ANALYSIS OF VEHICLE TECHNOLOGY AND FUEL EFFICIENCY IN INDIA AND CHINA

DRAFT FINAL REPORT

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1. INTRODUCTION

The rapidly growing car fleets of India and China has led to concern that greenhouse gases from transportation will increase significantly unless the vehicles sold in these countries are made very fuel efficient. There has been little analysis or data available on the technology and fuel economy of the vehicles sold in India and China relative to those sold in the OECD nations. The data situation is changing rapidly since China has introduced fuel economy standards and both India and China have an official test procedure to rate vehicle fuel economy. This report examines the new vehicle fleets for model year 2008 (the latest available) in India and China relative to the new vehicle fleets in USA and France, as two example OECD countries.

Outside of the US, the data issues are still somewhat problematic as there is no official data set that has detailed vehicle sales data by vehicle nameplate, engine and transmission along with data on the official fuel economy test value. The US has this data in the form of the US Corporate Average Fuel Economy compliance reporting data set, but such data has to be assembled for other countries. In all countries, this data has to be externally supplemented with data on technological characteristics of vehicles that affect fuel economy. The data is normally available for many (but not all) technologies that important from a fuel economy perspective at the vehicle manufacturer's local websites. Development of the data set to permit these detailed comparisons was a major part of the effort. However, it should be noted that vehicle models in France and China (defined as a unique combination of nameplate, engine size, power and transmission type) encompass many hundreds of different types and it was not possible to develop data on so many models. Rather, we selected the highest sales volume models in India, China and France to provide the comparisons required. This subset of 25 to 40 models usually accounts for 70 to 80 percent of all sales in each country. Section 2 of this report documents the data bases developed along with the data sources, and also the models selected for more detailed analysis

The comparisons of the new vehicle fleets in each country as conducted at two different levels. One is at the fleet-wide level, where sales data by vehicle nameplate is available but not the detailed technology and fuel economy data. The second is on the subset of the high sales volume models where we collected very detailed data to permit analyses of technology differences. The analysis provides a detailed representation of the new vehicle fleet fuel economy in each country and the reasons for the differences in fuel economy including vehicle size, weight, horsepower, and use of efficiency technology. The comparison is described in detail in section 3 of this report.

Section 4 provides our analysis of how the markets in each country will evolve in the near term (next 5 to 8 years), given the current regulatory scenario in each country and planned product offerings, under differing scenarios of fuel price in terms of world crude prices since local prices can sometimes be decoupled from world prices. It also proves an assessment of the technical potential to improve fuel economy in each of the four countries given the differences in vehicle characteristics. Conclusions regarding the policy implications of these findings are also provided in Section 4.

2. DOCUMENTATION OF DATA USED IN THE ANALYSIS

A detailed compilation of new vehicle data for four countries was a central part of the effort since such data are not available publicly. This section documents the data sources used to compile the data bases for the US, France, India and China and also provides some descriptive statistics on the data bases.

2.1 VEHICLE CLASSIFICATION

In order to provide statistics on a comparable basis across countries, light duty vehicles were classified into size or market classes using the European notation system that is approximately consistent with the US system for larger vehicles. In this system, cars are classified into five classes, as follows:

- A class which are 'entry' level very small cars with engines of 1 litre or smaller displacement. These cars have been introduced in the US only since 2007, but auto-manufacturers are planning several new models for introduction in the US by 2011/12. The Fiat 500, Smart car and the Suzuki Alto are typical models

- B class cars which are classified as sub-compacts in the US. This size of vehicle is very popular in Southern Europe and India, but is classified as 'entry' level in the US. The VW Polo, Peugeot 206 and Toyota Yaris are typical models and engine displacement is usually in the 1.1 to 1.6 liter range.

- C class cars classified as compacts in the US and are the most popular size in Northern Europe, Japan and China. Typical models include the VW Jetta, Toyota Corolla, Ford Focus and Honda Civic, with engine sizes typically in the 1.5 to 2.2 L range.

- D class cars are classified as midsize in the US and are the largest part of the market there, but are generally regarded as large cars in the rest of the world. The Honda Accord, Ford Fusion and Toyota Camry are typical models and engine sizes range from 2.2L to 3.5 L in the US, and 2L to 2.5L in the rest of the world.

- E class cars are restricted to luxury vehicles in most of the world except North America, and usually include only the large Mercedes, BMW and Jaguar sedans. In the US, Ford, GM, Chrysler and Toyota offer large non-luxury vehicles, but the market share of these vehicles has been declining for the last 20 years and now accounts for less than 5% of the US light vehicle market.

Light duty trucks have always been a major part of the North American market and have only recently increased in popularity in other parts of the world. They include pick-up truck, van and sports utility body styles and we have classified them in four size classes:

- Micro vans which are van body derivatives of A class or B class car platforms are used extensively in China and Southern Europe but are not sold in North America. Typical models include the Wuling utility van (similar to the Suzuki micro-van) and the Renault Kango, and engine displacement is similar to that for A-class cars.

- Compact vans and SUVs are popular around the world and typical models include the Honda CR-V, Fiat Ducato and Ulysse, and the Renault Espace and Express. In general, the vehicles are powered by engines in the 2 ± 0.5 L displacement range with the upper end of the range more popular in North America.

- Midsize pickup trucks, vans and SUVs are largely a North American phenomenon although some models like the Mercedes M class SUV, the Chrysler van, the Honda Odyssey and the Jeep Grand Cherokee have modest sales in Europe. Engine sizes are in the typically in the 3 to 4L range and have six cylinders, although some European versions offer four cylinder engines in the 2.5L range.

- Large pickup trucks, vans and SUVs are sold only in North America in any volume and are manufactured only in the US. The market share for these vehicles peaked in 2006, but even in 2008 they had over 10 percent of the North American market. Typical engines are eight cylinder 4+ L displacement.

In addition, sales were also allocated to engine type. The vast majority of sales are gasoline or diesel powered and the data indicated that less than 0.5% of new vehicles in any of the four countries were powered by CNG or LPG. Anecdotally, we have heard that percent of the fleet operating on CNG or LPG is in the 2 to 4 percent range, but these include aftermarket conversions for which we had no data. Hybrid vehicles are not yet sold in India but have very low sales in Europe and China (a few thousand or less than 0.1% of sales). Hybrid vehicles are rapidly increasing in popularity in the US and sales were nearly at 300,000 units in 2008, or at 2.5% of the fleet, which is still relatively small. On the other hand, diesels are well represented France, where fleet penetration stood at 78% in 2008 and in India where penetration is at 31.5%, but diesels are less than 1% of sales in China and the US. In the instances where engine types account for less than 1 % of the fleet, we have not analyzed any of their specific efficiency characteristics.

2,2 DATA FOR THE UNITED STATES

As noted, data on US light vehicles is very comprehensive as Department of Transportation provides a nameplate/ engine/ transmission specific listing of sales and fuel economy. In addition, detailed vehicle specifications are published in *Automotive News* and *Ward's* and we have appended the specifications to the DOT database. This allows very comprehensive analysis of all of the data instead of using a sub-sample as was required in other countries. Fuel economy data is based on the combined city and highway fuel economy with a 55/45 weighting, but we have used the actual test fuel economy, not the adjusted fuel economy to reflect on-road conditions.

