 60.5%, implying that the random alternative-specific terms are very effective. The signs of the coefficients of both models are consistent, but the magnitudes are different. This discrepancy suggests that heterogeneity exists in the error terms of the true choice model. Our following analyses are based on the MXL model.

### Socio-demographic Variables

Both income and automobile ownership increased lottery and auction participation but their interaction term had a negative coefficient. For non-car owners, income's influences on lotteries and auctions were both positive and of similar magnitude<sup>13</sup>. Income cannot distinguish between lottery and auction participants, and lotteries by no means benefitted the poor. Given the rigorous mandate that license winners need to register license plates within six months, the poor would not venture the lottery since they are not wealthy enough to afford and use an automobile. For car owners, high income decreased lottery participation slightly while increased the auction participation. Overall, income effects were positive, varying somewhat with the number of automobiles.

Residents with more automobiles strongly preferred lotteries and auctions to non-participation, This suggests a car-dependent trajectory: people tend to buy more cars once they own the first one. Regarding

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<sup>13</sup> A Wald test is used to compare them, and it fails to reject the null hypothesis that the income coefficients of auctions and lotteries are the same.

the relative impact between lotteries and auctions, higher automobile ownership encouraged lotteries more than auctions. This is intuitive since people with more automobiles needed automobiles less urgently. Auctions allowed the affluent households, particularly those with fewer automobiles, to obtain license plates quickly, while lotteries allowed the affluent households, particularly those with more automobiles, to speculate. Auctions and lotteries gave the well-off the opportunity of choices, but both are a luxury beyond the reach of the poor.

Age, gender, and education significantly influenced choices. Older people were less likely to choose lotteries and auctions, perhaps because the young needed to use automobile more often. Females were less likely to choose auctions, perhaps because men bear more social expectation of buying automobiles. Higher education discouraged participation, probably because higher education makes people to realize that automobile use is associated with air pollution and carbon emission.

#### **Mobility needs, attributes of alternatives, and others**

Both *Hukou* status and residence time had a significant impact on choice. Relative to local people, migrants with residence permits were more likely to participate, while migrants without residence permits were much less likely to participate. This is due to the fact that the government only allowed a portion of the migrants without residence permits to participate. Longer residence time led to more participation, as shown by the significantly positive coefficient of residence time.

Proxies of mobility needs, including household size, number of children, one-way commuting time, travel time to the nearest rail station, and the travel time to the nearest bus stop did not have significant impact on choice. A likelihood ratio test suggests that the impact of household size, commuting time, and travel time to rail stations or bus stops on the log-likelihood is trivial. Hence, the MXL model in Table 3 only includes the number of children as the proxy of mobility needs. More children increased the likelihood of choosing auctions and decreased that of choosing lotteries, although the coefficients are insignificant. The modeling results imply that this policy could not effectively differentiate people with different levels of mobility needs, casting doubts on the contention that auctions or the mixed mode could differentiate mobility needs.

Guangzhou residents responded to the attributes of lotteries and auctions. Higher prices of auctions increased auction participation, perhaps because people expected a higher price in the future, propelling them to choose auctions sooner. More entrants and higher winning rates of lotteries in the previous month increased lottery participation, probably because a higher winning rate represented a larger opportunity of

winning and a larger number of participants created a feeling of urgency. The number of auction entrants had similar effects. People were more likely to choose auctions when auction participants in the previous month became larger.

**Table 3 Results of MNL and MXL Models**

	VARIABLES	Multinomial Logit Model (MNL)		Mixed Logit Model (MXL)	
		Lottery	Auction	Lottery	Auction
<b>Socio-demographics</b>	Income (CNY 1,000)	0.0942*** (0.0193)	0.113*** (0.0239)	0.299*** (0.0328)	0.282*** (0.0239)
	Automobile number	2.552*** (0.296)	2.691*** (0.447)	8.287*** (0.617)	6.239*** (0.604)
	Income * Automobile	-0.121*** (0.0199)	-0.0925*** (0.0247)	-0.381*** (0.0337)	-0.129*** (0.0212)
	Age (Years)	-0.00621 (0.0132)	-0.0433** (0.0189)	-0.131*** (0.0220)	-0.197*** (0.0263)
	Gender (Male = 0)	0.0751 (0.145)	-0.597*** (0.204)	-0.00720 (0.284)	-2.398*** (0.301)
	Education (Years)	-0.0544 (0.0467)	-0.0553 (0.0771)	-0.306*** (0.107)	-0.578*** (0.117)
<b>Residence Status</b>	Migrants with Permits	0.601*** (0.208)	0.920*** (0.318)	2.972*** (0.476)	3.578*** (0.455)
	Migrants without Permits	-0.858*** (0.297)	-0.0772 (0.452)	-5.034*** (0.674)	-3.367*** (0.496)
	Residence Time	0.0161* (0.00847)	0.0443*** (0.0131)	0.0886*** (0.0211)	0.206*** (0.0234)
<b>Proxies of Mobility Needs</b>	Number of Children	-0.492*** (0.177)	0.216 (0.283)	-0.447 (0.351)	0.534 (0.330)
<b>Attributes of Alternatives</b>	Winning Rates of Lotteries	0.944*** (0.161)		5.219*** (0.507)	
	Participants of Lotteries	0.00795*** (0.00115)		0.0537*** (0.00332)	
	Price of Auctions (CNY 1,000)		0.0267*** (0.00363)		0.107*** (0.00903)
	Participants of Auctions		0.0893*** (0.0139)		0.550*** (0.0345)
	Auction dummy (mean)				-10.01*** (1.916)
	Auction dummy (SD)				7.496*** (0.441)
	Lottery dummy (mean)			-28.33*** (2.639)	
	Lottery dummy (SD)			7.764*** (0.378)	
	Constant	-5.488*** (1.054)	-4.177*** (1.343)		
	Pseudo R Square		0.120		0.605
	Final Log Likelihood		-7697		-3453

Based on the MXL model,

Table 4 summarized the marginal effects of ten variables, computed at the mean values of the variables. Automobile effects had a similar magnitude as income effects. A 1% income increase led to 1.43% and 1.35% probability increases of choosing lotteries and auctions. A 1% automobile increase led to 1.57% probability increase of choosing the lottery, and a 1.18% probability increase of choosing the auction. The magnitude of age and education effects is larger than income and automobile ownership. It is interesting that income, the most discussed socio-demographic variable, did not have a dominating impact on choice. On the contrary, education and age, the much less discussed variables, had a larger impact. The marginal impacts of the proxies of mobility needs and of migrant status had much smaller effects than socio-demographics, suggesting again that the policy is not capable of differentiating people with different mobility needs.

The attributes of lotteries and auctions, such as number of entrants and winning rates, are of much larger magnitude than all socio-demographics and the proxies of mobility needs. A 1% increase of the number of lottery entrants increased the probability of choosing lotteries by 5.82%. A 1% increase of the winning rates of lotteries increased the probability of choosing lotteries by 2.96%. The effect of auction prices is smaller. But overall, these effects are larger than socio-demographics and the proxies of mobility needs, which are the focal point in past studies. People chose lotteries not based on their mobility needs or even their economic condition, but rather, the opportunities of winning plates and the tendency of the whole society choosing lotteries and auctions.

**Table 4 Marginal effects<sup>14</sup> on choices by 1% value change of variables based on the MXL Model**

	Variables	Lottery		Auction	
		dy/ex (%)	P> z	dy/ex (%)	P> z
<b>Socio-demographics</b>	Income	1.430	0.000	1.348	0.000
	Automobile	1.568	0.000	1.180	0.000
	Age	-1.385	0.000	-2.085	0.000
	Education (Years)	-1.604	0.004	-3.026	0.000

<sup>14</sup> We have removed the dummy variables from this table, including gender and migrants status, because the elasticity of dummy variables does not have a valid interpretation.

