

Evaluation of real-world fuel consumption of light-duty vehicles in China: A 2021 update

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BACKGROUND

The gap between real-world carbon dioxide (CO₂) emissions/fuel consumption of light-duty vehicles (LDV), on one hand, and their laboratory type approval values on the other, is increasingly apparent around the world¹. This gap has been observed in China as well, with evidence of it coming from consumer-reported data. ICCT has been tracking the gap between real-world and type-approval fuel consumption of LDVs over time, and has documented changes in the gap, depending on technology type or segment, since 2017. The objective of this paper is to provide an updated analysis of consumer-reported fuel consumption data in order to evaluate real-world fuel consumption of China's LDV fleet from model year (MY) 2007 to MY 2021.

DATA SOURCE AND METHODOLOGY

Several unofficial platforms collect real-world fuel consumption information in China, including Sina auto, Sohu auto, and XiaoXiongYouHao (XXYH). Sina auto and Sohu auto are two mainstream websites that collect and summarize consumer-reported fuel

1 Uwe Tietge, Sonsoles Díaz, Zifei Yang, and Peter Mock. *From Laboratory to Road International: A Comparison of Official and Real-World Fuel Consumption and CO₂ Values for Passenger Cars in Europe, the United States, China, and Japan*. (ICCT: Washington, DC, 2017), <https://theicct.org/publications/laboratory-road-intl>.

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consumption by vehicle model. XiaoXiongYouHao is a mobile application that allows users to track and compare their fuel consumption.²

We use XiaoXiongYouHao information to summarize consumer-based fuel consumption, in part because the proprietor of XiaoXiongYouHao graciously provided the data set used in this study. The mobile application of XiaoXiongYouHao was launched in 2010. By the end of 2020, it had collected data on more than 2.4 million individual vehicles. The data set includes information on more than 34,000 vehicle model variants with model years ranging from 1986 to 2021.³ The number of users and vehicles tracked has increased dramatically in recent years because of the growing vehicle market and expanding use of smartphones.

Most fuel volume and odometer readings logged in the application are assumed to be accurate because the users' goal is to track their fuel consumption, and the app does not reward any data entries or fuel consumption information that would give users an incentive to enter fake data.

Data processing and statistical analysis of this study follow the standardized methods described in prior ICCT publications studies.⁴

The data proprietor removed outliers using reasonable ranges based on statistical analysis. For individual vehicles with more than five reported fuel consumption records, the average fuel consumption is considered normal if it lies within 2.5 standard deviations left of the mean and 4.5 standard deviations right of the mean of all data from the same vehicle variant (the same vehicle type and model year). It is normal for vehicles to have higher fuel consumption in real driving. As a result, the distribution of the sample fuel economy is somewhat skewed, since there is more scatter in the fuel consumption records that are higher than the average value. Therefore, the data proprietor chose different variance intervals to determine outliers on different sides of the mean value. For individual vehicles with five or fewer reported fuel consumption records, the average fuel consumption value is considered normal if it lies within two standard deviations of the mean of all data of the same vehicle variant.

For each vehicle model variant, the dataset included information on the model year, engine type (naturally aspirated or turbocharged), transmission type, vehicle segment, average on-road fuel consumption, official fuel consumption rating, and number of vehicles in the sample. After removing data for motorcycles, trucks, electric vehicles, and missing values, and removing model years 2002 to 2006 as they included fewer than 5000 samples per year, about 2,088,835 individual vehicles of more than 21,000 vehicle model variants remained, with model years ranging from 2007 to 2021. In this report, MY 2021 vehicles refers to vehicles with 2021 model variants sold in or before 2020, given that data records are collected by the end of 2020. Table 1 details the number of samples by model year. Vehicles from MY 2009 to MY 2020 constitute the majority of all the samples.

In addition to the overall analysis of the gap between real-world and type-approval fuel consumption, data divergence was also analyzed by transmission type, engine type and segment in this report. For analysis by vehicle features, results were removed if the sample size was too small (less than 500).

2 XiaoXiongYouHao website: <http://www.xiaoxiongyouhao.com/index.php>

3 Some vehicles of model year 2021 were sold in or before 2020. The sample size of vehicles of model year 2021 is larger than 12,000.

