Interested but unsure: Public attitudes toward electric vehicles in China

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Abstract
Efforts to commercialize electric vehicles by the Chinese government have been met with surprisingly subdued consumer responses and with sales targets that fall far short to targets. This paper examines the public attitudes towards electric vehicles in China, focusing on battery-only vehicles (BEVs). A national web-based survey was conducted to solicit views from Chinese residents in November 2012. The results indicated that although the majority of respondents expressed interests in BEVs and believed that BEVs were good for the environment and were cheaper to run, many respondents expressed concerns over them being inconvenient to charge, long charging times, limited battery longevity, limited vehicle range and high price. The analysis also showed that the level of interest, perception, and demands are significantly influenced by gender, age, income, education, and car ownership status.

Introduction
Since the turn of the twenty-first century, the central government of the People's Republic of China has been devoted to the greening of road transportation via the commercialization of electric vehicles. Since 2001, the government has made available approximately 2 billion RMB ($330 million) in research funding to key research institutes and domestic automakers to develop electric vehicles (Liu & Kokko, 2013). As a result, the technical capacity of domestic electric vehicle industry has developed rapidly. Further, in the latest nationwide economic planning document, the twelfth five-year-plan, the Ministry of Science and Technology announced an ambitious goal: by 2015, the sale of battery-only electric vehicles (excluding hybrid electric vehicles) should account for 1% of total sales. The electronic vehicle initiative joins other programs that aim to control greenhouse gases emissions in the transport sector, including mandatory bioethanol use (Tao, Yu, & Wu, 2011), fuel economy standards (Oliver, Gallagher, Tian, & Zhang, 2009; Wang, Jin, Wang, & Wei, 2010) and subsidies for energy efficient vehicles (Lo & Wang, 2013; Lo, 2014). Currently, the transport sector accounts for a relatively small share of China's total energy consumption and carbon emissions (8%). Nevertheless, given the magnitude and increasing rates of carbon emissions from road transport in China (in 2009 emitted 270.9 Mt CO_2, the increase of nearly 87 times since 1980 (Loo & Li, 2012), it is not surprising that these recent developments have attracted significant research attention in the transportation and climate change literature.

One emerging research theme on China's green vehicles is policy analysis; these studies typically focus on government actions. Liu and Kokko (2013) determined three phases in the evolution of electric vehicle policies in China over the past two decades. From 2001 to 2009, the government focused on the research and development of electric vehicles; from 2009 to 2010, the focus shifted to promoting the adoption of green vehicles in the public sector (buses, taxis, official vehicles and municipal service vehicles); from 2010 until present, the focus again shifted to encouraging the adoption of green vehicles in the private sector.

Gong, Wang, and Wang (2013) focused on the technological aspect and argued that technological developments have shifted their emphasis from hybrid technologies to battery-only electric vehicles. The authors further argued that the development of charging infrastructure has been trailing, in part due to delays in producing technical standards for charging facilities. Zheng, Mehndiratta, Guo, and Liu (2012) studied the local implementation of electric vehicle policies and identified local protectionism and a lack of monitoring as the key institutional deficiencies in successfully commercializing of electric vehicles. Overall, this body of literature highlights two interesting characteristics of China's recent foray into electric vehicles. First, the government, or more precisely, the Ministry of Science and Technology, has cherry-picked battery-only electric vehicles (BEVs) as the future of green vehicles. Second, the government relies mainly on subsidies for promoting electric vehicles. In 2010, the central government initiated a multi-billion dollar program that subsidizes the purchase of electric vehicles. The program was renewed in 2013 for another three years. The amount of subsidies depends on two factors: the capacity of the battery and the type of the vehicle. HEVs receive a standard 35,000 RMB ($5,800) subsidy; whereas BEVs are qualify a subsidy from 35,000 RMB to 60,000 RMB ($9,900), depending on the range of the vehicle. Local governments have made available additional funding, which, in certain cases, doubled the subsidies offered by the central government. The subsidy significantly reduces the cost of electric vehicles by up to 50%, making them as cheap if not cheaper than conventional vehicles of the same class (for example, BYD e6, China's most popular BEV, is officially priced at 309,800 RMB ($51,200) and is eligible for a total subsidy of 120,000 RMB ($19,800). SAIC's Rongwei E50, officially priced at 234,900 RMB ($38,800), is eligible for 110,000 RMB ($18,200).

