Energy Policy 148 (2021) 111983

Contents lists available at ScienceDirect

Energy Policy

journal homepage: http://www.elsevier.com/locate/enpol

Policy Perspective

A review of evolutionary policy incentives for sustainable development of electric vehicles in China: Strategic implications

Yang Andrew Wu [a], Artie W. Ng [a,*], Zichao Yu [b], Jie Huang [c], Ke Meng [d], Z.Y. Dong [e]

[a] Research Centre for Green Energy, Transport and Building, School of Professional Education and Executive Development, College of Professional and Continuing Education, The Hong Kong Polytechnic University, Hong Kong, China
[b] Paul H. O'Neill School of Public and Environmental Affairs, Indiana University, Bloomington, IN, United States
[c] State Grid Electric Power Research Institute, China
[d] School of Electrical Engineering and Telecommunications, University of New South Wales, Australia
[e] Director of UNSW Digital Grid Futures Institute, School of Electrical Engineering and Telecommunications, University of New South Wales, Australia

ARTICLE INFO

Keywords:
Electric vehicle
Sustainable development
Policy incentives
Financial subsidy
China

ABSTRACT

The Chinese government has introduced policy measures and financial incentives to promote electric vehicles (EVs) in alignment with its advanced industrial development and environmental sustainability. In order to stimulate market adoption and technological innovation, a dual-credits policy regime with strictly guided subsidies was first announced in 2017 and then tightened up in 2019 by relevant authorities of the central government. This study focuses on examining the latest development of EV policy in the Chinese mainland. It reviews the pertinent national-level policy measures and financial incentives for sustainable development of the EV industry in a macro scope over the past decade. Further, we develop a mathematical model to quantify the impact of the most update policy – the dual-credits policy regime. Our simulation results reveal a significant gap between the recent EV sales and the estimated future EV production needed under the new policy regime. Such significant gap implies remarkable policy pressure and inevitable execution challenges of the recently tightened dual-credits regime. In conclusion, we articulate strategic implications for EV market participants in China. Upcoming challenges including gradual phasing out of financial support and impending market competition are discussed.

1. Introduction

Facing the imperative of sustaining energy security, reducing pollution, and combating global climate change, both developed and developing countries have responded with policies to electrify their transportation sector (Aune et al., 2016; Poullikkas, 2015). China is of no exception. In 2010, the State Council issued the "Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries", which classified the electric vehicle (EV) industry, energy conservation industry, environmental protection industry, and other related industries as the strategically emerging industries in China (State Council, 2010). Strategically emerging industries are defined as industries with huge technological innovation potential and in their early stage of development. China's central government plays a major role in promoting strategically emerging industries by issuing a series of supportive policies (Hao et al., 2014; Wang et al., 2017a). China has emerged as a leading country in terms of EV sales numbers in the world and is expected to continue to promote EV technologies and applications in the future. Clearly, studying the policy incentives and influence from the national level has important theoretical and practical significance.

The EV industry is a typical example of strategically emerging industry in China and of great significance in leading China's economic and technological development over the past decade (Zhang et al., 2017). It is currently in the technical and commercial demonstration stage. Market demand is an important driving factor for the development of the EV industry in China, of which public and private demands are two different aspects that entail different policy incentives (W. Li et al., 2016). In recent years, relevant national ministries and

* Corresponding author. Research Centre for Green Energy, Transport and Building, School of Professional Education and Executive Development, College of Professional and Continuing Education, The Hong Kong Polytechnic University, Hong Kong, China.
E-mail addresses: andrew.wu@cpce-polyu.edu.hk (Y.A. Wu), artie.ng@speed-polyu.edu.hk (A.W. Ng), zichyu@indiana.edu (Z. Yu), huangjie1@sgepri.sgcc.com.cn (J. Huang), ke.meng@unsw.edu.au (K. Meng), zydong@ieee.org (Z.Y. Dong).

https://doi.org/10.1016/j.enpol.2020.111983
Received 3 May 2020; Received in revised form 2 September 2020; Accepted 12 October 2020
Available online 3 November 2020
0301-4215/

commissions and a few cities have successively introduced EV promotion policies, with government procurement and financial subsidies as the main methods (Wu and Guo, 2020). The government procurement and financial subsidies have played important roles in promoting the commercialization of EV and instilling manufacturers' enthusiasm (Zhou et al., 2015). In particular, with the gradual implementation of the financial subsidies since 2016, there has been a large boost in the production and sales of EV. This also demonstrated the reliance of EV manufacturers on financial subsidies (Y. Li et al., 2016). However, consumers' intention of purchasing EV still faced obstacles and issues pertinent to financial subsidies and convenience of ownership (Wang et al., 2017b). The effectiveness of government subsidies in stimulating public and private demand was a practical problem in the implementation of EV promotion policies. The state and local governments have continuously issued relevant supporting policies to promote the development of China's EV industry; in particular, these policy documents reflected the country's determination, intention and strategic approach (Wu et al., 2014; Liu et al., 2017).

The State Council of China has announced several guidelines on accelerating the promotion and application of EVs and related charging infrastructure in the past decade. The National Development and Reform Commission (NDRC), the Ministry of Finance (MOF), the Ministry of Industry and Information Technology (MIIT), the Ministry of Science and Technology (MST), and other relevant authorities have taken actions to introduce various policies, such as pilot demonstration, research and development (R&D), advancing industrialization, EV purchase subsidies, tax reductions and exemptions, easy market access, and infrastructure construction (Wang et al., 2019). Those policy documents have formed a policy system, which greatly motivates the enthusiasm of enterprises in R&D, production, market promotion and application, and have strongly supported the development of the electric vehicle industry (Ou et al., 2018). Although the development of EV industry in China may have achieved an early-mover advantage, its foundation of industrial development and related core technologies need to be upgraded. Thus, overall supportive environment, including policy system, needs to be improved as well (Sovacool et al., 2019).

Prior international studies in examining adoption of EVs have identified the significance of economic incentives and governmental regulations as part of an integrated framework (Rezvani et al., 2015; Sovacool, 2017; Kumar & Kumar, 2020; Ou et al., 2019). Pertinent policies are developed by governments through the design, organization and deployment of various policy tools, which are meant to be supportive of attaining certain policy goals.

Most of the previous researches on EV policy in China focused on micro analysis of several specific policy regimes, including case study and scenario analysis for some regional policies. For example (Lin and Wu, 2018), conducted a survey in four largest cities in China, namely: Beijing, Shanghai, Guangzhou, and Shenzhen. They analyzed general public's cognition of EV related policies in those four cities with consideration of network externality, price acceptability, government subsidies, vehicle performance, and environmental concerns. Specifically, local support and future development of EV market in Beijing have been investigated by Zhuge et al. (2019). EV market expansion in Beijing could influence the development of EV-related transport facilities, including parking lots, refueling stations, and charging posts at parking lots. Qiu et al. (2019) extended the statistical data from the above four largest cities to eighty-eight pilot cities in China. They assessed the effectiveness of EV related policies at city level, using regression analysis as quantitative tool. Positive relationships between EV sales volume and two demand-side policies related with charging discount and infrastructure construction subsidy were found. With respect to sustainability, environmental contribution of EV promotion as a result of supportive policies has been revealed by Guo et al. (2020).

However, previous studies on this subject matter may not yet be comprehensively in-depth, especially under the rapid development of EVs. Few researches have performed a macro analysis or a comprehensive review of the policy incentives in the past decade from a central planning perspective in China. Further research on industrial policies at a national level is needed, especially on the overall impact resulting from the EV market response to China's latest EV policies over the next few years. In fact, the dual-credits policy regime has been recently further tightened. Impacts of the tightened Corporate Average Fuel Consumption (CAFC) credits regime and New Energy Vehicle (NEV) credits regime on the automobile industry in China has not been revealed sufficiently. This article aims to fill the research gap in this particular policy area and to provide relevant reflections to the stakeholders of the emerging EV industry.

