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What are the barriers to widespread adoption of battery electric vehicles? A survey of public perception in Tianjin, China

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ABSTRACT

Battery electric vehicles (BEVs) are an effective way to reduce fossil fuel consumptions and greenhouse gas emissions. This study employs the structural equation model and chi-square test to explore public perception barriers to widespread adoption of BEVs in Tianjin. Based on a sample of 476 urban respondents collected by questionnaire, it finds that consumer interest in BEVs is relatively low and a large proportion of the respondents have a "wait and see" attitude. Consumers are unsure about BEVs performance, with safety, reliability, and range per charge being the top three concerns. Respondents who focus on vehicle performance express significantly lower BEV acceptance. High battery cost is the main technological barrier to widespread BEV adoption. In terms of public service support, poor public charging infrastructure ranks as the largest impeditive. In terms of respondent personal characteristics, older respondents have a more optimistic attitude to BEVs than younger generations, more respondents express interest to adopt BEVs as the second family car, experienced drivers are more concerned with the cost of battery and maintenance, and consumers who are more concerned about the environment are more likely to adopt BEVs.

1. Introduction

China has been the world's largest motor vehicle market since 2009. From 2005 to 2015, China's private vehicle stock increased from 18.5 to 124.4 million, and continuing rapid growth is expected in the future.[1] With the rapid increase of the motor market, transportation has become one of the three highest energy consumption sectors, and a major oil consumer and greenhouse gas emitter, with consequential serious resource and environmental challenges (Zhou et al., 2013). The transport sector accounted for 49.9% of total oil consumption, and 8.4% of national carbon dioxide (CO_2) emissions in 2015 (IEA, 2015a).

1.1. The development of Electric vehicles in China

Electric vehicles (EVs) are recognized to have the potential to substantially reduce fossil fuel dependency and CO_2 emissions, and to solve other environmental issues (Bubeck et al., 2016; Prud'homme and Koning, 2012).

To avoid misunderstanding, we define the terminology used in this paper as:

Electric vehicles (EVs): any vehicle that uses energy drawn from the electric grid and stored onboard the vehicle for some or all of its propulsion. Battery electric vehicles (BEVs): vehicles that run solely on electricity and store the energy in a battery pack in the vehicle which is generally re-charged through plug-in (e.g., Nissan Leaf). Plug-in electric vehicles (PHEVs): vehicles that use energy stored from the grid and also have an internal combustion engine to provide driving range and vehicle power.

Compared to the internal combustion engine vehicles (ICEVs), EVs offer substantial economic and environmental benefits by substituting grid based electricity for fossil fuels (Larson et al., 2014). They reduce greenhouse gas (GHG) and other emissions, enhance energy security, and promote use of renewable energy (Egbue and Long, 2012).

Realizing the benefits of EVs and the urgent air quality issues, China has been active in initiating policies to stimulate the production and adoption of EVs (Zheng et al., 2012). In January 2009, a demonstration project "Ten Cities Thousand Vehicles Project" (the Project) was initiated by the Ministry of Science and Technology (MOST), Ministry of Finance and National Development and Reform Commission (NDRS) to stimulate EV adoption. The project target was 1000 EVs in each of 10 pilot cities every year, and EV market share to reach 10% by 2012.

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[1] Ministry of Environmental Protection of China, Motor Vehicle Pollution Prevention Report of China, 2015.

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In June 2012, China issued *the Energy-efficient and Alternative-energy Vehicle Industry Development Plan (2012–2020)* to outline its development route, which set the target of more than 50,000 EVs by 2015 and 5 million EVs by 2020 (State Council, 2012). BEVs were selected as the major representative EV mode and was given priority in fostering its development. A series of incentive policies, including purchase subsidies and tax relief for private vehicle consumers have been proposed to stimulate the Plan's adoption. A consumer purchasing a BEV in the alternative fuel vehicles recommended models list is eligible for a purchase subsidy of up to 60,000 Yuan. On September 1st, 2014, the Ministry of Industry and Information and State Taxation Administration announced that BEVs in the list were free of purchase tax, which accounts for 8.5% of a BEV's purchase price on average. For example, the purchase price of EV160 from Beijing Automotive Industry Corporation (BAIC), which is a representative model of BEVs, is about 180,000 RMB. With the purchase subsidy from central and local government, the price of EV160 is reduced to 90,000 RMB and the purchase tax of about 7650 RMB is also relieved. Furthermore, EV cost per mile is approximately 50% less than gasoline fueled vehicles, which make it competitive relative to ICEVs.

Furthermore, in Beijing, Tianjin and Guangzhou, BEV adopters can obtain a license plate through a lottery separate from ICEVs, which is an attractive policy as lottery hit rates for ICEVs are very low in these cities.

The incentive policies succeeded in promoting EV sales from 12,791 in 2012 to 331,092 in 2015. However, EV market share remains only 1.34% of 24.59 million private vehicles. EVs face more barriers to adoption than ICEVS, and it is essential to investigate the relative importance of these barriers to help develop incentive policies and to promote wider adoption.