Engine technology data available include engine size, layout (OHV/OHC), number of cylinders, compression ratio, aspiration, valve lift and timing control (presence/absence) and fuel injection type (port/direct). Data on transmission type and number of gears, drive type (2wd/4wd) and vehicle curb weight are also available. No data on aerodynamic drag or rolling resistance is available but we do have data on the use of fuel efficient electric power steering. This data was used a reference set to be obtained for select high sales volume vehicles in other countries.

The total data set reflected light vehicle sales of 13.393 million in model year 2008, which was down significantly from the more typical 16 million sales. It should also be noted that 2008 was a year of record fuel prices in the US and the sales and fuel economy may be somewhat unusual compare to earlier years,

2.3 DATA FOR FRANCE

Detailed sales data at the nameplate/ engine/ transmission level was not publicly available and we used the registration data for calendar year 2008 obtained form R. L. Polk by IEA. The data is coded in an unusual format that identifies a "model year" that may be the year of first introduction for the nameplate, but there is some uncertainty in the exact vehicle model year. The total registrations reported for CY 2008 is about 2.51 million vehicles and the data includes light commercial vehicles and light trucks (van, SUV and pickup) which are reasonably consistent with reported sales data of 2.4 million light vehicles. The data is provided at not only the nameplate/ engine/ transmission level but also includes body style and trim option variations, requiring aggregation to the required level.

Data on vehicle fuel economy and on vehicle technical specifications were not included in the database, and because of the relatively complex layout of the database, it was not easy to match the registration data to any database containing vehicle technical specifications. The total number of models was over 900, thus making a complete dataset manually a daunting task. Instead, we selected the 45 top selling models in terms of nameplate sale and manually matched the data to fuel consumption and technical specifications. The sales of the top 45 models accounted for 1.563 million or 62.3% of total sales. Since most French sales are in small diesel cars, using the top 45 sellers to represent the fleet **over represents** small cars and gasoline engines, with virtually no large cars (most of which are diesel powered) in the sample. However, the fleet-wide averages are not affected significantly; for example, the diesel share among the top 45 sales models is 79.4% but is 81.2% for the fleet as a whole, a difference of less than 2%. The sub-sample is used to create the data on the attributes of the fleet.

Fuel economy data was obtained from the UK vehicle certification Agency which reports the EU official data from the NEDC test in both metric and English units, but the data was for MY 2009 creating some bias in the data since the 2009 year vehicles of the same nameplate may have had slightly better fuel consumption results relative to 2008. Checks against the reported actual GHG emissions and fuel economy for

France in 2008 suggest that this may have created a small downward fuel consumption bias in the order of 2 to 3 percent.

2.4 DATA FOR CHINA

Very detailed sales data for calendar year 2008 by nameplate and engine size (but not transmission type) was obtained from a magazine called China Automotive Intelligence, published by Fourin. The data is complete and indicates total China light vehicle sales of 6.755 million, which includes sales of vans, pickup trucks and SUVs of 1.71 million and 5.045 million cars. As in France, the Chinese market has hundreds of models making the development of a comprehensive database of all vehicles a daunting task. As a result, a sub-sample of the 38 highest sales volume models were utilized to develop a detailed database that included vehicle fuel consumption data and vehicle attributes. The 38 models represent sales of 3.686 million or 55% of the total data. We included all 40 models with sales over 50,000 units per year (2 were dropped due to lack of fuel economy data, see below), but there were at least 40 models with sales between 30,000 and 50,000 making more detailed capture of the fleet to (say) a 75% representation very difficult. Fourin data also provided the market share for automatic transmissions on the class level, which we used to estimate model fuel economy.

Fuel economy data was obtained from CATARC for 2008 but data on all models are not included in this database. We have no confirmation that the data represents the official Chinese test based fuel economy data, since the manufacturer's websites in China do not report this data but report fuel economy on unofficial tests such as a 60Km/h steady speed test. However, we obtained vehicle data from the manufacturer websites for technical attributes such as weight, engine size, engine technology and transmission type, This data was obtained only for the 38 models in the sub-sample for analysis. The sub-sample data over-samples the engines in the popular 1L to 1.6L displacement range relative to the engine size distribution data published in Fourin for the fleet as whole, while not providing any representation of engines over 2.5L which account for only 2 % of Chinese sales, as shown below. It is interesting to note that engines over 3L displacement are less than 0.5% of all sales in China, compared to almost 50% of sales in the US.

Engine Displacement Range		Chinese Fleet	China sample
Less than/ equal to 1L		10.5%	4.5%
1L < ED <= 1.6L		51.7%	70.7%
1.6L < ED <= 2L		24.5%	17.0%
2.0L < ED <= 2.5L		11.4%	7.8 %
2.5 < ED <= 3.0L		1.4%	0
3.0L < ED <= 4.0L		0.4%	0
4.0L < ED		0.1%	0

2.5 DATA FOR INDIA

Detailed sales data for India at the model/ engine/ transmission level are not publicly available and we relied in registrations data purchased by IEA from R. L. Polk for CY 2008. The data indicated total new light duty vehicle registrations at 1.659 million in reasonable consistency with sales data of about 1.6 million for 2008. The Polk data did not contain any vehicle attribute data or transmission data, which were externally input. Transmission data was available only on an anecdotal basis by vehicle size class, which yielded a fleet-wide penetration estimate for automatic transmissions at 19.5% which was in reasonable agreement with expert estimates of 20% penetration. As in the case of France and China, it was not possible to cover all vehicles and a sample of high sales volume vehicles were used to analyze vehicle characteristics. Unlike France and China, the Indian vehicle market is very concentrated, with a single manufacturer (Maruti) accounting for almost 50% of all light vehicle sales, and the 2 top selling models accounting for almost 30% of all sales. We selected the top 16 highest sales volume models and this accounted for 83.4% of total sales, with the sample representing 1.395 million sales. The sample under-represents vehicles in the larger classes, where many imported models compete but only sell a few hundred to a few thousand of any particular model.

Indian fuel economy data as measured on the official test was kept confidential until April 2009, but was released by the manufacturers in May. We were able to locate only one source of official data, and this is on a read-only file on the Website of the Society of Indian Auto-Manufacturers (SIAM). The file had to be manually transcribed into our data base. Vehicle attribute data were obtained from manufacturer websites.

Table 2-1 provides a summary of the data used in this project.

2.6 FUEL ECONOMY COMPARISON FACTORS

The official fuel economy test from which the fuel economy numbers are derived varies across the four countries. The US utilizes the Federal Test Procedure which has city cycle with an average speed of 31.5 km/h and a highway cycle with a an average speed of 77.6 km/h. Europe and China used the "New European Driving Cycle" or NEDS which is a stylized cycle consisting of 4 repeats of a city cycle with an average speed of 18.7 km/h and a highway cycle of with an average speed of 62.6 km/h and a maximum speed of 120 km/h. Because the US city cycle and the highway cycle are at higher average speeds, vehicles tend to operate more efficiently and the fuel consumption of the same vehicle will generally be lower on the US test than on the European test. The difference depends on the power to weight ratio of the vehicle but for an average car, studies (e.g., ICCT, 2007) have determined that the US fuel consumption multiplied by 1.13 equals the fuel consumption as measured on the EC test. We have used this correction factor to adjust the US fleet fuel consumption value to NEDC values.