Power generation in China is dominated by coal-fired power plants thus the research question arises - can the commercialization of electric vehicles reduce carbon emissions? Using a life-cycle analysis, Ou, Yan, and Zhang (2010) computed that the reduction of carbon emissions of electric vehicles powered by coal-fired plants could be 3-36% compared to conventional vehicles, depending on the specific power generation technologies under

consideration. Using provincial-level data, Huo, Zhang, Liu, and He (2013) estimated that, on average, electric vehicles can reduce carbon emissions by 20%, but significantly increase PM_{10}, $PM_{2.5}$, NO_x and SO_2 emissions because coal is heavily used in electricity generation. In modeling-based research, He and Chen (2013) found that by 2030, the reduction potential for carbon emissions, if the government pursues the development of electric vehicles, is 4.3 trillion tons, compared to 2.9 trillion tons if the government pursues the hybrid vehicles strategy.

In comparison to the fields of policy analysis and environmental impact analysis, research on public attitudes towards electric vehicles has been sparse. The filling of this knowledge gap is crucial because it is the views of the public, as potential consumers, that are most relevant in determining the long-term viability of electric vehicles (Hjorthol, 2013; Ewing & Sarigollu, 2000). In China, this question is particularly pertinent because the current aggressive subsidy policy has been met with failure – in the third quarter of 2011, for example, fewer than one thousand electric vehicles were registered, or less than 0.02 percent of new-vehicle registrations during this period (Krieger, Radtke, & Wang, 2012). This policy failure suggests that major barriers need to be overcome before electric vehicles will be widely adopted. This paper argues that without understanding the phenomenon from the public's perspective, it is impossible to accurately pinpoint such barriers. Following this rationale, the objective of the present study is twofold: (1) to study public attitudes towards electric vehicles in China; and (2) to compare and contrast the responses according to gender, age, education, income and car ownership. This study focuses on BEVs because, as discussed previously, BEVs have been handpicked by the government as the future of electric vehicles in China.

Method

This study used a quantitative, web-based survey that was hosted by a company specializing in online research panels. All survey participants were Chinese residents who agreed to participate in web-based surveys at the time of their registration. An invitation email containing survey information, point's reward and a hyperlink to the survey was sent to randomly selected panel members on November 12, 2012. The company collected 2,000 responses in two days. To focus on potential consumers of BEVs, respondents younger than 21 and those without a monthly income were eliminated, yielding 1,785 valid responses for analysis. As with other web-based surveys conducted in China, the sampling is confined to those with access to the Internet and therefore not representative of the population of China. Table 1 presents the demographic characteristics of respondents, including age, gender, income, education, and car ownership status. Compared to national statistics, our samples are biased towards younger people with high socioeconomic status. Studies from overseas have found that people from this socioeconomic and demographic

group are more likely to purchase electric vehicles because they are more concern about environmental issues and command more financial resources (Achtnicht, 2012; Hidrue, Parsons, Kempton, & Gardner, 2011). As a result, the findings reported here are likely to be biased in favors of electric vehicles.