4 Uwe Tietge, Sonsoles Díaz, Zifei Yang, and Peter Mock. *From Laboratory to Road International: A Comparison of Official and Real-World Fuel Consumption and CO₂ Values for Passenger Cars in Europe, the United States, China, and Japan*. (ICCT: Washington, DC, 2017). <https://theicct.org/publications/laboratory-road-intl>. Zifei Yang, and Liuhanzi Yang. *Evaluation of Real-World Fuel Consumption of Light-Duty Vehicles in China*. (ICCT: Washington, DC, 2018). https://theicct.org/publications/real_world_fuel_consumption_ldv_china.

Table 1. Summary of sample size by model year

Model year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Sample size	46	79	301	1,659	3,184	15,517	34,221	50,018	63,985	93,310
Model year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sample size	125,496	197,555	175,588	213,845	316,384	301,364	227,505	182,632	78,745	12,670

DATA REPRESENTATIVENESS

We compare the composition of the vehicle fleet from the XiaoXiongYouHao dataset with the entire light-duty vehicle fleet in market⁵, in order to show data representativeness. The market dataset includes sales information for the 2009–2010 year and the 2012–2019 period. It should be noted that “year” in the market dataset means sales year, whereas “year” in the XiaoXiongYouHao dataset refers to the model year of the vehicle.

Figure 1 presents the share of vehicles by transmission type. Continuous variable transmissions, dual clutch transmissions, and automated manual transmissions are all categorized as automatic transmissions. We compared the vehicle fleet composition of XiaoXiongYouHao data records with the composition of the vehicle fleet in the overall passenger vehicle market. Both data sets show the percentage of automatic transmission vehicles rising over time. For XiaoXiongYouHao data, the percentage of automatic vehicles is greater than 95% in MY 2020, and nearly 100% in MY 2021. However, market data lags several years behind sample data, which means that the market share of automatic transmission vehicles is not as high as that in our sample for the same year. One possible reason for this is that the year for market data is sales year, while the year for XiaoXiongYouHao data is model year. For a given sales year, vehicles for sale will include those of the current MY as well as previous MYs. As a result, the change of fleet composition by sales year lags behind the change by model year.

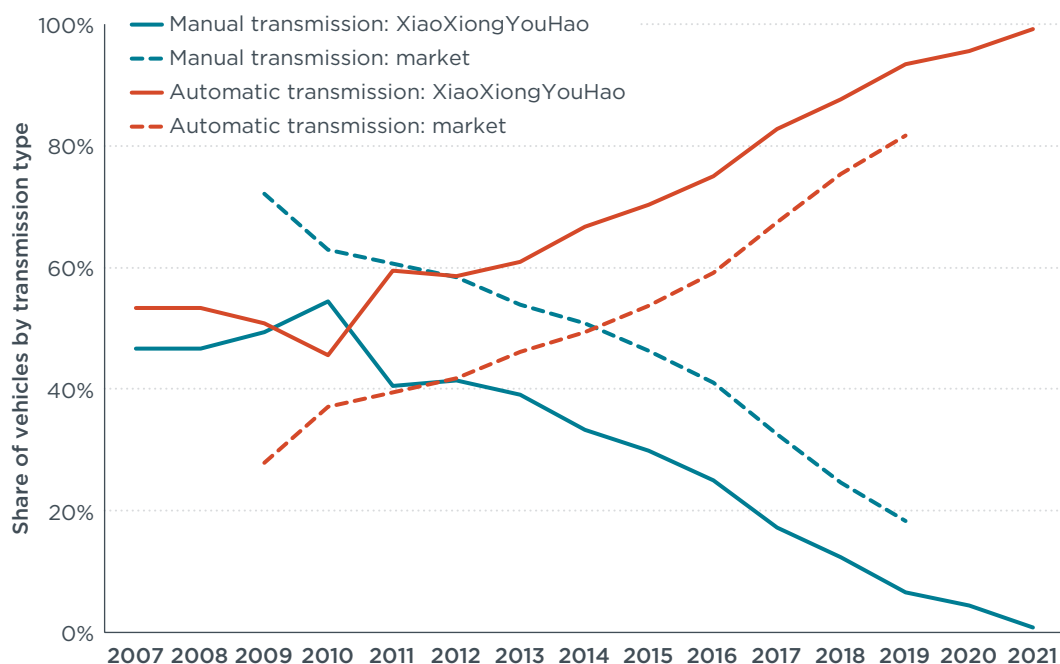


Figure 1. Share of vehicles by transmission type, comparing the XiaoXiongYouHao dataset and the market dataset

⁵ Market data was purchased from CATARC.