From the policy perspective of the central planning, this study initially reviews and analyzes the supportive incentives of EV market in China for the past decade in Section 3, following the research methodology in Section 2. Those policy tools have actively intervened in the development of industrial activities for long-term interests. In addition, the ministries and commissions of the central government further tightened the financial subsidy on the dual-credits policy regime since 2019. First, we build a mathematical model to quantify the impact of CAFC credits regime and NEV credits regime on the automobile industry in China in Section 4. Simulation and scenario analysis then follow to reveal a significant gap between the actual EV sales from 2013 to 2019 and the estimated EV production from 2020 to 2023 if to meet the tightened requirement of dual-credits policy. This study points out how the further tightened dual-credit regime would instigate the next stage of the EV market development in China towards a competitive basis. Section 5 discusses the strategic consequence of implementation of such a new policy for the EV industry to the market participants and their private investors let alone the economic incentives provided by the government during the earlier years. Conclusion and future research plans are summarized in Section 6.

2. Methodology

A longitudinal approach to review the significant policies at national level for sustainable development of EVs in China over the past decade is adopted for this study. A qualitative review of national policies over an extended period is complemented by quantitative analysis of the resultant EV sales in the country. These national policies are formulated and pronounced by various ministries and authorities of the country, namely the Ministry of Industry and Information Technology (MIIT), Ministry of Finance of China (MoF), Ministry of Science and Technology (MST), National Development of Reform Commission (NDRC) and the State Council. Mathematical model is built to quantify the dual-credits policy regime via CAFC credit and NEV credit. A comparison is made between domestic companies and joint venture enterprises under the CAFC credits regime and NEV credits regime following the further tightening of such dual-credits policy regime. Total EV production from 2020 to 2023 is then estimated at national level. A bottom-up approach is then utilized to review the EV sales in the past six consecutive years. As a result, a remarkable gap is revealed between the EV sales in the past and in the near future, which implies policy pressure and execution challenges of the dual-credits policy. In conclusion, suggestions for market participants are elaborated for coming challenges including gradual phasing out of financial support and impending market competition.

3. Review of past policy incentives for EV development

In the "12th Five-Year Plan for EV Development" issued in 2012, China officially proposed to implement the three-step strategy for the industrialization of electric vehicles and divided the process into three phases. Phase I: 2009–2012; Phase II: 2013–2015; Phase III: 2016–2020. So far, China has successfully completed the first two stages. The pertinent policies over the period of 2009 to 2020 and thereafter are highlighted in Fig. 1.

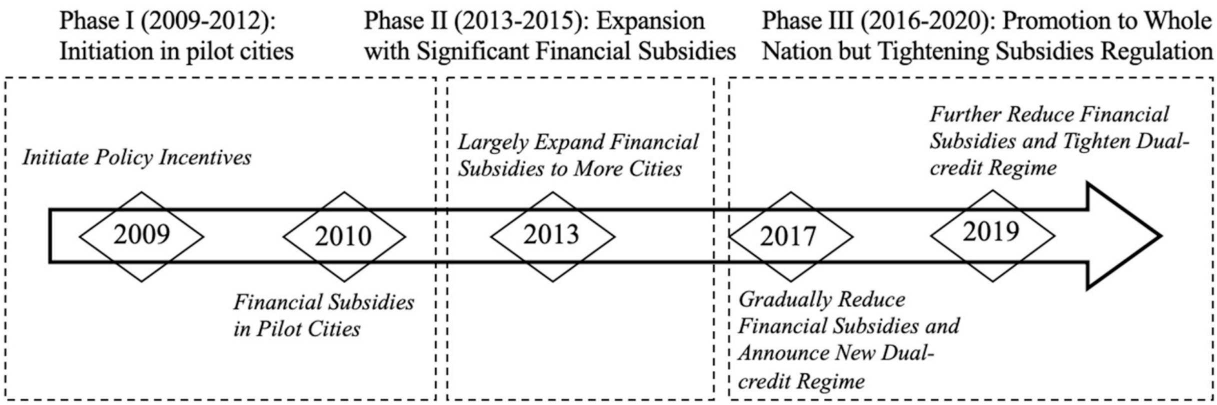

Fig. 1. Milestones of national EV policy incentives in China.

3.1. Phase I 2009–2012: initiation in 25 pilot cities

Policies in Phase I started from pilot projects in urban area of several key cities, as summarized in Table 1. Most pilot cities chose hybrid EVs for their demonstration projects. However, technological readiness and lack of resources were considered obstacles for success of those demonstration projects (Zheng et al., 2012; Hu et al., 2010). Financial subsidies mainly focused on public transportation sectors, yet the subsidies were lower than the market expectation.

The nationwide industrialization and commercialization for EV in China commenced in early 2009. By providing financial subsidies, public transportation followed by private consumption, and the steps from urban trials, regional trials, and nationwide promotion have been steadily advanced. The policy was set to stimulate investments, drive industry growth, and reduce the initiation period. However, the subsidy was planned to be phased out and its eligibility threshold increased gradually. Standards were to be updated to guide technological progress and industry upgrade, and form industrial clusters with global competitive advantages. Subsidy policies have undergone three various stages of adjustment for industrial development.

A total of 25 pilot cities, including Beijing, Shanghai, and other representative cities in each region of China, were gradually put into operation in the national project named “Ten Cities and Thousands of EVs”. In this phase, EV industry was in the very early stages of industrialization, and the infrastructure and the performance of supply-side models were under developed. The national project of “Ten Cities and Thousands of EVs” lagged behind the original plan. As a result, only around one-third of the original goals have been attained by October 2011 (Gong et al., 2013). The promotion activities and subsidy amounts were lower than the market expectation. However, Phase I managed to build an essential foundation for technological development and policy framework for the EV industry.

In December 2012, Ministry of Industry and Information Technology of China (MIIT) required the pilot cities to report on their working experience of demonstration projects and financial subsidies for the EV industry (MIIT, 2012), which wrapped up the first phase of EV-related policy incentives. Policy incentives in the first phase were mainly located in pilot cities rather than the whole nation. Guidelines for execution in pilot cities were then enhanced with more feasible details year by year. Phase I provided relevant experience and foundation for the subsequent policies in Phase II and III.

3.2. Phase II 2013–2015: expansion to 88 cities with significant financial subsidies

Policies in Phase II gradually promoted EV pilot projects to wider regions, in comparison with Phase I. Financial subsidies were provided to both public and private transportation sectors with subsidies amount increased rapidly. Domestic consumers began to adopt EV at comparable pricing in relation to the conventional automobiles. The rapid growth of EV adoption in this phase was a result of massive financial subsidies guided by the central government (Helveston et al., 2015; Wang et al., 2017c; Yuan et al., 2015).

In September 2013, the MIIT, the Ministry of Science and Technology (MST), the Ministry of Finance (MOF), and the National Development of Reform Commission (NDRC) jointly issued the financial subsidy policies for EV industry, based on the results of pilot projects in Phase I to further stimulate EV development, as shown in Table 2 below. Financial subsidies were distributed to 88 cities through the locally supportive procedures in 2014. The subsidy amounts were still relatively small, though it was considerably more extensive than those introduced in 2009–2012. More importantly, EV related infrastructure was been improved in those 88 cities during this phase. The technical performance of high-end EV models was also augmented. As a result, the EV market was observed to be taking off since late 2015 in China.

In Phase II, the EV-related policy incentives expanded from pilot cities to multiple provinces. In this phase, EVs were more widely adopted in China given the strong policy support and massive financial

Table 1
National-level policies on EV financial subsidies in China (phase I).

Timeline of Execution	Policies Documents	Financial Subsidies (in US dollar, approximate and rounded)				Remarks
		Private EV (pure electric)	Private EV (hybrid)	Public Electric Bus (pure electric)	Public Electric Bus (hybrid)	
2009	Announcement on the pilot demonstration projects for promoting energy conservation and EVs (State Council, 2009)	Maximum 8,500	Maximum 7,000	Maximum 71,000	Maximum 60,000	Private cars are subsidized by energy saving ratios.
2010	Announcement on expanding the demonstration projects for promoting energy conservation and EVs in public service sectors (MIIT, 2010a)	N/A	N/A	Same as above	Same as above	Requirement on battery capacity and cruise range
2010	Announcement on the pilot subsidies for EVs in private sectors (MIIT, 2010b)	Same as above	Same as above	N/A	N/A	Requirement on battery capacity and cruise range

Table 2
National-level policies on EV financial subsidies in China (phase II).