TABLE 1: Demographic characteristics of the respondents (N=1,785)

	Frequency	Percent	Mean (Std. Deviation)
Gender			1.51 (0.50)
1: Male	868	48.6	
2: Female	917	51.4	
Age			2.17 (0.90)
1: 21-25	476	26.7	
2: 26-30	647	36.2	
3: 31-40	539	30.2	
4: Over 40	123	6.9	
Education			1.94 (0.24)
1: High school or below	106	5.9	
2: University	1679	94.1	
Monthly income (RMB)			2.44 (1.01)
1: Under 3,000	291	16.3	
2: 3,001-5,000	544	30.5	
3: 5,001-8,000	442	24.8	
4: Over 8,000	282	15.8	
Car ownership			1.39 (0.49)
1: Yes	1096	61.4	
2: No	689	38.6	

The level of interest

Respondents were asked to rate their interest in BEVs on a 4-point Likert scale (1=not interested, 4=very interested). The overall responses indicated a very high level of interest, with 45.7% of respondents indicating that they were very interested in BEVs and 41.4% of respondents indicating that they were interested, with an average score of 3.31. The mean differences for car ownership status, gender, age, education and monthly income across the interest variable were analyzed using ANOVA. The tests revealed four statistically significant differences. First, males were more interested in BEVs than were females. Second, respondents in the 31-40-year-old age group expressed the highest level of interest in BEVs, whereas respondents in the over-40 age group reported the lowest. Third, respondents with high monthly incomes or those who already owned a car had a higher level of interest in BEVs.

Public Perceptions

To measure public perceptions of BEVs, respondents were asked to rate their level of agreement with four commonly claimed benefits and eight commonly claimed disadvantages of BEVs using a 5-point Likert scale that ranged from strongly disagree to strongly agree. The four benefits listed were reduced air pollution, reduced carbon emissions, enhanced energy security and low running costs. The eight disadvantages were insufficient speed, inconvenient to charge, long charge time, limited battery longevity, poor reliability, insufficient range, poor safety and high purchase price.

Two environmental advantages, reduction of carbon emissions and reduction of air pollution, were among the strongest perceptions of BEVs among respondents (see Figure 1). These were followed by a number of robust positive and negative perceptions: low running costs and energy security on the positives, and long charge time, inconvenience to charge, short battery life and high price on the negatives. Insufficient speed, poor reliability and poor safety were among the weakest perceptions.

The ANOVA results of the twelve perception variables are displayed in Table 2. Gender was a strong predictor. Male respondents had a higher mean than female respondents in six variables (one positive, five negatives). There was no variable in which female respondents had a higher mean than male respondents. Age was also a significant factor influencing perceptions, with significant differences across age groups found in eight out of twelve variables (three positives, five negatives). In general, respondents in older age groups had a higher mean in both positive and negative perceptions. Significant differences between education groups were found in seven variables (three positives, four negatives). The general trend is that education increases the perception of both the advantages and disadvantages of electric vehicles. Income is a strong predictor in nine variables (four positives, five negatives). A general trend is that respondents in higher income groups had higher levels of both positive and negative perceptions. Finally, respondents who owned a car had stronger perceptions in three of the positive variables.

