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The correlated impacts of fuel consumption improvements and vehicle electrification on vehicle greenhouse gas emissions in China

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ABSTRACT

Energy security and environmental issues have drawn great attentions to the energy consumption and greenhouse gas (GHG) emissions in the road transport sector. With economic development, travel demands and logistics demands will continue to rise in China. To solve the associated problems, policies related to electric vehicle (EV) promotion and fuel economy regulations are being adopted by the state government. Six scenarios, based on different policies, are analyzed to calculate vehicle fleet GHG emissions in this research by developing a bottom-up modeling framework from a life-cycle perspective. When only fuel economy regulations are considered, GHG emissions from the road transport sector will reach their peak in 2047. However, combined with EV deployment, the peak will arrive earlier, in 2026. In the short term, more stringent fuel economy regulations exhibit better results. Without EVs, fuel economy regulations will be tougher for corporations to meet than with the introduction of EVs. However, in the long term, with a higher proportion of EVs, GHG emissions will further decrease. In addition, the introduction of EVs will weaken the effects of fuel economy regulations, especially for passenger vehicles, due to credit policies. The lack of EVs in the commercial vehicle fleet will impart more significance to the fuel economy regulations. Commercial vehicles, particularly trucks, will account for the majority of GHG emissions by the whole vehicle fleet. In brief, the government should persistently focus on the fuel economy regulations to achieve an early and relatively low-level peak in vehicle fleet GHG emissions. Meanwhile, the promotion of EVs will have the long-term effect of de-carbonization. In addition, more effective measures should be taken to reduce the truck GHG emissions.

1. Introduction

Economic development has caused increased energy demand, and the burning of fossil fuels has led to a large amount of carbon dioxide emissions. China is in a stage of rapid economic development. According to the International Energy Agency (IEA), 28% of total CO_2 emissions in 2015 came from China (IEA, 2017a). China has already become the greatest source of greenhouse gas (GHG) emissions worldwide. The Chinese government has a responsibility and obligation to reduce energy consumption and GHG emissions, and therefore, the government has accordingly made efforts and commitments. Every five years, the state government in China releases a plan established for the entire country named the "Five-year Plan", which contains detailed guidelines for national economic and social development in the coming five years (Yuan and Zuo, 2011). During the 12th five-year period (2011–2015), the rate of energy consumption per unit of gross domestic product (GDP) decreased steadily, from −2.0% in 2011 to −5.6% in 2015, which led to a cumulative reduction of 18.4% over the whole period (National Bureau of Statistics of the People's Republic of China, 2015; National Development and Reform Commission and National Energy Administration, 2017). In addition, the CO_2 emissions per unit of GDP declined over 20% in the 12th five-year period, and a reduction of 18% is expected during the 13th five-year period (2016–2020) (National Development and Reform Commission and National Energy Administration, 2017). In addition, during the '2015 United Nations Climate Change Conference', the Chinese government promised to achieve a CO_2 emissions peak in China before 2030 (United Nations Climate Ch, 2015).

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The transportation sector accounted for approximately 24% of the world's CO_2 emissions from fuel combustion in 2015. For China, this value was 9.3%, which was much lower than the world average (IEA, 2017a). Road transport CO_2 emissions accounted for approximately 82.7% of the transport CO_2 emissions in the world, and the road freight generated more than 35% of transport-related CO_2 emissions (IEA, 2017a; IEA, 2017b). As the Chinese economy grows, travel and logistics demands will continue to increase (Hao et al., 2015a, 2015b). Additionally, China's dependence on foreign oil has been growing consistently each year (Yao and Chang, 2014), and therefore, controlling energy consumption and GHG emissions in the road transport sector is essential to limit the total amount of GHG emissions and ensure China's energy security.

From an international perspective, many countries have introduced the regulations and standards on vehicle fuel consumption rates to control energy consumption and GHG emissions in the road transport sector. For passenger vehicles, the European Union (EU) has set the most stringent regulations on vehicle CO_2 emissions. New passenger vehicles were required to reach a target of 130 g-CO_2/km (around 4.1 L/100 km) by 2015 and must reach 95 g-CO_2/km (around 3.0 L/100 km) by 2021 (European Commission, 2014). Japan issued new standards in 2011, which required new passenger vehicles to achieve consumption rates of 20.3 km/L (around 4.9 L/100 km) by 2020 (Ministry of Economy et al., 2011). The U.S., as the first country to enact regulations on vehicle fuel economy, updated its regulations in 2012, and demanded that new cars reach 54.5 miles per gallon (around 4.3 L/100 km) by 2025. The Chinese government also introduced the latest regulations on passenger vehicles and set targets of 5 L/100 km by 2020, 4 L/100 km by 2025 and 3.2 L/100 km by 2030 (MIIT, 2013; SAE-China, 2016). For commercial vehicles, only four countries worldwide, namely, Canada, China, Japan and the U.S., have regulations regarding fuel economy standards for heavy-duty vehicles (IEA, 2017b). For both passenger vehicles and commercial vehicles, the existence of fuel economy regulations and standards are expected to significantly promote the development of technology and solve energy-related and environmental problems.