Timeline of Execution	Policies Documents	Financial Subsidies (in US dollar, approximate and rounded)				Remarks
		Private EV (pure electric)	Private EV (hybrid)	Public Electric Bus (pure electric)	Public Electric Bus (hybrid)	
2013	Announcement on Continuing Promotion and Application of EV (State Council, 2013)	Maximum 8,500	Maximum 5,000	Maximum 71,000	Maximum 36,000	Private cars are subsidized by cruising range per full charge; Public buses are subsidized by vehicle length.
2014	Announcement on Further Continuing Promotion and Application of EV (MST, 2014)	Maximum 8,000	Maximum 4,700	Maximum 67,000	Maximum 34,000	Same as above

subsidies. However, some problems like adverse selection and moral hazard came up in a few cities. Therefore, central government began to consider introducing stricter constrains for financial subsidies and to promote technological innovation of EV industry at the same time.

3.3. *Phase III 2016–2020: promotion to whole nation but tightening subsidies regulation*

In this phase, the whole industrial chain of EV industry was established and upgraded at the national level. At the same time, financial subsidies from central government gradually declined, while technical entry barrier for EV industry increased. Strong intervention was implemented to guide and drive EV's sustainable development, especially to promote technological innovation and to improve energy efficiency (Rong et al., 2017; Wang et al., 2018a,b).

In 2016, the MIIT, NDRC and MOF jointly announced that a series of inclusive subsidy policies would be implemented from 2016 to 2020 (see Table 3 on related policies) (MOF, 2015; MOF, 2019). Adoption of EVs was promoted from the previous pilot cities to the whole nation. High subsidies were still maintained in 2016, but due to the exposure of several "fraudulent" incident in 2015, adjustment was considered necessary. Therefore, in 2017, these subsidies were reduced with increased thresholds. Commercial vehicle subsidies were significantly reduced in 2017, by 40-60%, and passenger vehicles were reduced by 20%. Land subsidies set an upper limit, which could not exceed 50% of national subsidies. Commercial vehicles continued to decline by 40-50% in 2018, leaning towards high-end passenger cars. Compared with 2017, subsidies for high-endurance passenger cars increased without falling. In 2019, the decline in financial subsidy was about 50%, and the supplementary compensation was cancelled. Technical indicators continued to be refined and tightened to drive technological upgrade in EV industry.

4. The new dual-credits policy as further tightened regime

4.1. *A quantitative approach to analyzing the new dual-credit policy regime*

Besides the above policies directly guiding financial subsidies for the EV industry, the State Council of China and related authorities introduced alternative policies that guide technological innovation and industrial upgrade beyond simply providing financial subsidiaries. In 2017, the Chinese government issued several instructive policies to guide the development of the EV industry. In April 2017, the MIIT, MST, MOF, and the NDRC, jointly issued the Medium- and Long-Term Development Plan for the Automotive Industry (MIIT, 2017a), which clearly required the development of advanced automotive technologies to form EVs, intelligent connected vehicles, and advanced energy-saving vehicles. This is considered the technological foundation for the subsequent policy making. The MIIT officially, then, issued the "Measures for the Parallel Management of Average Fuel Consumption and EV Credits for Passenger Car Companies" in September 2017, which was applicable to almost all automobile companies in China, including imported cars (MIIT, 2017b). Corporate Average Fuel Consumption (CAFC) credits and production of New Energy Vehicle (NEV) credits would be assessed by a system of "dual-credits". Therefore, this policy is also widely known as "Dual-credits Policy". The dual-credits policy is evaluated based on two dimensions: CAFC credits and NEV credits.

The CAFC credit is the scalar product between: (i) the difference between the standard value and actual value of the average fuel consumption of a specific automobile enterprise, and; (ii) the total automobile production of that enterprise in a calendar year. If the actual value of CAFC credit is lower than the standard value (defined by the authorities), a positive result will be generated. And if the actual value is higher than the standard value, a negative result will be generated. CAFC credits are updated every year. If the CAFC credit of one company is a positive number, the company may accumulate the points to its CAFC reserve pool. If CAFC credit is a negative number, the company

Table 3
National-level policies on EV financial subsidies in China (phase III).

Timeline of Execution	Policies Documents	Financial Subsidies (in US dollar, approximate and rounded)				Remarks
		Private EV (pure electric)	Private EV (hybrid)	Public Electric Bus (pure electric)	Public Electric Bus (hybrid)	
2016	Announcement on Financial Support for EVs 2016–2020 (MOF, 2015)	Maximum 7,800	Maximum 4,300	Maximum 71,000	Maximum 36,000	Private cars are subsidized by cruising range per full charge; Public buses are subsidized by vehicle length and battery capacity.
2017	Announcement on the Adjustment of EV Financial Subsidies Policy (MIIT, 2016)	Maximum 6,300	Maximum 3,400	Maximum 43,000	Maximum 21,000	Private cars are subsidized by cruising range per full charge and electric power consumption per 100 KM; Public buses are subsidized by vehicle length and battery capacity.
2019	Announcement on the Further Adjustment of EV Financial Subsidies Policy (MOF, 2019)	Maximum 3,600	Maximum 1,400	Maximum 13,000	Maximum 5,400	Same as above

has to utilize the accumulated credits in its CAFC reserve pool from past years to compensate the negative number this year. If there are not sufficient accumulated credits in the reserve pool, the company is required to purchase credits from other companies who have extra positive credits.

A mathematical model is developed for predicting the CAFC credits and NEV credits following the requirement of the dual-credits policy. The mathematical model is elaborated in this section. Furthermore, in the next section, we modify this mathematical model to estimate the total EV production quantity in national level in the next few years till 2023, in order to fulfill the requirement of the dual-credit policy. The result implies policy pressure and execution challenges in the national level when implementing the dual-credits policy.

Under the regulation of dual-credits policy regime, an automobile company is required to calculate its CAFC credit and update the result to related authorities on an annual basis as follows:

$$CAFC_{actual} = \frac{\sum_{i=1}^{n}(FC_i \cdot Q_i)}{\sum_{i=1}^{n} Q_i}$$

$$CAFC_{required} = \frac{\sum_{i=1}^{n}(FC_i \cdot Q_i)}{\sum_{i=1}^{n} Q_i} \cdot K$$

$$CAFC_{credit} = CAFC_{required} - CAFC_{actual}$$

Where,

$CFAC_{actual}$ is the actual CAFC credit that an automobile company obtained in a year;
$CFAC_{required}$ is the benchmark CAFC credit that national authorities required automobile companies to achieve in a year;
i is a conventional vehicle model produced by this company;
n is the total quantity of the vehicle models (not the vehicle) produced by this company;
FC_i is the fuel consumption of a conventional vehicle model i;
Q_i is the total production quantity of the specific vehicle model i;
K is the multiplier for calculating $CAFC_{required}$.
Multiplier $K$is set by related national authorities , the valye of which is shown in Table 4.

Similarly, under the regulation of dual-credits policy regime, an automobile company is required to calculate its NEV credit and update the result to related authorities on an annual basis as follows:

$$NEV_{actual} = \sum_{j=1}^{m}(C_j \;\; n \;\; Q_j)$$

$$NEV_{required} = Rn\sum_{i=1}^{n} Q_i$$

$$NEV_{credit} = NEV_{actual} - NEV_{required}$$

Where,

NEV_{actual} is the actual NEV credit that an automobile company obtained in a year;
$NEV_{required}$ is the benchmark NEV credit that national authorities required automobile companies to achieve in a year;
C_j is the NEV credit that earned by an EV model j of the automobile company;
Q_j is the total production quantity of a specific EV model j of the automobile company;
Q_i is the total production quantity of the specific conventional vehicle model i of the automobile company;
R is the multiplier for calculating NEV credits, which is a constant number but increasing from 2019 to 2023, as shown in the above Table 4, set by national authorities.

Table 4
Multipliers for calculating CAFC and NEV credits.