<b>Residence Status</b>	Residence Time	0.444	0.000	1.035	0.000
<b>Proxies of Mobility Needs</b>	Number of Children	-0.116	0.203	0.139	0.105
<b>Attributes of Alternatives</b>	Price of Auctions	NA	NA	0.726	0.000
	Winning Rates of Lotteries	2.959	0.000	NA	NA
	Number of Participants	5.816	0.000	1.695	0.000

### Limitations

We acknowledge the following limitations. Since respondents reported their choices for the past twelve months, errors are inevitable. Errors of the dependent variables in choice models cause inconsistency<sup>15</sup>. Our interpretation of the price effect involved expectation. However, the two models we employed cannot accommodate expectation. These modeling concerns are future research opportunities, beyond the scope of this paper. The distributional effects of this policy depend on long-term effects such as how the government used the revenue to improve public transit. It would be another research opportunity if the revenue transfer data could be collected and incorporated into our analysis.

### Conclusion

This paper examined the distributional effects of lotteries and auctions on residents under the license plate regulation in Guangzhou. We analyzed choices made between lotteries, auctions, and non-participation alternatives using individual-level data and multinomial and mixed logit models.

Our analysis shows that income and automobile ownership of the three groups overlapped significantly; however, differences did exist. All participants, including those choosing lotteries or auctions, had higher income and more automobiles than non-participants. License plates represent the potential of buying an automobile, which is a luxury good that the poorest cannot afford. Our findings also call into question the assumption that income could differentiate lottery and auction participants. Income effects of non-car owners on lotteries and auctions were of similar magnitude. Income was by no means the most influential factor; let alone the only factor in the license plate regulation, even though past studies often overly focused on income in examining the distributional effects of public resources. Our analysis illustrated a car-dependent trajectory, meaning that the individuals in households that owned cars were much more inclined to obtain another car; while non-car owners were less likely to switch to a car-dependent lifestyle. This tendency indicates that any car restriction policy should focus on the trajectory of controlling

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<sup>15</sup> A more advanced method proposed by Hausman, Abrevaya, and Scott-Morton (1998) could solve the problem.

automobile growth beyond policy impacts in one specific period. The effects of age and education were of larger magnitude than income, but their effects and reasons have not been fully discussed yet. The proxies of mobility needs, including household size, number of children, total travel time, and travel time to rail stations and bus stops had either no impact or a trivially small impact on choices. Hence, the mix of lotteries and auctions cannot differentiate people with different mobility needs. It raises doubts about the argument that auctions treated people fairly because they differentiated people with different mobility needs. All socio-demographic variables and the proxies of mobility needs only explained behaviors to a limited extent, suggesting that these commonly discussed variables could not capture a large amount of behavioral uncertainty.

However, people strongly responded to lottery and auction attributes such as winning rates and number of entrants. The marginal impacts of these variables were much larger than socio-demographic variables, proxies of mobility needs, and migrant status. People were more likely to choose lotteries and auctions when the past winning rates and the past entrants of lotteries and auctions increased. People chose lotteries or auctions based on the chances of winning plates and the opportunities for speculation, instead of individual economic factors, such as income and automobile ownership, or their mobility needs.

Our investigation of this license plate regulation sheds light on lotteries and auctions as generic ways to allocate public resources. Lotteries are often seen as an allocation rule that achieves equality or benefits the poor, but they may not function this way in all cases. In the Guangzhou case, lotteries were the tool for speculation by relatively rich people, instead of a solution for the poor. In the generic debates about the equality of allocating public resources, scholars often focus on the poorest or the richest; however, in reality, residents relevant to one concrete policy may not belong to the extreme of the social spectrum, as shown in Guangzhou's case.

## **Chapter 4 Risk biases in choosing between lotteries and auctions in license plate regulations Introduction and Policy Background**

Lotteries and auctions are two common ways of allocating public resources. Governments use lotteries to allocate opportunities to public housing and use auctions to sell pollutant emission permits (Chan, Laplagne, & Appels, 2003; Elster, 1989). In China, to address traffic congestion, the Guangzhou government allocates a limited number of license plates of automobiles by a mix of lotteries and auctions. Local residents need to choose between lotteries and auctions to obtain a license plate before buying an automobile. Past studies have largely focused on the normative side, such as the balance between efficiency and equity. However, this study turns to the positive side, exploring the determinants of public choices with a specific focus on risk biases related to lotteries and auctions.

Other local governments in China implemented similar license plate regulations before and after Guangzhou. From a policy-making perspective, local governments have been experimenting with different allocation methods, and the policy finally converges to the mixed mode. From a public choice perspective, local residents choose from different choice sets varying with policy designs. Shanghai residents choose between non-participation and auctions; Beijing residents choose between non-participation and lotteries; Guangzhou and other cities residents choose among non-participation, lotteries, and auctions. To analyze the different effects of the three policy scenarios, this study compares how people behave differently when faced with the three different choice sets.

Uncertain choices are ubiquitous. For example, voters perceive the characteristics of candidates as uncertain if they don't have transparent information. Insurance is uncertain because a customer needs to consider what the probability is to get a disease. This uncertainty, typically measured by probabilities, is often perceived with systematic biases, which numerous psychological and behavioral experiments have shown. Kahneman and Tversky (1979) described a S-shaped relationship between perceived and actual probability, indicating that people are overly optimistic about small probabilities and overly pessimistic about large ones. People with more optimism biases tend to gamble more, partially because they overestimate tiny chances of winning without an objective understanding. In the license plate cases, lotteries and auctions are uncertain because people have only some chances to win a license plate in either of them. Therefore, this study proposes and tests the idea that people overestimated the small winning rates of lotteries and underestimated the high winning rates of auctions. This study also posits risk biases, measured by the difference between perceived and objective winning chances, influenced public choices

among non-participation, lottery, and auction alternatives in the license plate regulations. Specifically, we focus on two primary questions.

- Did risk biases exist? In particular, did people mistakenly overestimate the probabilities of winning lotteries and underestimate the probabilities of winning auctions?
- If so, how risk biases affected choices among non-participation, lotteries, and auctions in three different policy scenarios?

In the following parts, we will first introduce the literature about lotteries and auctions as two generic ways to allocate scarce public resources, current policy conversations about license plate regulations, and the impact of risk biases on public choices. We test three choice models, which differ in their choice sets, corresponding to the three policy scenarios in Guangzhou, Shanghai, and Beijing. The models use the preferences stated by the same group of Guangzhou residents as dependent variables. Results show that the lotteries in Beijing and the auctions in Shanghai induced the behaviors based on risk biases, while the mixed mode in Guangzhou did not. This study demonstrates that risk biases could dominate public choices in some cases. These explorations can inform the discussion about the rational and irrational motivations of participating in public policies, particularly those policies involving the allocation of public resources by lotteries or auctions.

## **Literature Review**

### **Lotteries and auctions as common ways to allocate public resources**

Governments often allocate scarce resources by lotteries or auctions. Lotteries can be used to allocate tasks, scarce goods, and necessary burdens (Elster, 1989). The United States allocated lands to settlers by lotteries during the 19<sup>th</sup> century (Dale, 1983). Some universities allocated admissions by lotteries with weights determined by certain criteria (Elster, 1989). The Israel government allocated public housing by lotteries. It weighted the lotteries by the number of dependents and the current housing condition (Elster, 1989). Auctions are another common way to allocate public resources. Chan et al. (2003) find that some governments have long been allocating pollutant emission permits and trading water rights by auctions. In 2008, Canada launched an auction for 105MHz of spectrum and raised \$4.25 billion. Although lotteries and auctions seem two mutually exclusive methods, they can be complementary. A person may buy a ticket to enter a lottery, or sell the resource after winning a lottery, if transferability is allowed (Elster, 1989).

The discussion about lotteries and auctions has concentrated on the tradeoff between efficiency and equity, which is a normative perspective. Oi (1967) analyzes the draft for military service by comparing between using a lottery and hiring voluntary soldiers. He concludes that the lottery is less efficient if taking into account the costs of forcing productive people to join the army. In terms of equity, Sandel (2010) argues that conscription through lotteries ensures fairness between the rich and the poor; however, an option of buying-out after lotteries renders the process unfair because socially disadvantaged people are destined to the army. Similarly, in the license plate regulations, scholars in general see lotteries as fair, and auctions as unfair but efficient. Scholars critique that the auction in Shanghai is not fair because the auction benefits the rich to the detriment of the poor (Xue, 2004; Ye, 2007). The Beijing government mandated lotteries as its allocation rule, upholding fairness as its main principle in legal documents (Beijing Traffic Management Bureau, 2010). Scholars believe that the mixed mode in Guangzhou have combined fairness and efficiency concerns (Hou, Peng, & Ma, 2013; Jiang, 2013; Zhang, 2012). Despite the prevalent view that the lottery is fair, some scholars critique the lottery as unfair because the equal winning opportunity does not reflect the demand of mobility (Fan, 2013; Nie, 2013).