Because vehicles with automatic transmissions tend to have a larger type-approval versus real-world gap than manual transmission vehicles, we further dive into automatic transmission vehicle data and analyze the lab-to-road difference by engine type. Figure 2 plots the trend of automatic transmission vehicle fleet composition by engine type. The share of vehicles with turbocharged engines continues to rise dramatically. The engine type distribution of XiaoXiongYouHao data agrees very well with the distribution across the entire automatic transmission vehicle fleet in the market, which indicates that the sample data used in this analysis is representative. In sample data, the percentage of turbocharged engine vehicles reached around 70% in 2021, while this number was only 0.8% in MY 2007.

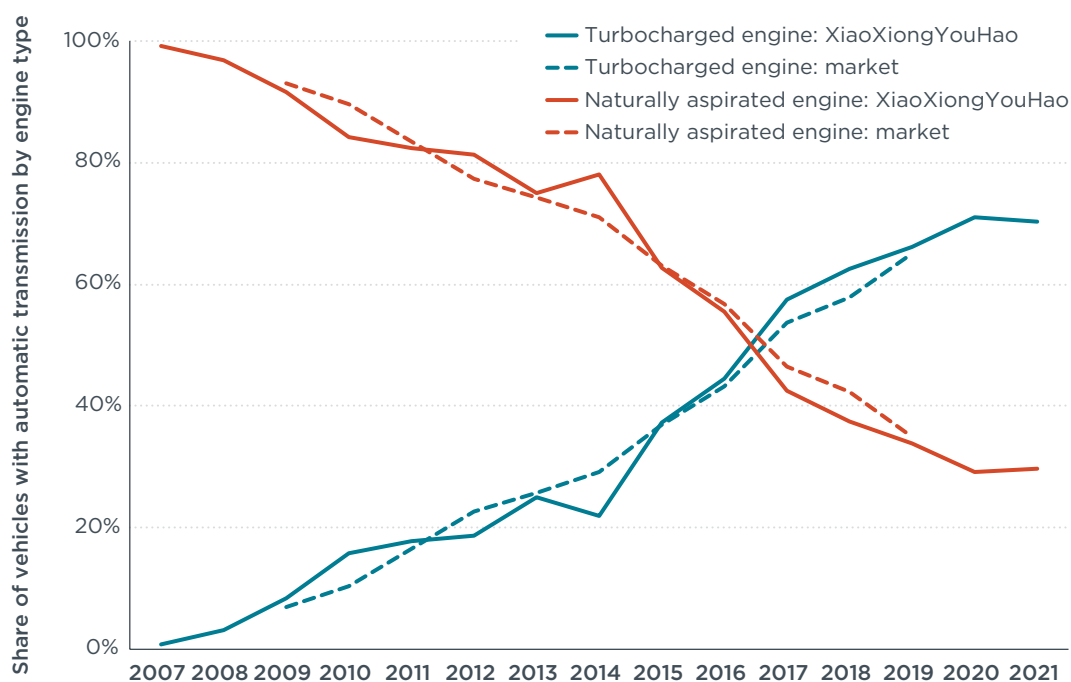


Figure 2. Share of vehicles with automatic transmissions, by engine type

Figure 3 indicates that the composition of vehicle samples changes over time. The share of lower medium-size and medium-size cars has remained relatively stable in recent years. Sport utility vehicles (SUVs) account for an increasing portion of the total sample while the shares of mini and small cars are decreasing, which is in line with changes in the overall passenger car market. The high consistency between the segment structure of our fleet sample and the structure of overall passenger vehicle fleet further indicates that XiaoXiongYouHao data is representative. Any difference between the two datasets probably results from how vehicles are categorized into seven segments. For example, multi-purpose vehicles (MPVs) include both regular MPVs and crossovers⁶ in the market dataset, while crossovers might be categorized into other segments in the XiaoXiongYouHao dataset.