	2019	2020	2021	2022	2023
K	110%	100%	100%	100%	100%
R	10%	12%	14%	16%	18%

The ultimate goal of the regime of NEV credits is similar to that of CAFC credits. The NEV credit is determined based on the difference between the actual value of an automobile enterprise and its standard value for manufacturing electric vehicles. If the actual value is higher than the standard value, a positive result is generated. However, if the actual value is lower than the standard value, a negative result is generated. Specifically, the NEV standard value increases year by year, as required in the further tightened dual-credits policy, which indicates the higher requirement for technological innovation. Negative points must be offset by purchasing positive points from other automobile companies. At the same time, fuel consumption standards would become more stringent year by year as well. Therefore, the difficulty of achieving CAFC points is expected to increase year by year.

In fact, the dual-credits policy was, then, revised and further tightened by the central government and related authorities in September 2019 (MIIT, 2019b). Such details, including policy reasons and market response, are deliberated in the following sections.

A selected list of some of the prominent players is produced for a preliminary comparison between domestic companies and joint venture enterprises (see Table 5).

Among the domestic companies, BYD, a well-known and iconic private EV manufacture in China, achieved most NEV credits and ranked champion in the list. Other notable examples are SAIC Motor and BAIC Group which obtained strong support from both central and local governments. SAIC Motor is based in Shanghai; meanwhile BAIC Group is based in Beijing. JAC Motors, on the other hand, achieved high NEV credits through providing OEM service for Nio Automobile, a relatively new but aggressive private manufacturer in China.

In addition to the above four companies, the list of automobile manufacturers with positive NEV credits includes GAC Group, FAW Group, and Great Wall. Accumulatively, they contributed more than

Table 5
Selected list of 2019 dual-credits of automobile enterprises in China.

Category	Company Name	Manufactory Amount of Passenger Cars	CAFC Credits	NEV Credits
Domestic Companies	BYD	404,417	1,645,597	885,561
	BAIC Group	210,244	763,447	676,442
	JAC Motors	125,282	501,128	263,637
	GAC Group	306,128	347,913	224,300
	SAIC Motor	549,694	555,191	171,321
	Great Wall	858,806	103,057	133,906
	FAW Group	339,609	84,902	120,010
Joint Venture Enterprises	SAIC-GM	2,637,386	(994,490)	23,176
	BMW-Brilliance	534,990	240,746	15,753
	Tesla (Shanghai)	927	5,608	5,562
	GAC-Toyota	670,638	152,427	(36,699)
	Beijing-Hyundai	646,118	(335,981)	(51,194)
	Beijing-Benz	564,665	(231,513)	(52,693)
	GAC-Honda	762,048	(68,584)	(57,735)
	SAIC-Volkswagen	1,913,991	(191,300)	(96,664)
	FAW-Volkswagen	2,034,960	(549,439)	(145,274)

90% of positive NEV credits all over the nation.

For joint venture enterprises, there were 6 companies whose NEV credits were positive, and 16 ones whose NEV credits were zero, and another 5 one with negative credits. Different from domestic automobile manufactures, most joint venture enterprises have not achieved high NEV credits in the list. In fact, among all joint venture enterprises, only SAIC-General Motor and BMW-Brilliance achieved positive NEV credits, almost all other joint venture enterprises held at the bottom of the list. Notably, the NEV credits of Tesla (Shanghai) were relatively low as well. The reason might be Tesla (Shanghai) just started their new manufacture plant in China since the fourth quarter of 2019. Thus, the total EV manufactory amount of Tesla (Shanghai) is lower than those domestic automobile manufacturers.

Some world-widely known brands, like FAW-Volkswagen, SAIC-Volkswagen, GAC-Toyota, GAC-Honda, Beijing-Benz, and Beijing-Hyundai, achieved the lowest NEV credits for the year 2019 in the list. One major reason was those joint venture companies emphasized their manufactory and sales business of conventional vehicles rather than EVs, especially in the Chinese market.

4.2. Recent development: tightened dual-credits regime

The dual-credit policy regime was introduced reflecting that the development of EV policies has turned from an era of initial design to an era of evaluating the effectiveness of the earlier policies with responsive and corrective measures. In China, two significant shortcomings in implementing such policies have been identified. The first shortcoming is the failure of policy coordination (Wang and Zhang, 2017). The reasons include deviations in the focus of policy incentives, incomplete policy objects, and untimely introduction of policy tools (Liu and Meng, 2017). The second shortcoming is moral hazard. Risks and adverse selection occur frequently (Li et al., 2019) in the past several years, because the government has a certain degree of failure. The exposure of such scam incidents in the EV industry was evidence of the above two shortcomings. It appears that future policies would deploy more market mechanisms to guide the use of subsidies and the effective development for the EV industry.

If one automobile enterprise's CAFC credit or NEV credit is negative, the enterprise needs to adjust its production plan so that extra positive credits will be generated via the adjusted production plan. The extra positive credits will be used to offset the negative credits. Therefore, automobile enterprises are discouraged to launch new products with high fuel consumption into the market until both credits meet the requirement. At the same time, the automobile enterprises are driven to produce more EVs.

Although the dual-credits policy may be able to slow down the growth of conventional vehicles with internal combustion engines but promoted sustainable development and growth of EVs (Wang et al., 2018a,b; Li et al., 2020a), without appropriate adjustment in the rules of credit calculation and more stringent targets of NEV credits, this policy could hardly meet the energy saving goals despite the existence of the CAFC credits. EV industry was at a considerably vulnerable position last year and the dual-credits regime may need some necessary refinements (Li et al., 2020b, 2020c). Therefore, the dual-credits policy regime was revised and further tightened by the central government and related authorities in September 2019 (MIIT, 2019a; MIIT, 2019b). Upon the further tightening, financial subsidies of EVs would be completely withdrawn by 2021. The dual-credits policy regime is expected to be relayed with a long-term prospect.

The further tightened dual-credits policy regime became effective in the fourth quarter of 2019, which brought about noticeable impact to the EV market. Since early 2020, only 50% of positive NEV credits could be accumulated into the reserve pool and carried forward to the next year. The carry-forward period would be capped up to three years. The punitive dual-credits policy has forced automobile companies to increase investments in technological innovation, and to provide more cost-effective and high-quality models. In fact, it is found the dual-credits policy has already stimulated EV sales and drove investments into technological innovation to improve energy efficiency for EVs (Ou et al., 2018b). Thereafter, the EV industry is expected to be able to maintain stable development after financial subsidies are completely withdrawn in the near future.

It is observed that the multiplier K is declined from 2019 to 2020 and expected to be kept constant from 2020 to 2023 as set by relevant national authorities. Thus, the will be increasing over the years if other variables kept unchanged. As required by the dual-credits policy, on one hand, the NEW ratios that automobile companies need to follow are increasing year on year from 2018 to 2023; on the other hand, the policy requires a declining average fuel consumption, as illustrated in Fig. 2 below. Therefore, there will be increasingly remarkable challenges for the automobile companies to meet the dual-credit policy especially under the CAFC regime.

Overall, the dual-credits regime is considered as a policy formulated at the national level to improve the energy saving level of automobiles, to ease energy and environmental pressures, and to promote the sustainable development of EV industry. In the context of a substantial decline of financial subsidies for EVs, the implementation of the dual-credits policy has undertaken the important task of driving the EV growth in domestic market in the near future.

By April 2020, the MIIT announced the average CFAC and NEV credits list of automobile companies in China for the year of 2019 (MIIT, 2020a), as the first official statistic result after further tightening the dual-credits policy. Notably, only about 52% of the automobile companies in the list have achieved positive NEV credits. Among them, over 90% are domestic manufactures. For domestic automobile manufacturers, there were overall 70 companies which NEV credits were positive, 19 with zero NEV credit, and another 30 with negative credits.

The central government further tightened dual-credits policy regime. On the one hand, the government expected to drive technological innovation of EV industry. On the other hand, the government also expected to improve energy security via reducing fuel consumption. However, as shown in Table 4, the strong contrast of CAFC credits between domestic companies and joint venture enterprises has revealed unexpected problems during implementation of the further tightened dual-credits policy regime. The further tightened dual-credits policy targeted to sustain the long-term market development of EV, especially technological innovation, in China.

