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Impacts of a super credit policy on electric vehicle penetration and compliance with China's Corporate Average Fuel Consumption regulation

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A B S T R A C T

A super credit policy provides favorable accounting rules for extremely low emission vehicles under several passenger vehicle fuel economy regulations. This policy was initially designed to promote promising advanced technologies complying with fleet-wide fuel economy regulations so that these technologies could achieve cost-effective breakeven points. The favorable multipliers offered range from 3.5 to 1.33 in the various fuel economy regulations by the year 2021. Under China's Corporate Average Fuel Consumption regulation, two types of super credit schemes are designed in the Phase IV Corporate Average Fuel Consumption regulation through 2020. One is the fuel-efficient vehicle super credit for vehicles with fuel consumption rates below the threshold of 2.8 L/100 km. Another is the new energy vehicle super credit for battery electric vehicles and plug-in hybrid electric vehicles. However, the effectiveness of this incentive in promoting electric vehicles and the optimal size of the multiplier are not well understood. This paper analyzes the impacts of the super credit policy from the perspective of automakers. A mathematical model based on combinational optimization is established to describe an automaker's decision-making process, and a genetic algorithm is employed to solve this problem. The conventional and plug-in hybrid electric vehicles cost-effectiveness frontier curves are fitted to illustrate the principle of new energy vehicle and fuel-efficient vehicle super credit schemes. Various multipliers of new energy vehicle and fuel-efficient vehicle super credit policy scenarios are simulated under the 2020 and 2025 Corporate Average Fuel Consumption targets. By analyzing the impact of the policy on the reduction of compliance costs, the super credit multiplier, the cost and the fuel consumption rates reduction effect are found to be the determining factors. The results confirm that the multiplier and China's super credit policy scheme will be effective by 2020, under which plug-in hybrid electric vehicles would account for 7.8% of the fleet at a cost of 6.6% Corporate Average Fuel Consumption target impairment. Under the assumed next phase of regulation by the year 2025, the optimal multipliers for the new energy vehicle and fuel-efficient vehicle super credit will be 1.5 and 1, respectively. It is noteworthy that the super credit policy may impair the energy saving target of Corporate Average Fuel Consumption regulations while promoting the market penetration of the targeted technologies. Despite other policies that benefit battery electric vehicles over plug-in hybrid electric vehicles, battery electric vehicles are not competitive with plug-in hybrid electric vehicles under either the 2020 or 2025 Corporate Average Fuel Consumption regulations. The fuel-efficient vehicle super credit policy will not promote the targeted advanced technologies under the next phase of regulation unless the 2.8 L/100 km fuel-efficient vehicle definition threshold can be adjusted along with the strengthened 2025 Corporate Average Fuel Consumption target.

1. Introduction

Electric vehicles (EVs) have been considered a promising technology for both reducing direct oil demand and mitigating

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greenhouse gas emissions in the road transport sector in the next half-century [1]. Major vehicle markets worldwide have issued preferential policies or established regulations to promote EVs in the past decade, such as EV demonstration programs, fleet-wide compulsory fuel economy targets or zero emission vehicle programs with credit systems, preferential tax and subsidy policies and target amounts of EV usage and access incentives [2]. The super credit, one of these incentives considered to be a favorable policy for extremely low emission vehicles, aims to promote market penetration by offering beneficial accounting rules under various fleet-wide compulsory fuel economy regulations. For instance, there are 2 super credit schemes in China's Phase IV Corporate Average Fuel Consumption (CAFC) regulation. One is for new energy vehicles (NEV), which consist of battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) with an over-50 km all electric range (AER). Another is for fuel-efficient vehicles (FEV), defined as those with a fuel consumption rate (FCR) below 2.8 L/100 km. By taking advantage of the super credit schemes, each NEV and FEV could be accounted for as 2 and 1.5 models, respectively, under the CAFC by the year 2020.

EV penetration has been remarkably accelerated by these incentives in the past 5 years. In 2016, the market share of passenger EVs reached 0.86%, and sales increased by 15 times to 774 thousand compared with 2011 [3]. Along with the dynamic automobile market in the past decade, China has also become the main contributor to this ongoing EV market explosion. In 2016, 336 thousand passenger NEVs consisting of 257 thousand passenger BEVs and 79 thousand passenger PHEVs were sold in China [4]. In Fig. 1, the left axis of the stacked column chart presents EV sales, and the right axis presents China's share in the world's EV market.

China's market share has increased remarkably during the past 5 years, accounting for 43.4% of global passenger EV sales by 2016. When electric buses are taken into consideration, the proportion reaches 53.7%.