⁶ Crossover, which is short for crossover utility vehicle, is a cross between a normal family passenger car and an SUV. Different from an SUV, a crossover vehicle is built with a unibody platform instead of a truck-based platform.

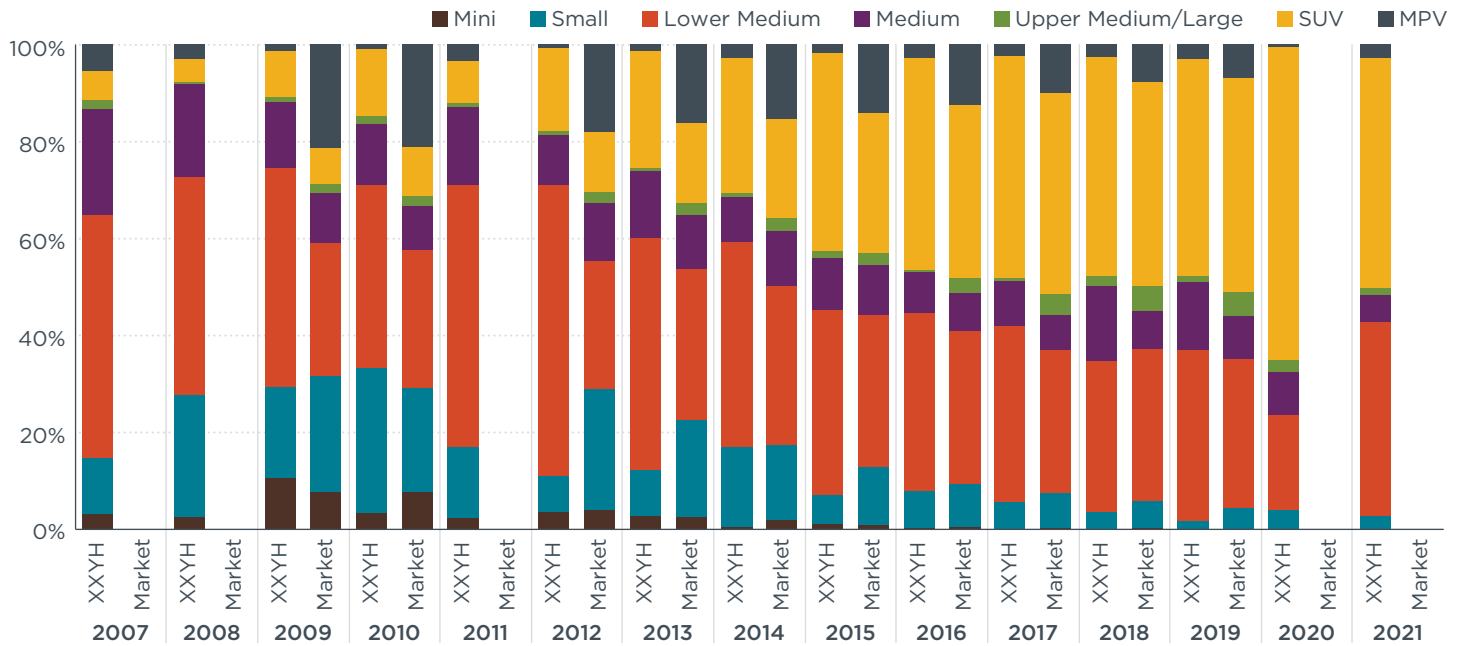


Figure 3. Share of vehicles by segment

RESULTS AND DISCUSSION

Figure 4 shows the development of the gap in average fuel consumption by the year of data analysis. In the latest 2021 study, the gap between real-world and type-approval fuel consumption reached 35% for MY 2020, and 37% for MY 2021. The divergence increased by 9 percentage points between MY 2017 and MY 2021. Results presented in this report differ slightly from the older 2007 to 2017 results published by Yang et al. in 2018, because existing users continuously add fuel consumption data to the database and because new users sign up. The results are similar, although the previous study may have overestimated the gap slightly between 2014 and 2017. The previous study gap for 2017 was more than 5 percentage points higher than the gap for 2017 in this study. A possible reason for the difference could be that MY 2017 vehicles are more popular in the 2021 study than in the 2018 study, since 2017 model variants were relatively novel in 2018. In the 2021 study, the sample size of MY 2017 vehicles is larger than 300,000, indicating that updated results should be more reliable.