To explain the normative judgments, some scholars adopted a positive perspective to question who chose the lottery and who chose the auction. Scholars often categorize people by income, car ownership, *hukou* status<sup>16</sup>, and demand. Some studies argue that the auction privileged the rich because it allowed the rich to utilize their economic power (Ye, 2007). Jiang (2013) argues that the lottery in Beijing exempted the prior-car owners from the burden of competing for license plates and it prohibited the migrants without residence permits from participation, rendering the lottery unfair. Li (2012) argues that the mixed mode is reasonable because people with urgent demand could choose the auction, and the poor could choose the lottery with some hope of winning a license plate. Chen and Zhao (2013) examine the benefits and costs of geographically disadvantaged people in the lottery policy. In general, however, as scholars primarily focused their attention on normative aspects, the current discussion lacks positive analysis. This weakness is partially because the local governments only provide aggregate-level datasets, but do not offer individual-level datasets.

### **Risk biases: theory, experiment, and impact on public choice**

Risks and uncertainty exist widely in public policies. Using ANES and SSI data, Kam (2012) argues that how people perceive risks has a significant impact on whether they participate in a wide range of activities, such as rallies, local meetings, petitions, and religious donations. Choosing between a

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<sup>16</sup> *Hukou* status distinguishes locals from migrants

challenger, who is seen as more uncertain, and an incumbent, who is seen as more certain, risk-averse people are more likely to vote for the incumbent (Eckles, Kam, Maestas, & Schaffner, 2014; Kam & Simas, 2012).

Decision-making under uncertainty is different from decision-making under certainty because people often perceive chances and risks with biases. Kahneman and Tversky (1979) described a S-shaped curve of the relationship between perceived and actual probability, indicating that people often over-estimate small chances and under-estimate large chances. To obtain a higher precision of this bias, Prelec (1998) suggests that the chances lower than 0.35 are usually over-estimated. People misperceive probabilities with enormous biases when the probability is tiny: probability of  $10^{-6}$  can be perceived as 2% (Prelec, 1998). Aside from theories, many experiments inside and outside laboratories have confirmed the existence of risk biases. Hsu, Krajbich, Zhao, and Camerer (2009) verifies the S-shaped weighing function by fMRI experiments, which is compatible with the theory proposed by Kahneman and Tversky (1979). Pratt and Zeckhauser (1996) verify this bias in the Russian Roulette experiment. Some experiments apply these laboratorial results to the real world. Weinstein (1980) demonstrates that students have unrealistic optimism about future success, which actually happens with a very small chance. In addition, risk biases vary with the attributes of choices, socio-economic variables, and mental capacity of decision makers (Frederick, 2005; Rottenstreich & Hsee, 2001). For example, Rottenstreich and Hsee (2001) suggest that affect-rich choices lead to more biases than affect-poor ones.

Risk biases can be measured by the difference between perceived and objective chances. Fehr-Duda and Epper (2012) review all the forms of probability weighting functions to illustrate how people exactly overestimate small probabilities and underestimate large ones. These function forms include power form, Tversky-Kahneman form (1992), Prelec form (1998), and Goldstein-Einhorn form (1987). For instance, the Prelec form of probability weighting function is  $w(p) = \exp(-\beta(-\ln p)^\alpha)$ , in which the  $\alpha$  determines the curvature of the weighting curve and measures risk biases. People with more risk biases typically have larger  $\alpha$  terms, and exaggerate small probabilities much more than average people. Some studies have shown the characteristics of people with more risk biases. Women tend to overweight small probabilities of gains more than men. The poor, young, and relatively less educated men, who live in urban areas and belong to specific ethnic minorities, have the largest risk biases (Croson & Gneezy, 2009; Fehr-Duda & Epper, 2012).

Many researches have applied past experimental and theoretical results to numerous policy fields, such as anti-terrorism, automobile accidents, seat belt regulation, disease control, and environmental issues.

Sunstein (2003) argues that people react excessively to terrorism because people focus too much on possible huge losses of terrorism, while neglect the low probability. Sunstein (2003) suggests that this is caused by the extensive emotion involved in this topic. The bias may have different sources (Gigerenzer, 2004). Peers or social media may misinform people (Combs & Slovic, 1979); or people may be intrinsically optimistic about an event (Weinstein, 1980).

Although the studies have connected risk biases to public policies, they usually lack a quantitative measure of risk biases. This missing piece is not surprising though, because, as Camerer and Kunreuther (1989) point out, a publically accepted objective probability is often absent. For example, even experts cannot reach a consensus about the risk of terrorism attacks, automobile accidents, or infectious disease. Without an objective risk as a reference, it is hard to measure any bias in public policies. However, in the license plate regulations, local governments publish the objective winning rates of lotteries and auctions every month. Given that the measurability of an objective probability poses the largest challenge for quantitative research (Camerer & Kunreuther, 1989), the objective winning rates allow us to measure the risk bias clearly in the license plate regulations.

## **Data Collection and Processing**

With the help of a survey company<sup>17</sup>, we conducted a questionnaire survey in Jan 2016. Each respondent was paid for answering a questionnaire survey, and payment was around \$3, taking various forms such as cash reward or gift coupons. In total 10,248 invitations were sent by emails, among which 3,074 people read the emails and 1,000 people responded.

We adopted a stratified sampling to collect data (Singleton Jr, Straits, & Straits, 1993). The reason is that, for each month, only a small fraction of Guangzhou residents enters the lottery, and an even smaller fraction enters the auction<sup>18</sup>. To increase the efficiency of data analysis, the two categories with small proportions of participation, namely lottery and auction participants, were assigned higher quota than the true fractions in the population. While in each month there are only around 10,000 auction participants and 400,000 lottery participants among 12 million Guangzhou citizens, we assigned the quota of 200 to auction participants, 400 to lottery participants, and 400 to non-participants. The lottery or auction participants refer to those who entered the lottery or auction during the past one year, including 12 times

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<sup>17</sup> A requested by the survey company, we need to remove their name from any publication.

<sup>18</sup> But the total number of the participants in this policy over the past few years was enormous.

for 12 months. While we adopted a stratified sampling scheme, we set the lower bounds for four dimensions to ensure that the sample can be representative of the Guangzhou residents to some extent. The survey company watched the IP address of each respondent to ensure that the respondent was from Guangzhou. The registered members of the company uploaded driver licenses to confirm their automobile ownerships. We filtered the responses when we collected data. The responses that had the same answers in a row, or that took only a short time to answer, were eliminated.

To simulate the policy conditions in Beijing, Shanghai, and Guangzhou, each respondent made choices three times, faced with three different choice sets. The three questions were far from each other to prevent correlation among them. The first choice consisted of non-participation, lottery, and auction alternatives, similar to the policy in Guangzhou; the second consisted of non-participation and auction alternatives, similar to Shanghai; and the third consisted of non-participation and lottery alternatives, similar to Beijing. We use multinomial logit (MNL) models to analyze the influence of risk biases on choices in the three policy scenarios. While more advanced models such as the cross-nested logit models and the mixed multinomial logit models can be used, we decide to retain the simple MNL form because it is simple to estimate and to interpret. Moreover, we focus on comparing the coefficients and choices across three scenarios, rather than on accommodating elaborate unobserved error terms of utility functions. We focus on taking advantage of the richness of the individual-level survey result, which is generally rare in China, to shed light on the determinants of the series of license plate regulations in China.

