



# Substitution effect of New-Energy Vehicle Credit Program and Corporate Average Fuel Consumption Regulation for Green-car Subsidy

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## ABSTRACT

The green-car subsidy program since 2009 has been successfully used to boost the nation's new-energy vehicle industry and cut vehicle emissions in China; however, it may cause financial burden on the governments at the same time. Therefore, alternatives including a New-Energy Vehicle Credit Program and Corporate Average Fuel Consumption Regulation (dual-credit policy) have been proposed to reduce the government's expenditure caused by subsidization. To examine the effectiveness of the new regulation, new energy vehicles' development under different scenarios have been quantitatively simulated by using a developed game theory-based analysis model. The obtained results show that: (i) the dual-credit policy can effectively promote the development of new energy vehicles, with this policy (in scenario NSC and SC) the proportion of NEV in the whole auto market will be up to 3.9%; (ii) compared with green-car subsidy, the dual-credit policy can significantly increase the amount of new energy vehicles to two times as much as that of current subsidy level; and (iii) when the dual-credit policy is implemented, green-car subsidy will not further promote the development of new energy vehicles.

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## 1. Introduction

China has become the world's largest motor vehicles market since 2009 [1]. During 2016, more than 27 million motor vehicles were sold in China, making-up around 30% of the world trading volume [2]. Meanwhile, the rapid development poses enormous challenges for the energy consumption and environment in China [3–6]. In recent years, new energy vehicles (NEVs) have been regarded as an useful alternatives to internal combustion engine vehicles (ICEVs) considering threats from air pollution and carbon emission [7–11]. Importantly, NEVs do not rely on fossil fuel. Therefore, NEVs decrease vehicle exhaust emissions and some even do not produce exhaust emissions. The Chinese government has been making substantial efforts in promoting NEV market penetrations [12–14]. Since 2010, China's government (at all levels) issued many policies designed to support the rapid development of NEVs as critical strategy for the automobile industry. In 2012, the NEV industry was listed as a strategic newly emerged industry [15].

In 2016, energy saving and NEV development were assigned as priority themes in the state long-term development plan (2016–2020) [16]. In addition, Chinese industry's goals for 2025 list the NEV industry as a key sector [17]. However, most auto companies lack sufficient economic incentive to produce NEVs because the prohibitive cost gives NEVs no advantage over conventional ICEVs with respect to the manufacturer's suggested retail price [18–20].

Traditionally, governments provide subsidies or tax exemptions to facilitate the development of new technologies [21]. Vehicle purchase incentives for NEVs have been adopted in many countries. In the U.S. activated by the Energy Policy Act of 2005, a maximum of \$3400 income tax credit was provided to hybrid electric vehicle (HEV) purchase after December 31, 2005. The incentive for PHEV and BEV purchase started in 2010, which offers \$2500–\$7500 tax credit to PHEV and BEV purchase depending on vehicle's battery capacity [22]. As the world's most determined NEV propellant, Chinese government adopted green-car subsidy policy to boost the NEV adoption since 2009 [23], which included a subsidy per unit of NEV and varied among different types [24]. The monetary subsidy policy has encouraged NEV market penetration effectively [23,25,26]. However, the policy has several drawbacks at the same

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Nomenclature			
<b>Acronyms</b>			
NEV	new energy vehicle	$n_2$	lower limit of production increasing rate of internal combustion engine vehicles
ICEV	internal combustion engine vehicle	$S_{NEV}$	green-car subsidy for one unit of new energy vehicle
CAFC	corporate average fuel consumption	$FCN_{NEV}$	new energy vehicle credits for a unit of new energy vehicle
NEVC	new energy vehicle credit	$FCT_{NEV}$	fuel consumption per 100 km of new energy vehicle
CAFC	corporate average fuel consumption credit	$FCT_{ICEV}$	fuel consumption per 100 km of internal combustion engine vehicle
<b>Indices</b>		$T_{CAFC}$	target corporate average fuel consumption value
i, j	auto company (I, II, III, IV)	a	proportion requirement for new energy vehicle credits
<b>Parameters</b>		b	ratio of corporate average fuel consumption to target corporate average fuel consumption value
$P_{NEV}$	market price of new energy vehicle	c, d, e	parameters of cost function of new energy vehicles
$P_{ICEV}$	market price of internal combustion engine vehicle	<b>Decision variables</b>	
$MC_{ICEV}$	marginal cost of internal combustion engine vehicle	$nq_{NEV}$	new production volume of new energy vehicles
$FC_{NEV}$	fixed cost of new energy vehicle	$nq_{ICEV}$	new production volume of internal combustion engine vehicles
$FC_{ICEV}$	fixed cost of internal combustion engine vehicle	$qp_{NEVC, i, j}$	annual credits company i purchase from company j to offset NEV credit shortfall
$OQ_{NEV}$	historical production of new energy vehicle	$qp_{CAFC, i, j}$	annual credits company i purchases from company j to offset CAFC credit shortfall
$OQ_{ICEV}$	historical production of internal combustion engine vehicle	$qs_{NEVC, i, j}$	annual new energy vehicle credits company i sells to company j
$m_1$	upper limit of production increasing rate of new energy vehicles	$p_{NEVC, i, j}$	selling price of new energy vehicle credits from company i
$m_2$	upper limit of production increasing rate of internal combustion engine vehicles	$p_{NEVC, j, i}$	selling price of new energy vehicle credits from company j
$n_1$	lower limit of production increasing rate of new energy vehicles		

