Research on the Prediction of Dual Credit Situation of Passenger Car Enterprises Based on Multiple Factors

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Abstract. Currently, China's new energy vehicle industry has entered a new stage of rapid development on a large scale. In order to ensure the advancement and innovation of the "Dual Credit Policy", the key assessment indicators such as the requirement ratio of NEV credits are in an urgent need to be made stricter. The strictness of the key assessment indicators is closely related to the development of China's energy-saving and new energy vehicle industry. However, currently, there is still a lack of systematic prediction methods for the medium- and long-term dual credit situation of passenger car enterprises in China. In this paper, a database for the prediction of the dual credit situation of passenger car enterprises is constructed using a combined "top-down" and "bottom-up" approach. Specifically, the NEV penetration rate in the industry is quantitatively evaluated using a multivariate regression model under the assumption of a discrete choice model, with the consideration of constraints such as resource endowment, charging infrastructure, and transformation costs of enterprises. The potential for fuel consumption reduction in conventional energy passenger cars of enterprises is determined using an optimal energy-saving technology choice model, which provides the annual decline in fuel consumption for enterprises. The calculation of the credits for NEV models and energy consumption is estimated using the rules of policy development and a simple conversion method. In order to make the prediction database more applicable to the real-world scenarios, it is also embedded with out-of-cycle energy-saving technologies, and research advancements in the latest policies and standards. This prediction database will greatly support the evaluation of the effectiveness of the "Dual Credit Policy" in the medium and long run, and assist enterprises in formulating credit compliance strategies.

1 Status Quo of Management Based on Dual Credit Policy

In April 2018, five ministries and commissions, including Ministry of Industry and Information Technology, jointly issued the Measures for the Parallel Administration of Corporate Average Fuel Consumption and NEV Credits for Passenger Car Enterprises (hereinafter referred to as the "Dual Credit Policy"). Since its official implementation, the Policy has been running smoothly for 7 consecutive years, during which, 5 NEV credit trading tasks have been completed, with the trading amount reaching RMB25.2 billion accumulatively[1]. Practice has proved that Dual Credit Policy has effectively promoted China's passenger car energy saving and emission reduction work and industrial transformation and upgrading, driving the scale of NEV production and sales and the development of power battery-related fields to lead the world. Meanwhile, the Dual Credit Policy has also played a very important and positive role in optimizing the allocation of industrial resources and promoting industrial integration.

Currently, China's new energy vehicle industry has entered a new stage of rapid development on a large scale, and the development of the auto industry is also facing the problem of meeting the requirements of carbon peaking and carbon neutrality goal. In order to cope with the new situation and new changes in the auto industry and ensure the advancement and innovation of the "Dual Credit Policy", the government authorities amended the "Dual Credit Policy" for 2021-2023 and for 2024-2025 in June 2020 and July 2023 respectively, proposing that the requirement ratio of NEV credits should be raised to 18% by 2023, and then be further raised to 38% by 2025. In view of the medium- and long-term electrification transition goals of Europe[2] and the United States[3], the requirement ratio of NEV credits under the "Dual Credit Policy" for 2026-2030 will rise rapidly, as shown in Fig. 1.