India also uses the NEDC but modifies it for Indian conditions by limiting the maximum cycle speed to 90km/h. There are also some other procedural changes to the test protocol that make the Indian test somewhat different. No specific study is available to estimate the effect of the Indian procedure relative to the NEDC procedure. As a result, we compared the reported fuel economy of 'identical' vehicles for Europe and India. The vehicles are identical in terms of published specifications but there may engine calibration differences and tire differences that could affect fuel economy but are unknown. As shown in table 2-2 below, the comparison yielded a figure that suggested that fuel consumption measured in India is 8% higher than he NEDC which is a surprisingly large difference given that the cycle change is relatively modest. We have used this value to adjust Indian fuel consumption to NEDC values, recognizing the potential for some error.

Table 2-1: Databases Used for China/India/Europe/US Comparison

US	Europe	China	India		
US EPA Fuel Economy Guide 2008	UK Vehicle Certification Agency, 2009	China FEDC Fuel Consumption Database	Society of Indian Automobile Manufacturer	Source	Fuel Efficiency
1247	4750	1147	182	# of Records	
50	51	33	16	# of OEMs	
621	524	153	90	# of Models	
ICF in-house data base derived from CAFÉ data	OEM Websites/EU Autocatalog 2009	OEM Websites/EU Autocatalog 2009	OEM Websites 2009	Source	Detailed Spec Comparison
All	6	6	6	# of Classes	
All	6	6	5	# of OEMs	
All	12	12	11	# of Models	
CAFÉ data	France, Polk 2008	Fourin, China Automotive Intelligence 2008	Polk 2008	Source	Total Fleet
	28,632	416	480	# of Records	
	79	65	48	# of OEMs	
	912	269	169	# of Models	
	2,509,230	6,755,609	1,673,862	Total Sales	
NA		OEM Websites 2009, Fourin, China Automotive Intelligence 2008	OEM Websites 2009, Polk 2008		"Most Popular"
		65	21	# of Records	
		23	6	# of OEMs	
		37	16	# of Models	
		3,680,627	1,395,566	Total Sales	

3. ANALYSIS OF COUNTRY FLEETS AND FUEL CONSUMPTION

3.1 METHODOLOGY

The comparison of vehicle and fuel economy differences, and an analysis of the cause of the differences requires an understanding of the major reasons for the differences in fuel economy. The vehicles sold in the four countries include some common models as identified by nameplate but also include many models that are unique to specific countries. Moreover, the most obvious and visible difference is the size mix of vehicles sold; the sample includes the US with the largest size mix in the world to India, which has the smallest size mix among major countries. The vehicle technology mix differs but outside of diesel engine penetration, this is certainly less obvious. Diesel engine penetration does vary widely, with France having one of the highest levels of diesel penetration in the world at about 80% of all new vehicles, while diesel penetration in the US and China is less than 1% of the new vehicle fleet in 2008. Hence, we have used a methodology to assess the fleet both from a "top down" viewpoint of aggregate data analysis and a bottom-up viewpoint of examining individual high sales volume models in each country.

The first step was detailed qualitative assessment of the fleet of new cars in terms of manufacturers, vehicle sizes, model availability, and vehicle pricing. Second, a quantitative analysis of the differences in the fleet in terms of mix by size class, weight engine size, power and fuel economy is provided in charts. Third, a detailed difference analysis is documented, with the results illustrating the actual causes of differences in fuel economy between countries, especially to examine if there are substantial technology differences contributing to fuel economy. Finally, the bottom-up analysis is used to examine the results of the difference analysis and lend substance to the arguments.

3.2 QUALITATIVE ASSESSMENT OF THE FLEET

The four countries examined in this analysis span the range of size and diesel penetration mix observed in the world, but overall sales volumes and sales growth also differ enormously. The US sales levels of light-duty vehicles had averaged levels of 16 to 1 7 million cars and light trucks over the 2003-2007 period but sales turned down in 2008 to 13.4 million vehicles and has since declined further to around 10 million expected in 2009. Although sales are expected to rebound in 2010, it is widely anticipated that a return to the 16 to 17 million sales levels will not occur soon and perhaps not even by 2015. Chinese sales were at 6.75 million in 2008 and although there was a modest downturn in the first half of 2009, sales have already recovered to 2007 levels and growth to 10 million in light vehicle sales is anticipated by 2012, with the Chinese market expected to be the biggest in the world by 2015. Sales in France were at 2.1 million cars and 0.4 million light commercial vehicles in 2008 but like the US, sales have declined recently. Moreover, the market is mature and sales may remain at the 2.5 + 0.3 million level for the next decade. India's market was slightly above 1.6 million units in 2008, and like China, seems to have recovered following a small downturn. The market is expected to be around 3 million units by 2015, reflecting a 10+ percent rate of growth. The discussion below focuses on the differences of the Indian and Chinese markets relative those in the US and France which are briefly reviewed.

US Market

The US market is unique in having a market share for light trucks of about 48% in 2008, down slightly from 51% in 2007. The three domestic manufacturers accounted for about half the market and specialize in larger vehicles. The three Japanese manufacturers (Toyota, Nissan and Honda) and the Korean manufacturer Hyundai account for over 35% of the market and are strong in smaller vehicles and compact trucks, while the European manufacturers specialize mostly in luxury and performance vehicles. As noted, the US has the largest average vehicle size. The D-class car is considered a "mid-size" car and is the middle class family vehicle, as is the compact van and midsize SUV. Luxury cars and large trucks each account for almost 10 % of the market. Corporate

Average fuel Economy regulations mandate a fuel economy of at least 27.5 mpg for cars and 22.5 mpg for trucks in 2008, and actual levels are at 32.2 mpg and 23.6 mpg respectively for actual CAFÉ. These numbers include some credits for manufacture of ethanol capable vehicles and for test procedure changes, and the actual test fuel economy levels are at **26.4 mpg combined or 8.91 L/100km**. This is the value for the US test, and in terms of the NEDC test, fuel consumption would be 13% higher at **10.08 L/100km**. Diesel penetration was very small since VW (the major seller of light duty diesels) had temporarily suspended diesel sales in 2008 and about 14,000 diesels were sold mostly be Mercedes. Hybrids, though popular had a relatively limited market of 358,000 vehicles with about two-thirds sold in the D segment. Virtually all cars and light trucks have automatic transmission with manual transmission share of the fleet at 6%, mostly in small cars

French Market

The French market is the most fuel efficient market in Europe and France was the only major country in Europe to attain the 140 g/km carbon dioxide standard in 2008. Fleet wide diesel penetration is slightly over 80% and gasoline vehicles are sold primarily in the smallest vehicles, with diesel penetration in cars larger than B class at over 90%. Vehicle size mix is also weighted heavily towards the B-segment which is the typical family car in France. Compact and medium trucks have approximately a 20% market share, and micro trucks like the Renault Kango have about a 6% market share. The local French manufacturers, Peugeot-Citroen and Renault have the largest market shares, followed by Fiat, VW and Ford. The market for vehicles of class D and E size is quite small at about 10% of the market and luxury car sales are also quite small relative to the US or Northern Europe. Based on published carbon dioxide emission averages, we estimate **new car fuel consumption at 5.47 L/100 km**, but our sample of cars over samples small cars (by focusing on best sellers) so that the **sample FC is 5.16 L/100km**, which is 6% lower than the fleet average. France also has a relatively low automatic transmission penetration rate of 7.6 percent.