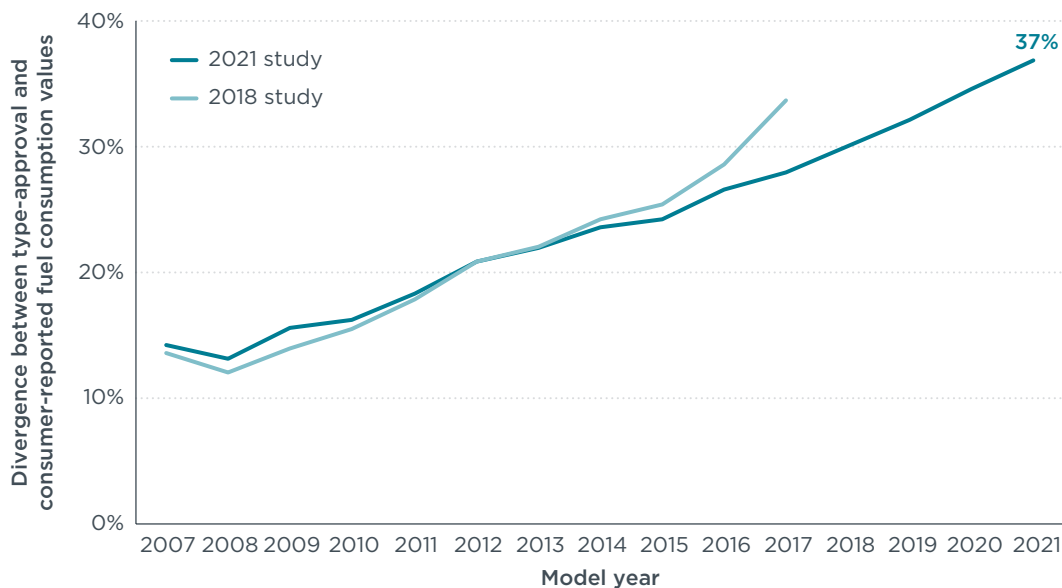


Figure 4. Divergence between XiaoXiongYouHao and official fuel consumption, by year of study

The gap between XiaoXiongYouHao and official CO₂ emissions by transmission type continues to rise (see Figure 5). The average divergence has increased from 14% to 37% from MY 2007 to MY 2021 at an accelerating rate, from less than one percentage point to around three percentage points per year. The divergence increased for both automatic and manual transmission cars, although vehicles with automatic transmissions consistently exhibited a higher divergence than vehicles with manual transmissions. Divergence seen in automatic vehicles increased from 17% to 38% between MY 2007 and MY 2021. Divergence of manual vehicles increased from 9% to 20% between MY 2007 and MY 2020. The result of MY 2021 manual transmission vehicles has been removed, because the sample size (106) is less than 500.

The sampled vehicle fleet of MY 2021 is dominated by automatic vehicles (99% of the sample), which is possibly because data we use for this report was collected by the end of 2020. As a result, the fleet-average divergence shows little difference from the divergence seen in automatic transmission vehicles.

