Energy Policy 37 (2009) 3803–3811

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Structure and impacts of fuel economy standards for passenger cars in China

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ARTICLE INFO

Article history:
Received 28 May 2009
Accepted 15 July 2009
Available online 8 August 2009

Keywords:
China
Fuel economy
Passenger cars

ABSTRACT

By the end of 2006, there were about 24 million total passenger cars on the roads in China, nearly three times as many as in 2001. To slow the increase in energy consumption by these cars, China began implementing passenger car fuel economy standards in two phases beginning in 2005. Phase 1 fuel consumption limits resulted in a sales-weighted new passenger car average fuel consumption decrease of about 11%, from just over 9 l/100 km to approximately 8 l/100 km, from 2002 to 2006. However, we project that upon completion of Phase 2 limits in 2009, the average fuel consumption of new passenger cars in China may drop only by an additional 1%, to approximately 7.9 l/100 km. This is due to the fact that a majority of cars sold in 2006 already meets the stricter second phase fuel consumption limits. Simultaneously, other trends in the Chinese vehicle market, including increases in average curb weight and increases in standards-exempt imported vehicles, threaten to offset the efficiency gains achieved from 2002 to 2006. It is clear that additional efforts and policies beyond Phase 2 fuel consumption limits are required to slow and, ultimately, reverse the trend of rapidly rising energy consumption and greenhouse gases from China's transportation sector.

1. Introduction

The recent growth of China's automobile industry has been staggering. Rapid rises in production and sales more than doubled the number of on-road civil vehicles in China, from 18 to 37 million, during the period 2001–2006 alone (CSY, 2007). In addition, in 2006, there were over 24 million rural vehicles (CAAMS, 2007) and 81 million motorcycles in China (CATARC, 2007b). Though there are certainly many economic and personal benefits to an increasingly motorized population, this explosion of vehicles has also contributed to a host of negative effects throughout China, including heavily congested streets, stifling urban air pollution, and rapidly increasing national oil dependence and greenhouse gas emissions.

In 2004, with primary concern over mitigating China's rising oil dependence, the Chinese government issued first-ever national fuel economy standards for passenger cars. The first phase of the standards took effect over the period 2005–2006. With the implementation of the first phase now complete, there is increasing interest in evaluating and understanding both the impacts of the current standards as well as the potential impacts of the upcoming second phase of standards.

In this paper, we summarize the current Chinese passenger car fuel economy standards in the context of China's automobile industry growth, national oil consumption, and CO_2 emissions. We then explore existing precedents for estimating the historical fuel economy of China's passenger car fleet, and investigate current Chinese vehicle fuel economy data sources. We then perform our own analysis of Chinese passenger car fuel economy, comparing these results against other estimates and noting trends. Finally, we describe additional efforts the Chinese government is making to limit the fuel consumption by China's passenger car fleet.

2. Background

2.1. Vehicle definitions

Officially, highway vehicles in China are classified according to Chinese national standard GB/T 15089-2001, "Classification of Power-driven Vehicles and Trailers" (SAC, 2001). This standard defines vehicle classes in China according to M (passenger vehicles) and N (commercial vehicles) classification labels similar to those used in Europe; these are shown in Table 1. All vehicle fuel economy regulations in China, including current and future passenger vehicle fuel economy standards as well as commercial vehicle regulations, are based on the categorizations shown in Table 1.

However, vehicles in China are additionally classified according to a slightly different classification system dictated by the Ministry of Public Security. These classifications are used both for official statistical reporting by the National Bureau of Statistics as well as for administrative management, e.g. licensing. Under this system, highway vehicles are categorized as passenger

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doi:10.1016/j.enpol.2009.07.009

Table 1
Chinese vehicle classifications defined by the Standardization Administration of China.

Classification	Definition
M1	Passenger vehicle with 9 or fewer seats
M1G	SUV with 9 or fewer seats
M2	Passenger vehicle with more than 9 seats and with curb weight less than or equal to 5000 kg
M3	Passenger vehicle with more than 9 seats and curb weight above 5000 kg
N1-–3	Vehicle used for transporting goods

vehicles, trucks, or others. Among passenger vehicles, vehicles are further classified by size as large, medium, small, or minicar. This classification system is shown in Table 2 (MPS, 2008).

From Tables 1 and 2, it can be inferred that M1-type vehicles, including M1G, are either "small" or "minicar" passenger vehicles.

In this report, we consistently use the term "passenger car" to refer to all vehicles with nine or fewer seats designed primarily for carrying passengers. This refers to all M1 and M1G-type vehicles as defined by the Standardization Administration of China, which is same as all small and minicar passenger vehicles as defined by the Ministry of Public Security. The term includes MPVs and SUVs.

2.2. Historical vehicle population growth

The National Bureau of Statistics of China publishes annual data on the possession of civil vehicles in China (CSY, 2007). As described previously, vehicles are categorized as passenger vehicles, trucks, or others. Data is given both for total possession of civil vehicles as well as for private vehicles, a subset of civil vehicles. Among passenger vehicles, beginning in 2002, vehicles are further classified by size as large, medium, small, or minicar. Passenger vehicle size definitions were given previously in Table 2.

According to the definitions in Table 2, we calculate the possession of passenger cars in China as the sum of the small and minicar data for each year. Prior to 2001, though cars are not separated out from passenger vehicles in official statistics, for the purposes of this analysis we have roughly approximated car possession by assuming 85% of all civil passenger vehicles are passenger cars, and 90% of all private passenger vehicles are private passenger cars. These percentages are rough extrapolations based on the figures shown in Table 3.