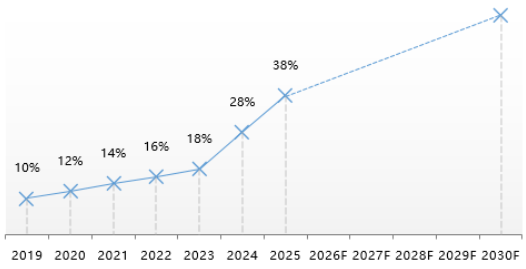

Fig. 1. Requirements on NEV Credit Ratio from 2019 to 2030

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In order to clarify the strength of key assessment indicators of the "Dual Credit Policy" for 2026-2030, it is necessary to forecast the development situation of the energy saving and NEV industry in the medium and long term, and put forward the targeted policies and measures based on the difference. However, due to a large number of uncertainties in the economic environment both at home and abroad, supply chain security and infrastructure construction, there is still a lack of systematic prediction methods for the medium- and long-term production and sales scale and dual credit situation of passenger car enterprises in China. This paper quantitatively evaluates the 3 major influencing factors, namely, the penetration rate of new energy passenger cars in the industry, the potential for the decline in the fuel consumption of conventional energy passenger cars, and conversion of credit per vehicle and energy consumption for new energy passenger cars. Meanwhile, a database for the prediction of the dual credit situation of passenger car enterprises is constructed using a combined "top-down" and "bottom-up" approach. The prediction database is designed to support the government authorities to reasonably and comprehensively assess the effect of the policy setting and assist the enterprises in formulating the efficient and reasonable credit compliance strategies.

2 Analysis of Influencing Factors for the Prediction of Dual Credit Situation

2.1. Construction of Prediction Database of Dual Credit Situation

In this paper, the combination of "top-down" and "bottom-up" methods is used to construct a prediction database of dual credit situation for passenger car enterprises from 2023 to 2030, as shown in Fig. 2.

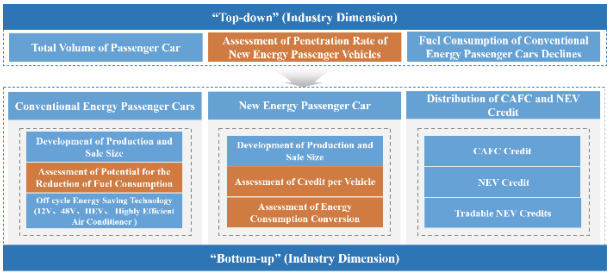

Fig. 2. Logic Diagram for the Construction of Prediction Database of Dual Credit Situation for Passenger Car Enterprises

"Top-down" method is based on the passenger car market size, development of penetration rate of new energy passenger car and decline of fuel consumption of traditional energy passenger cars as the constraints of industrial development. "Bottom-up" method is used to calculate the distribution situation of dual credits through multiple factors, such as the decline potential of fuel consumption of conventional energy passenger cars, credits for NEV models and energy consumption conversion, and exemption of CAFC credit accounting for vehicles featuring the out-of-cycle energy-saving technologies, etc. The accounting equation is shown as below:

$$C_{CAFC} = \left(\frac{M_{ICE}\times(\alpha-\varphi)+M_{BEV}\times FC_{BEV}+M_{PHEV}\times FC_{PHEV}}{M_{ICE}+W\times M_{NEV}} - \beta T_{CAFC}\right)\times M \quad (1)$$

Where,

C_{CAFC}: CAFC credit, Credits;

$M, M_{ICE}, M_{NEV}, M_{BEV}, M_{PHEV}$: Production of passenger cars, production of traditional energy passenger cars, production of new energy passenger cars, BEV production, PHEV production, units;

α : Corporate Average Fuel Consumption of Conventional Energy Passenger Cars, L/100km;

φ: The exemption of CAFC credit accounting for vehicles featuring out-of-cycle energy-saving technology, L/100km;

FC_{BEV}: Equivalent fuel consumption of BEV models, L/100km; of which, the equivalent fuel consumption for 2023-2025 is accounted by 0L/100km, while that for 2026-2030 is accounted according to the requirements of the draft of the GB/T 37340 Standards;

FC_{PHEV} : Equivalent fuel consumption of PHEV models, L/100km; of which, the equivalent fuel consumption for 2023-2025 is accounted according to the comprehensive fuel consumption of models, while that for 2026-2030 is accounted according to the requirements of the draft GB/T 37340 Standards;

W: Accounting preferential multiplier of new energy passenger cars for 2023-2025 is 1.6, 1.3, 1.0, respectively, while that for 2026-2030 is set according to the requirements of the draft GB 27999 standards;