Another effective solution to reduce energy consumption and GHG emissions is to introduce electric vehicles (EVs) into the vehicle fleet. The EV stock all over the world increased from 16.8 thousand vehicles in 2010–2014.2 thousand vehicles in 2016 (IEA, 2017c). Many countries issued different policies to stimulate the EV market from both a manufacturing perspective and a consumer perspective. The U.S. Environmental Protection Agency (EPA) introduced an incentive multiplier in fuel economy regulations for EVs based on different model years (EPA (U.S. Environmental Protection Agency), 2012). Different states in the U.S. also adopted various incentives to promote the development of EVs, such as fiscal subsidies (Zhou et al., 2015). As mentioned before, China has strong motivation to reduce its reliance on conventional fuels. In 2009, the Chinese government officially began to provide subsidies for the purchase of EVs, and some regional subsidies were also released in succession. Various subsidy standards were applied depending on regions and model years.

Most previous studies have focused on the introduction and comparison of fuel economy regulations in different countries and suggested technological strategies to meet the targets. Hao et al. and Nan et al. both introduced energy efficiency standards in China's transport sector (Hao et al., 2017; Nan et al., 2010). Li et al. analyzed vehicle fuel consumption standards and their impact on curb weight (Li et al., 2016a). Oliver analyzed the first and second fuel economy standards of passenger vehicles in China and assessed their impacts, including fuel economy improvement, technology changes, etc. (Oliver et al., 2009). Zhao et al. analyzed the fuel consumption rate target for passenger vehicles in 2020 and provided technological strategies (Zhao et al., 2016a). Above-mentioned studies only introduced the latest fuel economy regulations in China or analyzed their impacts on the vehicle models, but none of these studies illustrated the impact of fuel economy regulations on the whole vehicle fleet energy consumption or GHG emissions.

When GHG emissions are considered, few studies have focused on the importance of the latest fuel regulations. In addition, most of the researchers only pay attention to passenger vehicles while ignoring the impacts of commercial vehicles. Ou et al. mentioned fuel economy regulations. However, they did not provide specific analysis of their impacts, and only fuel economy regulations for passenger vehicles were considered in their research (Ou et al., 2010a). Yan et al. referred to fuel economy regulations on passenger vehicles and light duty commercial vehicles, and did not further analyze the influence of fuel economy regulations (Yan and Crookes, 2009). Due to the development of regulations and technologies, the validity of the results, which were based on previous regulations and data and only considered part of the vehicle fleet, will be challenged. Especially, because the latest fuel economy regulations took EVs into consideration, it is essential to re-evaluate the impact of latest regulations on vehicle fleet energy consumption and GHG emission. In addition, much attention has been paid to passenger vehicles. While, because of high fuel consumption rates, it is really also important to include commercial vehicles to make the research more objective and comprehensive.

Many scholars also analyzed the environmental impact of EVs. Qiao et al. compared the life cycle energy consumption and GHG emissions of battery electric and internal combustion engine vehicles in the vehicle production phase. (Qiao et al., 2017). The results indicated that battery electric vehicles cause 50% higher GHG emissions than internal combustion engine vehicles from a cradle-to-gate perspective. Peng et al. analyzed the life-cycle energy consumption and GHG emissions of EVs at the national level (Peng et al., 2017). Zhou et al. studied the impact of regional power grids on the GHG emissions of EVs (Zhou et al., 2013). Hao et al. considered five GHG emissions mitigation measures, which included both promoting EVs and strengthening the fuel consumption rate (Hao et al., 2011a). However, the research was only based on the passenger vehicle fleet, and the data in the research is not the most current. All in all, most studies regarding EVs are based on the individual vehicle model comparison, and the EV deployment in the latest plans in China grew faster than previous assumptions in former studies.

Studies of the vehicle fleet GHG emissions of other countries have also been conducted. Bandivadekar et al. compared the GHG emission reduction effects of different kinds of technologies in the U.S. light-duty vehicle fleet. The results indicated that the market penetration of emerging vehicle technologies should be large to realize a remarkable benefit. In the future, a combination of different kinds of technologies and incentive policies should be applied to achieve better results instead of choosing a winning technology (Bandivadekar et al., 2008). Bastani et al. also concluded that the major factors contributing to vehicle fleet GHG emissions in the U.S. would change over time from the short term to the long term and emphasized the importance of dynamic policy making (Bastani et al., 2012). Pasaoglu et al. analyzed the deployment of different powertrains for passenger vehicles and light commercial vehicles in the EU until 2050. The results show that after 2030, the technological improvement rate slowed, and the reduction of fleet GHG emissions would mainly be caused by the use of alternative fuel vehicles (Pasaoglu et al., 2012). Thus, evaluating the GHG emissions of the vehicle fleet in China is important, both to compare different solutions to GHG emissions and to make some policy recommendations for future development.