Impacts of China's CAFC Standards on Light-weighting Strategy of Automotive Manufacturers

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Abstract: China's corporate average fuel consumption (CAFC) standards are curb weight based with discrete fuel consumption targets for different weight classes, which imposes significant impacts on the light-weighting strategy of automotive manufacturers. In this paper, the curb weight of all models in domestic passenger car market from 2010 to 2014 is investigated. And from the perspectives of brands, classes and curb weight changes, curb weight distribution of each weight subclass in CAFC standards is analyzed. Meanwhile, by employing cost-effectiveness analysis, the incentive for curb weight abnormal distribution is described. Our analysis indicates that automotive manufacturers manipulate curb weight of many models to comply with more favorable standards target. The discrete stepped characteristics of China'sCAFC standards is not in favor of the application of light-weighting technologies.

Key words: CAFC standards, vehicle light-weighting, cost-effectiveness

Introduction

China's domestic automotive production and sales ranked first globally for 6 consecutive years, which rose to 23.72 million and 23.49 million respectively in 2014. By the end of 2014, China's vehicle stock reached 154.47 million (including 9.72 million 3-wheel vehicles and low-speed trucks), implying anownership level of 113 vehicles per 1000 people. Although 2.5 times higher than the level 10 years ago, it is still lower than the world average level of 146 vehicles per 1000 people and far below the levels of U.S., Japan, EU and other developed countries and regions, which is more around 500 vehicles per 1000 people. Growth of China's auto market still has great potential.

Like other countries in the world, due to the staggering development of China's auto industry and spread of vehicle usage in the past decade, great concerns have been raised over energy supply and environment issues. China's reliance on oil import reached 59.2% in 2014 (Fig. 1), and energy security issues have become increasingly prominent. Meanwhile, a lot of vehicle emissions of pollutants and GHG offset the national energy saving and emission reduction targets greatly.

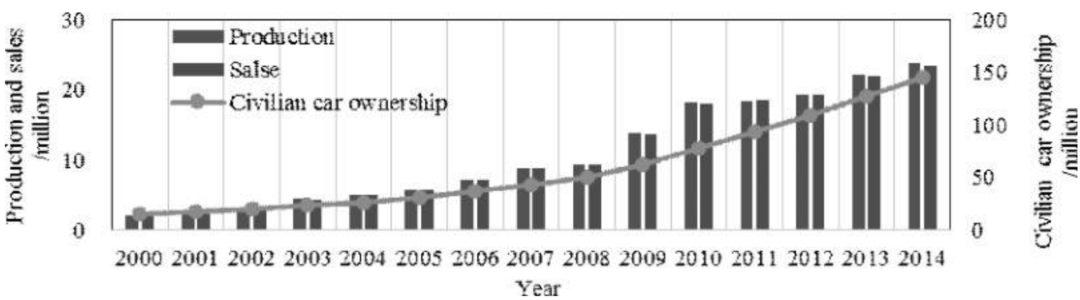


Fig. 1 China's domestic automotive production, sales and car ownership

In order to constrain fuel consumption and GHG emissions from China's automotive industry, China has released 4 phases of fuel economy standards. The Corporate average fuel consumption (CAFC) assessment system was incorporated under the Phase 3 fuel consumption standard, mandating the production of more fuel-efficient and environment-friendly vehicles, encouraging the development and application of energy-saving technologies. The China Phase 4 fleet-wide target of 5.0L/100km was established in 2014, with expected outputs of saving 35 million tons of fuel and reducing 113 million tons of CO_2 emissions.

To comply with the standards, auto-makers need to develop technology roadmap and make strategic decisions according to characteristics of the standards and cost-effectiveness of available technologies. As the mainstream of vehicle product development, light-weighting technologies have great potential and impacts on fuel-saving. The degree of light-weighting decisions and specific technology choices are important parts of vehicle technology roadmap. Many updates have been made to maximize the development and application of fuel-efficient technologies in the process of improving the standards. One of the most important goal is to curb the growth of larger cars sales and promote the application of light-weighting technologies.

In this paper, with a focus on the characteristics of discrete fuel consumption targets based on different weight classes in China's CAFC standards, the curb weight of all models in domestic passenger car market from 2010 to 2014 is investigated and analyzed. By employing cost-effectiveness analysis, the incentive for curb weight abnormal distribution is described. Finally, improvement suggestions for the present phase standards are proposed.