Dependent variables are three groups of stated choices. The primary independent variable of interest is risk biases. We measure the risk bias in three ways. Regarding the lottery, it is measured by the difference between the perceived winning rate of lotteries and the true winning rate, and the difference between the expected average waiting time to obtain a license plate and the true waiting time<sup>19</sup>. With respect to the auction, risk biases are measured by the difference between the perceived average winning rate and the true average winning rate of auctions. We will test which measurement is more effective in predicting choices. The controlling variables include income, *hukou* status, and other socio-demographics.

Table 2 compares age, *hukou*, gender, and household size distributions of our sample to those of the public dataset provided by the Guangzhou government. Overall, the sample nearly replicates the entire distribution of all the variables, although it is different from the population in some dimensions. However, our stratified sampling scheme causes the most important discrepancy between the sample and the

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<sup>19</sup> Theoretically there is a one-to-one mapping between the winning rate and expected waiting time. But since people are not good at translating the two variables, we ask people to report them separately for comparison.

population. Hence in the following models, we will weight models by the real fractions of people who choose between lottery, auction, and non-participation alternatives.

**Table 5 Socio-demographics of the sample and the population**

	Sample Total	Sample Total	Population Total	Population Total
	No.	%	No.	%
<b>Age Groups</b>				
20 - 24 Years Old	114	11.4	1,862,543	18.1
25 - 35 Years Old	589	58.9	2,688,113	26.2
35 - 45 Years Old	261	26.1	2,378,475	23.1
Older than 45 Years Old	36	3.6	3,346,027	32.6
Total	1000	100	10,275,158	100
<b>Hukou (Residence Status)</b>				
Local Citizens	701	70.1	8,077,303	62.5
Non-local Citizens with Residence Permits	147	14.7		
Non-local Citizens without Residence Permits	141	14.1	4,849,497	37.5
	11	1.1	NA	NA
Total	1000	100	12,926,800	100
<b>Gender</b>				
Male	520	52.0	6,639,745	52.3
Female	480	48.0	6,062,203	47.7
Total	1000	100	12,701,948	100
<b>Automobile numbers before participation</b>				
0	391	39.1	NA <sup>20</sup>	NA
1	599	59.9	NA	NA
2	10	1.0	NA	NA
Total	1000	100	NA	NA
<b>Household Income Groups (Month)</b>				
5,000 Yuan and Less	156	15.6	NA	NA
5,000 - 10,000 Yuan	161	16.1	NA	NA
10,000 - 20,000 Yuan	519	51.9	NA	NA
20,000 - 40,000 Yuan	134	13.4	NA	NA

<sup>20</sup> We cannot obtain the distribution of income, automobile numbers, and the status of license plates simply because there is no publically available data

More than 40,000 Yuan	30	3	NA	NA
Total	1000	100	NA	NA
Household Size				
1	46	4.6	979,690	12.0
2	111	11.1	1,807,830	22.2
3	611	61.1	2,904,603	35.6
4	109	10.9	2,032,616	24.9
5	123	12.3	425,318	5.2
Total	1000	100	8,150,057	100

## Findings

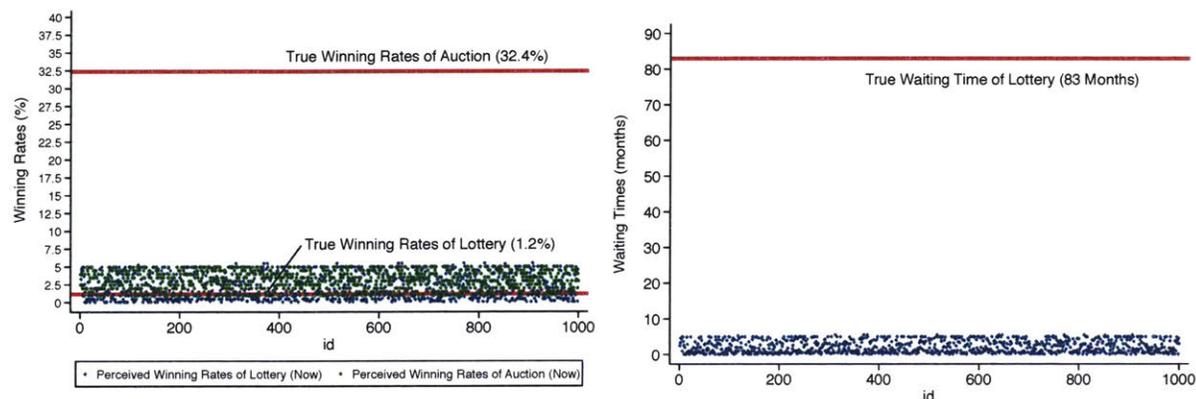
### Did risk biases exist?

We would like to address the first question that whether risk biases existed, and whether it was consistent with the theory that people overestimated the low winning rates of lotteries and underestimated the high winning rates of auctions. Figure 5 shows that it was exactly the case. In the left graph of Figure 5, the green dots are the perceived winning rates of auctions, and the average is 3.05%, while the true winning rate of the auction is 32.4%. The blue dots represent the winning rates of lotteries, and the average is 2.18%, while the true winning rate of lotteries is 1.20% only. We compare the means by two t-tests, showing that the two differences between objective and perceived winning rates are statistically significant. We compared the perceived winning rates of lotteries and auctions, showing statistical significance as well. It implies that the perceived winning rates of lotteries and auctions were not random. The perceived winning rates absorbed the true information of lotteries and auctions to some extent.

People overestimated the winning opportunities of lotteries again when converting these rates to expected waiting times. The graph on the right of Figure 5 compares perceived waiting time of lotteries to the true expected waiting time. People were overly optimistic about the average waiting time of lotteries. Although the average waiting time in the lottery was 83 months, the average of the perceived waiting time was only about 8.4 month, one tenth of the true value. Moreover, we compared the perceived waiting time to the perceived winning rates of lotteries. Given the average of perceived winning rates being 2.18%, the corresponding waiting time should be about 46 months<sup>21</sup>, which was much smaller than the perceived waiting time and much larger than the true waiting time. Therefore, the public is even more excessively optimistic about lotteries if we measure risk biases by perceived waiting time.

<sup>21</sup> It is a Bernoulli process, and we use a standard formula to compute it.

**Figure 5 A Comparison of perceived winning rates of lotteries and auctions to true rates (left) Comparison of perceived waiting time of lotteries to true expected waiting time (right)**



**Did risk biases have an impact?**

After showing that risk biases did exist, we now turn to the second question that how risk biases influenced choices. We measure risk biases by subtracting the true numbers from the perceived winning rates of lotteries and auctions, and the expected waiting time of lotteries. Table 6 shows the results of three Logit models, which use three different choice sets as dependent variables, similar to the three policy scenarios in Guangzhou, Shanghai, and Beijing. All three models use the choice of non-participation as the benchmark group to facilitate their comparison. The socio-demographic variables are control variables. The three models have been weighed according to official data.

**Table 6 Choice models in three policy scenarios**

VARIABLES	Mlogit_Choice Set1 (Non-participation, Lottery, Auction)			Mlogit_Choice Set2 (Non-participation, Auction)		Mlogit_Choice Set3 (Non-participation, Lottery)	
	Non-participation (296)	Lottery (227)	Auction (61)	Non-participation (267)	Auction (317)	Non-participation (31)	Lottery (553)
Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)	Column (8)
Perceived winning rate biases of lotteries		-0.0766 (0.0729)					-0.0988 (0.145)
Expected waiting time biases of lotteries		0.0187 (0.0201)					-0.0701** (0.0296)
Perceived average winning rate biases of			-0.133		0.201**		

auctions		(0.152)		(0.0826)			
Income	0.0112	-0.0262		-0.0298*		-0.0259	
	(0.0231)	(0.0526)		(0.0161)		(0.0379)	
Number of automobiles	-3.389***	-3.325***		0.187		0.810	
	(0.280)	(0.584)		(0.241)		(0.585)	
Hukou (migrants without permits)	0.606	0.269		-0.843***		-0.482	
	(0.430)	(1.061)		(0.248)		(0.535)	
Age	-0.00475	0.00640		-0.0645***		-0.0272	
	(0.0225)	(0.0325)		(0.0190)		(0.0321)	
Gender (Male = 0)	0.0750	-1.577**		-0.115		0.674	
	(0.276)	(0.619)		(0.218)		(0.517)	
Number of Children	-0.301	-0.773		0.323		0.485	
	(0.305)	(0.596)		(0.270)		(0.504)	
Total travel time	0.00443	0.00711		-0.00647		-0.00630	
	(0.00677)	(0.0139)		(0.00624)		(0.0132)	
Travel time to Rail Station	0.0345	-0.0103		-0.000106		-0.00832	
	(0.0236)	(0.0645)		(0.0196)		(0.0516)	
Constants	-0.360	-0.604		2.120***		4.602***	
	(0.819)	(1.508)		(0.718)		(1.487)	
Observations	296	227	61	267	317	31	553

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

All the three models have been weighted. Since the weighted choice model uses pseudo-maximum likelihood estimation, the log likelihood cannot be used to compute accuracy measurement. Hence we do not report the log likelihood, nor pseudo R square.