The growth of on-road vehicles by selected categories in China is shown in Fig. 1. By the end of 2006, there were nearly 24 million total passenger cars on the roads in China, nearly three times as many as in 2001.

Though Fig. 1 shows tremendous growth in possession of all types of vehicles, the growth of private passenger cars is particularly remarkable. In 1990, there were less than 250,000 private passenger vehicles (of all sizes) in China; by 2006, there were over 17.5 million private passenger cars alone. Accordingly, the growth of total on-road vehicles has been increasingly fueled by the growth of private passenger cars. This can be seen from Fig. 2, showing the percentage growth in overall on-road vehicles coming from various vehicle types. In 2006, 80% of the growth of on-road vehicles came from the growth of private passenger cars; in 2000, it was just 35% of total growth.

The increasing importance of private passenger cars in China is no surprise. As China's per capita GDP has risen, so has demand and ownership of vehicles, echoing a common trend around the world (Ng and Schipper, 2005). In 2006, there were approximately 18 passenger cars per 1000 people in China, 14 of which were privately owned. Though these ownership rates are significantly

Table 2
Chinese passenger vehicle size classifications defined by the Ministry of Public Security and used by the National Bureau of Statistics.

China vehicle size classification		Definition
Passenger Vehicles	Minicar	Vehicle shorter than 3.5 m and with an engine capacity of 1 l or less
	Small	Vehicle shorter than 6 m with 9 or fewer seats
	Medium	Vehicle shorter than 6 m and holding 10–19 people
	Large	Vehicle longer than 6 m or holding 20 or more people

Table 3
Percentages of passenger vehicles in China that are passenger cars (calculated from CSY, 2007, and our estimates).

Year(s)	Civil passenger cars as percentage of civil passenger vehicles (%)	Private passenger cars as percentage of private passenger vehicles (%)
1990–2001	85 (estimate)	90 (estimate)
2002	85	93
2003	87	94
2004	88	95
2005	90	96
2006	91	96

smaller than those of developed countries – passenger car ownership in the United States being above 800 per 1000 people (Ellis et al., 2008) – the recent, rapid rise of vehicle ownership in China is a major source of concern with respect to the current and future energy, environmental, and social impacts of China's passenger car fleet.

2.3. Passenger car population projections

Chinese passenger car population projections considering various different growth scenarios were recently made by Wang et al. (2006) and Ng and Schipper (2005). These projections are shown in Fig. 3. Wang et al. projected China's passenger car population to equal that currently in the United States by just after 2030, while Ng and Schipper projected faster growth.

Though projecting future passenger car population is beyond the scope of this paper, it is worth noting that, due to higher-than-expected growth rates of all areas of the Chinese economy, including the automotive sector, projections of future vehicle population from even just a few years ago are already outdated. Because Chinese passenger vehicle growth rates from 2003 to 2006 were 26%, 19%, 25%, and 25%, respectively, the 2006 population of passenger cars in China, 24 million, is already almost equal to the 2010 estimate in most of Wang et al. and Schipper and Ng's projections. This may be seen in Fig. 4.

2.4. Vehicle energy consumption and CO_2 emissions

China's rapid economic growth has demanded more and more energy from all sources and for all sectors. Although China's official energy statistics do not report specific energy consumption by the complete transportation sector, a recent report by the Institute for Energy and Environmental Research Heidelberg estimated that, in 2003, China's transportation sector was responsible for 17% of total national energy consumption (Knörr and Dünnebeil, 2008). This is still significantly lower than that of Europe, for which the transportation sector uses 27% of total

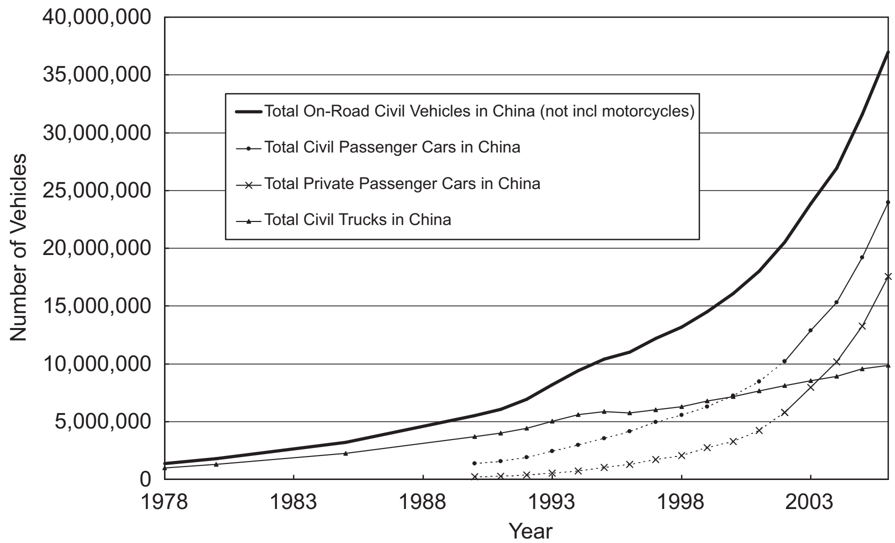

Fig. 1. Possession of civil vehicles in China, by type, 1978–2006. Solid lines show data from the China National Bureau of Statistics (CSY, 2007). Dotted lines show our estimates.

