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The impact of stepped fuel economy targets on automaker's light-weighting strategy: The China case

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ABSTRACT

In China's fuel consumption rate regulation for passenger vehicles, the vehicle curb weight-based fuel consumption rate targets are specified in a stepped pattern, which is supposed to have considerable impact on automaker's light-weighting strategy. In this study, this impact is quantitatively evaluated based on China's domestic automotive market data. From the cost-effectiveness perspective, this paper firstly demonstrate that under stepped fuel consumption rate targets, automakers have strong incentives to manipulate curb weights to get qualified for more favorable targets. Then China's 2010–2014 domestic vehicle models are examined. A significantly imbalanced curb weight distribution is observed, with a considerable number of vehicle models bunching on the targets-preferred end of each weight class. By establishing multiple criteria, the vehicle models which are mostly likely to have been manipulated with curb weights are identified, which account for around 10% of all vehicle models. With an assumed shift from stepped targets to smooth targets, these affected vehicle models would have an average of 17.92 kg mass reduction and 0.073 L/100 km fuel consumption rate improvement. Our analysis suggests that the stepped targets have thwarted automakers from applying light-weighting technologies. China should consider shifting from stepped targets to smooth targets in the next phase of regulation.

1. Introduction

China's vehicle market has grown explosively over the past decade, with an average growth rate of 17.5% since 2000. China's vehicle sales have ranked first globally for 6 successive years. The domestic vehicle sales reached 23.5 million [5], which constituted 29.8% of the global sales in 2014 [36]. Accordingly, vehicle stock rose to 154.5 million (including 9.7 million low-speed trucks and 3-wheel vehicles) and 113 vehicles per thousand people by the end of 2014 [6], 8 times higher than the level in 2000. However, compared to the vehicle ownership of over 500 vehicles per thousand people in the US, Japan and EU, there is still great growth potential in China's vehicle market. Vehicle stock was projected to reach 184.8, 363.8 and 606.7 million by 2020, 2030 and 2050 respectively [14]. Along with the booming auto industry, concerns over CO_2 emissions and energy security have been raised.

Fuel economy standard is one of the most potential transportation energy saving approaches [18]. In order to enhance the vehicle fuel economy and mitigate the rising oil dependence, China's government has issued several compulsory national standards, such as FCR (fuel consumption rate) labeling and the phase-in implementation of FCR standards. The Phase I standards, issued in 2004 by GAQSIQ (General Administration of Quality Supervision, Inspection, and Quarantine of China) and SAC (Standardization Administration of China), specified the FCR limits of vehicles divided into different weight classes. Vehicle models failing to comply with the limits could not be administratively licensed to be sold in China's domestic vehicle market [9]. The Phase III standards established a sales-weighted CAFC (corporate average fuel consumption) standards structure, and specified preferential FCR targets and calculation methods to promote fuel efficient vehicles and new energy vehicles [10]. In China, fuel efficient vehicles are vehicles with FCR of lower than 2.8 L/100 km, and new energy vehicles include PHEVs (plug-in electric vehicles), BEVs (battery electric vehicles) and FCVs (fuel cell vehicles). In 2014, the Phase IV FCR standards were released, with the aim of reducing the national average FCR of passenger vehicles to 5.0 L/100 km by 2020 [11], in which the FCR targets of Phase III are set as mandatory FCR limits in

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Nomenclature

BEV	Battery electric vehicle
CAFC	Corporate average fuel consumption
FCR	Fuel consumption rate
FCV	Fuel cell vehicle
ICE	Internal combustion engine
NEDC	New European driving cycle
PHEV	Plug-in hybrid electric vehicle

Phase IV [12]. As shown in Fig. 1, the fleet-wide average FCR has decreased by over 12% during the 9 years since Phase I standards took into effect [22]. Nevertheless, it is still a formidable challenge for automotive manufacturers to achieve the fleet-wide target of 5 L/100 km in 2020.

Fuel economy targets are normally dependent on the vehicle attributes, such as curb weight, footprint and engine size, which could considerably diminish the disparity of different vehicles in regulatory stringency [3]. For vehicles with comparable types of powertrains, the weight attribute influences the fuel economy inherently [31]. The fuel economy targets of China, EU and Japan are based on vehicle weight, while the fuel economy targets of the US and Canada are set as footprint-proportionate. Light-weighting had proven the largest potential for energy saving expect for battery electric vehicle [32]. However, weight-based targets standards provide less incentives to apply advanced light-weighting materials and light-weighting designs, which may adversely impact consumer utility and safety [23]. In comparison, footprint-based targets would create an incentive to reduce the footprint-to-weight ratio or even motivate vehicle manufacturers to increase the size of vehicles [37].

