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Effects of personal carbon trading on the decision to adopt battery electric vehicles: Analysis based on a choice experiment in Jiangsu, China

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HIGHLIGHTS

- We used a choice experiment to analyze the effect of PCT on BEV adopting decision.
- We compared the effect of PCT with BEV performances and other policy incentives.
- Except for government subsidy, the PCT was more powerful than other policies.
- The PCT was less effective than the improvement of some BEV performances.

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ABSTRACT

The implementation of personal carbon trading (PCT) to influence transport choices has recently been suggested as a method to reduce private carbon emissions. In this study, we conducted a choice experiment in Jiangsu, China, to evaluate if PCT influences individual decisions to adopt battery electric vehicles (BEVs). The results showed that PCT can effectively change the decision to adopt and encourage the adoption of BEVs. PCT was shown to be more effective than free parking as well as eliminating road tolls, vehicle and vessel tax, and purchase tax, but less effective than government subsidies. In addition, we found that improving some BEV performance attributes was preferred to policy incentives, including PCT. These results improve our understanding of the effectiveness of PCT and the individual decision to adopt BEVs. Our findings could facilitate the practical implementation of PCT and provide suitable guidelines for developing BEV promotion strategies.

1. Introduction

Historically, energy consumption by transportation throughout the world has been dominated by fossil fuels, particularly gasoline and diesel. This dominance has contributed to the provision of cheap and reliable transport services and thus to global economic growth, but it has made the transport sector one of the major emitters of greenhouse gases and a major contributor to climate change, which is one of the major challenges currently faced by humans. For example, in 2010, the transport sector produced 7.0 $GtCO_2eq$ of emissions, which accounted for almost one-quarter of global emissions [1]. Furthermore, in the absence of major actions to de-fossilize the transport sector, global transport emissions are expected to double by 2050 and triple by 2100 (compared with the levels in 2010) [1].

Therefore, efforts have been made in recent years to find ways to de-fossilize the transport sector, especially in major developing countries such as China (the focus of the present study), where major growth in emissions by the transport sector will occur in the coming decades, driven primarily by population and income growth [2,3]. These efforts have initially focused on improving the carbon efficiency of transportation systems [4,5]. More recently, attention has also been attracted to low-emission vehicles, particularly battery electric vehicles (BEVs) [6,7]. For example, the Chinese government has set an ambitious target of 5 million BEVs on the road by 2020 [8]. Several policy measures are being implemented to promote the deployment of BEVs. These policy measures include government-directed subsidies (such as direct payments, tax benefits, and toll waivers) and regulatory measures (such as free registration) [9]. For example, a national subsidy program for electric vehicles was introduced in 2010. This program allows for a one-time bonus up to a maximum of ¥ 60,000 (about US $ 9000)[1]

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[1] The average exchange rate of U.S. dollar against RMB is about 0.15.

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depending on the battery capacity of the vehicle [10]. In addition, several local governments (such as Beijing, Shanghai and Shenzhen) have also introduced programs to support the deployment of BEVs. These programs include a one-time bonus for purchasing BEVs (double the national bonus in some cases), toll waivers on city roads, bridges, tunnels, and free registration [9].

However, in recent years, there has been an increase in public concern that the existing policy support may have limited effectiveness at promoting the deployment of BEVs in China [11], which is primarily reflected by the slow progress of BEV deployment where it has fallen short of the targets. For example, the BEV stock in China was around 480,000 vehicles by the end of 2016, which accounted for less than l0 per cent of the 2020 target [9]. Clearly, there is a need to find more effective policy measures to promote the deployment of BEVs. Personal carbon trading (PCT) is one of the measures that is currently under consideration. The PCT scheme is an emissions trading scheme for individuals, where individuals are allocated certain amounts of emissions credits and they need to surrender these credits when purchasing fuel or electricity. Also, they need to purchase additional credits from others if they want to purchase fuel or electricity above the level permitted in their initial credit allocation. This scheme is expected to provide market-based incentives so individuals can reduce the emissions associated with their activities, such as by adopting low-carbon technologies (e.g., BEVs) [10]. Some variations of the PCT scheme have been implemented or considered in some areas, already, such as in Norfolk Island, Australia, Guangdong province, China, Korea, and the United Kingdom.

Given the background described above, the main objective of this study was to analyze the impacts of the PCT scheme on shaping the intentions of consumers to adopt BEVs. The results of this study make several main contributions. First, we provide new insights into the intention to adopt BEVs and guidance for consumers. Second, our results may be of interest to policy makers because they could contribute to the development of more effective policy support for BEVs. Third, this empirical study of PCT may provide a reference to facilitate the application of PCT in the future. The remainder of this paper is organized as follows. In Section 2, we present a review of related literature. In Section 3, we explain the details of the choice experiment. In Section 4, we specify the model employed. The empirical results are presented in Section 5 and discussed in Section 6. We give our conclusions and discuss policy implications in Section 7.