β : The ratio of CAFC (corporate average fuel consumption) to the target CAFC is 115%, 108% and 100% respectively for 2023-2025, and such ratio is accounted in accordance with the requirements of the draft GB 27999 standards for 2026-2030;

T_{CAFC}: Target CAFC, L/100km.

$$C_{NEV} = P_{BEV}\times M_{BEV} + P_{PHEV}\times M_{PHEV} - \gamma M_{IEC} \quad (2)$$

Where,

C_{NEV}: NEV Credits, Credits ;

P_{BEV}: Credits per BEV, Credit/Unit;

P_{PHEV}: Credits per PHEV, Credit/Unit;

γ: Requirements for the ratio of NEV credits; the ratio is 18%, 28% and 38% respectively for 2023-2025, while that for 2026-2030 will be predicted and assessed in accordance with the research achievements of "Dual Credit Policy".

2.2 Penetration rate of new energy passenger cars

By sorting out the influencing factors of passenger car market development from 2012-2022, it is found that consumers' decision to purchase a car is jointly determined by such 4 aspects as product selection, purchase cost, usage cost and convenience of use. Among them, product selection includes the number and type of NEV products, purchase cost includes production costs and profits of enterprises, price of license plate, NEV credit price, and purchase tax; usage cost includes charging price, fuel price, vehicle and vessel tax, insurance cost, and maintenance cost; and convenience of

use means e-range, charging duration, density of charging stations, and right-of-way.

Based on the assumption of the discrete choice model[4], consumers purchase cars based on the basic principle of "utility maximization"[5]. A multiple regression model is constructed after fully considering the influence of multiple factors on consumers' decision to purchase a vehicle.

$$U_{jt} = U_{j0} + \Delta U_{jt} + \sum_k \beta_k \times X_{jkt} + \varepsilon_{ij} \quad (3)$$

Where,

k: Serial number of utility influencing factors, including product selection, purchase cost, usage cost and cost for convenience of use;

t: Time;

U_{jt}: Total utility, RMB/vehicle;

U_{j0}: Fixed utility, RMB/vehicle;

ΔU_{jt}: Utility variable, RMB/vehicle;

β_k: Elasticity coefficients of utility influencing factors;

X_{jkt}: Indicators of elasticity coefficients of utility influencing factors;

ε_{ij}: Random error term, unobservable utility;

Meanwhile, the qualitative analysis of China's resource endowment, charging infrastructure layout, grid carrying capacity and enterprise transition costs is carried out to comprehensively assess the resource and social risks arising out of the switch to the NEV technological routes. Further revise the model conclusion on the penetration rate of new energy passenger cars.

After the multiple regression model is used and development constraints assessment is carried out, it is found that the penetration rate of new energy passenger cars will reach 50% by 2025 and 70% by 2030, as shown in Fig. 3.

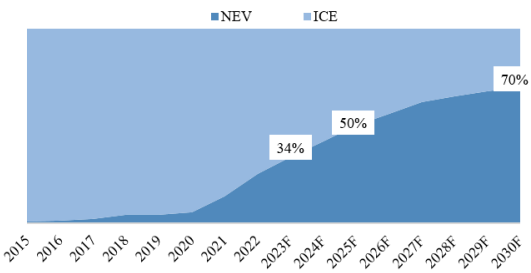

Fig. 3. Prediction to the Development of Penetration Rate of New Energy Passenger Cars from 2015 to 2030

2.3 Fuel Consumption of Conventional Energy Passenger Cars

Establishing an optimal energy-saving technology selection model for enterprises is an effective way to achieve the reasonable fuel consumption reduction potential of conventional energy passenger cars for enterprises. Within the range permitted by cost increase, enterprises' choice of reasonable energy-saving technology routes to maximize the fuel consumption reduction of their models is the main driving force behind enterprise to upgrade technologies. As a result, the minimum cost increment brought about by the energy-saving technology upgrade of enterprises is set as the objective function of the optimization problem model[6].