4.3. Policy pressure and execution challenges

4.3.1. Dilemma of tightened dual-credits regime: increasing EV sales pressure whilst slowing down of actual EV sales

While the mathematical model for quantifying the dual-credits policy impact is illustrated in Section 4.1 of CAFC and NEV credits, this section estimates the national EV sales in the next few years from 2020 to 2023, which is then compared with the actual EV sales in the past six years (MIIT, 2020b). A significant gap between the past sales and estimated sales in the future reveals policy pressure and execution challenges of the dual-credits regime.

4.3.1.1. Increasing EV sales pressure to meet the tightened dual-credits regime. It is widely recognized in the automobile industry that the tightened Dual-credits policy regime requires more EV production and sales in the next few years. But to what extent? This section estimated the required EV production from 2020 to 2023 at national level, in order to meet the requirement of tightened dual-credits policy regime. It is assumed that, in the base scenario, total production of passenger vehicles would increase at a mild and steady year-on-year rate of 3% from 2019 to 2023. Multiplier R is a constant but expected to be escalating moderately as determined by the national authorities. NEV credits and CAFC credits were then calculated following the equations explained in

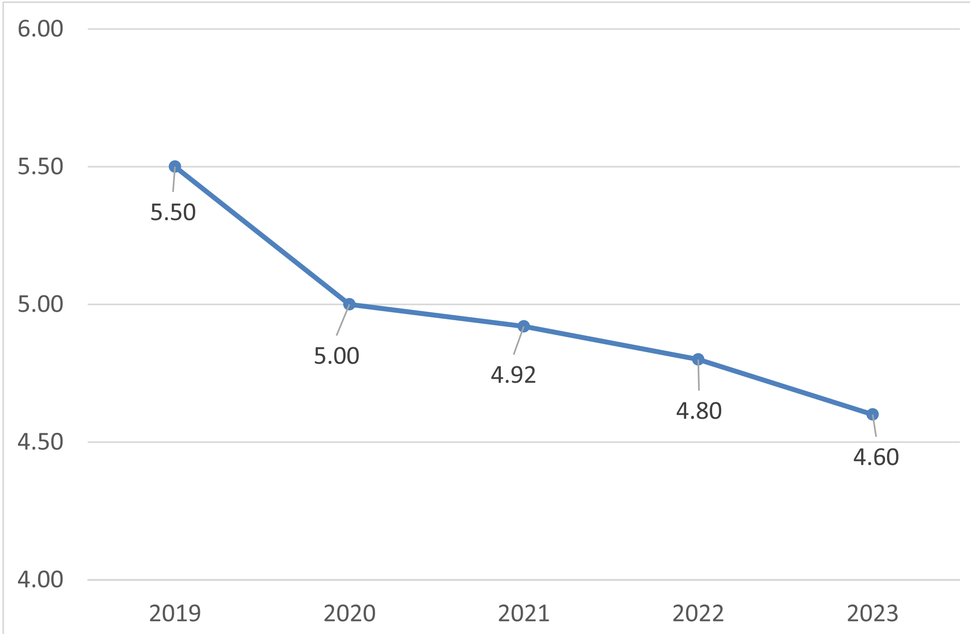

Fig. 2. Required average fuel consumption (liter/100 km) under dual-credits policy.

Section 4.1. As shown in Table 6, EV production units in the near future are estimated in the last row, in order to fulfill the tightened regulatory requirement of dual-credits regime. Further discussion on scenario analysis is provided in the following Section 4.3.2.On one hand, EVs need to be produced to offset the negative CAFC credits resulting from the sales of conventional passenger cars. On the other hand, EVs need to be produced to meet the strict requirement of positive NEV credits. It is noted that the estimated EV production in 2020–2023 would be much higher than the actual EV sales in 2013–2019. The tightened dual-credits policy regime has brought higher pressure on the EV production and sales in the Chinese market.

4.3.1.2. Actual EV sales began to slow-down. The tightened dual-credits policy regime requires significant increment in EV production and sales over the next few years, in order to meet the strict CAFC credits and NEV credits. However, the actual EV sales began to decrease since 2019 as shown in the below Fig. 3 due to the gradual phasing out of the financial subsidies.

According to the statistics from MIIT (MIIT 2019a), the sales figure of EV in China was at a relatively low level of 18,000 in 2013. Although the absolute size appeared to be relatively small, industrialization had been initialized effectively. Starting from 2015, sales number of EV has been rapidly growing with an annual growth rate over 50%, for four consecutive years till 2018. In 2018, sales reached 1.255 million and the whole industrial chain of EV was soundly established (MIIT, 2019a). As illustrated in Fig. 3 below, it is noted that the sales number in 2019 slightly declined for around 4% comparing with that of 2018. This is due to the application of reducing financial subsidies on EV of private transportation sector.

4.3.2. Scenario analysis

4.3.2.1. CAFC only vs. NEV only vs. dual-credits regime. This section compares impacts of dual-credits regime on the estimated EV production

Table 6
Estimation of EV production (2020 to 2023) in base scenario.

	2019	2020E	2021E	2022E	2023E
Passenger Car (conventional) Production	21,446,488	22,089,883	22,752,579	23,435,157	24,138,212
Increase (year on year, estimation)	3.0%	3.0%	3.0%	3.0%	3.0%
R	10.0%	12.0%	14.0%	16.0%	18.0%
NEV Credits (Estimation)	2,144,649	2,650,786	3,185,361	3,749,625	4,344,878
Required Average Fuel Consumption	5.50	5.00	4.92	4.80	4.60
Actual Average Fuel Consumption *(actual number in 2019, estimation in 2020 and after)*	5.80	5.35	5.20	5.10	4.90
Decrease (year on year, estimation)	5.2%	6.5%	5.4%	5.9%	6.1%
CAFC Credits (Estimation)	(6,433,946)	(7,731,459)	(6,370,722)	(7,030,547)	(7,241,463)
Pure EV Credit (per car)	4.0	4.0	3.4	3.4	3.4
Hybrid EV (per car)	2.0	2.0	1.6	1.6	1.6
Pure EV (weighting)	78%	80%	83%	85%	88%
Hybrid EV (weighting)	22%	20%	17%	15%	12%
Average EV Credit (per car)	3.56	3.60	3.09	3.13	3.18
EV Production (to meet NEV credits)	602,429	736,329	1,029,528	1,197,963	1,364,597
EV Production (to meet CAFC credits)	1,807,288	2,147,628	2,059,057	2,246,181	2,274,329
Total EV Production	**2,409,718**	**2,883,957**	**3,088,585**	**3,444,144**	**3,638,926**

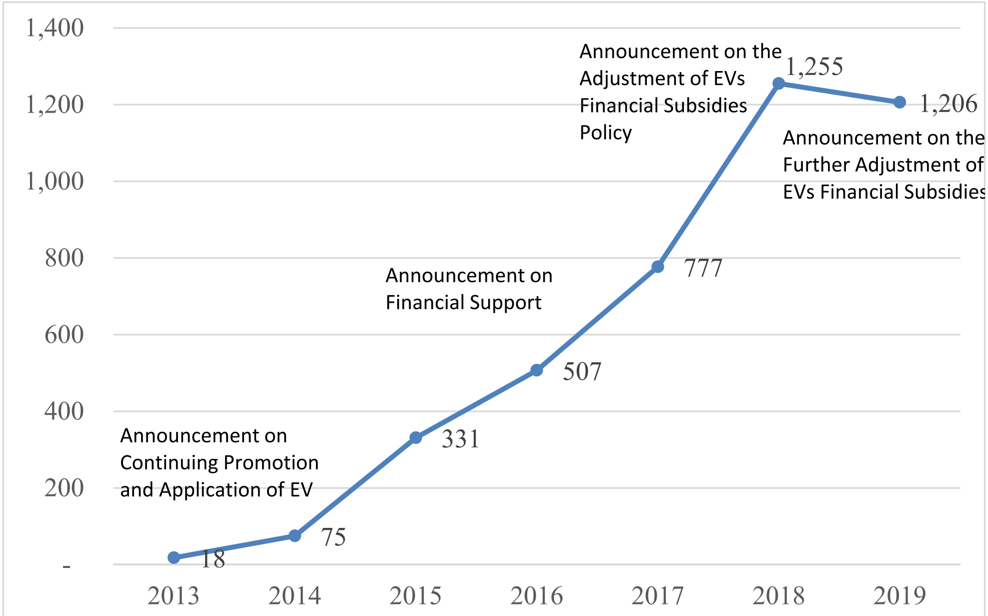

Fig. 3. EV Sales Upon Key National Policies in China (Unit: thousand).

under three scenarios of fulfilling the requirement of: (i) CAFC credits only, (ii) NEV credits only, (iii) and both credits. As shown in Fig. 4 below, although the estimated EV production by NEV credits is expected to increase year on year from 2019 to 2023, CAFC credits regime would consistently drive higher EV production than NEV credits regime, especially in first few years. The difference between EV production from CAFC credits regime and that from NEV credits regime is expected to become smaller in later years. This also stimulates the automobile companies to reduce their average fuel consumption rate among conventional passenger cars, possibly through intensive technological innovation as supported by investments in research and development (R&D).