time. Firstly, large number of subsidies for NEVs imposed a heavy fiscal burden on the Chinese government which has made the subsidy unsustainable, by the estimation from existing studies, subsidy that Chinese government afforded during the 13th Five-Year Plan was up to 400 billion RMB [27]. Subsidies alone may not be sufficient for accelerating market penetration in the future; thus, the policy could be costly and ineffective [28]. Secondly, large subsidies as well as incomplete policy drove enterprise to cheat on the NEV production number to gain more profit. The generous and huge subsidies from governments easily caused fraudulent actions to obtain subsidies [29]. A survey conducted by the Ministry of Finance about the cheating phenomenon which involved 93 motor vehicle enterprises, the result of which showed that 77% of the enterprises within the survey cheated to gain more subsidies, and the money related to the cheating behavior was up to 10 billion RMB [30]. Therefore, the Chinese government determined to adjust the former policy and emphasized a stepwise decline of the subsidy rate till 2020, after which subsidy policy will be completely cancelled [31].

To further boost the development of the new energy vehicle industry and achieve structural reform of the supply side, governments in other countries have implemented repressive regulations such as Corporate Average Fuel Economy (CAFÉ) and California's Zero Emission Vehicle (ZEV) program. Learning from America's experience, China's government added a new NEV credit program to the existing corporate average fuel consumption regulation [32] for passenger cars [33]. The New-Energy Vehicle Credit Program and Corporate Average Fuel Consumption Regulation (hereinafter referred as "dual-credit policy [34]") was finalized in September 2017 and will enter implementation on April 1, 2018. Different from the green-car subsidy policy that pays a fixed subsidy for NEV production, the dual-credit policy changes the incentive for NEV

production from subsidy-driven to market-driven which, in turn, transfers the fiscal burden from the Chinese government to the enterprise. Enterprises which cannot adapt to the no-emission production structure and achieve the goal to improve NEV production will be eliminated from the market, due to the heavy financial burden from the cost of credit-purchasing or penalties.

Existing studies about NEV industry policies have addressed problems in many aspect, with a focus on financial incentives, such as tax credits and direct subsidies. Sierzchula et al. [35] examined the relationship between policies and electric vehicle market shares, concluding financial incentives were statically significant. Langbroek et al. [36] investigated the effect of several potential policy incentives on EV-adoption, using constructs of the Trans-theoretical Model of Change and the Protection Motivation Theory. The results show that financial policies could increase the probability of EV-adoption by decreasing the generalized cost of EV-use. Some scholars also studied these issues in the context of China. Han et al. [22] presented the rationale of China's phase I and phase II EVSS (Electric Vehicle Subsidy Scheme) and estimated their impacts on vehicle ownership cost on battery electric passenger vehicles. Their study indicates that China's EVSS is very necessary for battery electric passenger vehicles to be cost competitive compared with conventional passenger vehicles in the short time, especially before 2015. Ma et al. [37] established a multivariate co-integration model and an error correction model to analyze the long- and short-term effects of a number of NEV policies instituted by Chinese government, and The results demonstrate positive co-integration for the relationship between the NEV market share and the NEV purchase subsidy, tax exemption.

While some studies explored auto companies' responses to repressive regulations such as CAFÉ (Corporate Average Fuel Economy) and ZEV (Zero Emission Vehicle) program and examined

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