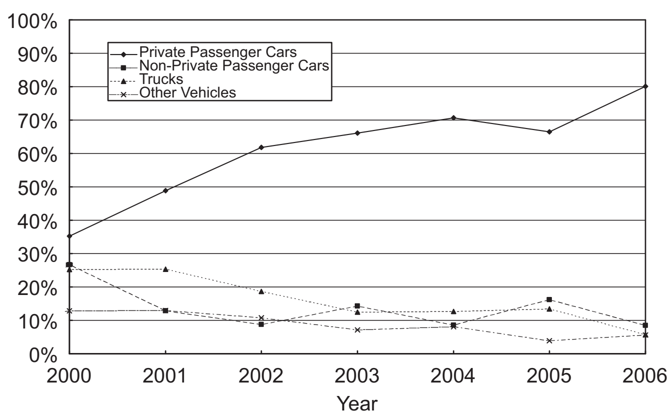

Fig. 2. Percentage growth in overall on-road vehicles coming from various vehicle types.

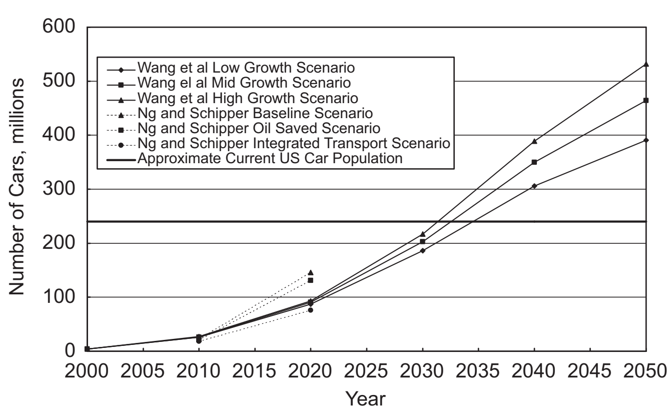

Fig. 3. Recent Chinese passenger car population projections.

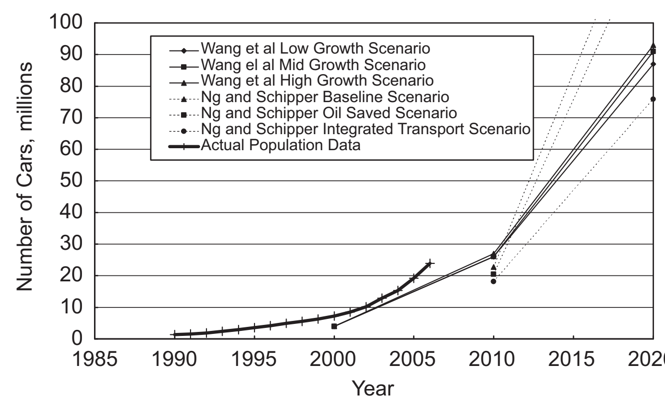

Fig. 4. Chinese passenger car population projections compared with actual population growth. Note that 2006 real passenger car population is already greater than 2010 population estimates in most of the projections.

energy consumed (Knörr and Dünnebeil, 2008). However, this percentage is likely to grow as China's automobile industry continues to grow and as other industries improve efficiency.

The Chinese government is particularly driven to limit energy use by the transportation sector because this sector is one of the major consumers of petroleum in the country. As a result of rising petroleum demand coupled with limited domestic supply, China became a net importer of petroleum in 1993. As shown in Fig. 5, China's petroleum import percentage has grown ever since, reaching 50% in 2006 (CSY, 2007).

Because China's on-road transportation vehicles are fueled almost exclusively by gasoline and diesel, much of the rapid growth of petroleum consumption in China can be linked to the growth of on-road transportation vehicles. CATARC data indicate that, in 2006, motor vehicles consumed 86.4% of all gasoline consumed in China and 24.1% of all diesel (CATARC, 2007b). Controlling petroleum consumption by this sector is a critical goal for China in order to slow the growth in its oil dependence.

Though China's current energy saving policies primarily target energy security, there is increasing pressure internationally – and domestic recognition of the need – for China to slow the growth of its CO_2 emissions. This is especially true now that China is thought to be the world's largest emitter of greenhouse gases (Rosenthal, 2008).

Within the transportation sector, the increased use of petroleum has led to a corresponding increase in CO_2 emissions from on-road transportation. Wang et al. estimate that, as early as 2028, China's total on-road CO_2 emissions could match those of the United States in 2004 (Wang et al., 2006). However, this may even be a low estimate due to higher-than-expected growth, as mentioned previously.

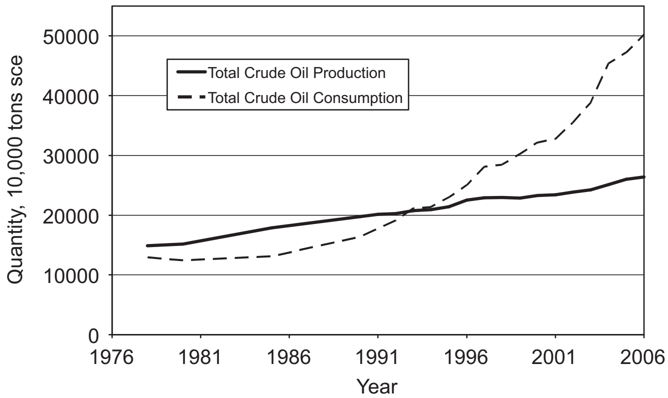

Fig. 5. China's total crude oil production and consumption from 1978 to 2006.

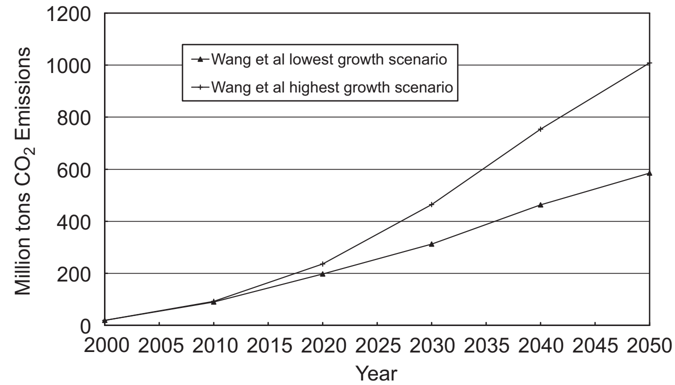

Fig. 6. Projections of CO_2 emissions from China's passenger cars, converted from oil consumption figures.