Indian market

Unlike many other markets, sales in the Indian market are concentrated in a few vehicle models. In fact, just two models (the Suzuki/Maruti Swift and Alto) account for almost one third of total sales and 16 vehicle models account for over 80% of sales. The Indian market is primarily concentrated in the very small classes of cars with small engines. As shown in Figure 3-1, over 30% of most 16 most popular vehicles are powered by engines with less than 1 litre displacement (a size not sold in North America) and 90% of these vehicles are powered by engines under 1.5 L displacement. The very small engine size is also indicative of the relatively low performance of the fleet which enhances fuel economy.

Anecdotal information from the ARAI (Automotive Research Association of India) is that 2006 new vehicle fleet average fuel economy on the official Indian test was about 6.3L/100km. Our fuel consumption estimate from the **sample for 2008 is 5.86 L/100km**, but this may be due to sample bias of selecting the most popular vehicles, and the actual estimate for 2008 may be about 5% higher at **6.15 L/100km**. However, on the NEDS cycle, the sample base fuel consumption is 8% lower due to the test procedure correction factor, at 5.43 L/100km. Diesel market share in 2008 was about 20% in cars but nearly 100% in light trucks, and the Polk data provides a combined estimate of 34.8% diesel penetration. In addition, manual transmissions are dominant although the use of automatic transmissions is increasing in larger vehicles; the smallest vehicles do not offer an automatic option.

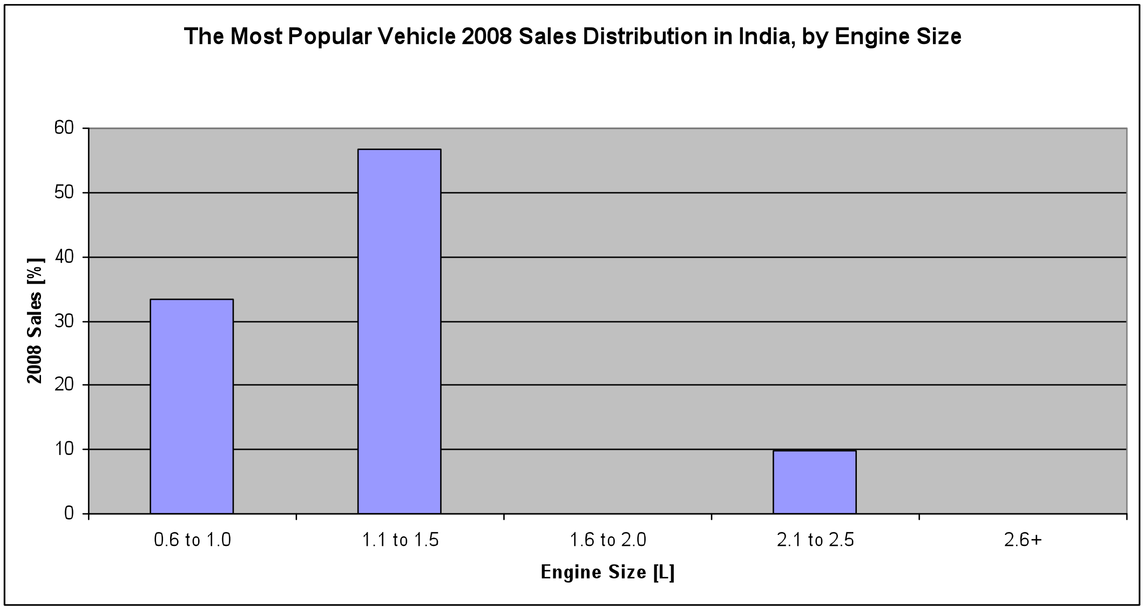


Figure 3-1: Engine size mix of the Analysis Sample

Technologically, the fleet can be divided into three vehicle types

- modern vehicles of European or Japanese design manufactured locally
- older models of European or Japanese design still sold in India but phased out in the EC
- models of Indian design

New cars of European or Japanese design appear to have virtually the same technology as that offered worldwide and these models including the Suzuki Alto and Swift, the Hyundai i10 and Santro, and the Chevy Spark, account for almost 60% of the market. Many models offer advanced electric power steering, and almost all models in this category offer fuel injection. The only adjustment for the Indian market relative to models sold in the OECD is a modest reduction in compression ratio (by about half a point) to account for the lower octane of Indian gasoline.

Older models of foreign origin are sold as price leaders, but their sales are declining rapidly and they represented no more than 10% of the market in 2008. These models like the Maruti 800 and Omni use old design 2-valve carbureted engines, but will likely be phased out with increasingly stringent emission standards.

The third segment includes all models manufactured by Tata Motors and Mahindra who jointly account for about 30% of the market. Mahindra markets small SUVs exclusively and they are mostly diesel powered. The Tata Motors engines are not up to the latest international levels in design with 2valves/ cylinder and relatively low specific output. Many of Mahindra's SUVs still use a naturally aspirated diesel although a modern turbocharged common rail diesel has been introduced in their new Scorpio model. This segment may fall between the first two segments in technological sophistication.

Use of air-conditioning has also been rising rapidly and anecdotal information suggests that penetration is over 50% in new cars. Their use with small engines results in very significant loss in fuel economy, but no information is available on the sophistication of the air-conditioning equipment. Air conditioner use will also not be reflected in any official fuel economy test data since the accessories are turned off for the test. In addition, we found that some low cost models still use bias ply tires as radial tires are not widely available in India.

Chinese Market

Unlike the Indian market, the Chinese market does not have sales concentrated in a few models. Instead, there are a very large number of makes and models available with many makes and models unique to the Chinese market. Even though China total light vehicle sales in 2008 are over four times Indian sales at 6.75 million, sales of the top selling car models are approximately similar to sales of India's top selling models at about 200,000 per year,. Only the GM- Wuling utility vehicle sold in cargo and passenger versions has very high sales of over 500,000 per year. As a result, the combined sales of the top 38 models account for only about 55% of total sales. Many models sell in the range of 20,000 to 40,000 per year making detailed analysis more difficult.

Vehicles in the Chinese market can also be grouped into the same three vehicle types as in India, but unlike India, China has relatively large fraction of imported vehicles which are mostly luxury vehicles or midsize SUV models. Almost all the world's major manufacturers have joint ventures in China offering virtually the same products as those sold in OECD countries, although the smaller engine size options appear to have the dominant market share in these vehicles in China. In addition, several older designs, notably the VW Santana and the Suzuki micro-van dating from the 1980s, are still produced in quantity and serve as price leaders in their class. As in India, the market share for the older designs is declining rapidly. Chinese manufacturers with their own indigenous designs have proliferated in the last decade with about 20 manufacturers making from 10 to 500 thousand vehicles per year. Many joint venture partners are also developing their own indigenous designs that are planned for the export market.

The Chinese market's distribution of engine sizes are significantly different from those in India. About half the vehicles have engines between 1.1 and 1.6L displacement, but 40% have engines over 1.6L displacement. Even the small but significant sales fraction of vehicles with engines under 1.1L is largely due to the GM- Wuling mini-utility van that had no counterpart in India. Figure 2 shows the distribution of vehicles by engine size for CY 2008 in China.