1.2. Research site

Vehicle emissions have become the main source of air pollution in large cities of China.[2] Tianjin is one of the four largest municipalities and the largest harbor in North China. It had a population of 15.5 million by the end of 2014,[3] which makes it one of the six megacities (population exceeding 10 million) in China. With the economic development and urbanization, Tianjin has experienced vigorous growth of private vehicles from 0.2 in 1999 to 2.3 million in 2015, which places a heavy burden on energy consumption and atmospheric environment. In 2015, Tianjin air quality failed to reach acceptable quality level for 145 days (Environmental Protection Agency of Tianjin, 2015), i.e., the citizens breathed heavily polluted air for more than 1/3 year. Frequent smog incidences have been observed. The appalling air quality in China aroused public concern about green cars like BEVs and urged the government to promote BEVs adoption.

With unbalanced regional development patterns across China, Tianjin's development mode is being imitated by many cities in underdeveloped areas. Secondary industries accounted for 46.7% of its GDP in 2015, compared to 31.8%, 19.7%, and 32.0% in Shanghai, Beijing, and Guangzhou (the most three developed Chinese cities), respectively. However, 21 of 31 of China's provincial capital cities have over 40% GDP in secondary industry, which makes Tianjin a typical model for these cities.

EV range is constrained by its maximum travel distance, so daily travel patterns in metropolitans such as Tianjin are expected to be most conducive to EV use and adoption (Sánchez-Braza et al., 2014). Accordingly, Tianjin was approved as EV adoption pilot city in November 2013. As well as central government subsidies, BEV adopters in Tianjin also receive a local government subsidy of matching value, to total maximum subsidy of almost 100,000 Yuan. Other incentive policies include a license plate lottery, tax relief, etc. By March 2016, Tianjin EV stock had reached 13,006 vehicles. According to *the Promotion and Implementation Plan for New Energy Vehicles in Tianjin (2016–2020) (the Plan)*, Tianjin aims to increase EV stock to 50,000 by the end of 2020. According to data of Tianjin Science & Technology Council,[4] the EV stock in Tianjin has increased to 38,500 by the end of 2016, accounting for 1.4% of the total stock of motor vehicles. Therefore, it is essential to explore the barriers to EV adoption from the consumer's perception, which will also provide policy inspiration for other cities in China.

1.3. Research questions

China is not alone in facing difficulties fostering EV adoption. By the end of 2014, EV stock was only 0.08% of total passenger cars worldwide, with market share over 1% in only four countries, Netherlands, Norway, Sweden, and the US (IEA, 2015b). Some studies attribute consumer perception to the failure of massive EV adoption (Egbue and Long, 2012; Schuitema et al., 2013; Sovacool and Hirsh, 2009). Therefore, it is important to understand how consumers perceive EVs and the possible barriers. This study explores the consumer perspective of:

What are barriers to the widespread EV adoption? Are these barriers affecting public acceptance of EVs significantly? Are there significant differences of public perception of barriers and purchase intentions among groups?

2. Literature review

Despite EV environmental benefits, significant barriers remain to their widespread adoption. Previous research has investigated opinions of manufacturers, investors, and government agencies for barriers to market penetration of sustainable transport and classified them into several groups: shortcomings of the technology (Foxon and Pearson, 2008);poor supporting infrastructure (Nie et al., 2016); customers' resistance to innovation (Heidenreich and Kraemer, 2016); and preparedness of relevant industrial capacity, missing standards and regulations, and electric grid barrier (Bühne et al., 2015). Even though these barriers play major roles for EV adoption, they may not reflect consumer viewpoint as the acceptance of consumers is another urgent issue that warrants further analysis (Peters and Dütschke, 2014). Therefore, this study concentrated on demand related barriers for EV adoption. Reviewing empirical studies of consumer perspectives, this study sorted the barriers to EV adoption into three aspects: financial, vehicle performance, and infrastructure barriers (See Table 1). To overcome these barriers, many countries, including China, have implemented incentive policies to promote EV adoption. Therefore, studies of these policies were also included.

When reviewing previous literatures of public acceptance of EVs, it's worth noting that many studies trying to understand consumer behavior from psychological framework besides functional and infrastructural aspects. Rezvani et al. (2015) presented a comprehensive overview of the theoretical perspectives that have been utilized to understand the intentions and adoption behavior towards EVs for consumer. More typically, Klöckner (2014) focused on the dynamics of purchasing an EV from a prospective of decision-making process. Turrentine and Kurani (2007) emphasized that consumers in the U.S. also valued the symbolic meaning of EVs for fuel economy and non-monetary meaning to fuel prices. However, unlike Norwegian and American market, EVs are relatively new issues in China and the public still have limited knowledge and awareness on EVs. Therefore, this study focused more on barriers from financial, functional and infra-

[2] Ministry of Environmental Protection of the People's Republic of China, 2015. China Vehicle Emission Control Annual Report, 2015.

[3] National Bureau of Statistics of China (NBS), 2014. China Statistical Yearbook, 2014.

[4] www.tstc.gov.cn.