2 Background and Main Characteristics of China's CAFC Standards

2.1 Background of CAFC Standards

Since July 2005 when GB 29588—2004 took effect, China has adopted several compulsory National Standards in terms of test methods, evaluation methods, fuel consumption limits and fuel consumption label, which build up the standards structure preliminarily. GB 19578 set fuel consumption limits by weight classes, with which vehicles fail to comply could not get administrative licenses to be sold, registered and used in domestic market. GB 27999 specified the Corporate Average Fuel Consumption (CAFC) evaluation system to enable auto-makers to meet the standards with certain product diversities. During the 9-year period of CAFC's implementation, several updates have been made and the average fuel consumption of domestic passenger carshas declined by more than 12%. However, it is still challenging to achieve the energy-saving target of fleet-wide 5L/100km in 2020 (Fig. 2).

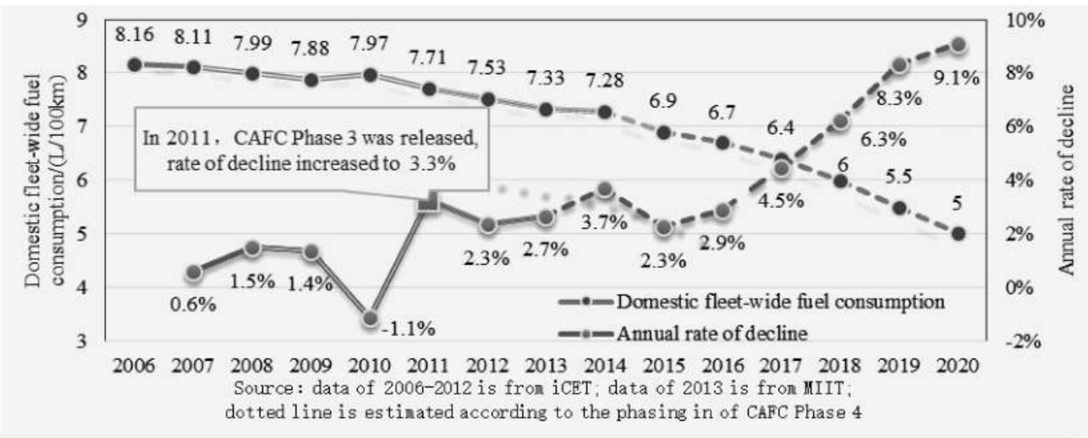


Fig. 2 China's fleet-wide fuel consumption of new passenger vehicles

2.2 Curb weight based characteristics of CAFC Standards

GB 27999—2014 and GB 19578—2014 were launched on Dec. 22, 2014, and China Phase 4 fuel consumption standards have firmly established. Most curb weight based characteristics following from China Phase 3 are analysed below.

2.2.1 Encouragement of light-weighting technologies

Footprint and vehicle weight are two main vehicle attributes that most fuel economy standards in the world are based on. The US fuel economy standards are based on footprint, while standards in Japan, EU and China are weight-proportionate. There are trade-offs between them. Footprint-based CAFE standards would create an incentive to increase vehicle size or motivate vehicle manufacturers to reduce weight without reducing footprint. By contrast, weight-based standards provided less incentive to reduce weight and apply advanced lightweight materials and structures.

The fuel consumption limits and targets are both based on vehicle curb weight in China's CAFC standards. Officially, it is designed to decrease vehicle size and promote weight reduction. However, in weight-based standards, the slope of fuel consumption targets reflect the promotion of light-weighting technologies. By employing test cycle conversion factors, Table 1 displays the slopes of NEDC equivalent fuel consumption targets in different weight-based standards. The slope of CAFC is between that in Japan and EU. Compared to Phase 3, Phase 4 significantly reduces the slope, which indicates a greater incentive to promote light-weighing technologies. Driven by this characteristic, automotive manufacturers should adjust their products assortment, invest more in small cars and develop mass reduction technologies appropriately.