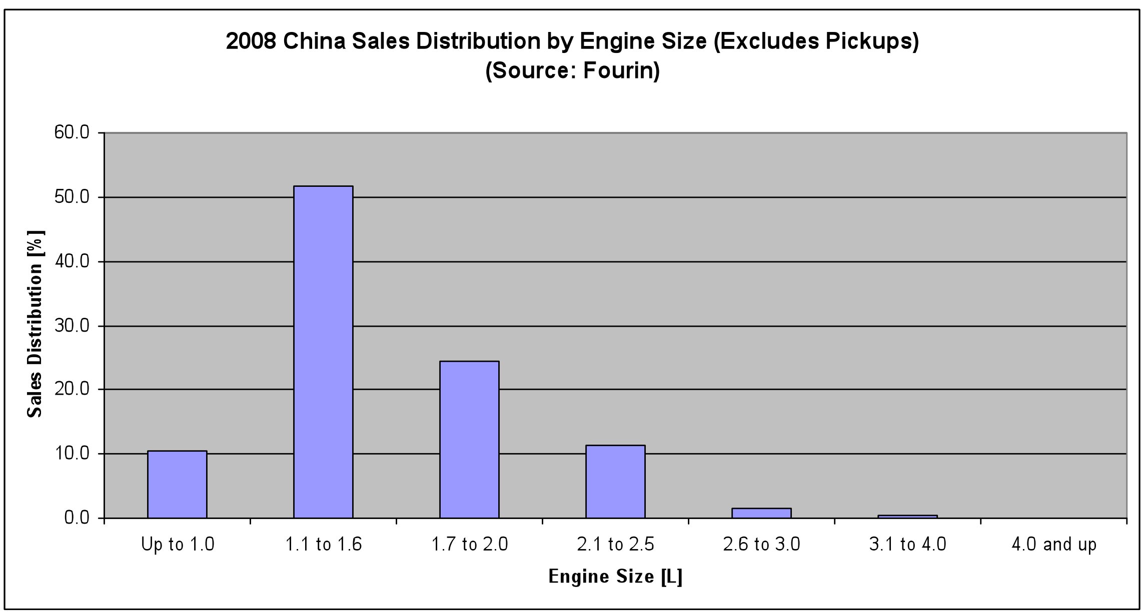


Figure 3-2: Engine size distribution for the Chinese fleet

As noted, most joint venture vehicles are technologically equivalent to OECD models, and many indigenous models have engine technology that is essentially on par with engines sold in the OECD with 4-valves/ cylinder, variable valve timing and port fuel injection. Direct injection (gasoline) technology has not yet been adopted in locally produced cars, and diesel passenger cars have a near zero market share. Diesels are not used even in the utility and SUV models. Transmission technology in many indigenous models appears to behind OECD levels and 4-speed automatic transmissions are still the most common transmission for indigenous design cars, while 5 and 6 speed transmissions are more common in Europe and North America. However, there are reports that transmission technology will soon be significantly upgraded with a number of world class transmission suppliers like ZF and Aisin setting up joint ventures in China.

3.3 SAMPLE DISTRIBUTIONS

A detailed picture of fleet differences can be established by analyzing the sample data (note that the US sample is the entire fleet while the sample data for other countries is based on the most popular vehicles). The following charts compare the distributions of vehicle attributes across the four countries. Figures smaller than 1% of the fleet are not shown for clarity.

Figure 3-3 shows the market share for the different size classes by country. India has the highest share of small A size cars while the largest single segment in both India and France is the B class. It is noteworthy that Chinese cars are, on average, **larger** than the cars sold in France with the C class being dominant. A second major factor in the Chinese market is the micro-truck; we understand that these trucks are very popular in rural areas and for intra-city pickup and delivery. Compact trucks and vans are also quite popular in France and have established themselves as the alternative to wagons. The unique size distribution of US vehicles is also obvious.

Figure 3-4 shows vehicle weights in each country by class. In general, Indian vehicles are the lightest within class, with China, France and the US following and this is because of increasing option content and larger engine sizes, and also due to the higher level of safety options (air bags, impact barriers). The high weight of the compact trucks in India is due to the fact that they are all domestic models with older body-on-frame designs.

Figure 3-5 shows the average engine size by class, and the differences between India, China and France on engine size by class are relatively small (the odd case of the Indian micro-truck is due to the fact that it is unusual product with a very small 2 cylinder diesel engine). Most US vehicles feature much larger engines, except in the B class, which is a ‘entry level’ economy product in the US. This is confirmed by the data on average horsepower by class shown in figure 3-5 . The average HP values for France are somewhat lower for the engine sizes due to the high prevalence of diesels which have about 5 to 10 percent lower HP per unit of displacement, but much higher torque.

Fig 3-6 shows the fuel consumption by size class. In this figure, the French fuel economy advantage is obvious, with Indian vehicles having higher fuel consumption than French vehicles in every class in spite of lower weight and engine power. Chinese fuel consumption is significantly higher, largely reflecting the lower dieselization, but is also higher than Indian and French vehicle consumption in the A class where diesel penetration is not high in France and zero in India. Figures 3-7 and 3-8 show the consumption by fuel type; of course, there is no diesel data for the US or China. French vehicles have a small but significant advantage in both gasoline and diesel vehicle consumption in most classes.

The charts do not fully capture the effects of multiple variables since vehicle weight, performance, engine size and diesel mix vary across nations. Hence a detailed multi-variate difference analysis was constructed to examine these multiple variables simultaneously as described below.