4.3.2.2. Impacts from high-growth vs. low-growth vs. negative growth of conventional passenger cars under the dual-credits regime. Under the tightened dual-credits policy regime, how will the changes in manufacturing of conventional passenger car impact the EV production in the near future? This section compares impacts of dual-credits regime on the estimated EV production under four scenarios: (i) high-growth of conventional passenger car, (ii) low-growth of conventional passenger car, (iii) negative-growth of conventional passenger car, as well as (iv) the benchmark scenario. Annual increase rate of conventional passenger car is set as 3% in the benchmarks scenario, equivalent to the average rate in the past five year in China (MIIT, 2020b). Annual increase rate of conventional passenger car is 5% in the high-growth scenario. The rate is adjusted to 1% in the low-growth scenario and -1% in the negative-growth scenario.

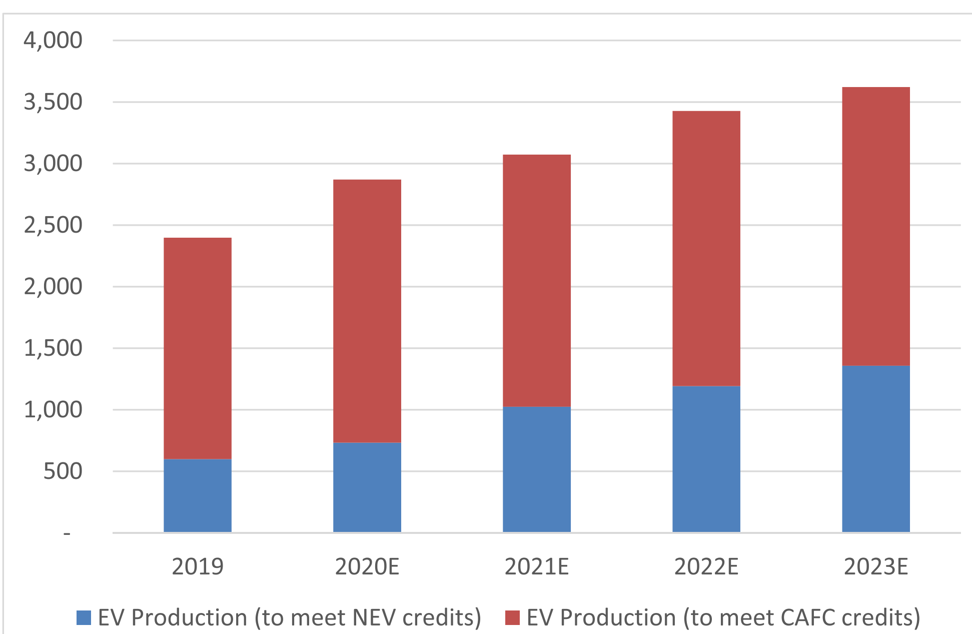

Fig. 4. Estimation of EV Production under CAFC Only and NEV Only Scenarios (in thousand).

The results show a significant gap between the actual EV sales in the past six years and the estimated EV sales in the next four years till 2023, which implies an inevitable challenge for executing the tightened dual-credits policy regime. Policy implications and suggestions to tackle this significant gap are elaborated in the next section (see Fig. 5).

5. Policy implications and suggestions

In the near future, the dual-credits policy would effectively drive the technological innovation in China's automobile industry by implementing tightened regime of CAFC credits and NEV credits. Average fuel consumption of conventional passenger cars needs to be reduced, in order to lower the negative CAFC credits. In particular, the quality of electric passenger cars needs to be improved in order to obtain higher positive NEV credits. The R&D investments by EV companies are expected to increase with the growth of its market size. Corporate R&D investments would also create real options while improving one's competitiveness in a technology-based sector for both first and second movers (Cottrell and Gordon, 2002; Shil and Allada, 2007; Ng and Nathwani, 2011). The dual-credit policy regime requires manufacturers to offset negative credits, which in return, will need to increase R&D investments into their EV technologies. Seeking advancement of their competitiveness encourages continuous and intensive investments into pertinent tangible and intangible assets. Nevertheless, the further tightened dual-credits policy regime clarifies the development direction for EV industry, and thereby enhances the enthusiasm and initiatives taken by EV companies. Specifically, the further tightened dual-credits policy regime is expected to stimulate the R&D investments in both EV models and battery manufacturers to improve cruise range and energy performance; therefore, to increase consumers' willingness to purchase.

Controlling the manufactory costs, providing convenient transportation networks, and differentiating the consumers' experience of driving EVs from conventional automobiles, are considered the necessary strategies for current automobile companies to tap consumers' deep demand and to stand out in the increasingly competitive environment as anticipated.

From the perspective of strategic risk management on China's rapidly emerging EV sector, market participants have to be aware of two significant fundamentals in the forthcoming development cycle. First, continuous optimal allocation resources into R&D would be likely to maintain one's competitive advantage over time even for the second movers despite uncertainty in the near term (Cottrell and Gordon, 2002). Second, the on-going development of a market-based green financing in China would provide an alternative source of low-cost funding for the further development of the EV sector (Ng, 2018). To survive and excel, the incumbents would have to take a proactive approach to anticipating early decline of financial subsidies by formulating and executing a strategic response plan in advance to the challenges of turning from a policy-driven to a market-driven industry.

6. Conclusion and future research work

Based on the observed progressive policy development over the last decade, the Chinese government evidently considers the further advancement of the EV industry as an important driver for the growth and development of its automobile industry. The central government has adopted national policy incentives at intervals to guide the sector's sustainability with noticeable interventions, which are aligned with the government's policy for the country's green and sustainable development. However, the further tightened dual-credits policy regime will likely result in a significant gap between the slowed down EV sales in the past and the predicated increasing EV production pressure in the near future in order for the industry to fulfill the requirements of CAFC credits and NEV credits. China's EV subsidy policy could be bound to undergo further adjustments. This may not be only due to the expectation that the central government is about to face increasing financial constraints, but further interventions would facilitate establishment of necessary principles of market fairness in order to turn the EV market into a market-oriented industry.

All in all, this paper reviews the supportive EV policy at national level and discussed the policy impact over different phases in the last decade. By simulating the newly tightened dual-credits policy scenarios in the mathematical model, this paper compared the impacts of dual-

