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How hyperbolic discounting preference affects Chinese consumers' consumption choice between conventional and electric vehicles

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HIGHLIGHTS

- Theoretical model and survey based on psychological experiment are used for study.
- Time inconsistency preferences may affect consumers' rational purchasing choice.
- Present bias is correlated with irrational behavior, but long-term discount is not.

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ABSTRACT

This paper presents a theoretical model and addresses several issues related to life cycle cost analysis to illustrate how time-inconsistent preferences affect consumer choice. The particular case study selects involved consumer choice between a vehicle with high initial acquisition cost but low ownership cost (e.g., an Electric Vehicle, EV) and one with a low initial acquisition cost but high ownership cost (e.g., a conventional Internal Combustion Engine Vehicle, ICEV). To test our theoretical analysis, we conduct an empirical study on how time discounting rates affect consumer choice between ICEVs and EVs with different initial cost ratios. From the survey results, we find that individuals with higher present bias showed irrational purchase behavior even when controlling for wealth level. Specifically, people making some "stronger bias to present" decisions chose higher total cost ICEVs with lower initial cost but higher ownership cost over lower total cost EVs with higher initial cost and lower ownership cost. However, people's long-term discount is not correlated with irrational vehicle purchase behavior. Furthermore, we study the present bias and long-term discount rate in one scenario and found present bias to be correlated with irrational behavior.

1. Introduction

Energy consumption and GHG emissions are two of the major issues in transportation in China. Governments are under growing pressure to launch various policies to curb the amount of carbon emissions (Benjaafar et al., 2013; Kok et al., 2014). Additionally, there exists an increasing focus on traffic congestion in mega cities. Two main strategies are currently being applied to address these issues in the Chinese vehicle markets. The first strategy is that mega cities have implemented quotas for vehicle ownership and other policies to control growth in ownership of conventional Internal Combustion Engine Vehicles (ICEVs), such as Shanghai's vehicle plate auction, Beijing's vehicle plate lottery and Guangzhou's hybrid of these two mechanisms (Feng and Li, 2013). The second strategy is the promotion of Electric Vehicles (EVs) in the market, such as through the *Electric Vehicle Subsidy Scheme* (EVSS) launched in January 2009 (Hao et al., 2014a, 2014b). Here is the terminology used in this paper, following the specification of difference between the NEV and EV used in Zhou et al. (2015).

- EVs: any vehicle that uses energy drawn from the electric grid and stored onboard the vehicle for some or all of its propulsion (i.e., PHEVs and BEVs).
- HEVs: vehicles that generate all of their power onboard the vehicle.

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Table 1
The quota and lottery success rate in Beijing in the last four times.

	Applicants		NEVs	ICEVs
Oct 2015	Individuals	Quota	17,150	17,806
		Effective Applications	17,150	3,497,915
		Lottery Success Rate	**1.00:1**	**196.45:1**
	Private companies and government agencies	Quota	1513	1200
		Effective Applications	1513	82,952
		Lottery Success Rate	**1.00:1**	**69.13:1**
Dec 2015	Individuals	Quota	8717	17,804
		Effective Applications	8717	3,647,274
		Lottery Success Rate	**1.00:1**	**204.86:1**
	Private companies and government agencies	Quota	1299	1200
		Effective Applications	1299	84,719
		Lottery Success Rate	**1.00:1**	**70.60:1**
Feb 2016	Individuals	Quota	12,214	13,700
		Effective Applications	12,214	9,107,786
		Lottery Success Rate	**1.00:1**	**664.80:1**
	Private companies and government agencies	Quota	1819	900
		Effective Applications	1819	40,332
		Lottery Success Rate	**1.00:1**	**44.81:1**
Apr 2016	Individuals	Quota	10,252	13,688
		Effective Applications	10,252	9,487,847
		Lottery Success Rate	**1.00:1**	**693.15:1**
	Private companies and government agencies	Quota	1139	900
		Effective Applications	1139	60,353
		Lottery Success Rate	**1.00:1**	**67.06:1**

Data Source: Beijing Quota Management Office for Passenger Cars, http://www.bjhjyd.gov.cn/.