Table 1 Parameters of weight-based standards in different counties and regions

Country/Region	Slope of fuel consumption targets (L/100km)/100kg		Rate of decline	Curb weight (class) benchmark kg	
Year	2012-2015	2016-2020		2012-2015	2016-2020
China	0. 342	0. 184	46. 2%	1205-1320	1320-1430
EU	0. 197	0. 144	26. 9%	1372	Avg. of pre. 3 years
Japan	0. 404	0. 276	31. 7%	1081-1195	1196-1310

2.2.2 Discrete stepped fuel consumption limits and targets

There are two methods to calculate fuel economy (fuel consumption) targets with dependent attributes, one is linear method used by the US and EU, and the other is discrete stepped method used by Japan and China. The CAFC standards establish fuel consumption limits and targets for vehicles divided into 16 weight classes. Since evidence has been provided that in order to be qualified for more favorable treatment, automakers in the US slightly modified vehicles close to cut-off points in the multiple pivot points featured tax system, causing negative net social benefits. An analogy can be made between vehicle fuel economy standards and the tax system. China's CAFC standards are also discrete stepped featured based on curb weight. Therefore, it is reasonable for automakers to manipulate vehicle curb weights to the left side of each weight class for more favorable standards target, or even slightly add weight to some models to the upper class, which will consequently discourage the application of light-weighting technologies rather than promoting it. However, to the best of our knowledge, no research has provided relevant evidence.

3 Curb Weight Distribution

In this paper, the curb weight of all models in domestic passenger car market from 2010 to 2014 is investigated. The data is sorted in brands, classes and curb weight changes. All data is from the Ministry of Industry and Information Technology (MIIT). Table 2 is number of models investigated each year.

Table 2 Number of models investigated each year

Year	2010	2011	2012	2013	2014
Number of models	297	483	586	670	696

Weight classes in the standards are divided into 10 sub-classes by 10% of each class width, and the numbers of models whose curb weight fall into in each sub-class are counted. For example, 0 ~ 10% indicates the total number of models whose curb weight fall into the left 10% of each weight class, while 90% ~ 100% indicates the right 10% in each weight class.

Firstly, we analyzed the distribution trend of the past 5 years. As shown in Fig. 3, the number of models in 0 ~ 10% sub-class increased significantly to 21%, while the number of models in 90% ~ 100% sub-class decreased to nearly 5%. The entire distribution tilts to the left side. With the restriction of technology availability and cost, there are no notable differences among the numbers of models distributed in the middle sub-classes.

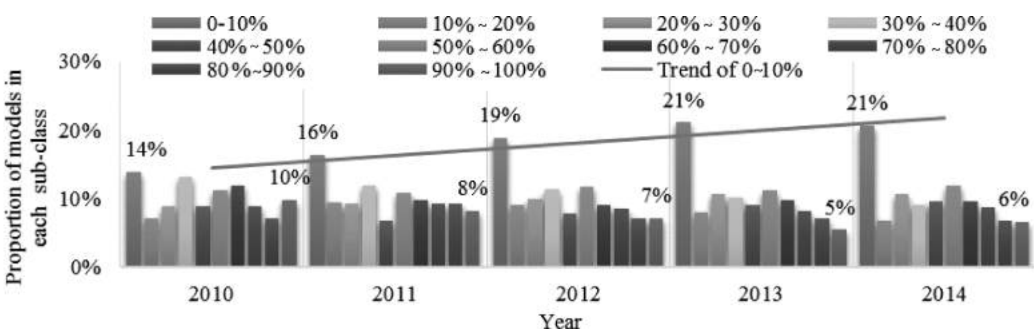


Fig. 3 The overall trend of curb weight distribution in MY 2010 to 2014

Among the models whose curb weights have changed (same model re-skinned or re-styled without altering the platform) from 2010 to 2014, some have been changed for more than twice. Therefore, orange bars and grey bars are applied to indicate the first-time changed curb weights and the final curb weight respectively.

As shown in Fig. 4, in order to adapt to the discrete stepped characteristics, automakers changed curb weights to the left end of weight classes and models were piled up at the left 10% sub-class consequently. With the standards phasing in, the difficulty of compliance has increased. Therefore, automakers implemented light-weighting technologies to more models and finally some curb weights were decreased from 0 ~ 20% of upper weight classes to 70% ~ 90% of lower weight classes.

As to the weight-increased models shown in Fig. 5, the proportion of 0 ~ 10% sub-class rises to over 26%, which implies most models in 90% ~ 100% sub-class were shifted to the upper 0 ~ 10% sub-class for more favorable targets.