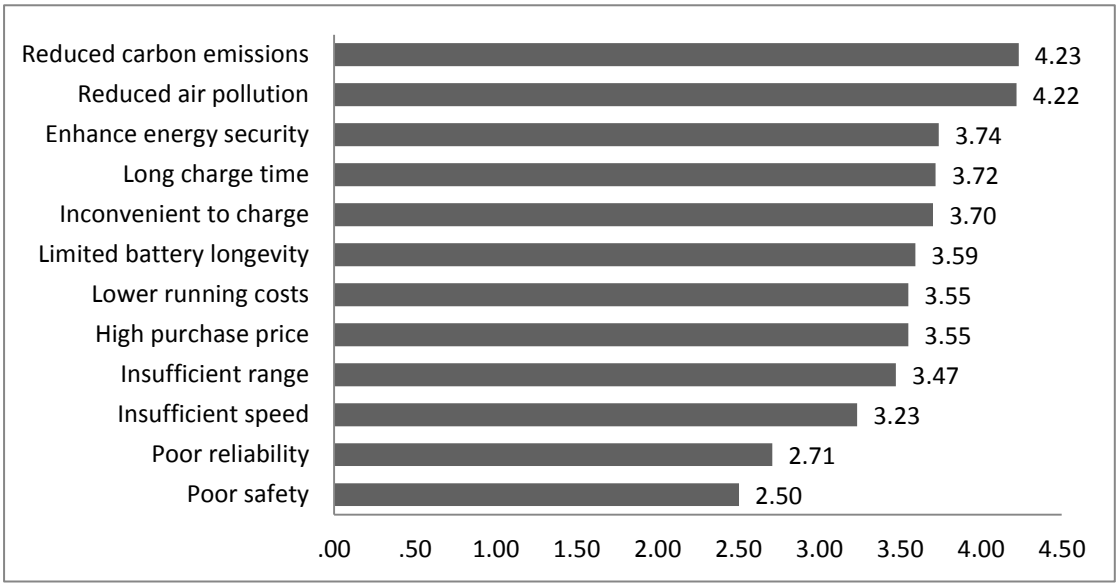

FIGURE 1: Perceptions about BEVs

TABLE 2: Mean differences of perceptions regarding BEVs

	Air pollution	Carbon emissions	Energy security	Running costs	Speed	Charge facilities
Gender						
Male	4.25	4.25	3.74	3.55	3.29	3.75
Female	4.18	4.21	3.73	3.56	3.18	3.66
F	4.433*	1.479	0.058	0.036	7.201**	5.340*
Age						
21-25	4.09	4.14	3.59	3.55	3.12	3.54
26-30	4.22	4.22	3.74	3.58	3.26	3.70
31-40	4.30	4.32	3.88	3.56	3.28	3.81
Over 40	4.32	4.25	3.72	3.36	3.39	3.91
F	8.145***	5.415**	8.720***	1.751	5.561**	10.130***
Education						
High school	3.97	4.03	3.64	3.58	3.19	3.44
University	4.23	4.25	3.75	3.55	3.24	3.72
F	12.392***	8.939**	1.303*	0.132	0.356	9.556**
Monthly income (RMB)						
Under 3,000	4.09	4.10	3.60	3.56	3.19	3.65
3,000-5,000	4.24	4.27	3.73	3.51	3.28	3.75
5,001-8,000	4.22	4.25	3.72	3.48	3.30	3.76
Over 8,000	4.31	4.30	3.92	3.69	3.15	3.63
F	6.565***	6.380***	8.539***	3.561*	3.266*	2.450
Car ownership						
Yes	4.25	4.28	3.82	3.58	3.23	3.71
No	4.16	4.17	3.61	3.50	3.25	3.69

F	5.515*	9.706**	24.225***	2.495	0.242	0.197

*p<0.05; **p<0.01; ***p<0.001

TABLE 2: Mean differences of perceptions regarding BEVs (cont.)

	Charge time	Battery life	Reliability	Range	Safety	Price
Gender						
Male	3.77	3.62	2.69	3.56	2.49	3.62
Female	3.68	3.57	2.73	3.40	2.52	3.48
F	5.731*	1.705	1.162	15.605***	0.693	10.175**
Age						
21-25	3.58	3.50	2.66	3.32	2.55	3.38
26-30	3.73	3.63	2.75	3.46	2.53	3.60
31-40	3.81	3.63	2.69	3.60	2.45	3.64
41-50	3.89	3.65	2.72	3.60	2.42	3.55
F	8.621***	3.327*	1.192	10.446***	1.975	8.079***
Education						
High school	3.53	3.49	2.68	3.25	2.47	3.36
University	3.74	3.60	2.71	3.49	2.51	3.56
F	6.444*	1.898	0.154	8.345**	0.177	4.954*
Monthly income (RMB)						
Under 3,000	3.63	3.59	2.77	3.41	2.61	3.42
3,000-5,000	3.78	3.66	2.71	3.52	2.52	3.57
5,001-8,000	3.81	3.60	2.67	3.51	2.41	3.56
Over 8,000	3.65	3.50	2.69	3.43	2.47	3.66
F	5.413**	2.884*	1.327	1.928	4.526**	4.866**
Car ownership status						
Yes	3.75	3.60	2.70	3.48	2.47	3.58
No	3.69	3.59	2.72	3.46	2.56	3.50
F	2.275	0.009	0.122	0.265	5.839	3.277