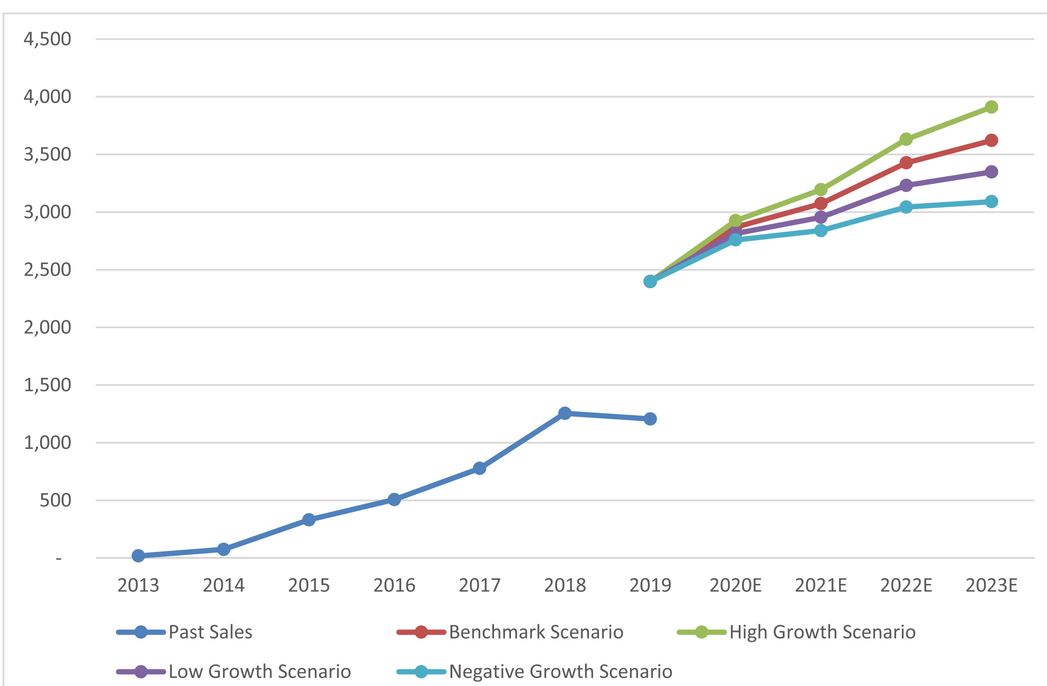

Fig. 5. Significant Gap between EV Sales (in thousands) in the Past and Estimated EV Sales in the Near Future under the Tightened Dual-credits Policy (2013 to 2023).

credits policy regimes on the automobile market in China based on a quantitative approach. Suggestions are made to market participants with reference to the following observations.

- The newly tightened dual-credits policy regime is expected to bring significant impact to the automobile industry in China, especially in the coming few years.
- Simulation results show that CAFC credits regime will drive much greater pressure on EV production and sales, than the NEV credits regime, though the difference may become smaller in later years.
- Investment into R&D is expected to stimulate technological advancement for reducing the average fuel consumption of conventional vehicles as well as the adverse effects of CAFC credits.
- Investment into R&D is expected to improve the EV production quality and to obtain higher positive NEV credits.
- With a higher aggregate in production of conventional passenger cars, more EV production is required to comply with the tightened dual-credits policy regime.

Under the development of EV infrastructure and transportation system, more enterprises would become willing to invest in R&D for technological innovation of new EV models. With the execution of newly tightened dual-credits policy regime, there will be variation in credit balance among automobile enterprises in the market. The higher the positive credit balance, the stronger the willingness to allocate resources into R&D for the EV manufacturers. However, the market players would still have to face the challenges of predicting how the EV market would evolve in China when financial subsidies decline gradually in the next few years. They will be subject to the dynamics of market competitions and possibilities of further changes in pertinent policy.

In future research work, it is desirable to expand our research to quantitative analysis of financial subsidies in the past years since 2013. Besides, it would be complementary to include an in-depth elaboration by categorizing reasons pertinent to tightening dual-credits policy regimes in our mathematical model and scenario analysis. Such challenges could be interrelated to consumers' behavior and policy information asymmetry throughout the implementation process of the tightened dual-credits policy regime.

CRediT authorship contribution statement

Yang Andrew Wu: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Artie W. Ng:** Validation, Writing - review & editing, Supervision. **Zichao Yu:** Investigation. **Jie Huang:** Investigation. **Ke Meng:** Investigation, Writing - review & editing. **Z.Y. Dong:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The first author and the corresponding author would like to acknowledge that they are respectively Principal Investigator and Co-Principal Investigator of the Project titled "*Emerging Research Directions on Adoption of Electric Vehicles for the Development of Smart Cities through Complementary Policy and Green Financing: GBA as the Cluster for Technological Innovation*" (Ref. UGC/IIDS24/E01/20) funded under the Inter-Institutional Development Scheme by the Research Grants Council of the Hong Kong Special Administrative Region. Both of them are also founding members of the Project titled "*Establish the Research Centre for Green Energy, Transport and Building*" (Ref. UGC/IDS(R)24/20) funded under the Institutional Development Scheme by the Research Grants Council of the Hong Kong Special Administrative Region.

Abbreviations

The following abbreviations are used in this manuscript

CAFC	Corporate Average Fuel Consumption
EV	Electric Vehicle
MIIT	Ministry of Industry and Information Technology of China
MOF	Ministry of Finance of China
MST	Ministry of Science and Technology
NDRC	National Development of Reform Commission of China
NEV	New Energy Vehicle
OEM	Original Equipment Manufacturer
R&D	Research and Development

References

Aune, M., Godbolt, Å.L., Sørensen, K.H., Ryghaug, M., Karlstrøm, H., Næss, R., 2016. Concerned consumption. Global warming changing household domestication of energy. Energy Pol. 98, 290–297.
Cottrell, T., Gordon, S., 2002. Real Options and Follower Strategies: the loss of real option value to first-mover advantage. Eng. Econ. 47 (3), 232–263.
Gong, H., Wang, M.Q., Wang, H., 2013. New energy vehicles in China: policies, demonstration, and progress. Mitig. Adapt. Strategies Glob. Change 18, 207–228.
Guo, J., Zhang, X., Gu, F., Zhang, H., Fan, Y., 2020. Does air pollution stimulate electric vehicle sales? Empirical evidence from twenty major cities in China. J. Clean. Prod. 249, 119372.
Hao, H., Ou, X., Du, J., Wang, H., Ouyang, M., 2014. China's electric vehicle subsidy scheme: rationale and impacts. Energy Pol. 73, 722–732.
Helvestonal, J.P., Liu, Y., Feit, E.M., Fuchs, E., Klampfl, E., Michalek, J.J., 2015. Will subsidies drive electric vehicle adoption? Measuring consumer preferences in the U. S. and China. Transport. Res. Pol. Pract. 73, 96–112.
Hu, X., Chang, S., Li, J., Qin, Y., 2010. Energy for sustainable road transportation in China: challenges, initiatives and policy implications. Energy 35 (11), 4289–4301.
Kumar, R.R., Kumar, A., 2020. Adoption of electric vehicle: a literature review and prospects for sustainability. J. Clean. Prod. 253 https://doi.org/10.1016/j.jclepro.2019.119911.
Li, J., Jiao, J., Tang, Y., 2019. An evolutionary analysis on the effect of government policies on electric vehicle diffusion in complex network. Energy Pol. 129, 1–12.
Li, W., Long, R., Chen, H., 2016. Consumers' evaluation of national new energy vehicle policy in China: an analysis based on a four paradigm model. Energy Pol. 99, 33–41.
Li, Y., Zhan, C., de Jong, M., Lukszo, Z., 2016. Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China. J. Clean. Prod. 134, 371–383.
Li, J., Ku, Y., Yu, Y., Liu, C., Zhou, Y., 2020a. Optimizing production of new energy vehicles with across-chain cooperation under China's dual credit policy. Energy 194. March 116832.
Li, Y., Zhang, Q., Tang, Y., Mclellan, B., Ye, H., Shimoda, H., Ishihara, K., 2020b. Dynamic optimization management of the dual-credit policy for passenger vehicles. J. *Clean. Prod.* 249. March 119384.
Li, J., Ku, Y., Liu, C., Zhou, Y., 2020c. Dual credit policy: promoting new energy vehicles with battery recycling in a competitive environment? J. Clean. Prod. 243. January 118456.
Lin, B., Wu, W., 2018. Why people want to buy electric vehicle: an empirical study in first-tier cities of China. Energy Pol. 112, 233–241.
Liu, C., Huang, W., Yang, C., 2017. The evolutionary dynamics of China's electric vehicle industry – taxes vs. subsidies. Comput. Ind. Eng. 113, 103–122.
Liu, J., Meng, Z., 2017. Innovation model analysis of new energy vehicles: taking toyota, Tesla and BYD as an example. Procedia Eng. 174, 965–972.
MIIT, 2010a. Announcement on Expanding the Demonstration Projects for Promoting Energy Conservation and EVs in Public Service Sectors released in June 2010. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c3757140/content.html.
MIIT, 2010b. Announcement on the Pilot Subsidies for EVs in Private Sectors released in June 2010. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c3757144/content.html.
MIIT, 2012. Announcement on Summary of Pilot Demonstration Projects for Energy Conservation and EV Promotion. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c3757511/content.html.
MIIT, 2016. Announcement on the Adjustment of EVs to Promote the Use of Financial Subsidies Policy. Released in Dec. 2016. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5449722/content.html. Dec. 2016.
MIIT, 2017a. Medium and Long-Term Development Plan for the Automotive Industry in China released in April 2017. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5600356/content.html.
MIIT, 2017b. Measures for the Parallel Management of Average Fuel Consumption and EV Credits for Passenger Car Companies released in September 2017. http://www.miit.gov.cn/n1146295/n1652858/n7280902/c5824932/content.html.
MIIT, 2019a. Statistics and Operations of Automobile Industry in PR China. http://www.miit.gov.cn/n1146312/n1146904/n1648362/n1648363/index.html.