Within the Chinese transportation sector, trucks are the largest consumers of energy and emitters of CO_2. Wang et al. estimate that cars in 2000 only consumed 9% of the transportation sector's total oil consumption.[1] He et al. estimate that in 2002, cars accounted for only about 16% of oil consumption by China's transportation sector (He et al., 2005).

However, cars were the first sub-sector of transportation targeted by the Chinese government for fuel consumption regulation for two reasons. First, as we have seen, the proportionally faster growth of cars as compared with other types of vehicles means CO_2 emissions from cars as a percentage of transport sector emissions will certainly grow. Indeed, Wang et al.'s projections show an increasing share of oil consumption from motor vehicles coming from cars; the percentage of motor vehicle oil consumption by cars rises from 9% in 2000 to 17% in 2010, then up to 28–29% by 2030.[2] The second reason Chinese policy makers targeted cars initially for fuel consumption regulation is that there is stronger international precedent for regulating fuel consumption by passenger cars than for commercial vehicles, as the commercial vehicle sector tends to self-limit fuel consumption for economic reasons.[3]

Wang et al.'s oil consumption projection figures are given in million metric tons (MMT) oil. After applying a simple conversion factor,[4] highest and lowest growth scenario projections for CO_2 emissions from Chinese passenger cars are shown in Fig. 6. Under the highest growth scenario, CO_2 emissions from passenger cars in China would exceed one billion tons by 2050.

3. Structure of Chinese passenger vehicle fuel consumption standards

Rapidly growing passenger vehicle fleet oil consumption and CO_2 emissions led China in 2004 to adopt National Standard GB 19578-2004, "Limits of Fuel Consumption for Passenger Cars" (SAC, 2004). Though these standards are primarily designed to help mitigate China's increasing dependence on foreign oil, other objectives include encouraging foreign manufacturers to bring state-of-the-art, efficient vehicle technologies to the Chinese market and squeezing out small and less competent domestic manufacturers.

The standard establishes maximum allowable fuel consumption limits for vehicles divided into 16 weight classes. The standards are implemented in two phases. Phase 1 was implemented on July 1st, 2005, for new models, and July 1st, 2006, for continued models; Phase 2 was implemented on January 1st, 2008, for new models, and will be implemented January 1st, 2009, for continued models. Vehicles are tested using the New European Drive Cycle (NEDC).

The 16 weight classes range from less then 750–3500 kg. The standards cover M1 and M1G-type vehicles, including passenger cars, SUVs, and multi-purpose vans (MPVs). Within each weight class, vehicles are additionally sub-divided into two categories. "Vehicles with special structures" are defined as those that meet one of three criteria: (a) have automatic transmission; (b) have three or more rows of seats; (c) are of the type M1G (SUVs). If a vehicle meets all the three criteria, it is granted a 6% exemption of the limits. For simplicity, this paper will label the two groups as MT (manual transmission) and AT/SUV (automatic transmission and/or SUV).

One distinctive feature of the Chinese standards is that, rather than being based on fleet average, they establish maximum allowable fuel consumption limits by weight category. China chose a weight-based limit-value approach for more practical – as opposed to theoretical – reasons. During the time of the creation of the fuel consumption standards, the Chinese car market was highly fragmented, with over one hundred manufacturers. There were very few multiple-line manufacturers; many manufacturers offered only one or two models, thus making the fleet average approach meaningless. Additionally, vehicle sales figures in China have been historically secret, unknown, and/or difficult to obtain, making a sales-weighted average approach unpractical. The weight classification is based on EU emission testing protocol, with more stringent requirements on heavier models; this is designed to curb large vehicle and SUV growth in China.

Another unique feature of the Chinese fuel economy standards is that every vehicle manufactured in China is required to meet the standard for its weight class. There are neither exceptions nor a credit system to allow vehicles that exceed compliance to offset those that do not.

The Chinese passenger car fuel consumption limits are shown in Table 4 and graphed in Fig. 7.

Using a methodology to standardize drive cycles, a recent report by An et al. noted that China's passenger car fuel economy standards are more stringent than those in other developed nations, including the United States, Canada, South Korea, and Australia, although not as stringent as the fuel economy standards in Europe and Japan (An et al., 2007).

[1] Estimated from Wang et al. oil consumption data, pp. 44–46.
[2] Estimated from Wang et al oil consumption data, pp. 44–46.
[3] Though China has recently enacted fuel economy standards for commercial vehicles, as described in Section 4.
[4] Conversion factor of units CO_2 per unit weight oil calculated as $44/12 \times 88.5\%$, the approximate carbon content of oil.

Table 4
Chinese passenger car fuel consumption limits.