*p<0.05; **p<0.01; ***p<0.001

The greatest concern

Respondents were also asked to select one of the eight supposed disadvantages of BEVs that concerned them the most (Figure 3). Being inconvenient to charge a BEV was selected by the largest number of respondents as their most significant concern, followed by insufficient range and limited battery longevity. In general, the ranking of concerns did not differ significantly amongst demographic groups, although chi-square analysis showed a significant association between the greatest concern and gender. Male respondents were primarily concerned about range whereas female respondents were primarily concerned with the inconvenience of recharging.

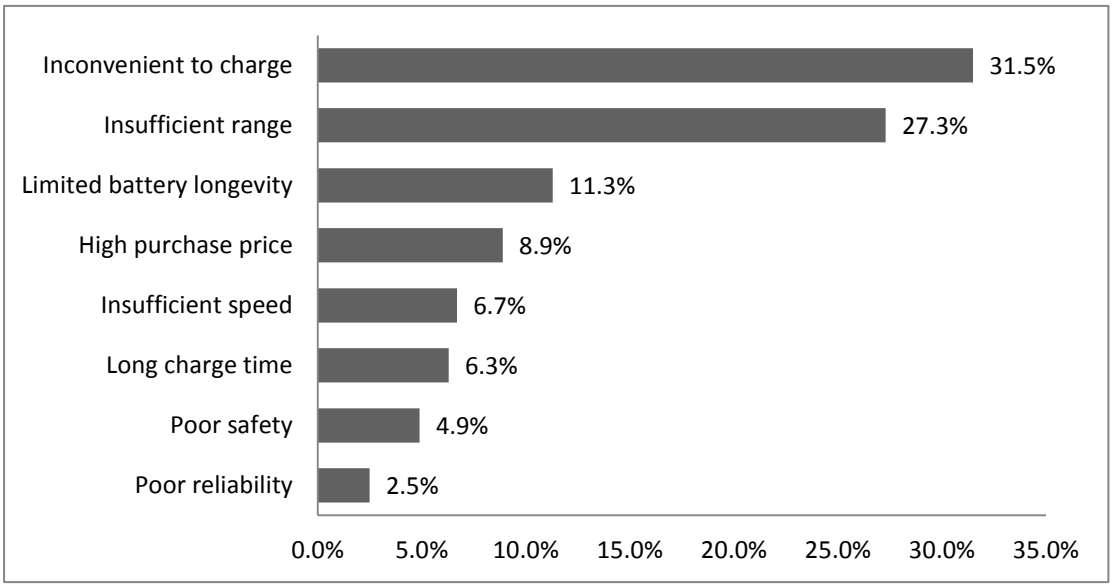

FIGURE 2: Greatest concerns about BEVs

Demands

Respondents were asked to indicate the level of performance they demand from BEVs. Most respondents demanded a BEV to fully charge within either 15 minutes (35.1%) or 30 minutes (39.7%) at a charging facility. The majority of respondents demanded that a BEV fully charge within 2 hours (40.3%) or 4 hours (32.7%) when charged at home. Most respondents expected their batteries to function without a significant decline in capacity for at least 4-5 years (39.3%) or 6-7 years (32.2%). The demand for vehicle range was more diverse, with a substantial number of respondents indicating that they expected a range of 200-300 km (23.7%), 300-400 km (37.7%) or 400-500 km (20.2%). Interestingly, the majority of respondents (86.1%) accepted a price premium for BEVs, and most respondents accepted a price premium of 10,000-50,000 RMB (38.4%) or 50,000-100,000 RMB (24.2%).

Respondents with higher income and education levels demanded more from BEVs, particularly in battery longevity and vehicle range, while accepting a higher premium. Gender and car ownership played no significant roles in shaping demands, except regarding the price premium—male respondents and respondents with a car demonstrated more acceptances towards a larger price premium. Age had no impact on demands. Note that demands on charging time, whether at home or at charging station, were universal and were not affected by demographic variables.