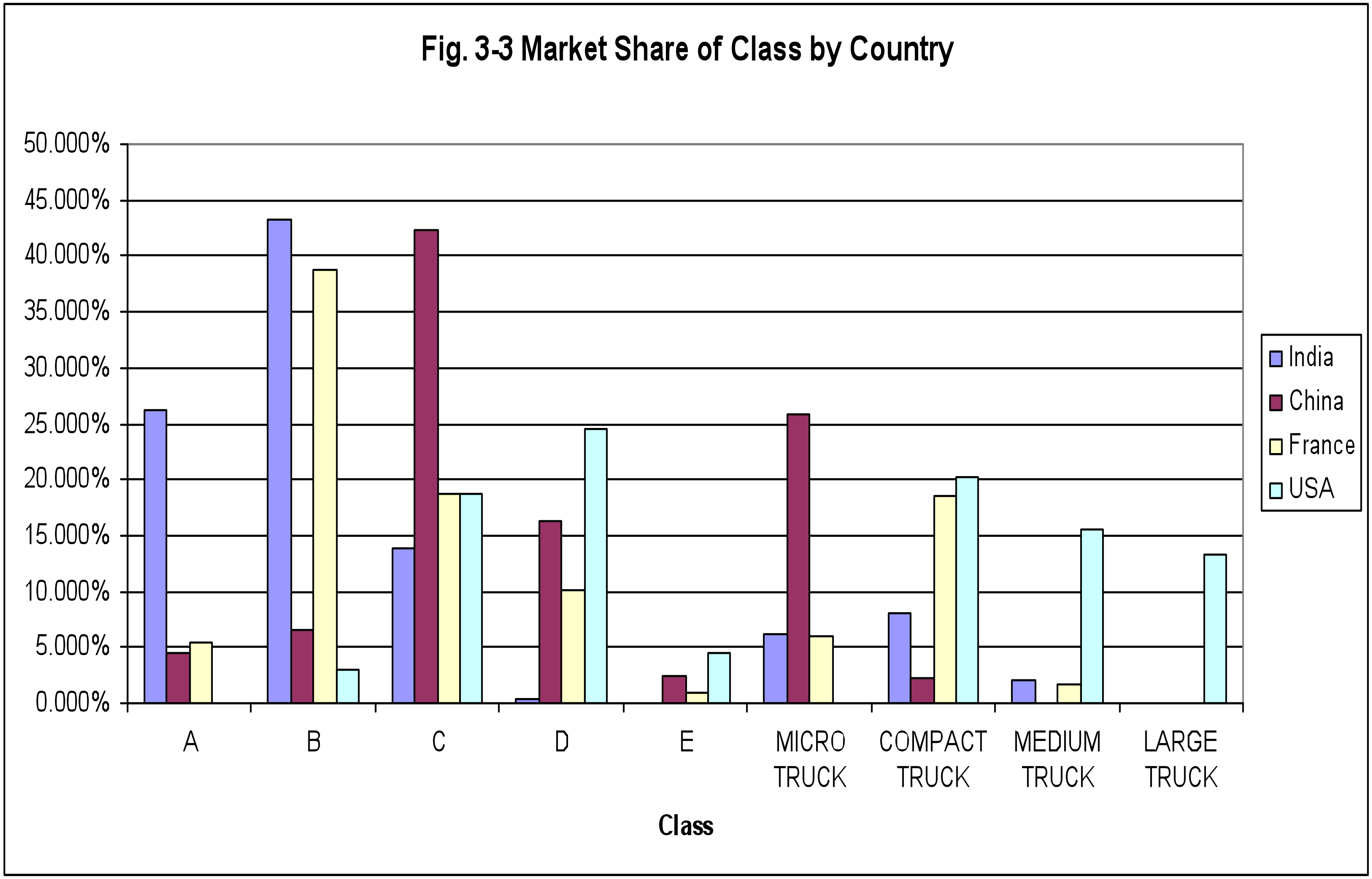


Fig. 3-3 Market Share of Class by Country
50.000%
45.000%
40.000%
35.000%
30.000%
25.000%
20.000%
15.000%
10.000%
5.000%
0.000%
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

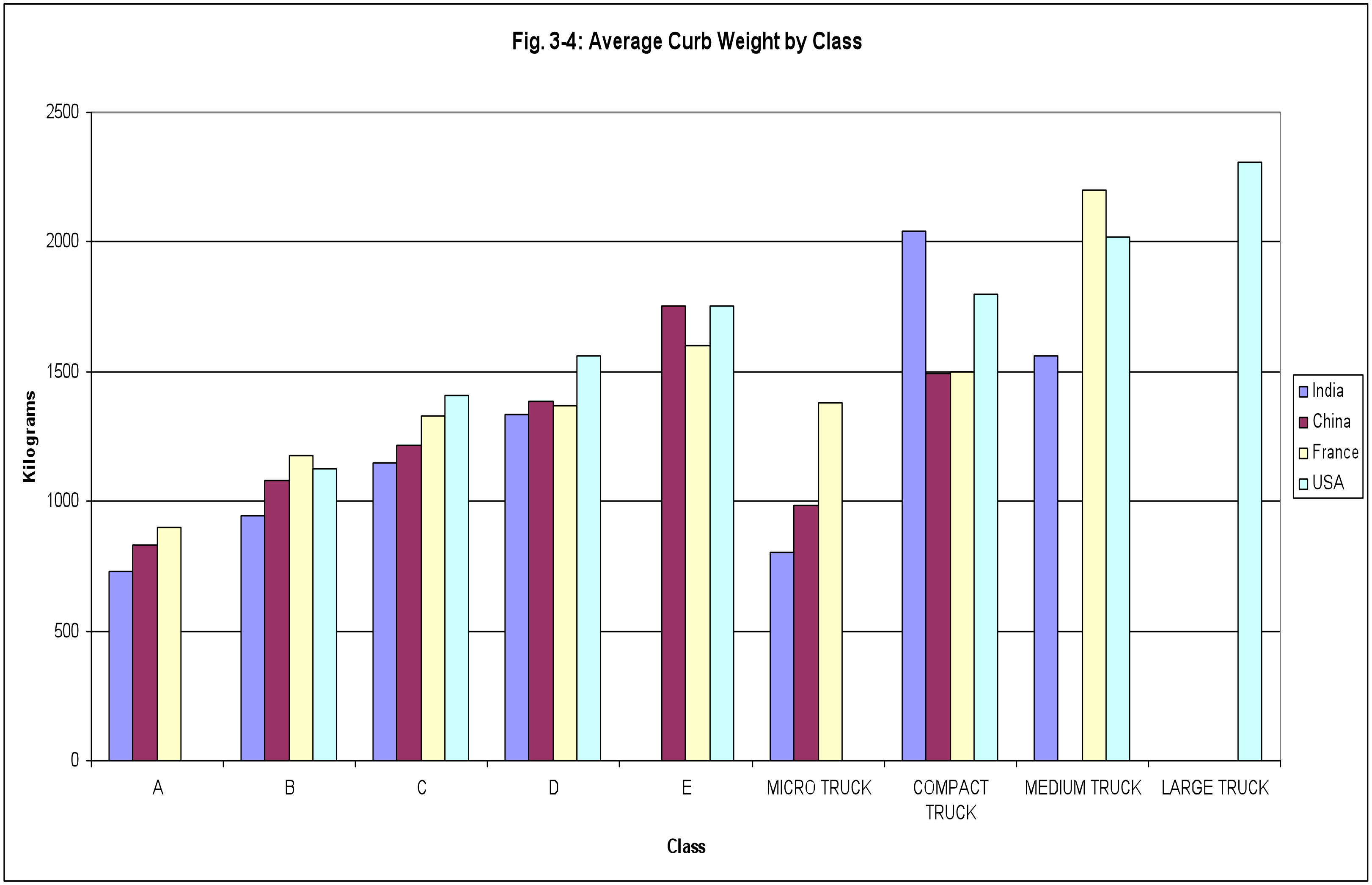


Fig. 3-4: Average Curb Weight by Class
Kilograms
2500
2000
1500
1000
500
0
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