$$min f(x) = [c_1 \cdots c_n] \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \cdots \\ s_m \end{bmatrix} \quad (4)$$

$$\text{s.t.} \begin{cases} c_n > 0 \\ x_{nm} = 0 \text{ or } 1 \\ s_1 + s_2 + \cdots + s_m = 1 \\ T = [\vartheta_1 \cdots \vartheta_n] \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \cdots \\ s_m \end{bmatrix} \\ T \le T1 \end{cases} \quad (5)$$

Where,

$f(x)$: The minimum cost increment brought about by the enterprise's energy-saving technology upgrade, RMB/vehicle;

c_n: The upgrade cost of the nth energy-saving technology, RMB/vehicle;

x_{nm}: Selection matrix of energy-saving technology, the value is taken as 0 or 1, 1 representing that the mth model chooses to carry the nth energy-saving technology, while 0 representing no technologies have been selected;

s_m: The production and sales share of the mth model;

ϑ_n: The fuel saving rate of the nth energy saving technology ;

$T1$: The energy-saving target of the enterprise.

At present, by sorting out the key energy-saving technologies, 15 technologies in 4 categories are selected as research objects, as shown in Table 1 below.

Table 1. Fuel Saving Rate and Cost Increase of Energy-Saving Technologies for Conventional Energy Passenger Cars
Note: Based on the enterprise research data 2022

Technology Classification	Before Technology Upgrade	After Technology Upgrade	Fuel-saving Rate (%)	Cost (RMB/Vehicle)
Engine Technology	Naturally Aspirated	TCI	0.7%	1900
	MFI	GDI/Hybrid Injection	3.0%	1400
	Otto Cycle	Miller Cycle/Atkinson Cycle	7.4%	900
	—	Cylinder Deactivation	3.2%	1200
Transmission Technology	4AT	CVT	7.3%	1100
		7DCT	8.6%	1500
		6AT	6.5%	1600
		8AT	10.8%	4000
		9AT	11.3%	5800
Electrification Technology	—	12V Brake Energy Recovery System	2.0%	1000
		48V Mild Hybrid System	3.9%	4400
		HEV Hybrid System	16.8%	20000
Progressive Technology	—	Reduce Friction	4.5%	1000
		Reduce Wind Resistance	2.8%	1000
		Reduce Rolling Resistance	3.7%	1000
		Reduce Rolling Resistance	3.7%	1000

The selection of optimal energy saving technology obtained from the solution is brought into the equation of the fuel consumption reduction potential of the enterprise's conventional energy passenger cars:

$$\varepsilon = \delta \prod_n (1 - \vartheta_n) \quad (6)$$

Where,

δ : The corporate average fuel consumption of conventional energy passenger cars in the previous year, L/100km;

ε : The corporate average fuel consumption of conventional energy passenger cars in the next year, L/100km;

Based on the conventional energy passenger cars of various enterprises under production in 2022, by using the optimal energy saving technology selection model, the decline situation in fuel consumption of conventional energy passenger cars of enterprises from 2023 to 2030 can be obtained, as shown in Table 2.

Table 2. Assessment of Fuel Consumption Reduction Potential of Conventional Energy Passenger Cars Manufactured by Typical Enterprises from 2023 to 2030

Year	FC of Enterprise A (L/100km)	FC of Enterprise B (L/100km)	FC of Enterprise C (L/100km)
2022	6.74	5.63	6.82
2023F	6.66	5.59	6.77
2024F	6.60	5.55	6.73
2025F	6.55	5.49	6.70
2026F	6.51	5.43	6.67
2027F	6.48	5.38	6.65
2028F	6.46	5.34	6.63
2029F	6.44	5.31	6.62
2030F	6.43	5.29	6.61
Annual Average Reduction Rate	0.59%	0.78%	0.39%