Significant gaps exist between these demands and what BEVs are currently capable of delivering. To use BYD e6 as an example, which was released in 2011 and remains China's only commercial passenger-class BEVs, the largest discrepancies are in vehicle range and charging time. With a maximum range

of 300 km, the BYD e6 can only satisfy 28.6% of respondents. Fully charging a BYD e6 at charging facilities using quick-charge technology requires 40 minutes (only 11.5% of respondents would be satisfied); whereas fully charging at home requires 6 hours (only 27.1% of respondents would be satisfied).

Discussion and Conclusions

While the Chinese government has committed significant funding to promote the adoption of green vehicles, especially BEVs, the results have been disappointing so far. This study seeks to understand the reasons for this policy failure through surveying the public attitudes towards electric vehicles in China. The findings of this study indicate that while most respondents were interested in BEVs and were aware of their advantages, they were unsure about purchasing a BEV due to concerns over charging locations, charging times, battery longevity, vehicle range and price. Interestingly, the relationship between positive and negative perceptions towards electric vehicles is complementary rather than contradictory. In other words, respondents with stronger positive perceptions also tend to have stronger negative attitudes. This finding suggests that the public have nuanced perceptions about BEVs that are neither overwhelming negative nor positive.

The results indicate that the greatest concern over BEVs in China is inconvenience to charge. This finding differs from those reported elsewhere, which usually identify price or vehicle range as the greatest concerns (Egbue & Long, 2012; Franke, Neumann, Buhler, Cocron, & Krems, 2012). Although one of the advantages of BEVs is the possibility of recharging at home, not everyone can do so. Charging can be especially difficult for those living in apartments and parking their cars either on the street or in apartment parking garages (Axsen & Kurani, 2012). Because few Chinese urban-dwellers have garages that can be wired to charge electric vehicles overnight, owners of BEVs must rely on the very limited number of publicly available charging points (Krieger et al., 2012). Therefore, accessibility to charging facilities become a greater concern in China than in western developed countries, where many people live in detached houses with their own garage. This finding also indicates that the current subsidy-based policy is not sufficient and that the government should accelerate the construction of charging infrastructures.

The findings show that the gap between consumer expectations, particularly for the range and charging time, and what commercial BEVs can currently offer, is significant. However, this gap is likely to diminish in the future for two reasons. First, advancements in electric vehicle technologies, particularly battery technologies, can significantly increase the range of BEVs and shorten the charging time. Second, improvements of charging infrastructures can alleviate consumer concerns regarding range and charging time.

One of the purposes of this study is to understand the effect of demographic variables on consumers' interest and perceptions on BEVs. In general, male respondents expressed higher levels of interest, were more aware of both the positives and negatives of BEVs and accepted a higher price premium. Older respondents had a higher level of interest in BEVs and were more knowledgeable about BEVs, although respondents over 40 reported the lowest interest. The group with university educations had stronger perceptions of both the advantages and disadvantages of BEVs than did the group without university education. The former group also had higher expectations of electric vehicles. Respondents with higher monthly incomes expressed more interest in BEVs and were also likely to view them in a more positive light. Respondents who already owned a car were more interested in BEVs and were more likely to perceive the benefits of BEVs. They also accepted higher price premium.

Given the finding that charging inconveniences are the most significant barrier to the adoption of BEVs from the perspective of consumers, the next logical step would be to understand the barriers to the construction of charging infrastructure. Existing studies have provided some cursory clues. For example, Zheng et al. (2012) suggested that the main problems with charging stations are that they are expensive to build and require significant land space. Gong et al. (2013) theorized that the delay in releasing technical specifications for charging stations contributed to the slow progress. These insights are helpful as a starting point for a systematic stakeholder analysis on the construction of charging infrastructure in China that will be based on in-depth, qualitative interviews.

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