In Model 1 (Column 2 – Column 4), where the choices included non-participation, lottery, and auction alternatives, risk biases did not play an important role. The three indicators of risk biases are all insignificant. Non-car owners were much more likely to choose either the lottery or the auction, as shown by the significantly negative coefficients of automobile numbers in Model 1. The two coefficients of the number of automobiles are similar: -3.389 and -3.325. This indicates that non-car owners were indifferent between choosing lotteries and auctions. Most of other socio-demographic variables are not significant, including income, *hukou* status, age, and number of children. Only gender is statistically significant. Females were less likely to choose auctions in the Guangzhou scenario. Travel related variables, such as total travel time and travel time to rail stations, are not significant.

In Model 2 (Column 5 – Column 6), where the choice set included only non-participation and auctions, the risk bias became statistically significant. People who were more optimistic about the average winning rates of auctions were more likely to choose auctions, as implied by the significantly positive coefficient of perceived winning rate biases. People with higher income were less likely to choose auctions, although

the negative income effect is significant at a relatively low confidence level. This result is different from our common belief that high-income people were more likely to choose auctions to take advantage of their economic power. Migrants were less likely to choose auctions, holding all the other variables constant. Compared to Model 1, the coefficient of automobiles became insignificant. Again, travel attributes did not have any impact on choices in this model.

In Model 3 (Column 7 – Column 8), where the choice set included only non-participation and lottery, only risk biases had a statistically significant impact on choices. People who expected longer waiting time were less likely to choose lotteries, although the bias of perceived winning rates was not significant. This difference suggests that the measurement based on expected waiting time could capture risk biases better than perceived winning rates. All socio-demographic variables did not have impact on choices. Similarly, travel attributes did not have impact on choices either. Given that 957 out of 1,000 respondents chose lotteries, we can see that optimism biases of lotteries drew nearly everyone to the choice of lotteries in Model 3.

By comparing the three models, we conclude that risk biases significantly influenced choices, although its importance varied with models. In Model 1, neither the bias in the auction nor in the lottery had a statistically significant impact on how people made a choice. In contrast, the measurements of risk biases in Model 2 became statistically significant, while socio-demographic variables still had some impacts on choices. In Model 3, only the risk bias had statistically significant impact on choices; it dominated the process of making choices between non-participation and lotteries.

The difference of the three models suggests that the policy design regarding choice sets propelled people to make choices in different ways. The choice set in Model 3, consisting of non-participation and lotteries, propelled people to make a choice based on their optimism biases rather than their needs or economic status. The choice set in Model 1, on the contrary, drives people to think about the number of automobiles, and forget about their cognitive biases. Therefore, we argue that the first policy scenario, which is consistent with the policy design in Guangzhou, mitigated the impact of cognitive bias and stimulated people's concerns related to true need. We would also argue that the second and third scenario, especially the third, which is consistent with the policy design in Beijing, amplified the impact of optimistic bias on people's choices.

In addition, the two measurements of risk biases demonstrate that people were less able to conceptualize the winning rates of individuals, but relied more on the expected waiting time to make a choice. Model 3

shows that the expected waiting time had more predictive power than the perceived winning rate in lotteries. People could conceptualize uncertainty to different extents varying with measurements. People seem more numerate about the time measurement, but less so about the probability measurement.

### **Limitations**

One threat of this study is its external validity. The sampling scheme is confined to the residents in Guangzhou, while we expand the frame of analysis to other cities, such as Beijing and Shanghai. Another type of experimental design should be the test of the three choice sets on the residents in Guangzhou, Beijing, and Shanghai separately. This study cannot do this because it is practically expensive and time-consuming to do one survey for three groups of people in three cities. But this weakness is closely related to a benefit of our approach. By testing three choices on the same group of people, we exclude the impact of heterogeneity caused by different local contexts.

The models have some weaknesses as well. Stated preferences and perceived winning rates are presumably inter-correlated. It could be the case that people decide to choose the lottery in the first place and overestimate the winning rates after this choice. This weakness, although can be addressed by some advanced models, are not the focus of this paper. We only utilize the richness of the data to compare the role of risk biases in three scenarios, and it would be overly complicated to compare three models that have addressed all endogeneity threats, which are usually based on structural equation models or control functions. Moreover, the three models were weighted choice models, which pose technical difficulties of testing nested structure or doing likelihood ratio tests because the pseudo likelihood cannot handle these tests. While the models have demonstrated the existence of excessive optimism and pessimism and the impacts of risk biases, this study does not analyze the sources of the biases. The source may include misinformation, instead of only cognitive bias. Since the effect of misinformation exists across three models, the comparison across the three models can cancel out this common factor. But we believe that this is a crucial topic for policy intervention, the analysis of the sources of risk biases should be the focus in the next stage.

Models based on stated preferences typically have large noises. This exactly happened in our analysis: many coefficients in the three SP models were not significant. People may forget the constraints in reality when they state preferences. People may be very sensitive to survey formats, question phrasing, and information provided to them (Ben-Akiva et al., 1994). We compared revealed preferences and stated preferences for the Guangzhou policy. The comparison shows that people did behave differently in reality and in stated preference surveys. For more details, please look at Appendix 4.

## Conclusions

This study examined the impact of risk biases on choices under three policy scenarios. By using the survey data from Guangzhou and examining three choice models, this study yields the following results. First, risk biases existed: people overestimated the small winning rates of lotteries and underestimated the large winning rates of auctions. Second, risk biases had a significant impact on public choices, although the extent of its impacts varied with policy scenarios. If the choice set included non-participation, lottery, and auction alternatives, as in Guangzhou, risk biases did not play an important role. But its impact could be very significant and even dominated the public choices under some policy designs, especially when the choice set included only non-participation and lotteries or non-participation and auctions. Third, risk biases were better measured by perceived waiting time rather than probabilities. People were more numerical about time length than probabilities.

Embedding the findings in the real contexts, this study can inform policy discussions about automobile regulations in Beijing, Shanghai, and Guangzhou. The history of a series of automobile regulations illustrated that the mode of automobile regulation converged to the mixed mode, which is the mode in Guangzhou. This study provides some insights into why the regulation converged to the mixed mode from a public choice perspective. The mixed mode in Guangzhou precluded the impacts of over-optimism and over-pessimism biases. The mixed mode can even approximate the need by reminding people of the number of automobiles, although people may change preferences under more realistic constraints. Models 2 and 3 in Table 6, simulating the scenarios in Shanghai and Beijing, showed that the public choices followed cognitive biases, which cannot be interpreted by socio-demographics or economic status. Especially faced with only non-participation and lotteries, people only see lotteries as a windfall benefit without considering their travel needs or economic status.

This study attempts to draw our attention to the impacts of risk biases on public choices. Although over-optimism and over-pessimism have long been a topic in scholar discussions (Akerlof & Shiller, 2010; Keynes, 1937), this study endeavors to fit it into the framework of choice models and ground it in a specific policy context. We argue that the design of choice sets matters in public policies. An appropriate policy design can make the desirable attribute salient in people's minds, while an inappropriate policy design may drive people to follow cognitive biases. The lessons learnt from this study can extend to other policies that allocate public resources by lotteries or auctions. For instance, if only lotteries are used to

allocate any public resource, people may participate only out of their excessive optimism about their winning, rather than their needs of the resource.