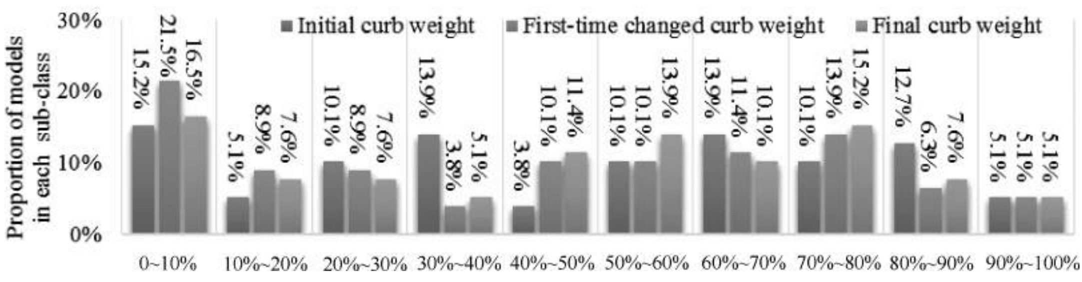


Fig. 4 Curb weight distribution of weight-decreasing models

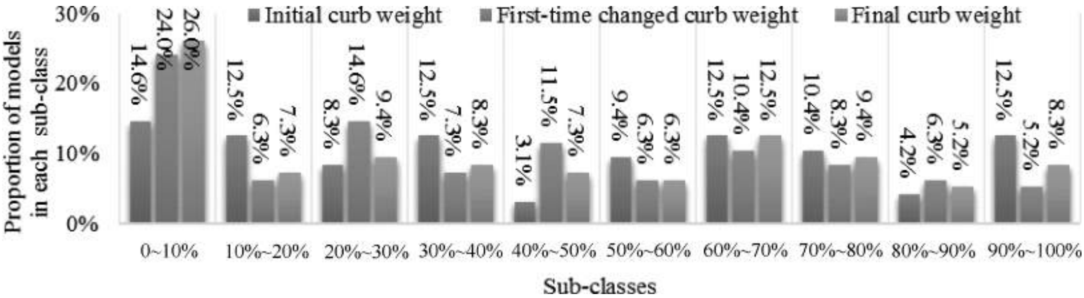


Fig. 5 Curb weight distribution of weight-increasing models

Fig. 6 illustrates the distribution result of data sorted by vehicle class. Models in A and A0 class adjust to the discrete stepped characteristics the most, while curb weights in C + class are evenly distributed. On one hand, because of the high curb weights of C + class models, it is more challenging to achieve the standards target; on the other hand, the market segments of C + class models are limousine and luxury, and the relatively small market share makes C + models contribute less to the CAFC of an automaker. Meanwhile, high curb weight is a selling point in these market segments in China.

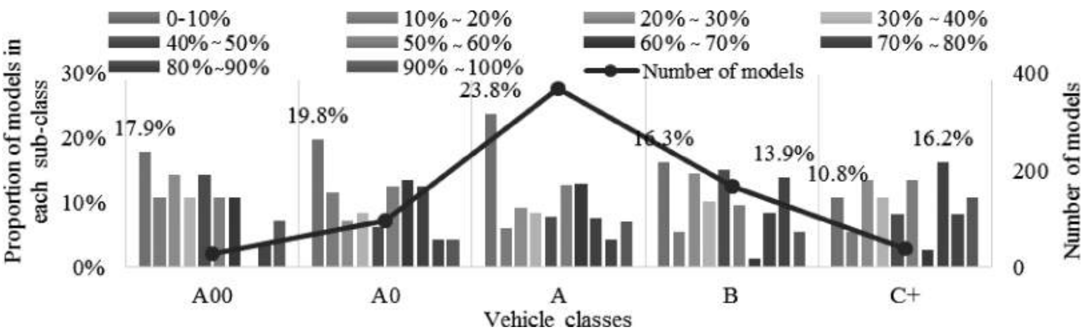


Fig. 6 Curb weight distribution of different classes (sorted by wheel base) in MY2014

At last, we classify domestic automakers into self-owned brands and joint brands and analyse the curb weight distribution. As shown in Fig. 7, in the past 5 years, the number of joint brands models distributed in 0 ~ 10% subclass has increased by 4.8%, while the number of self-owned brands models has increased remarkably from 19.5% to 29.3%, which implies the huge pressure and challenge of self-owned brands' compliance. They have to take the best advantage of the characteristics to achieve the standards targets.