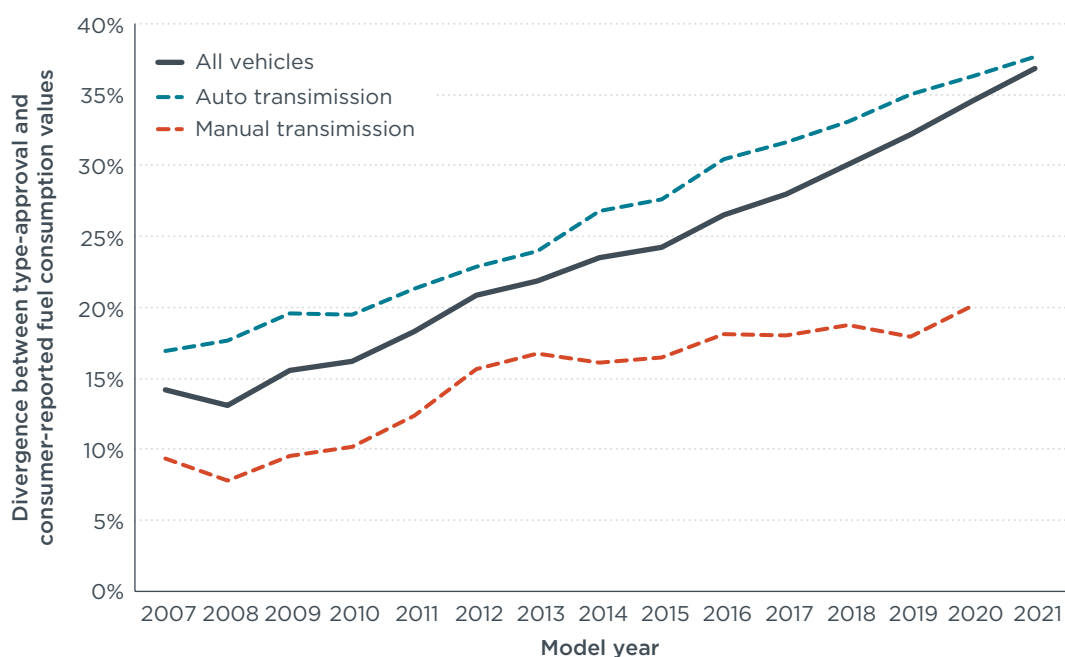


Figure 5. Divergence between XiaoXiongYouHao and official CO₂ emissions, by transmission type

We further explore the influence of engine type on divergence between XiaoXiongYouHao and official data on CO₂ emissions of automatic transmission vehicles. Figure 6 illustrates that the gap between XiaoXiongYouHao and official CO₂ emissions increased for both turbo and naturally aspirated engines. In addition, automatic transmission vehicles with turbocharged engines consistently exhibited a higher divergence than vehicles with naturally aspirated engines, especially in the past ten years. Divergence for turbocharged vehicles reached 38% in MY 2020, while that of vehicles with naturally aspirated engines reached 28% in the same model year. One possible explanation for the large gap for turbocharged vehicles is that consumers may use the higher torque to accelerate faster in the real world, increasing real-world fuel consumption compared with that of the lower load type-approval driving cycle. Therefore, the fuel benefits from turbocharged engines may not be fully realized in real-world driving.

Divergence of turbocharged vehicles of MY 2007 has been removed from the plot, since the sample size is merely 67, which is too small to be representative.