2.4 Credits for NEV Models and Energy Consumption Conversion

Since the official implementation of "Dual Credit Policy", the government authorities have made 2 adjustments to the credits for NEV models. Among them, the credit for NEV models from 2021 to 2023 has been tightened by 20% compared to that from 2016 to 2020 and by 40% from 2024 to 2025 compared to that from 2021 to 2023. Therefore, it is assumed that if the tightening trend in the previous stage is continued from 2026 to 2030, the credit for NEV models will decrease by about 40%; meanwhile, the credit for BEV and PHEV will be given in a different way, as shown in Table 3.

Table 3. Calculation Method of Credits for NEV Models from 2016 to 2030

Model Type	Credit of Standard Vehicle Type			
	2016-2020	2021-2023	2024-2025	2026-2030F
BEV	0.012×R+0.8 (Upper limit 5.0 credits)	0.0056×R+0.4 (Upper limit 3.4 credits)	0.0034×R+0.2 (Upper limit 2.3 credits)	It is expected to be about 1 credit per vehicle on an average, with credits given to the vehicles of various fuel types in a different way
PHEV	2.0	1.6	1.0	

Based on the product structure of new energy passenger cars in 2022, the distribution of credits for NEV models of enterprises from 2023 to 2030 is calculated, as shown in Fig. 4.

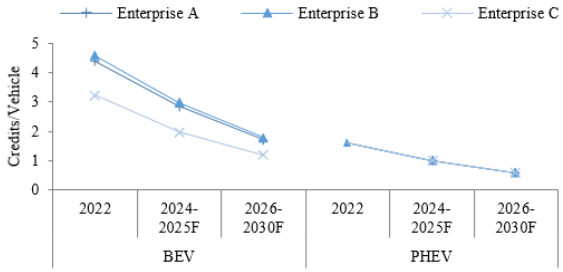

Fig. 4. Assessment of Enterprise's New Energy Passenger Car Credit per Vehicle

In the standard GB/T 37340-2019 Energy Consumption Conversion Methods for Electric Vehicles, there are three methods for converting the electric energy consumption equivalent of electric vehicles to fuel consumption: simple conversion method, fuel life cycle conversion method and CO_2 emission conversion method. Among them, the simple conversion method refers to the conversion of calorific value of electricity consumed by electric vehicles in the driving phase to the calorific value of fuel consumed by conventional energy vehicles. The fuel life cycle conversion method takes into account not only the driving phase, but the energy consumption from power plant to vehicles; throughout the fuel life cycle, the calorific value of the electricity consumed by electric vehicles is converted to coal used for power generation, and the fuel consumed by the conventional energy vehicles is converted to the fuel at the refinery plant; and then the calorific value of the two is converted. The CO_2 emission conversion method has the same accounting scope as the fuel life cycle conversion method, which converts the CO_2 emission produced during the power generation phase from the electricity consumed by electric vehicles to the CO_2 emission produced by the combustion of fuels in conventional energy vehicles. Based on the three conversion methods, the energy consumption conversion equations for BEV and PHEV are shown as below:

$$FC_{BEV} = FE \times E_{BEV} \quad (7)$$

$$FC_{PHEV} = FC + FE \times E_{PHEV,CD} \times UF \quad (8)$$

Where:

E_{BEV}: Electric consumption of BEV, kW·h/100km;

FC: Combined fuel consumption of PHEV, L/100km;

$E_{PHEV,CD}$: Electric consumption of PHEV under CD mode, kW·h/100km;

UF: Utilization factor of PHEV under battery driving mode;

FE : Conversion factor (focusing on the study of conversion of equivalent gasoline fuel consumption), L/(kW · h). Among them, the conversion factor of the simple conversion method, fuel life cycle conversion method and CO_2 emission conversion method is 0.1161L/(kW · h), 0.23L/(kW · h) and 0.31L/(kW · h), respectively.