Curb weight (kg)	Maximum allowable fuel consumption, in l/100- km, as measured using NEDC			
	MT vehicles, Phase 1	MT vehicles, Phase 2	AT/SUV vehicles, Phase 1	AT/SUV vehicles, Phase 2
750	7.2	6.2	7.6	6.6
865	7.2	6.5	7.6	6.9
980	7.7	7	8.2	7.4
1090	8.3	7.5	8.8	8
1205	8.9	8.1	9.4	8.6
1320	9.5	8.6	10.1	9.1
1430	10.1	9.2	10.7	9.8
1540	10.7	9.7	11.5	10.3
1660	11.3	10.2	12	10.8
1770	11.9	10.7	12.6	11.3
1880	12.4	11.1	13.1	11.8
2000	12.8	11.5	13.6	12.2
2110	13.2	11.9	14	12.6
2280	13.7	12.3	14.5	13
2510	14.6	13.1	15.5	13.9
3500	15.5	13.9	16.4	14.7

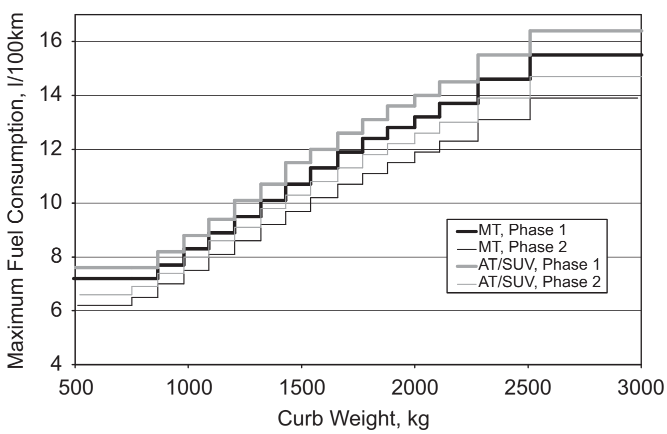

Fig. 7. Chinese passenger car fuel consumption limits.

4. Impacts

4.1. Estimates of historical fuel economy

Lack of data makes accurately estimating the historical fuel economy of China's passenger car fleet challenging. Still, there have been at least four estimates. The first, performed by He et al. (2005), estimated average on-road fuel consumption of cars in China from 1997 to 2002 to be 9.07 l/100 km[5] (He et al., 2005). He et al.'s methodology was to take manufacturer-supplied best-case fuel economy values ("label fuel economy") for dominant vehicle models in China and revise them downward by a real-world adjustment factor.

The second estimate was performed by the China Automotive Technology and Research and Center (CATARC) in 2007. They estimated the 2002 average fuel consumption of new cars in China to be 9.11 l/100 km (CATARC, 2007a). CATARC used manufacturer-supplied data, but it is unclear how their data and methodology were different from He et al.'s, and what correction factors (if any) were applied.

A recent, third estimate performed by the Institute for Energy and Environmental Research Heidelberg (IFEU) estimated Chinese passenger car 2003 fuel consumption to be 8.4 l/100 km (Knörr and Dünnebeil, 2008). The IFEU's complete methodology for determining this number is not stated, and it is unclear why it is significantly lower than the other estimates from 2002.

A final estimate, performed by An et al. (2007), estimated China's 2005 fuel economy to be 8.19 l/100 km[6] (An et al., 2007). This estimation was based on proprietary sales figures of new vehicle models sold in China, with fuel economy rates and vehicle weight estimates.

4.2. Estimates of current and future fuel economy

Full implementation of Phase 1 fuel economy standards was completed in 2006. As such, there is increasing interest in evaluating their impacts on new vehicles in China. The first such impact analysis was completed in late 2007 by CATARC. They estimated the 2006 fuel consumption of new passenger cars in China to be 8.06 l/100 km, 11% lower than their 2002 estimate (CATARC, 2007a). CATARC's methodology roughly estimated new fleet fuel consumption based on manufacturer average fuel consumption and manufacturer total sales. CATARC's average was only manufacturer-specific, not model-specific. Though CATARC's report presents the manufacturer data, the data are anonymous (CATARC, 2007a).

The only existing future projection of fuel economy of new passenger cars in China is an estimate by An et al. of the future impact of Phase 2 fuel economy standards. An et al. projected 2008 fuel consumption of new passenger cars in China to be 7.13 l/100 km[7] (An et al., 2007). This projection was largely based on an assumption that the future vehicle weight mix would be the same as in 2002, the year of the data compiled for the analysis.

For this paper, using a sales-weighted, model-specific methodology described in the following section, we estimate the 2006 average fuel consumption of new passenger cars in China to be 7.95 l/100 km, and project, upon complete implementation of Phase 2 fuel economy standards, a 2009 new passenger car average fuel consumption of 7.87 l/100 km.

A summary of estimates of Chinese new passenger car average fuel consumption is shown in Table 5, and graphed in Fig. 8.

4.3. Methodology

The first-ever public database of fuel consumption of passenger vehicles in China was released in two batches by China's National Development and Reform Commission (NDRC) in October 2006, and July 2007 (NDRC, 2006, 2007). The first batch consisted of 409 passenger car models, all of which passed the Phase 1 fuel consumption limits. The second batch consisted of 2374 passenger car models which passed the Phase 1 fuel consumption limits, and 444 vehicles which failed. Fuel consumption data were not given for the vehicles which failed.

Batches 1 and 2 combined to form a database of 2783 passenger car models for sale in China. Of these, 1264 (45%) are general type vehicles, while 1519 (55%) are special structure vehicles. As described previously, general type vehicles are manual transmission vehicles, while special structure vehicles are defined as those that meet one of the three criteria: (a) have automatic transmission; (b) have three or more rows of seats; (c) are of the type M1G (SUVs). Again, for simplicity, this paper will label the two groups as MT (manual transmission) and

[5] Converted from the published value, 11.03 km/l.

[6] Converted from the published value, 193 gCO_2/km.

[7] Converted from the published value, 168 gCO_2/km.

Table 5
Summary of estimates of Chinese new passenger car average fuel consumption.