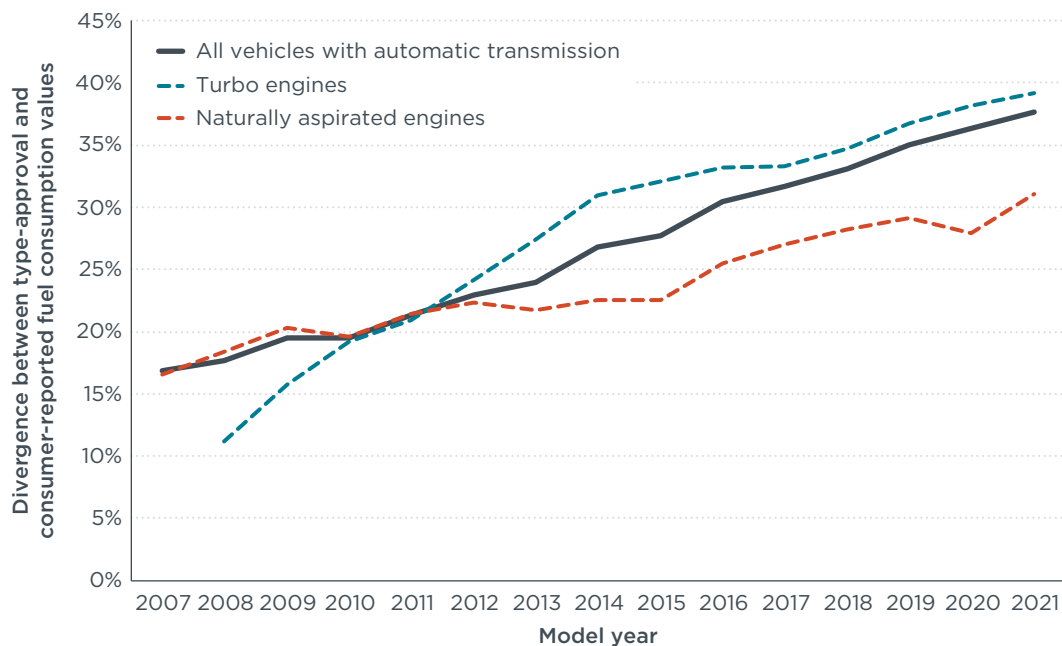


Figure 6. Divergence between XiaoXiongYouHao and official CO₂ emissions of automatic transmission vehicles by engine type

Despite the change in composition of the vehicle fleet, the divergence between consumer-reported and official fuel consumption increased across all segments (see Figure 7). Lower medium cars and SUVs exhibited a divergence close to the average for all segments. The medium, upper medium, and large segments tended to show a higher divergence than the other segments, but the market share of these segments has been relatively consistent over time and consequently these vehicles do not contribute to the widening divergence for the entire fleet over time.

Results for mini cars are only kept for MY 2008–2015, a period in which the sample size exceeded 500 for each MY. Some results of small vehicles (MY 2021), upper medium/large vehicles (MY 2007–2008, 2021), and MPV (MY 2020–2021) are also removed due to small sample sizes.

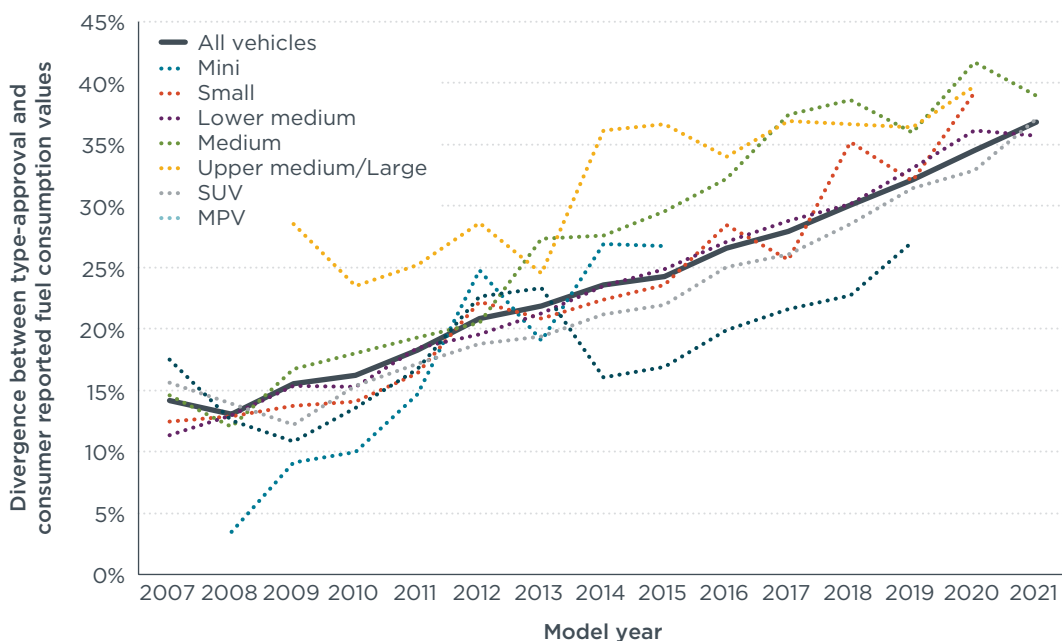


Figure 7. Divergence between XiaoXiongYouHao and official CO₂ emissions, by segment

CONCLUSIONS AND POLICY RECOMMENDATIONS

The findings from the updated analysis of XiaoXiongYouHao data illustrate that the gap between real-world and official fuel consumption in China has widened from 14% for MY 2007 to 37% for MY 2021. The accelerated expansion of the gap clearly indicates the need for regulatory changes to reverse the trend and close the gap.