MIIT, 2019b. Amended Measures for the Parallel Management of Average Fuel Consumption and EV Credits for Passenger Car Companies. Released in September 2019. http://www.moj.gov.cn/news/content/2019-09/11/zlk_3231865.html.
MIIT, 2020a. Announcement on the Average Fuel Consumption of Passenger Car Companies and New Energy Vehicle Points in 2019 released in April 2020. http://www.miit.gov.cn/n1146285/n1146352/n3054355/n3057585/n3057592/c7027601/content.html.
MIIT, 2020b. Economic Operation of the Automobile Industry released in Jun 2020. http://www.miit.gov.cn/n1146312/n1146904/n1648362/n1648363/index.html.
MOF, 2015. Announcement on Financial Support for EVs 2016-2020 released in April 2015. http://fgk.mof.gov.cn/law/getOneLawInfoAction.do?law_id=83837.
MOF, 2019. *Announcement on the Further Adjustment of EVs to Promote the Use of Financial Subsidies Policy* released in March 2019. http://www.gov.cn/xinwen/2019-03/27/content_5377123.htm.
MST, 2014. Announcement on Further Continuing Promotion and Application of EV released in Febury 2014. http://www.most.gov.cn/tztg/201402/t20140212_111801.htm.
Ng, A., 2018. From sustainability accounting to a green financing system: institutional legitimacy and market heterogeneity in a global financial centre. J. Clean. Prod. 195, 585–592.
Ng, A., Nathwani, J., 2011. Strategic development and growth of emerging renewable energy ventures from China: real options through mergers and acquisitions. J. Technol. Manag. China 6 (2), 116–124.
Ou, S., Lin, Z., He, X., Przesmitzki, S., 2018a. Estimation of vehicle home parking availability in China and quantification of its potential impacts on plug-in electric vehicle ownership cost. Transport Pol. 68, 107–117.
Ou, S., Lin, Z., Qi, G., Li, J., He, X., Przesmitzkic, S., 2018b. The dual-credit policy: quantifying the policy impact on plug-in electric vehicle sales and industry profits in China. Energy Pol. 121, 597–610.
Ou, S., Hao, X., Lin, Z., Wang, H., Bouchard, J., He, X., Przesmitzki, S., Wu, Z., Zheng, J., Lv, R., Qi, L., La Clair, T.J., 2019. Light-duty plug-in electric vehicles in China: an overview on the market and its comparisons to the United States. Renew. Sustain. Energy Rev. 112, 747–761.
Poullikkas, A., 2015. Sustainable options for electric vehicle technologies. Renew. Sustain. Energy Rev. 41, 1277–1287.
Qiu, Y.Q., Zhou, P., Sun, H.C., 2019. Assessing the effectiveness of city-level electric vehicle policies in China. Energy Pol. 130, 22–31.
Rezvani, Z., Jansson, J., Bodin, J., 2015. Advances in Consumer Electric Vehicle Adoption Research: A Review and Research Agenda, vol. 34. Transportation Research Part D: Transport and Environment, pp. 122–136.
Rong, K., Shi, Y., Shang, T., Chen, Y., Hao, H., 2017. Organizing business ecosystems in emerging electric vehicle industry: structure, mechanism, and integrated configuration. Energy Pol. 107, 234–247.
Shil, P., Allada, V., 2007. Evaluating product plans using real options. Eng. Econ. 52 (3), 215–253.
Sovacool, B., 2017. Experts, theories, and electric mobility transitions: toward an integrated conceptual framework for the adoption of electric vehicles. Energy Res. Soc. Sci. 27, 78–95.
Sovacool, B.K., Abrahamse, W., Zhang, L., Ren, J., 2019. Pleasure or profit? Surveying the purchasing intentions of potential electric vehicle adopters in China. T*ransport. Res. Pol. Pract.* 124, 69–81.
State Council, 2009. Announcement on the Pilot Demonstration Projects for Promoting Energy Saving and EVs released in Febury 2009. http://www.gov.cn/zwgk/2009-02/05/content_1222338.htm.
State Council, 2010. Decision on Accelerating the Cultivation and Development of Strategic Emerging Industries released in October 2010. http://www.gov.cn/zwgk/2010-10/18/content_1724848.htm.
State Council, 2013. Announcement on Continuing Promotion and Application of EV released in September 2013. http://www.gov.cn/zwgk/2013-09/17/content_2490108.htm.
Wang, L., Zhang, Y., 2017. Research on policy synergy of EV industry in China - based on three dimensional analysis framework of structure, process, and content. Chin. Publ. Adm. Rev. 3, 101–107.
Wang, N., Pan, H., Zheng, W., 2017a. Assessment of the incentives on electric vehicle promotion in China. Transport. Res. Pol. Pract. 101, 177–189.
Wang, N., Tang, L., Pan, H., 2017b. Effectiveness of policy incentives on electric vehicle acceptance in China: a discrete choice analysis. Transport. Res. Pol. Pract. 105, 210–218.
Wang, Y., Zhao, F., Yuan, Y., Hao, H., Liu, Z., 2018a. Analysis of typical automakers' strategies for meeting the dual-credit regulations regarding CAFC and NEVs. Automot. Innovat. 1, 15–23.
Wang, N., Tang, L., Pan, H., 2019. A global comparison and assessment of incentive policy on electric vehicle promotion. Sustain. Cities Soc. 44, 597–603.
Wang, S., Li, J., Zhao, D., 2017c. The impact of policy measures on consumer intention to adopt electric vehicles: evidence from China. Transport. Res. Pol. Pract. 105, 14–26.
Wang, S., Zhao, F., Liu, Z., Hao, H., 2018b. Impacts of a super credit policy on electric vehicle penetration and compliance with China's Corporate Average Fuel Consumption regulation. Energy 155, 746–762.
Wu, Y., Yu, Z., Ngan, H.W., Tan, Z., 2014. Sustaining China's electricity market development. Energy Pol. 73, 30–37.
Wu, Y.A., Guo, S.N., 2020. In: Fu, J., Ng, A.W. (Eds.), Penetration of Electric Vehicles into the Greater Bay Area - *Sustainable Energy and Green Finance for a Low-Carbon Economy: Perspectives from the Greater Bay Area of China*. Springer International Publishing, Cham, ISBN 978-3-030-35411-4, pp. 111–128.
Yuan, X., Liu, X., Zuo, J., 2015. The development of new energy vehicles for a sustainable future: a review. Renew. Sustain. Energy Rev. 42, 298–305.
Zhang, X., Liang, Y., Yu, E., Rao, R., Xie, J., 2017. Review of electric vehicle policies in China: content summary and effect analysis. Renew. Sustain. Energy Rev. 70, 698–714.
Zheng, J., Mehndiratta, S., Guo, J.Y., Liu, Z., 2012. Strategic policies and demonstration program of electric vehicle in China. Transport Pol. 19, 17–25.
Zhou, Y., Zhang, H., Ding, M., 2015. How public demonstration projects affect the emergence of new industries: an empirical study of electric vehicles in China. Innovation 17, 159–181.
Zhuge, C., Wei, B., Dong, C., Shao, C., Shan, Y., 2019. Exploring the future electric vehicle market and its impacts with an agent-based spatial integrated framework: a case study of Beijing, China. J. Clean. Prod. 221, 710–737.