Year	Report authors and year				
	He et al. (2005)	CATARC (2007a)	An et al. (2007)	Knörr and Dünnebeil (2008)	This study
1997–2002	9.07				
2002		9.11			
2003				8.4	
2004					
2005			8.19		
2006		8.06			7.95
2007					
2008			7.13		
2009					7.87

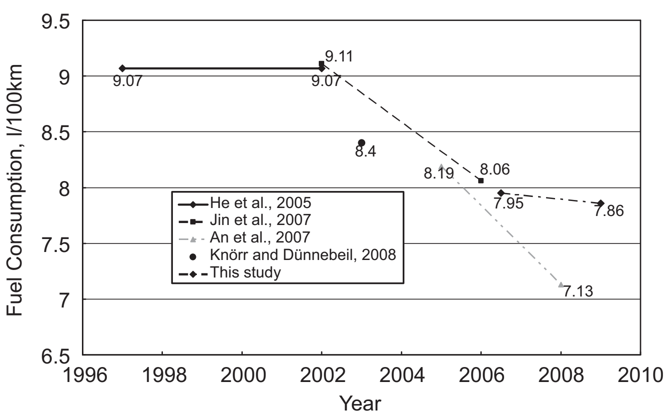

Fig. 8. Summary of estimates of Chinese new passenger car average fuel consumption.

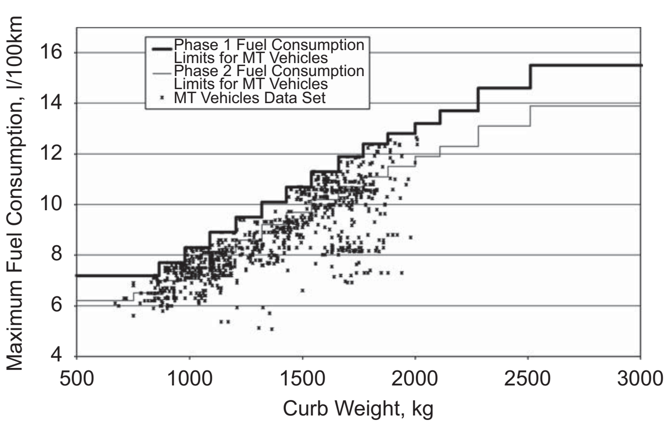

Fig. 9. NDRC fuel consumption and weight data for manual transmission passenger cars for sale in China.

AT/SUV (automatic transmission and/or SUV). Though the NDRC provided no supporting information regarding completeness of the database, it is assumed that this database covers all passenger car models available for sale in China during approximately the first year after Phase 1 fuel economy standards went into effect for all vehicles. The fuel economy and weight data provided in the two NDRC data sets are graphed in Figs. 9 and 10 against both Phase 1 and Phase 2 fuel consumption limits.

In this paper, we assume that the analysis of these combined data sets yields reasonable estimates of the fuel economy of new passenger vehicles sold in China over the period late 2006 to early

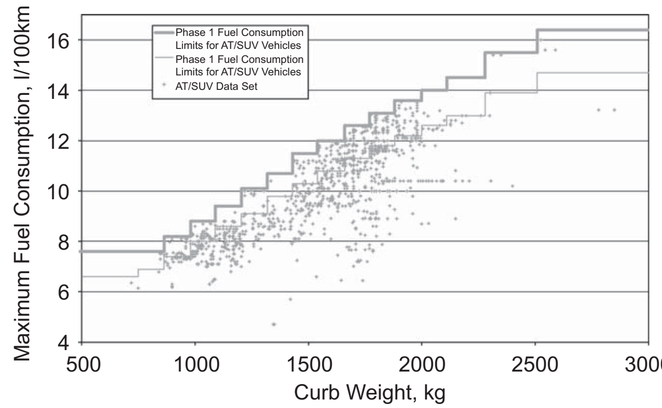

Fig. 10. NDRC fuel consumption and weight data for automatic transmission and SUV passenger cars for sale in China.

2007. However, two caveats must be mentioned. First, we apply no "real-world driving" correction factor to the NDRC data, due to lack of data comparing Chinese driving behavior – across hundreds of cities – to the NEDC. Second, it is unknown and unclear what level of production compliance to the current fuel economy standards exists. Whether fuel economy achieved by drivers in China matches those reported by the NDRC is a critical area for further study.

For this paper, we matched the NDRC data sets with 2006 sales data by model for 731 vehicle models whose combined sales totaled 87% of overall passenger car sales. The sales data were taken from the "Automotive Industry of China" yearbook published by CATARC (2007b). We then performed the following analysis:

(1) Estimate overall and manufacturer-specific sales-weighted average fuel economy of new vehicles sold in China in 2006.
(2) Estimate overall sales-weighted percentage of current vehicles that will not meet Phase 2 fuel economy standards.
(3) Estimate potential effect of Phase 2 standards using a rough assumption that all vehicles currently exceeding Phase 2 standards will meet them by the final implementation date, January 1st, 2009.

There are at least two areas where potential error may be introduced into our analysis. First, because of lack of available data, we were unable to consider sales of 100% of all passenger cars in China. Second, because the NDRC data sets do not provide clear dates as to their validity, we were forced to match 2006 sales matched to what are presumably 2006–2007 fuel consumption data.

4.4. Sales-weighted fuel economy

The sales-weighted fuel consumption (overall and by manufacturer) is calculated by the following equation, where m is the model:

$$\text{Average fuel consumption} = \sum_m (\text{Fuel consumption}^*_m \text{sales}_m)/\text{total sales}$$

The overall result plus individual results for the top 27 passenger car manufacturers in China are shown in Table 6.