2. Literature review

BEVs are low carbon technology products that have been promoted widely in countries throughout the world to mitigate global climate change. Many previous studies have focused on the topic of BEVs and they can be divided into several categories: analyses of BEV-related technical problems, such as batteries [12], drive systems [13], and energy storage systems [14]; explorations of the economic and environmental benefit of BEVs, such as comparisons of the internal combustion engine and BEVs [15], assessments of different types of energies for BEVs [16], and life cycle cost and emission analyses [17]; and studies of market penetration by BEVs, such as using different methods to model consumer acceptability [18] and identifying factors that affect adoption behavior [19]. In the final category, many studies have evaluated the effects of support policies, which are key drivers of the mass adoption of BEVs [20]. The current support policies mainly comprise financial subsidies, preferential taxes, free parking, and driving privileges [21]. Previous studies have demonstrated that these policies had positive effects on the intention of consumers to adopt BEVs [22–24]. However, some studies found that the impact of support policies was not as powerful as expected. Thus, Hoen and Koetse [25] showed that policies such as road tax exemption and fiscal incentives contributed to the intention to adopt among Dutch consumers, but they were far less effective in eliminating doubts about the reliability of BEVs. Furthermore, Green et al. [26] suggested that the current policies aim to promote the large-scale application of BEVs by targeting mainstream consumers, but these policies were inefficient and costly in the United States. Similar results were found in China, where Han et al. [27], Zhang et al. [28], and Zhou et al. [29] also suggested that more effective policy measures should be implemented.

As a market-oriented policy measure, carbon trading has been considered widely around the world in order to cope with climate change and reduce emissions. Previous studies have focused mainly on carbon trading among enterprises. The establishment of PCT schemes was first proposed by Fleming based on the importance of reducing individual emissions [30]. PCT is a generic term for several emission trading schemes, such as personal carbon allowances, tradable energy quotas, and cap and share [30]. In these schemes, emissions permits are freely allocated to individuals based on the national annual carbon reduction target [31]. Individuals need to surrender these permits to meet their energy consumption and transport needs, and these permits are tradable [32]. A PCT scheme could yield three incentives for individuals to reduce the emissions associated with their daily activities (such as cooking, entertainment, and transport) by using low carbon technologies, where these incentives are economic, psychological, and social [33]. The economic incentive is driven by the price of carbon permits in the market, which provides incentives for using low-carbon energy and investing in energy efficiency instruments. People respond to PCT through the purely economic incentives but also by increasing their carbon awareness. The value of carbon emissions is visual in PCT, thereby increasing people's knowledge of their energy consumption behavior. This intrinsic mechanism is called a psychological incentive. The final incentive describes how human behavior moves away from individualism and how it is subject to social influences. PCT will lead to the creation of new institutions, businesses, and discourses, which might alter traditional social relationships. The behavior of people may be constrained by these changes.

Some empirical studies have analyzed the impacts of PCT schemes on individuals. For example, Parag et al. [34] and Zannia et al. [35] verified the positive effects of PCT in reducing family energy consumption, while Raux et al. [36] showed that PCT can effectively change travel behavior to decrease transport carbon emissions. However, insufficient knowledge is available about the impact of PCT on the adoption of low carbon technologies, such as household power generation systems (e.g., stand-alone photovoltaic systems [37]), battery energy storage systems (e.g., battery integration into photovoltaic modules [38]), and vehicle electrification (e.g., BEVs [39]). Zhang et al. [6] found that carbon emissions by private vehicles accounted for most of those by transport in China, e.g., more than 88% in Beijing. Thus, the choice of private vehicle type directly determines the amount of individual travel carbon emissions and this is a very important issue. People who always drive conventional fuel vehicles (CFVs) are generally considered to produce more carbon emissions than those who drive BEVs under the same conditions [39,40]. In particular, BEVs without an internal combustion engine cannot produce emissions while driving but their associated carbon emissions depend mainly on the electricity source employed. If wind, sun, water, and other clean sources of energy dominate the electric power sources, then the emissions when driving BEVs are far less than those by CFVs [41]. Even if fossil fuels dominate the electric power sources, BEVs can still provide greater environmental benefits, mainly because the energy efficiency of electric power plants is higher than that of internal combustion engines, and the emissions by electric power plants are easier to clean than those by millions of CFVs [42]. However, if PCT is introduced, will it encourage more people to abandon CFVs and adopt BEVs? At present, answering this question requires more evidence. Fan et al. [43] found that PCT can motivate people to adopt hybrid electric vehicles when the price of carbon permits increases above a critical value, but their results were based mainly on an equilibrium model rather than actual individual data.