Table 1 illustrates the effects of these strategies on vehicle ownership rates and the lottery success rate in Beijing. Since 2014, Beijing implemented the revised *Beijing Passenger Car Number Control Policy*, which differs from previous car control measures in three respects: (1) the lottery opens to the public once every 2 months; (2) the car quota was lowered to reduce the number of newly registered ICEVs; (3) a separate lottery system was set up for New Energy Vehicles (NEVs) to encourage individuals, private companies and government agencies to purchase NEVs.

As shown in Table 1, eligible applicants for ICEVs have far exceeded the quota, and the lottery success rate for individual entrants once reached 693.15:1. In contrast, the number of applicants for NEVs is often less than the quota, rendering the lottery unnecessary. The underlying reasons for consumers choosing ICEVs rather than EVs have been studied and identified as primarily being: the high cost of vehicle batteries (e.g., Delucchi and Lipman, 2001; Hidrue et al., 2011; Kihm and Trommer, 2014), limited charge cycles and short lifespans of vehicle batteries (Pollet et al., 2012; Lin et al., 2013), limited driving range of EVs (e.g., Hidrue et al., 2011; Ralston and Nigro, 2011; Benysek and Jarmut, 2012; Egbue and Long, 2012; Peterson and Michalek, 2013), scarcity of public charging infrastructure (e.g., Becker et al., 2009; Sweda and Klabjan, 2011; Zhang et al., 2013; Liu, 2012), and security and stability issues associated with vehicle batteries (e.g., Xing et al., 2011; Pollet et al., 2012; Lu et al., 2013). Among the above studies, the common perspective is that EVs will become as attractive to consumers as ICEVs if these challenges can be resolved. In other words, consumers will be equally inclined to consider either EVs or ICEVs if advances in technology increase EV usability and affordability. However, such a conclusion may be too short-sighted because it ignores temporal discounting in consumer choice. Here is the definition of hyperbolic discounting, following Laibson (1997), Doyle (2013), Greene et al. (2004), Joshi and Fast (2013), Gilman et al. (2014).

- Temporal discounting: the tendency of people to discount rewards as they approach a temporal horizon in the future or the past (i.e., become so distant in time that they cease to be valuable or to have additive effects).
- Hyperbolic discount function: address the phenomenon of preference reversal that induces dynamically inconsistent preferences, implying a motivation for consumers to constrain their own future choices.
- "Stronger bias to present" behavior: as "irrational" behavior, as most of the psychology papers do.

According to the theory of life-cycle private cost (LCPC), EVs enjoy an advantage in terms of lower ownership cost (OC, which describes a consumer's ownership and use of a vehicle) during the use-phase due to electricity being far cheaper than oil, but simultaneously suffer a disadvantage in their relatively high initial cost (IC, which describes a consumer's initial purchase of a vehicle) associated with vehicle purchase (Wu et al., 2012; Lin et al., 2013). Here the cost during using a car, such as oil consumption, is termed as the ownership cost. While the purchase price of a car is termed as the initial cost. Therefore, consumers with time inconsistency and hyperbolic discounting preferences may choose vehicles with lower initial cost over vehicles with lower privately-incurred life-cycle cost. We demonstrate this point in the next section.

Considerable previous research has focused on the vehicle choices related issues. Brownstone et al. (1996) performed a large-scale survey of 4747 urban households to estimate alternative-fuel vehicles demand, based on vehicle type and vehicle miles traveled for all vehicles and on recharging demand by time of day for electric vehicles. Brownstone et al. (2000) extended the analysis in Brownstone et al. (1996) to capture the large heterogeneity in respondents' preferences for alternative-fuel vehicles. The models presented in Brownstone et al. (2000) show large heterogeneity in preference for fuel types. On this basis, several applied researches emerged at a historic moment. For example, with decreasing hybrid prices and reducing particulate and nitrogen oxide emissions for diesel vehicles, Greene et al. (2004) analyzed the market