Overall, we estimate the 2006–2007 fuel economy of new passenger cars in China to be 7.95 l/100 km. The sales-weighted most efficient manufacturer is Chery, while the sales-weight least

Table 6
2006 sales figures and sales-weighted weight and fuel economy averages for top 27 passenger car manufacturers in China.

Manufacturer	2006 passenger vehicle sales	Sales-weighted average weight (kg)	Sales-weighted average fuel consumption (l/100- km)
Chery Automobile Co. Ltd.	274,242	1010	6.93
Tianjin FAW Xiali Automobile Co. Ltd.	196,817	924	6.95
Jiangxi Changhe Automoblie Co. Ltd.	116,167	1061	7.13
Hafei Motor Co. Ltd.	202,862	1034	7.25
Zhejiang Geely Holding (Group) Co. Ltd.	182,938	968	7.46
BYD Auto Co. Ltd.	60,116	855	7.52
Changan Automobile (Group) Liability Co. Ltd.	497,877	1087	7.63
FAW Haima Motor Co. Ltd.	80,218	1212	7.74
SAIC GM Wuling Automobile Co. Ltd.	408,432	1000	7.8
Guangzhou Honda Automobile Co. Ltd.	224,319	1213	7.81
Dongfeng Yueda-Kia Automobile Co. Ltd.	110,377	1290	7.88
Dongfeng Honda Automobile Co. Ltd.	63,373	1445	7.88
Dongfeng Peugeot Citroen Automobile Co. Ltd.	201,316	1162	7.89
Dongfeng Yuan Vehicle Co. Ltd.	46,801	1032	7.97
FAW Car Co. Ltd.	52,075	1404	8.05
Dongfeng Nissan Passenger Vehicle Co. Ltd.	188,270	1322	8.13
FAW Toyota Motor Sales Co. Ltd.	208,235	1375	8.36
FAW-Volkswagen Automobile Co. Ltd.	345,529	1332	8.41
Nanjing Automobile (Group) Corporation	28,139	1103	8.47
Shanghai General Motor Co. Ltd.	370,114	1353	8.58
Shanghai Volkswagen Automotive Co. Ltd.	329,367	1325	8.59
Beijing Hyundai Motor Company	289,990	1480	8.87
Shenyang Brilliance Jinbei Automotive Co. Ltd.	61,837	1449	9.26
Great Wall Automobile Holding	40,062	1718	9.63
BMW Brilliance Automotive Co. Ltd.	23,735	1556	9.65
Guangzhou Toyota Automobile Co. Ltd.	61,254	1520	10.1
Beijing Daimler-Benz Chrysler Automobile Ltd.	18,155	1610	10.34
Overall			7.95

These sales numbers total 87% of 2006 passenger car sales in China.

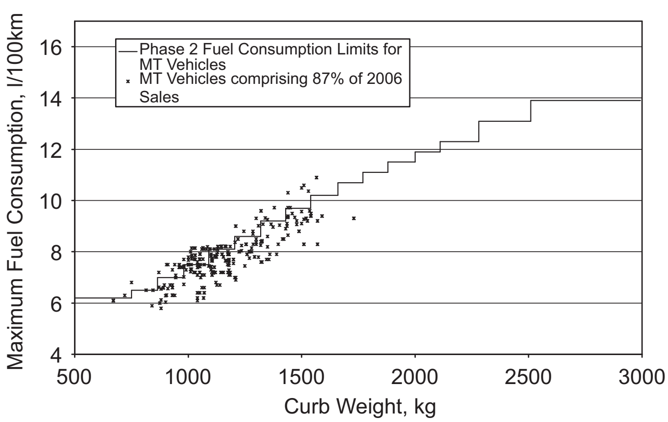

Fig. 11. Fuel consumption and weight data for manual transmission passenger cars comprising 87% of car sales in China.

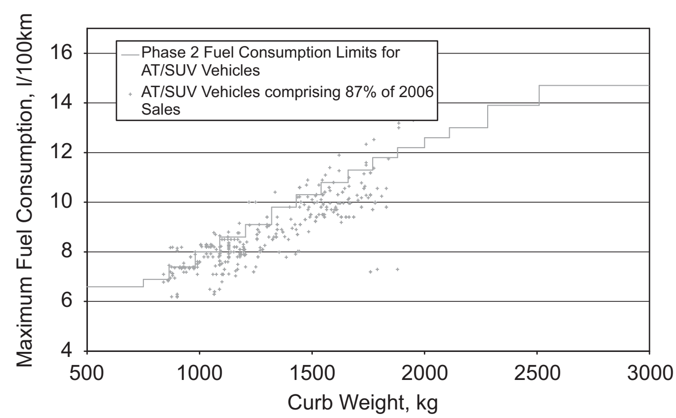

Fig. 12. Fuel consumption and weight data for automatic transmission and SUV passenger cars comprising 87% of car sales in China.

efficient manufacturer is Daimler-Benz. The sales-weighted lowest weight manufacturer is BYD, while the sales-weighted highest weight manufacturer is Great Wall.

4.5. Impacts of Phase 2

China Phase 2 fuel economy standards for passenger cars took effect on January 1st, 2008, for existing models, and will take effect on January 1st, 2009, for continued models. The NDRC has not yet released any data regarding compliance to the new standards.

Within the NDRC data sets described previously, 32% of overall vehicle models do not meet Phase 2 standards. Among MT vehicles, 34% do not meet the standards, while among AT/SUV vehicles, 30% do not meet the standards.