Why can the mixed mode in Guangzhou preclude risk biases, while the mode in Beijing and Shanghai cannot? Although there is no clear evidence, we would like to explain it in an intuitive manner. When faced with the mixed mode, people made a choice to participate as the first step before examining the features of lotteries or auctions. In the decision of participation vs. non-participation, people thought about their needs rather than the attribute of lotteries or auctions because the tradeoff between lotteries and auctions were too complicated to think. However, when faced with the choice between non-participation and lotteries directly, people paid much more attention to the windfall effect of lotteries, which looked like an opportunity of pure gain without any cost. In this case, people ignored their own need. This effect led to the result in Beijing, where 3 million people participated in free lotteries, and was reflected in Model 3 in Table 6, in which the majority of respondents decided to enter lotteries.

Given the fact that risk biases are inevitable in many settings, and it is important to ponder how to leverage the positive aspects of this phenomenon and mitigate the negative aspects. Policy makers can change people's risk biases without influencing the objective levels of uncertainty. This issue is related to the sources of the bias, which we do not attempt to address in this study. But we believe this perspective can yield more opportunities of effective policy interventions in the future.

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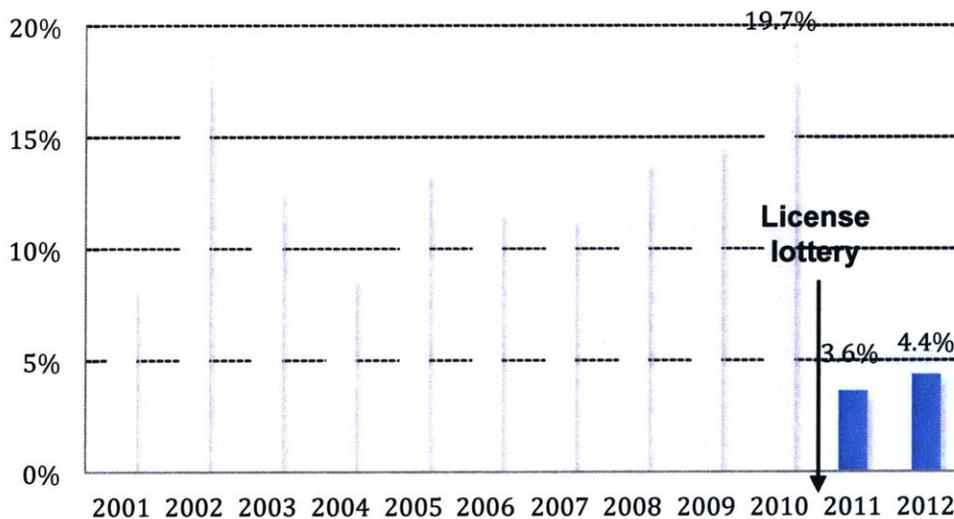
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## Appendices

### Appendix 1: Beijing's Lottery Policy and Its Evolution

In December 23, 2010, the Beijing local government announced the “Temporary Provision on Number Control of Small Passenger Cars in Beijing” (TPNCSPC), enumerating goals, distributive rules, entry eligibilities, and other generic requirements. On the same day, the Beijing Transportation Management Bureau (BTMB) also announced the “Implementation Specifics of Temporary Provision on Number Control of Small Passenger Car in Beijing”, in which implementation details were listed. The two documents enumerated five main goals of the policy, including 1) fulfilling regional planning; 2) controlling the growth of automobiles; 3) mitigating traffic congestion; 4) reducing energy consumption; and 5) reducing environment pollution. The TPNCSPC required the BTMB to coordinate other organizations to implement this policy. All the relevant organizations should cooperate at the beginning of a year to set up this year's quota, and the residual quota of one year cannot carry over to the next year. After its implementation in 2010, the car license policy was revised twice on December 27, 2011 and November 28, 2013, respectively. Figure 4 shows the growth rates of automobile before and after the lottery policy. The policy can successfully control the growth rate of the automobiles.

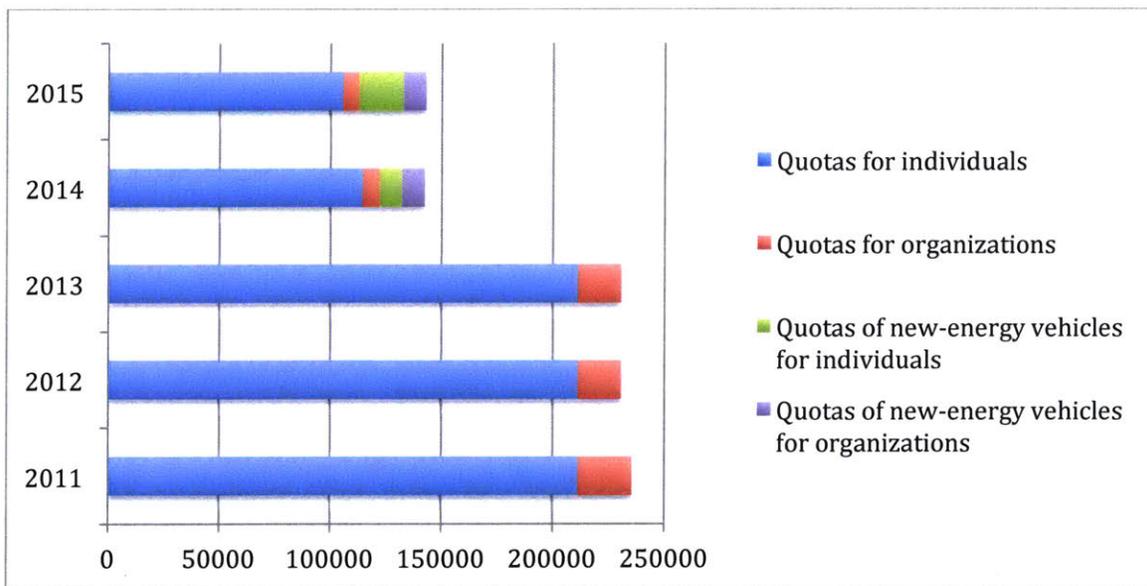
**Figure 6 Annual motor vehicle growth rates in Beijing**



The policy document required to divide the quota into three pools, including individuals, organizations, and commercial vehicles. Figure 5 shows the number of quota for individuals and organizations. The annual quota was kept constant from 2011 to 2013, and decreased by about 40% in 2014 and 2015. This

change indicates that this car-detering policy became more severe over the past few years. Another change between 2013 and 2014 was the new quota type added specifically for new-energy vehicles. In 2014, the Beijing government added 20,000 car licenses for new-energy vehicles, and this number increased to 30,000 in 2015 even though the total number of car licenses did not change between 2014 and 2015. This change shows the government’s intention to encourage the use of new-energy vehicles. Despite the varying ratios of quota in the past five years, the quota for individual licenses accounted for the highest proportion, around 80–90%, thus serving as the focus of this paper’s analysis.