Two methods are mainly employed to determine the fuel economy targets. The US, Canada and EU use smooth targets, which consequently derives continuous targets based on the vehicle attributes. By contrast, the FCR targets and limits in China and Japan are in stepped pattern, vehicle models are divided into 16 and 9 weight classes with different targets, as China's stepped FCR targets illustrated in Fig. 2. The concepts of China's CAFC and US CAFE (corporate average fuel economy) are very similar, the calculation methods of which are both fleet-wide fuel economy of corporate level. The basic schemes of typical fuel economy standards shown in Table 1 [2], and the scheme comparison of typical light-duty vehicle taxes are shown in Table 2 [17].

The characteristic of targets steps with pivot-points are common in many tax and subsidy structures, such as the US Gas Guzzler Tax based on fuel economy and China's new energy vehicle subsidy based on battery capacity. Evidence has been provided that in the multiple pivot-points featured stepped Gas Guzzler Tax structure, automotive manufacturers in the US would slightly modify the fuel economy of a vehicle model to get qualified for more favorable treatment, which accordingly brings negative net social benefits [34]. An analogy could be made between the tax system and the stepped FCR targets. The footprint attribute is related to a platform that could be shared by several vehicle models. In comparison, a vehicle's curb weight and fuel economy attributes are less integral to the vehicle's design, which could be altered easily between model years at less cost. Thus it is reasonable for vehicle manufacturers to manipulate these attributes to shift the vehicle models to other classes with favorable targets. For automotive manufacturers under the stepped targets of China's FCR standards, the wasteful manipulation of curb weights would be inefficient and costly. However, to the best of our knowledge, no research has provided such evidence relevant to the impacts of stepped FCR targets.

In this study, by employing cost-effectiveness analysis method, the impacts of stepped FCR targets on an automotive manufacturer's short-term and long-term light-weighting strategies are analyzed. The abnormal distribution of passenger car curb weights in China's domestic market between 2010 and 2014 is described. In order to describe the impacts of stepped FCR targets, by using the indicators and criteria defined, the vehicle models which are affected by the stepped FCR targets are identified and redistributed under an assumed smooth FCR targets scenario. The fleet-wide FCR and curb weight changes under the smooth FCR targets are compared with that under the stepped ones.

2. Cost-effectiveness analysis on automaker's light-weighting strategy

2.1. Cost-effectiveness definition

Cost-effectiveness analysis is a normal method to compare different projects by providing the justification and feasibility. For example, Noori investigated current reflective cracking mitigation methods by employing life cycle cost analysis, which provided policy makers a method of exploring the most cost-effective mitigation technique [29]. In the field of energy analysis, marginal abatement costs of different measures can be derived by employing cost-effectiveness method [25]. With the remarkable innovation

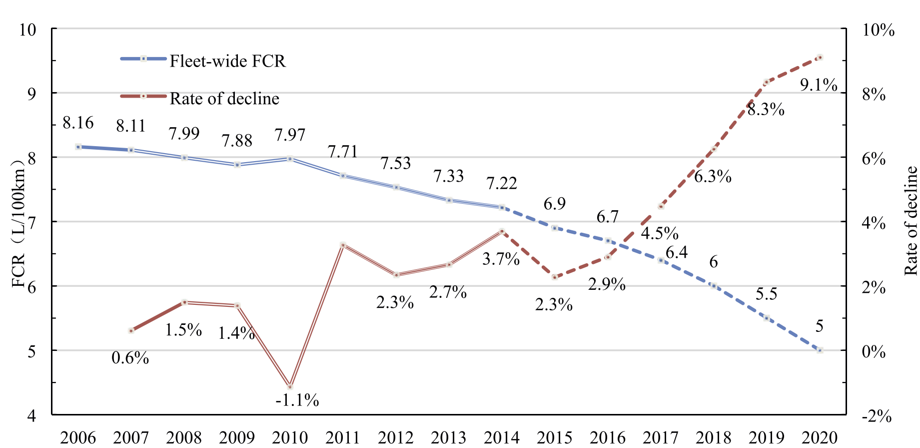

Fig. 1. China's fleet-wide FCR of light duty vehicles. *Note*: dotted line is estimated according to the phasing in of CAFC Phase IV.