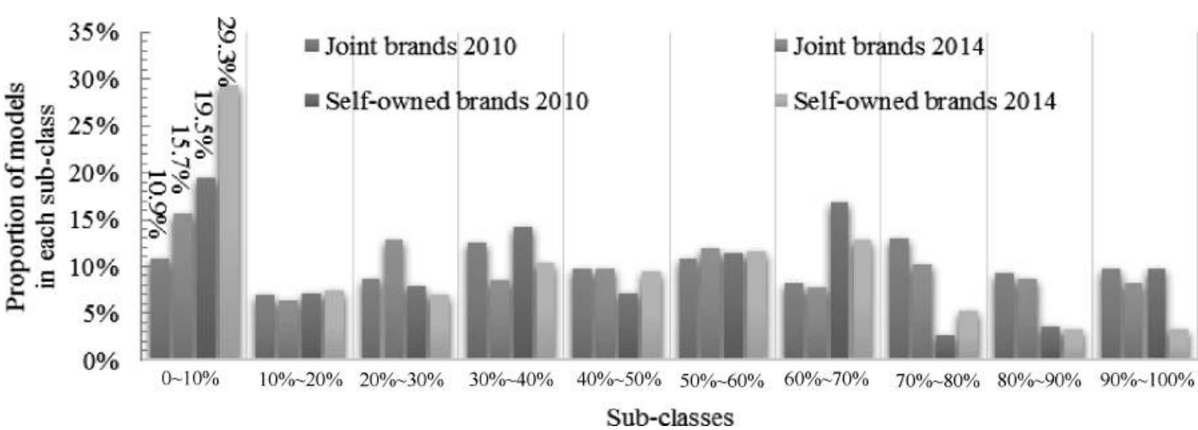


Fig. 7 Comparison of curb weight distribution between self-owned brands and joint brands

4 Cost-effectiveness of Light-weighting Technologies under CAFC

Cost-effectiveness analysis is an economic method to compare relative costs and effects. It could be employed to analyze the feasibility and justification of an investment or provide a basis for comparing different projects. This method is often used for resource allocation and decision-making in the fields of medical and healthcare. In recent years, with the innovation and development of vehicle fuel efficient technologies, the method was also used in the assessment of vehicle advanced technologies, electrification and light-weighting technologies. Marginal abatement cost curves were derived using the ranking of different GHG emission reduction means and employing cost-effectiveness analysis.

Impact of CAFC standard on the automaker decision making of light-weighting is analyzed. The cost-effectiveness of light-weighting is defined as:

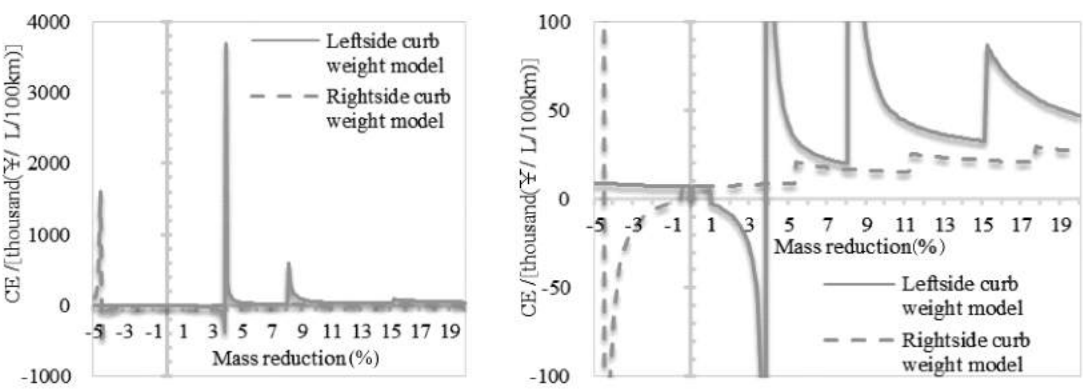
$$CE = \frac{C}{(T-R) - (T'-R')} \quad (1)$$

Where C is the cost of light-weightingapplication; T and T' are fuel consumption targets before and after the application; R and R' are fuel consumption of one model before and after the application of light-weighting respectively.

The denominator is the difference of the gaps between fuel consumption target and vehicle tested fuel consumption before and after the application of light-weighting technologies, which indicates the effect of technology application. CE indicates the cost of reducing a unit gap between target and tested fuel consumption.