**Figure 7 Quota allocated to individuals and organization from 2011 to 2015**



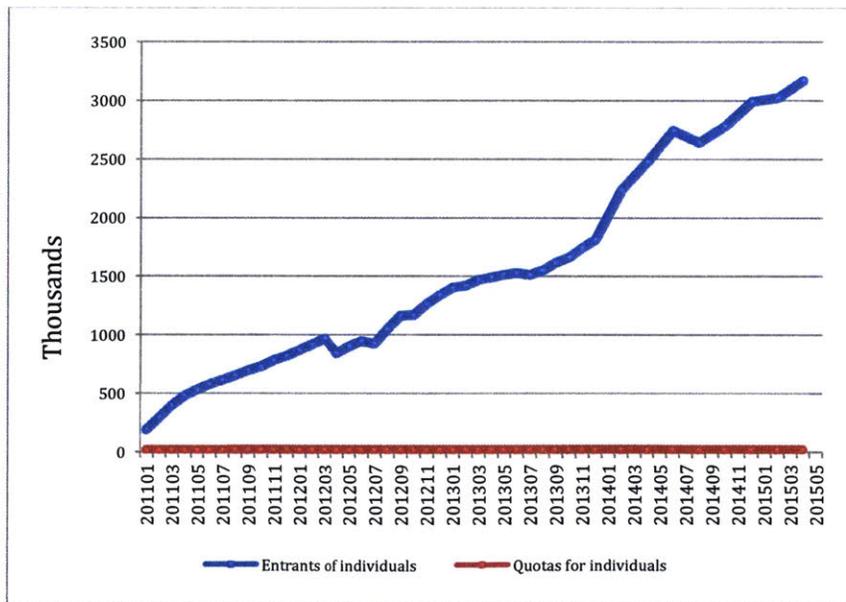
*The pool for individuals*

The quota for individuals was allocated by a lottery. The allocation occurred every month before 2014 and its frequency dropped to once every two month since the beginning of 2014. The Article 4 of the TPNCSPC listed five criteria, one of which any individual applicant must fulfill to be eligible for entry. The five criteria were: (1) Local residents with a Beijing *hukou*; (2) police forces and servicemen; (3) foreigners living in Beijing for more than one year; (4) residents holding a working permit; or (5) residents holding a temporary residence permit and having paid social insurance and personal income taxes continuously for 5 years. Each person satisfying any of the five requirements could become eligible for the lottery process, and all the individuals had an equal winning rate. Any individual applicant could apply for the entry either on the Internet or in local agencies. Local agencies need to respond to the application in eight days. The local agencies also need to specify the reasons why some applicants cannot get entry in a specific website. Successful lottery winners must register the license to a vehicle within six

months, and the transaction of a car license is not allowed. Unsuccessful individual applicants, meaning those who fail to become entrants, could require a double check of the application. Unsuccessful individual entrants, meaning those who enter the lottery but fail to get a car license, are automatically transferred to the next round. This rule of automatic transfer was changed by subsequent policy amendments so that the automatic transfer could only last for three months (2011) and six months (2013). In 2013, Beijing’s government changed the lottery rules to favor repeat entrants. People who applied continuously over 12 months could double their odds of winning, and those who did so 24 times could triple their chance, etc. In effect, the new rule attempts to detect entrants’ demand by measuring persistence.

The following Figure 6 shows the entrants and quota for individuals. The number of entrants constantly increased for the past five years. The number increased from the 0.2M at the beginning of 2011 to around 3.2M in April 2015. In contrast to the increase of the number of entrants, the quota remained nearly constant over the past five years, around 18,000 for each round of lottery. Figure 6 also shows the decrease of the lottery frequency from once a month before 2014 to once every two months after 2014.

**Figure 8 Entrants and quota for individuals**



*The pool for organizations*

While every individual applicant could apply for one license and had an equal probability of winning, organizations could apply for a number of licenses determined by the amount of sales tax paid. For each

additional 500,000 yuan in sale taxes paid, a company could apply for one more car license, with an upper limit of eight for any organization. Any organizational applicant must satisfy any of the following two criteria to be eligible for the lottery process: 1) Enterprises that have a valid business license, an organization code certificate, and a tax registration certificate, paying the sales tax above 50,000 yuan; 2) social or other organizations with a valid organizational certificate. The process of the application and the lottery for organizations resembles but is not identical to individuals. One difference is that unsuccessful organizational entrants could remain in the lottery process until the end of the year without renewing the application, whereas individuals had to reapply every six months. Another difference is that the lottery process occurred every two months for organizations, as opposed to once a month for individuals before 2014.

Figure 7 indicates the number of quota and entrants for organizations over the past five years. There is a periodic drop in the number of entrants at the beginning of each year, probably due to some organizational entrants being removed from the pool in January after forgetting to renew their applications before the end of a year. Aside from the periodicity, the total number of entrants has increased from 8,000 to around 70,000 in April 2015, while the quota remained low, decreasing from 3,000 before 2014 to 1,300 after 2014 for each round of a lottery. Both the increase in entrants and the reduction in available licenses have reduced winning rates for organizations.

**Figure 9 Entrants and quota for organizations**

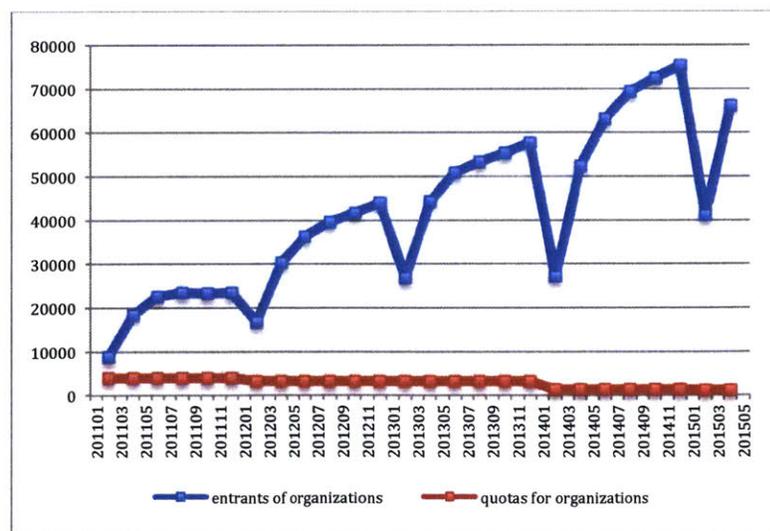
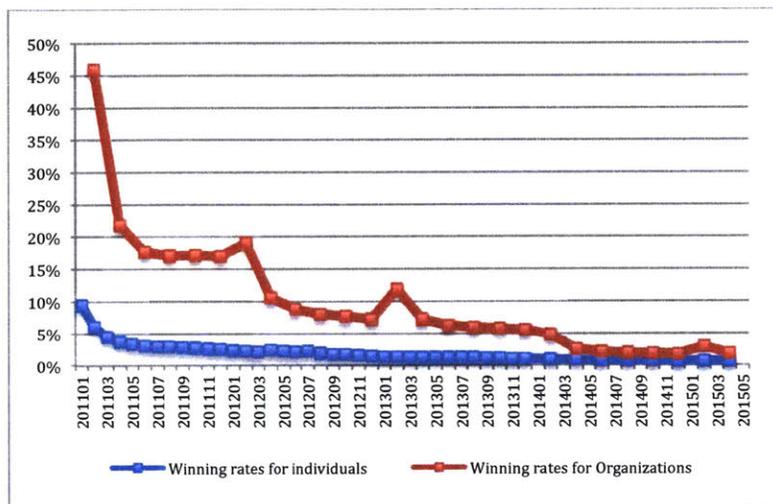


Figure 8 indicates the two winning rates for individuals and organizations during the past five years. Overall the winning rate for individuals was much lower than organizations. The winning rate for

individuals decreased from 10% at the beginning to 0.5% currently. This rate for organizations decreased from 45% to 1.8% in April 2015. The curve for organizations is fluctuating with a few small jumps, and it is caused by the sudden decrease of the number of entrants at the beginning of each year.

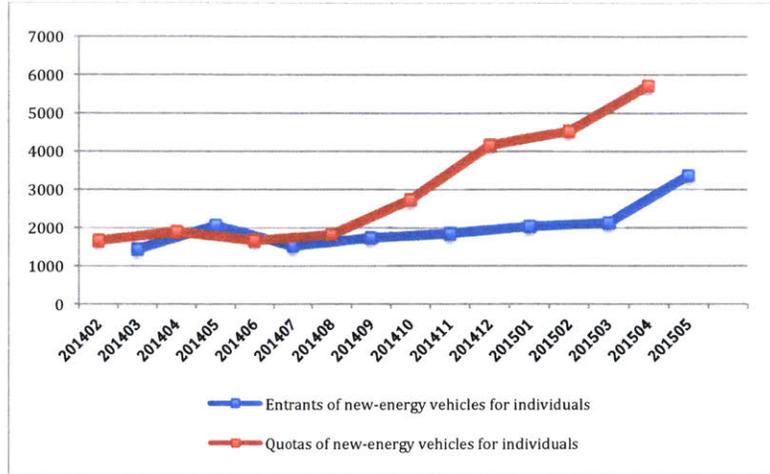
**Figure 10 Winning rates for individuals and organizations**



*The pool for new-energy vehicles*

In 2014, BTMB developed a new pool specifically for new-energy vehicles. The quota of this pool, including individuals and organizations, is 30,000, accounting for 20% of the total quota. People could opt to apply for either new-energy vehicles or conventional vehicles. This separate quota shows the Beijing government’s goal to encourage the new-energy vehicles. However, people rarely apply for this type of vehicles. Figure 9 indicates the number of entrants and quota of new-energy vehicles for the past two years. Since its inception, the quota has almost always exceeded the number of entrants, meaning that the winning rates were 100%, in an enormous contrast to the extremely low winning rates of individuals’ and organizations’ normal vehicles. This conflict may be caused by high prices and the lack of supporting services for new-energy vehicles, which we do not explore in this paper.