It's found that the 3 conversion methods for energy consumption have a greater impact upon PHEVs. Among them, the fuel life cycle conversion method and CO_2 emission conversion method will lead to a higher level of fuel consumption in PHEVs than in HEVs, and their energy saving and emission reduction effects will decline significantly, as shown in Fig. 5.

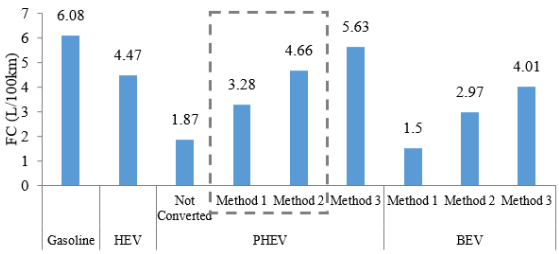

Fig. 5. Fuel Consumption Distribution of PHEV and BEV Models Under 3 Energy Consumption Conversion Methods

Note: Measured based on the parameters of the 2022 A-Class sedans.

In October 2020, General Office of the State Council officially issued the Development Plan for the New Energy Vehicle Industry (2021-2035), which still takes the PHEV technology route as a key link in the "three verticals" layout of the vehicle technology innovation chain; in June 2023, Ministry of Finance, State Taxation Administration and Ministry of Industry and Information Technology decided to extend the purchase tax reduction and exemption policy for PHEVs until 2027. It can be seen that the PHEV technology route still plays an important role in the stable development of NEV industry in China. As a result, this paper has chosen the simple conversion method as the energy consumption conversion method for new energy passenger cars. Based on the product structure of new energy passenger cars in 2022, the energy consumption conversion of new energy passenger cars of each enterprise from 2026 to 2030 is calculated, as shown in Table 4.

Table 4. Assessment of Energy Consumption Conversion of New Energy Passenger Cars of Enterprises

Enterprise	BEV L/100km	PHEV L/100km
Enterprise A	1.67	3.91
Enterprise B	1.48	3.00
Enterprise C	1.75	4.69

3 Application Value of the Prediction Database of Dual Credit Situation

It is expected by Development Research Center of the State Council that the overall sales of China's auto market will register around 33 million units by 2030[7], of which the passenger car market will see about 30 million vehicles. Meanwhile, combined with the multiple regression model, the development of new energy passenger car penetration rate is assessed, and this, along with the historical development law of the decline in the fuel consumption of conventional energy passenger car, is thought as the constraint on the development of the industry.

The prediction database of dual credit situation for passenger car enterprises covers 62 enterprises, whose production and sales account for more than 95%. Using the market share of key enterprises in 2022, and taking into account the development constraints on the total number of passenger cars and penetration rate of new energy passenger cars, the production and sales of conventional energy passenger cars and new energy passenger cars of each enterprise are obtained by "top-down" disassembly. Based on the development level of fuel consumption decline of traditional energy passenger cars in the industry, the top-down adjustment model obtains the potential of fuel consumption decline of traditional energy passenger cars in each enterprise. Meanwhile, by embedding the results of credits for NEV models and energy consumption conversion, situation of out-of-cycle energy saving technologies in 2022, and research advancements in the latest policies and standards related to credit accounting, the prediction data on the dual credit situation of both enterprises and industry is obtained, as shown in Table 5 and Fig. 6.

Table 5. Development Scenarios for the Industry's Dual Credit Situation in 2030

Influencing Factors	Development Scenario Baseline
Passenger Car Market Size	30 Million Units
Penetration Rate of New Energy Passenger Cars	70%
Average Annual Reduction in Fuel Consumption of Conventional Energy Passenger Cars in the Industry	1%
Other Influencing Factors	Out-of-Cycle Energy Saving Technologies Credit Pool Credit Surpluses Carried Forward from the Previous Period "Dual Credit Policy" 2026-2030 GB 27999, GB36980, GB/T37340, etc....