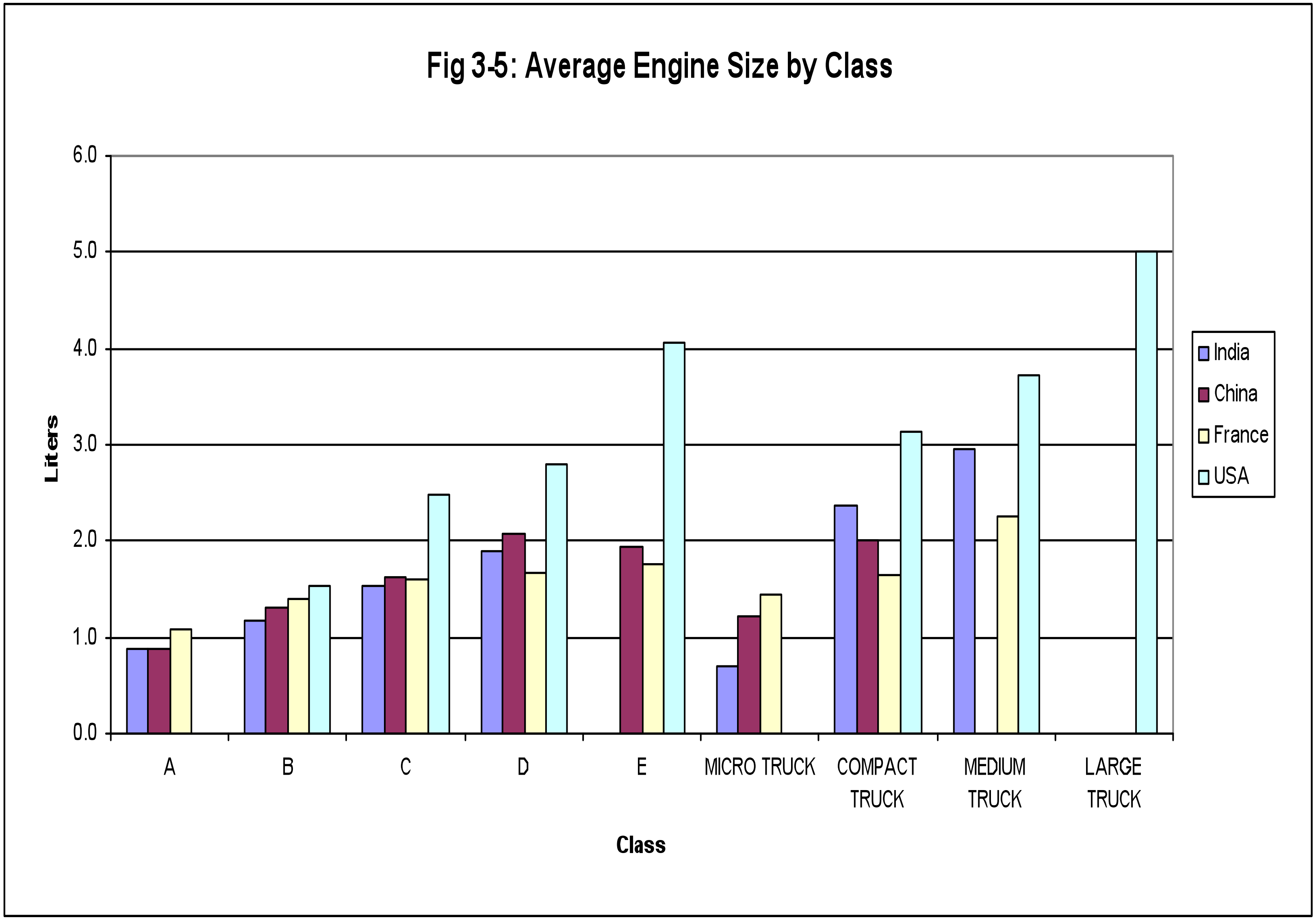


Fig 3-5: Average Engine Size by Class
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Liters
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

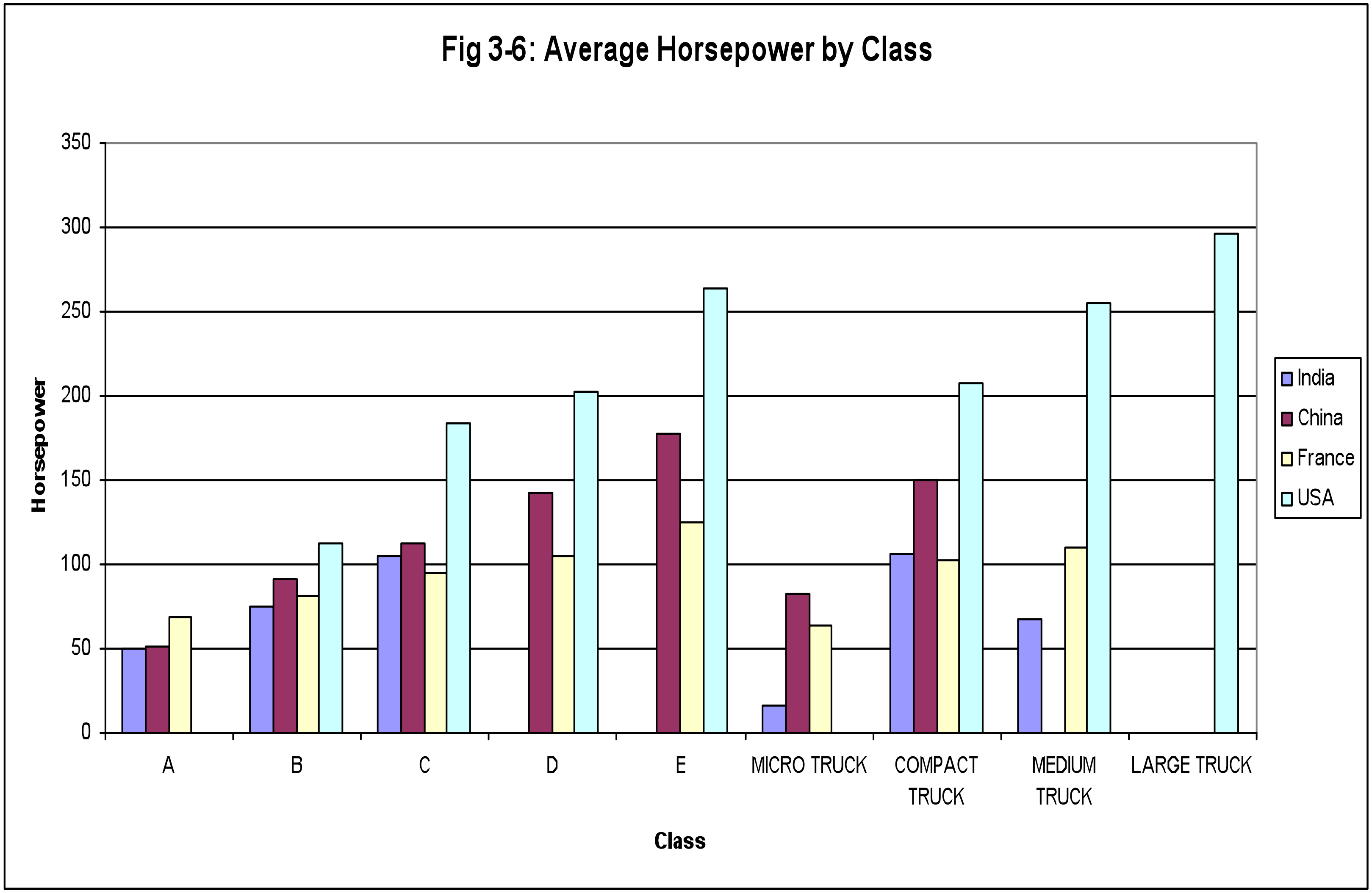


Fig 3-6: Average Horsepower by Class
Horsepower
350
300
250
200
150
100
50
0
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