**Figure 11 Entrants and quota of new-energy vehicles**



## Appendix 2: Beijing Sample and Population Statistics

Table 7 Demographic, socioeconomic and locational variables of Beijing sample (N=1505)

Sample Variables	Values	Sample Distribution (before weighting)	Population Distribution (matched by weighting)
Demographic Indicators			
Gender	Male	55%	51.6%
	Female	45%	48.4%
Age	18–34	48.5%	40.5%
	35–59	38.9%	44.4%
	60+	12.6%	15.1%
Has Children	Yes	57.3%	51.5%
	No	42.7%	48.5%
Household Size	Small ( $\leq 2$ )	24.9%	27.8%
	Medium (3)	51.9%	51.9%
	Large (4+)	23.3%	20.3%
Hukou Registration	Beijing Hukou	57.3%	63.2%
	Other Hukou	42.7%	36.8%
Socioeconomic and Location Indicators			
Education Level	High School or below	31.4%	65.7%
	College/university	68.6%	34.3%
Household Income (CNY, monthly)	Low ( $\leq 5K$ )	18.3%	25.4%
	Middle (5–10K)	34.5%	36.2%
	High ( $\geq 10K$ )	47.2%	38.4%
Car Ownership	Yes	49%	31.3%
	No	51%	68.7%
Location	Within 2nd Ring	8%	10.7%

	2nd–6th Ring	84%	48.8%
	Outside 6th Ring	8%	40.5%

### Appendix 3: Lotteries and Auctions in Guangzhou

**Table 8 Statistics of lotteries and auctions from January to December 2015 in Guangzhou**

	Quota of Auctions	Auction Entrants	Lowest Winning Prices in Auctions	Average Winning Prices in Auctions	Quota of Lotteries	Lottery Entrants
01/2015	3551	7747	12000	13137	5193	252678
02/2015	3545	8064	13200	14331	5212	263874
03/2015	3568	7800	14500	15436	5747	273623
04/2015	3564	9550	16800	17798	5899	296910
05/2015	3564	10834	20200	21506	5917	315495
06/2015	3573	10942	26000	27672	5724	341329
07/2015	3520	9236	35000	37805	4400	370013
08/2015	3564	5803	10000	36231	4898	399927
09/2015	4625	10817	13500	16886	4775	423085
10/2015	3607	12893	16000	17487	4933	415271
11/2015	3536	14376	19000	20609	5051	420523
12/2015	3548	12804	24600	27077	4840	415644

### Appendix 4: Compare stated preferences and revealed preferences in Guangzhou

Many studies provide cautionary remarks about the analysis based on stated preference (SP) surveys (Ben-Akiva et al., 1994). In particular, respondents may be more unrealistic in SP surveys than in reality because they forget some realistic constraints. SP results are usually noisier than RP results, so the estimators are less statistically significant. To understand how people behaved exactly in reality in Guangzhou, we ran another choice model, which used revealed preferences (RP), namely respondents' past choices from January 2015 to December 2015, as dependent variables. The first model in Table 9 uses RP as dependent variables, and the second model uses SP as dependent variables, which is the same as Model 1 in Table 6. We did not include risk biases in the RP model because the perceived

measurements could impair models by introducing endogeneity. When people chose lotteries or auctions more in the past, they were more likely to adjust their risk biases towards the truth. Therefore, we are not able to compare different impacts of risk biases on RP and SP, but the two models do allow us to compare the effects of other variables.

Three major coefficients, income, automobile numbers, and migrant status, have different signs in RP and SP models. People with higher income were more likely to choose auctions in reality, while they reported that they would be indifferent between lottery, auction, and non-participation alternatives, as shown by the significantly positive income coefficient in the RP model and the insignificant income coefficient in the SP. People in the households with more automobiles were more likely to choose either lotteries or auctions in reality, while they reported that they would be less likely to do so in the stated preference surveys, as shown by the significantly positive automobile effect of the RP model and the significantly negative automobile effect of the SP model. Migrants without residence permits were less likely to choose lotteries and auctions in reality, while they became indifferent between the three alternatives in the SP survey.

Instead of creating any self-contradictory dilemma, these differences between RP and SP reveal people's preferences under different constraints. In reality, people needed to face more realistic concerns. Income is one. High-income people were more likely to be able to afford a car, so they were more likely to choose auctions in reality. Low-income people may have the same eagerness as high-income people to buy automobiles, and they expressed the wishes in surveys; however, they would not choose auctions in reality after they thoroughly considered the costs of owning and using a car in the long run. Car owners were less likely to report the choices of auctions and lotteries in surveys because they had already got cars, however, their family could easily buy new cars in reality because they were more familiar with car usage or any car-related businesses or because they were simply wealthier than non-car owners. Guangzhou government did not allow one portion of migrants to participate in the policy, so the coefficients of migrants are negative in the RP model. But migrants can have the same willingness to choose lotteries or auctions as local residents in surveys, as shown by the insignificant migrant coefficients in the SP model. Other coefficients of the RP model do not conflict with the SP model, except that some insignificant coefficients in the SP model become significant in the RP model. The RP model shows that older people were less likely to choose auctions, that females were less likely to choose auctions, and that the households with more children were less likely to choose lotteries. Since these socio-demographics are controlling variables, we don't include them in our main argument. Nonetheless, the discrepancy between RP and SP has no impact on our main conclusion related to risk biases.

**Table 9 Choice models of revealed preferences and stated preferences in Guangzhou scenario**

VARIABLES	Mlogit_Choice Set1 (RP)			Mlogit_Choice Set1 (SP)		
	Non-participation	Lottery	Auction	Non-participation	Lottery	Auction
Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)
Perceived winning rate biases of lotteries		NA			-0.0766 (0.0729)	
Expected waiting time biases of lotteries		NA			0.0187 (0.0201)	
Perceived average winning rate biases of auctions			NA			-0.133 (0.152)
Income		-0.0106 (0.0130)	0.0406** *		0.0112 (0.0231)	-0.0262 (0.0526)
Number of automobiles		1.336*** (0.223)	1.384*** (0.316)		-3.389*** (0.280)	-3.325*** (0.584)
Hukou (migrants without permits)		-1.411*** (0.291)	-1.078*** (0.374)		0.606 (0.430)	0.269 (1.061)
Age		-0.0162 (0.0166)	-0.0380* (0.0218)		-0.00475 (0.0225)	0.00640 (0.0325)
Gender		0.136 (0.183)	-0.599** (0.255)		0.0750 (0.276)	-1.577** (0.619)
Number of Children		-0.404* (0.233)	0.194 (0.336)		-0.301 (0.305)	-0.773 (0.596)
Total travel time		0.00807 (0.00543)	-0.00165 (0.00697)		0.00443 (0.00677)	0.00711 (0.0139)
Travel time to Rail Station		-0.0168 (0.0181)	-0.0243 (0.0237)		0.0345 (0.0236)	-0.0103 (0.0645)
Constants		-0.360 (0.819)	-0.604 (1.508)		-0.360 (0.819)	-0.604 (1.508)
Observations	6031	2691	1061	712	227	61

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

All the three models have been weighted. Since the weighted choice model uses pseudo-maximum likelihood estimation, the log likelihood cannot be used to compute accuracy measurement. Hence we do not report the log likelihood, nor pseudo R square.