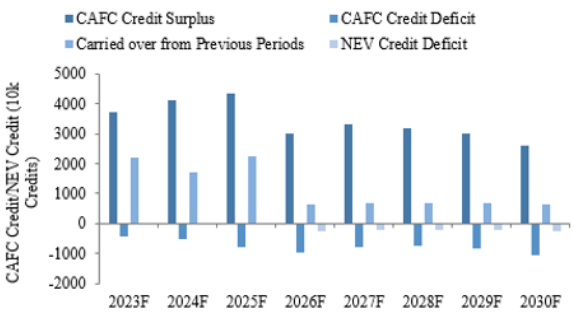

Fig. 6. Prediction to the Dual Credit Distribution of Passenger Car Enterprises from 2023 to 2030

From the perspective of prediction data distribution of the dual credit situation in the industry, and with the continued tightening of "Dual Credit Policy" and related standards from 2026 to 2030, the scale of credit deficits in the industry will be increased significantly, especially in 2030 when the total scale of both CAFC and NEV credit deficits is expected to approach 13 million credits. Among

them, the CAFC credit deficits are still mainly generated by some joint ventures, especially the Germany-Sino and Japan-Sino enterprises with slow electrification transition process. Taking into account the credit surpluses carried forward by enterprises from the previous period and the regulating effect of the credit pool, and using the simulation software of "Supply and Demand Situation of CAFC and NEV Credit"[8], it is found that under the expectation of high-speed development of the new energy passenger car market, the credit pool may start the release function by 2030, and the credit supply and demand pattern of the industry will be relatively stable, with the price of NEV credit surplus expected to go within a reasonable range, as shown in Fig. 7.

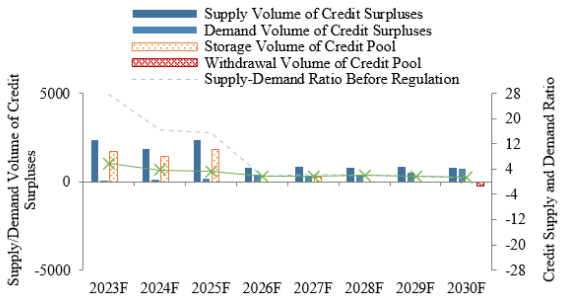

Fig.7. Prediction to the Credit Supply and Demand Situation of the Industry Based on the Prediction Database of Dual Credit Situation of Enterprises

4 Conclusion

This paper makes a comprehensive quantitative assessment of the 3 major influencing factors, namely, the penetration rate of new energy passenger cars in the industry, the potential for the decline in the fuel consumption of conventional energy passenger cars, and credit per vehicle and energy consumption conversion for new energy passenger cars. Taking into account the out-of-cycle energy-saving technologies and the latest policies and standard research progress, a unique dual credit prediction database for passenger car enterprises is constructed via the combination of "top-down" and "bottom-up" methods. The application value of the prediction database has been proved to be outstanding:

(1) The supply and demand pattern of credit and the storage/release of credit pool in the industry is comprehensively and quantitatively assessed, which can provide valuable reference for the further revision of the "Dual Credit Policy";

(2) An in-depth analysis of credit supply and demand pattern in the industry can effectively support the research on the development trend of NEV credit prices by government authorities, research institutes and enterprises;

(3) Based on the measurement results of credit deficit demand or credit surplus supply, enterprises can set their own credit trading strategies and new product planning in advance.

In the future researches, the dual credit prediction database will continue to update the embedded accounting parameters and methods in accordance with the "Dual Credit Policy" and the amended related policies and standards, and further incorporate the research data of the medium- and long-term corporate planning on passenger car products, with a view to promoting the prediction database to be more in line with the actual application scenarios in the future, and providing the competent governmental departments, scientific research organizations and enterprises with a reasonable, real and comprehensive reference for quantitative assessment.

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