A booming EV adoption rate is usually promoted by a series of incentives, including fiscal and nonfiscal incentives [6]. The incentives can be further categorized into regulatory incentives, direct consumer incentives, indirect consumer incentives, charging infrastructure and complementary policies [7]. Four obstacles need to be overcome to promote EV penetration, namely costs, infrastructure for recharging, consumer acceptance and the evolution of other technologies [8]. China has been promoting the development of EVs for over 20 years [9]. After 2000, China accelerated the adoption of EVs. The “EV key project” program was established in 2002 [10] and was proposed to significantly improve national EV technology. In 2009, the EV demonstration project was launched [11]. Additionally, to improve the cost competitiveness of NEVs, which are defined as BEVs, PHEVs and fuel cell vehicles (FCVs) in China, subsidies based on battery capacity were issued in 2010 [12]. This policy continued subsidizing NEVs based on AER: BEV and PHEV consumers could acquire ¥ 60,000 and ¥ 35,000, respectively, at most in 2013 [13]. Considering technological evolution and the economy of scale effect, the subsidy is phasing down to ¥33,000 and ¥18,000 respectively for BEVs and PHEVs in 2020 [14]. Based on the ownership cost compared with conventional internal combustion engine (ICE) vehicles, this subsidy scheme is assessed to be necessary for NEVs to become cost competitive [15]. Among these incentives, the subsidy policy plays a dominating role in China's NEV market penetration and powertrain options, particularly for commercial electric vehicles [16]. The results from a discrete choice experiment also show that exemption from purchase and driving restrictions has the most significant positive effect on passenger NEV acceptance in China [17].

Regulatory incentives also play a remarkably important role in the market adoption of NEVs, in addition to demonstration programs, technology projects and purchasing subsidies in China. China published the NEV development plan in 2012, in which the accumulative sales volume of NEVs was set at a target of 500,000 and 2,000,000 by 2015 and 2020, respectively [18]. To mitigate carbon dioxide emissions and reduce oil consumption by vehicles, four phases of vehicle fuel economy regulations have been issued since 2004. Vehicles failing to satisfy the FCR limits specified by the regulation cannot acquire a selling license in the domestic market [19]. Furthermore, the CAFC system was established in 2011, and vehicle models are divided into different categories based on the curb weight and specified with an FCR target [20].

Many studies have explored the effects of fiscal and nonfiscal policy incentives on improving the adoption of EV, aiming to determine the major driving factors or barriers. EV incentives are usually adopted in the phases of EV purchase and usage. Van der Steen et al. compared policy incentives in countries and found that most policies focus downstream of the EV value chain, which in the short term has paid off. However, policies on the service segment would be more effective in further introducing EVs in the long run [21]. Regarding the policies on the EV usage stage, some studies explored the impact of policies such as free parking, access to high occupancy vehicle (HOV) lanes, preferential access to registrations in vehicle purchase quota cities, etc. The impact of EV incentives on different groups of people was studied based on a state-choice experiment, and the results showed that nonfiscal measures such as free parking and access to fast bus lanes are highly valued by consumers [22]. Merksy et al. examined the effectiveness of road toll exemptions, access to bus lanes and charging infrastructure policies in Norway by using sales, policy and demographic data and a standard linear regression method. They concluded that access to charging infrastructure, adjacency to major cities and regional income are the most influential factors determining BEV sales [23]. Vehicle purchase quotas and lottery policies were taken into

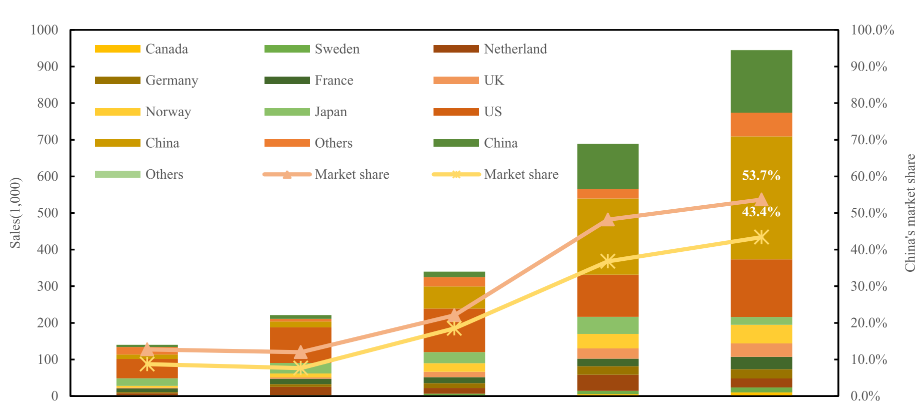

Fig. 1. Historical global EV sales data and China's market share [5].