Although 32% of passenger car models for sale in China in 2006 did not meet Phase 2 fuel economy standards, by closely examining sales figures we can see that the vast majority of passenger cars sold in 2006 either already meet the Phase 2 standards or only barely exceed them. Therefore, we do not expect to see a significant decrease in sales-weighted average fuel consumption for new passenger cars in China upon complete implementation of Phase 2 fuel economy standards. Figs. 11 and 12 show the 731 vehicle models which make up 87% of 2006 passenger car sales mapped against the Phase 2 fuel consumption limits alone.

Here, we make a rough estimate of the potential impact of the Phase 2 standards by taking a sales-weighted fuel economy average using the assumption that all vehicles not currently meeting Phase 2 standards will meet the maximum fuel consumption standard upon implementation. Using this methodology, we roughly approximate 2009 new Chinese passenger car fuel economy to be 7.87 l/100 km.

4.6. Other issues and effects

Overall, the average fuel consumption of new passenger cars in China is decreasing. However, there are several troubling signs that this trend may not continue if additional measures are not in place. CATARC recently published additional analysis showing changes to the Chinese passenger car fleet from 2002 to 2006, including:

- an increase of 8%, from 150 to 162 km/h, in the average maximum design speed of passenger cars (CATARC, 2007a); and,
- an increase of 10.2%, from 1230 to 1356 kg, in average curb weight of passenger cars in China (CATARC, 2007a).

Paralleling average maximum design speed and weight increases are increases in numbers of SUVs sold, largely due to a surge in SUV imports. In the first part of 2007, SUV market growth in China outpaced overall passenger car market growth by a factor of three (Ellis et al., 2008). Though the Chinese passenger car fuel economy standards are designed to be "bottom heavy" – intended to curb the growth of heavier and less efficient vehicles – the results are mixed. While most domestically-made models have been kept smaller in power and engine size than their US and European counterparts, a general trend towards faster, larger, heavier vehicles is still pervasive and could offset potential additional gains in sales-average fuel consumption in the next few years.

Additionally, it should be mentioned that, while all the passenger car models manufactured within Chinese boarders are subject to the fuel consumption limits, imported vehicle models are exempt. Most of the imported models are luxury models with large engines (>2.5 l) or large SUVs, and as such most almost certainly do not meet the standards. The Chinese government has been struggling with how to control energy consumption by these vehicles, particularly because banning luxury models is not a pragmatic option. Developing a penalty tax scheme for vehicle models which exceed fuel consumption limits is clearly the most logical approach; however, progress on this development has been slow.

In recent years, the number of vehicles imported into China has increased dramatically. According to a report by China Trading Center for Automobile Imports, imports increased 41% from 2005 to 2006, and more than 30% from 2006 to 2007 (CTCAI, 2008). The total imported vehicles jumped from 160,000 to more than 300,000 units in two years, with SUVs leading, increasing more than 100% in the past two years. This "imports loophole" has created a serious concern that wealthy and powerful consumers can get away from fuel economy regulations, and the imported models could significantly undermine the efficiency progress that has been made in the domestic market. Further, detailed analysis of the energy impact of imported vehicles in China is an important area for future study, especially as the Chinese government debates measures to deal with this issue.

5. Other policies and future fuel economy standards

Fuel consumption limits on passenger cars are only one of several policies China has implemented to control energy use and greenhouse gas emissions by vehicles in the transportation sector.

Table 7
Manufacturer taxes levied on passenger vehicles in China (auto.china.com, 2008; MOF, 2008).

Automobile category by engine displacement (l)	Tax rate prior to 4/1/2006 (%)	Tax rate 4/1/2006–8/31/2008 (%)	Tax rate beginning 9/1/2008 (%)
<1.0	3	3	1
1.0–1.5	5	3	3
1.5–2.0	5	5	5
2.0–2.5	8	9	9
2.5–3.0	8	12	12
3.0–4.0	8	15	25
4.0+	8	20	40

Some additional policies and programs are described briefly in this section.

5.1. Vehicle taxation

China has implemented a series of progressively stricter vehicle manufacturing taxes that are significantly higher for larger engines. The current and historical taxation rates are shown in Table 7.

As described previously, the growth of vehicle weight and SUV sales has continued to outpace smaller passenger cars, despite the significantly higher taxes levied on these vehicles' larger engines. Presumably, this is because the purchasers of these vehicles are wealthier customers with less susceptibility to price changes. The new tax rates effective September 2008 are designed to limit this growth, though it is unclear yet what the impact is.

5.2. Fuel economy labeling

To promote consumer awareness of energy consumption, on July 1st, 2008, China implemented first-ever mandatory fuel economy labeling for passenger vehicles. The label, to be placed on the vehicle's window, displays fuel consumption estimates for highway, city, and overall average driving patterns.

5.3. Other fuel economy standards

Besides Phase 1 and 2 fuel consumption standards for passenger cars, China has also implemented fuel consumption standards for commercial N1-type vehicles with gross vehicle weight rating less than 3.5 tons (SAC, 2007) and rural vehicles (SAC, 2008a,b). Fuel economy regulations for heavy commercial trucks are also under development.

Phase 3 and 4 fuel economy standards for passenger vehicles are under discussion, though it is unclear when or if these standards will be issued.

6. Conclusions

With China's car ownership still relatively low, there is a key opportunity now for the Chinese government to implement a series of fiscal and fuel economy policies designed to guide the development of the automobile industry in a sustainable, energy efficient direction. Though significant progress has been made – particularly the implementation of Phase 1 and Phase 2 fuel economy standards and progressive vehicle taxation based on engine size – there are concerns that further efficiency gains will be leveled off by rising average vehicle weight and increasing sales of SUVs and imported vehicles exempt from the regulations. There is an urgent need to significantly tighten the fuel economy standards for passenger cars in the next phase.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2009.07.009.

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