Available light-weighting technologies provide a vehicle mass reduction potential of 0 to 20% with an increasing cost. For a specific model, by using more economic materials and simplifying machining processes, the cost would decrease with an increase in curb weight. To simplify the analysis, we assume the increase of curb weight from 0 to 5% creates a negative cost whose absolute value equals to the cost of mass reduction from 0 to 5%. Two typical models with curb weights close to the left and right sides of a weight class are selected. Fig. 8 presents the CE values of each model.

As to the model whose curb weight is close to the left cut-off point of the weight class (shown in solid lines in Fig. 8), curb weight drops quickly to the cut-off point between 2 weight classes when applied light-weighting technologies. With more technologies applied, the curb weight drops to the lower weight class and the model needs to comply with a more stringent fuel consumption target. The gap between target and tested fuel consumption increases sharply, which offsets the fuel economy gained by light-weighting. In some cases, the weight class change even causes a worse situation than initial, resulting in a negative value of CE, which indicates that technologies investment creates a negative effect. A rational automaker would choose the mass reduction percent with a positive and local-minimum CE value. According to the result of Fig. 8, the scales of 0 to 0.9%, 7% to 8% and 14% to 15.1% could be considered. Only when available technologies of a specific automaker were able to precisely reduce vehicle mass to the 3 scales above could the automaker apply them. Otherwise, it would abandon light-weighting strategy of the model, since in other scales light-weighting strategy is uneconomical in terms of complying with CAFC standards. This results in a curb of technology application by the models close to the left side of each weight class. Therefore, most automakers would manipulate their models to the extreme left side of one weight class instead of crossing weight class boundaries and getting a worse CE value. The phenomenon has been validated by the curb weight abnormal distribution discussed above.



a)

b)

Fig. 8 The mass reduction cost-effectiveness of two typical models

a) The overall trend of cost-effectiveness b) The partial enlarged cost-effectiveness

As to the model whose curb weight is close to the right cut-off point of the weight class (Fig. 8), when mass reduction is positive, as what has been discussed above, an automaker would consider the scale of 0 ~ 5.4%, 9.5% ~ 11.1% and 16% ~ 17.6%. However, when considering negative mass reduction, which means add weight to a model, the model could comply with a more favourable target on condition that the curb weight increased slightly by 0.4% and entered the upper weight class. In this case, cost is negative while effectiveness is positive, and CE is negative, which indicates that the automaker not only cuts manufacturing cost, but also meets the standards better. Under the situation that compliance with CAFC standards is not too difficult, automakers have strong incentives to qualify for more favourable targets by slightly modifying vehicle curb weightin order to get a better CE value. Therefore, with respect to vehicle models of this type, the discrete stepped characteristicsof CAFC

Standards are discouraging the application of light-weighting technologies practically instead of promoting it.

5 Conclusions and Policy Recommendations

This study summarizes the weight-based technical characteristics of China's CAFC Standards. Aiming at the discrete stepped fuel consumption limits characteristics, the curb weight of all models in domestic passenger car market from 2010 to 2014 is investigated. From the perspectives of brands, classes and curb weight changes, curb weight distribution of each weight subclass in CAFC standards is analysed. The incentive for curb weight abnormal distribution is described by employing cost-effectiveness analysis method.

The results indicated abnormal distribution of curb weight in China domestic car market. The data distribution tilts to the left end of each weight class, which is particularly evident in the range of 0 ~ 10% of each class. As to the data sorted by vehicle classes and brands, the phenomenon is evident in A and A0 class models and in own brands models. By analysing the cost-effectiveness of light-weighting technologies under CAFC, results show that the discrete stepped characteristics restrains automakers from implementing light-weighting strategy to a number of models. It even creates an incentive to increase the curb weight of some models, which imposes negative impacts on achieving the goal of promoting light-weighting technologies in China.

The analysis suggests that two forms of modification could be considered in the next CAFC phase to encourage advanced light materials and light-weighting technologies in China. First, the function to determine fuel consumption limits and targets should be linear instead of a discrete one, ensuring that automakers could implement light-weighting strategy to all their models the most by applying every available and cost-effective technology. Second, further flatten the slope of the function determining fuel consumption limits and targets based on curb weight, which would increase the compliance pressure of large cars and reduce the difficulty of small cars.

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