Policy recommendations are summarized as follows:

» **Stringent test procedures to reflect real-world driving patterns.**

- » CO₂ and fuel economy standards should be based on test values which correspond to real-world condition. Policies that fail to consider the gap between lab and road will overestimate air quality improvement and climate change mitigation benefits.
- » In China, the Worldwide Harmonized Light Vehicles Test Cycle (WLTC) has been applied to light-duty passenger vehicles from July 1, 2021. It is critical to ensure that the new test procedures be adopted effectively as soon as possible. If possible, the China cycle with test procedures that are equal to or more stringent than Worldwide Harmonized Light Vehicles Test Procedure (WLTP) test procedures should be adopted.
- » It is also important to keep monitoring vehicles' real-world performance, and to be prepared to further revise test procedures as needed. The fact that the gap between lab and road results increased steadily over time indicates that manufacturers learned to "adapt" their vehicles to the test procedures. With new procedures, the gap could close significantly at the beginning of a new test cycle, then increase again over time, unless monitoring is ongoing.

» **Add real-world fuel consumption/GHG test requirements.**

- » Introduce the Real Driving Emissions (RDE) test to complement the laboratory test procedure and better represent the range of real-world driving conditions. The RDE test better reflects the wide range of driving habits and conditions of real-world driving. This would push manufacturers to make their systems more robust and reduce fuel consumption over a wider range of driving behaviors and conditions. The RDE test has been applied in China 6 emissions standards to collect real-world CO₂ emission data for research purposes. We suggest that data collected be used for regulatory purposes in the next stage of emission standards.
- » Add in-use conformity testing requirements to check compliance against standards throughout the useful life of the vehicle. The RDE test should be required for in-use conformity testing, in the same way it is required in China 6 emissions standards. Regulators need to conduct more RDE tests to determine the proper conformity factor to be applied in RDE tests for fuel consumption. The conformity factor could be somewhat lenient when the RDE test procedure is first introduced, then tightened over time.

» **Monitor real-world fuel consumption.**

- » Apply on-board fuel and energy consumption monitoring devices (OBFCMs) to monitor real-world fuel consumption of light-duty vehicles. OBFCMs have been mandatory in all new passenger cars and light commercial vehicles in Europe since Jan 1, 2020, in order to meet the requirement of the new EU light-duty CO₂ standards⁷. Measuring real-world fuel consumption is a key recommendation since this data is needed to evaluate the efficacy of CO₂ and fuel economy standards.

7 Dornoff, Jan. *One Goal, Multiple Pathways: A Review of Approaches for Transferring on-Board Fuel Consumption Meter Data to the European Commission*. (ICCT: Washington, DC, 2019). https://theicct.org/publications/transferring_obfcm_fuel_data_ec.

- » Develop a national website similar to the My MPG service, a national platform established by the U.S. Environmental Protection Agency and U.S. Department of Energy to collect real-world fuel consumption information from vehicle owners. This consumer-reported information should be used to verify the real-world fuel consumption collected from OBD systems.
- » **Coordinate co-management of fuel consumption, greenhouse gases (GHGs) and atmospheric pollutants.**
 - » In China, vehicle fuel economy standards and emission standards of air pollutants and CO₂ are the responsibility of two different ministries, MIIT and the Ministry of Ecology and Environment (MEE), respectively. In order to mitigate climate change and improve air quality simultaneously, coordinated control of GHGs and atmospheric pollutants should be considered during the upcoming stage of emission standards.
- » **Provide consumer information that is close to real-world experience.**
 - » Consumers need access to realistic fuel consumption values to make informed vehicle purchasing decisions. Since 2018, MIIT has required vehicles to apply a revised label design which emphasizes city-driving fuel consumption value more than combined city/highway driving. The revised fuel consumption label design is an improvement, but the credibility of the label could be further raised by establishing an adjustment method that brings the fuel consumption value available to consumers close to the average real-world performance, perhaps with the help of stringent test procedures.