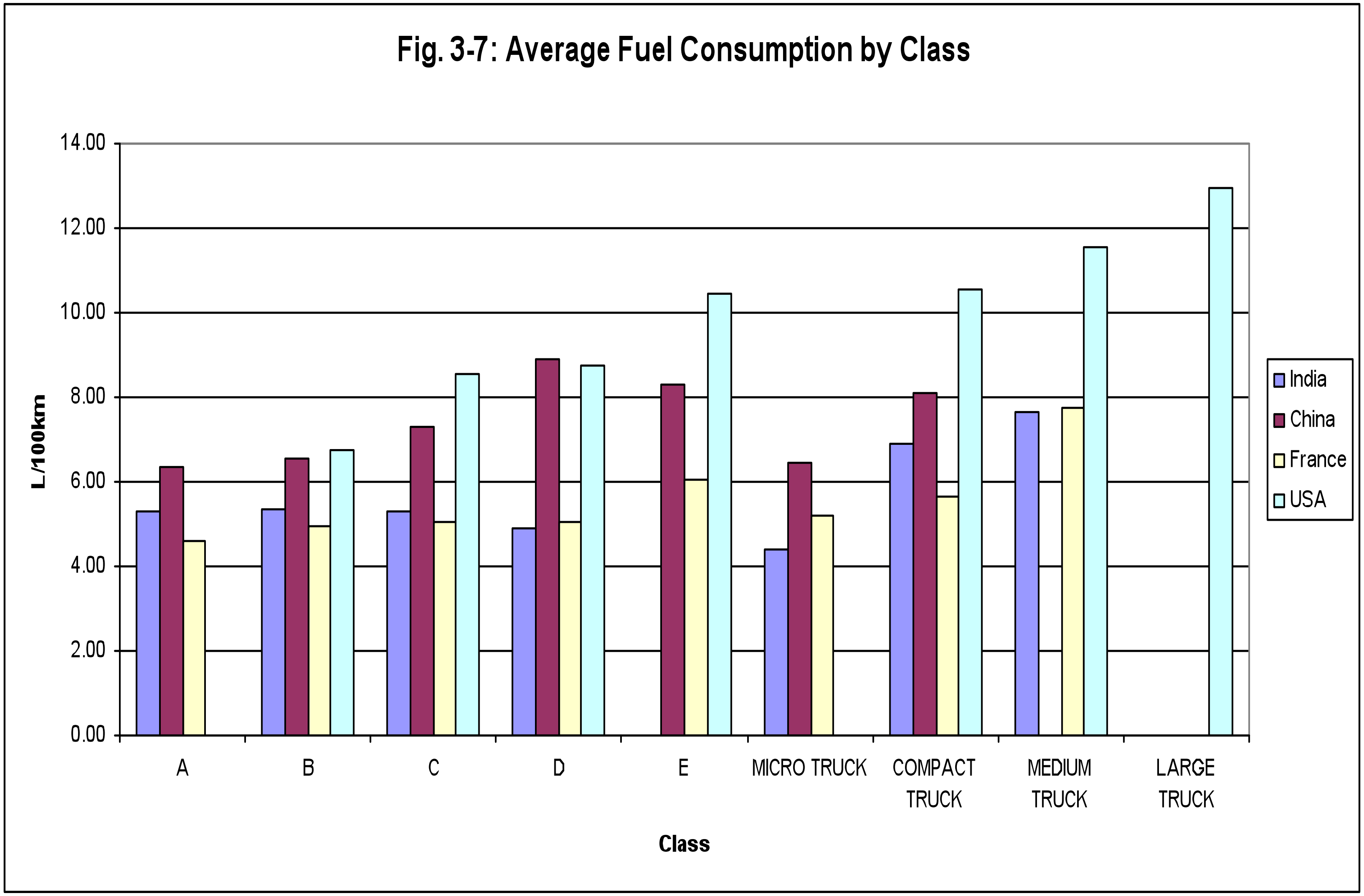


Fig. 3-7: Average Fuel Consumption by Class
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
L/100km
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

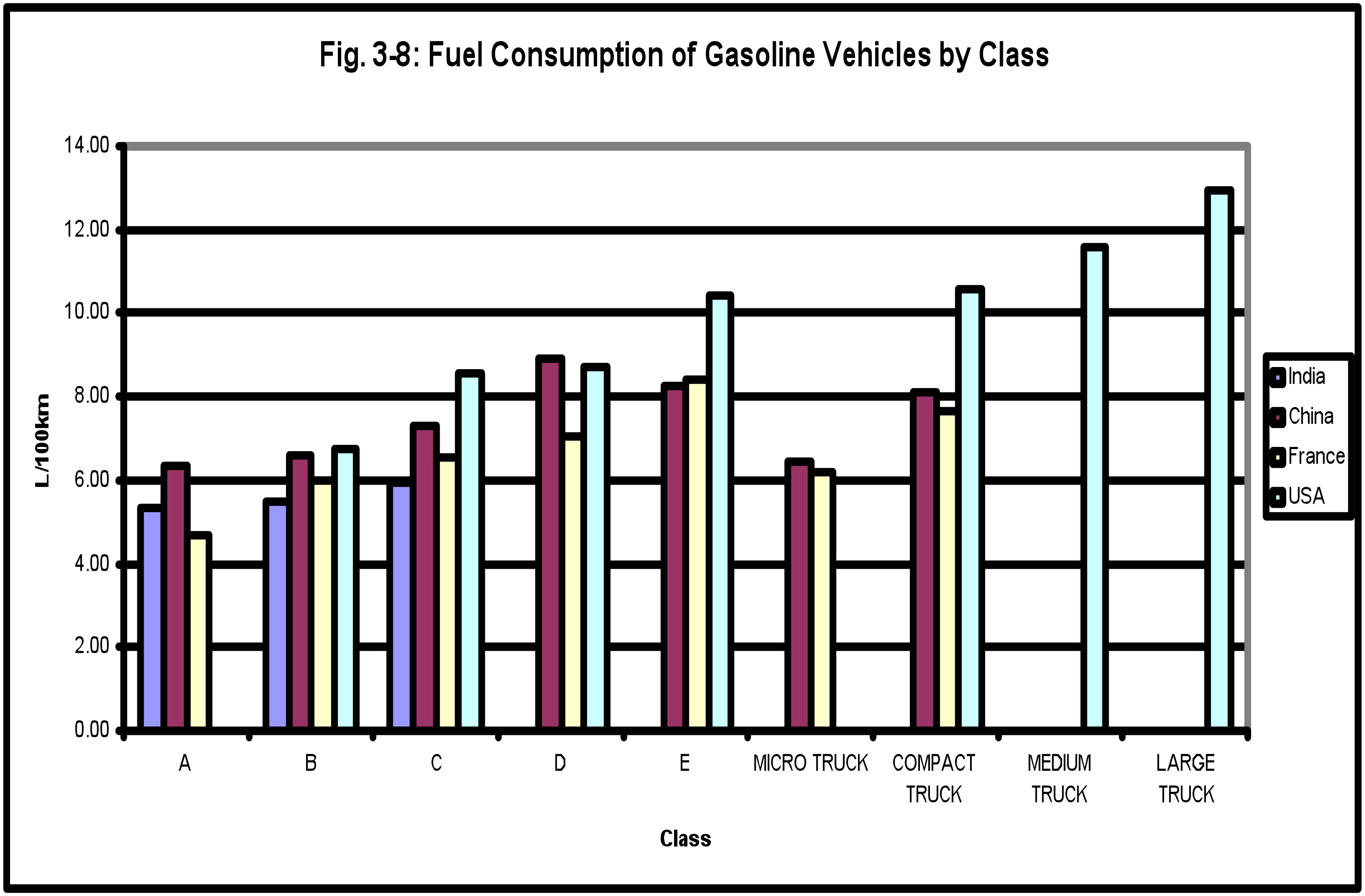


Fig. 3-8: Fuel Consumption of Gasoline Vehicles by Class
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
L/100km
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
LARGE TRUCK
Class
India
China
France
USA

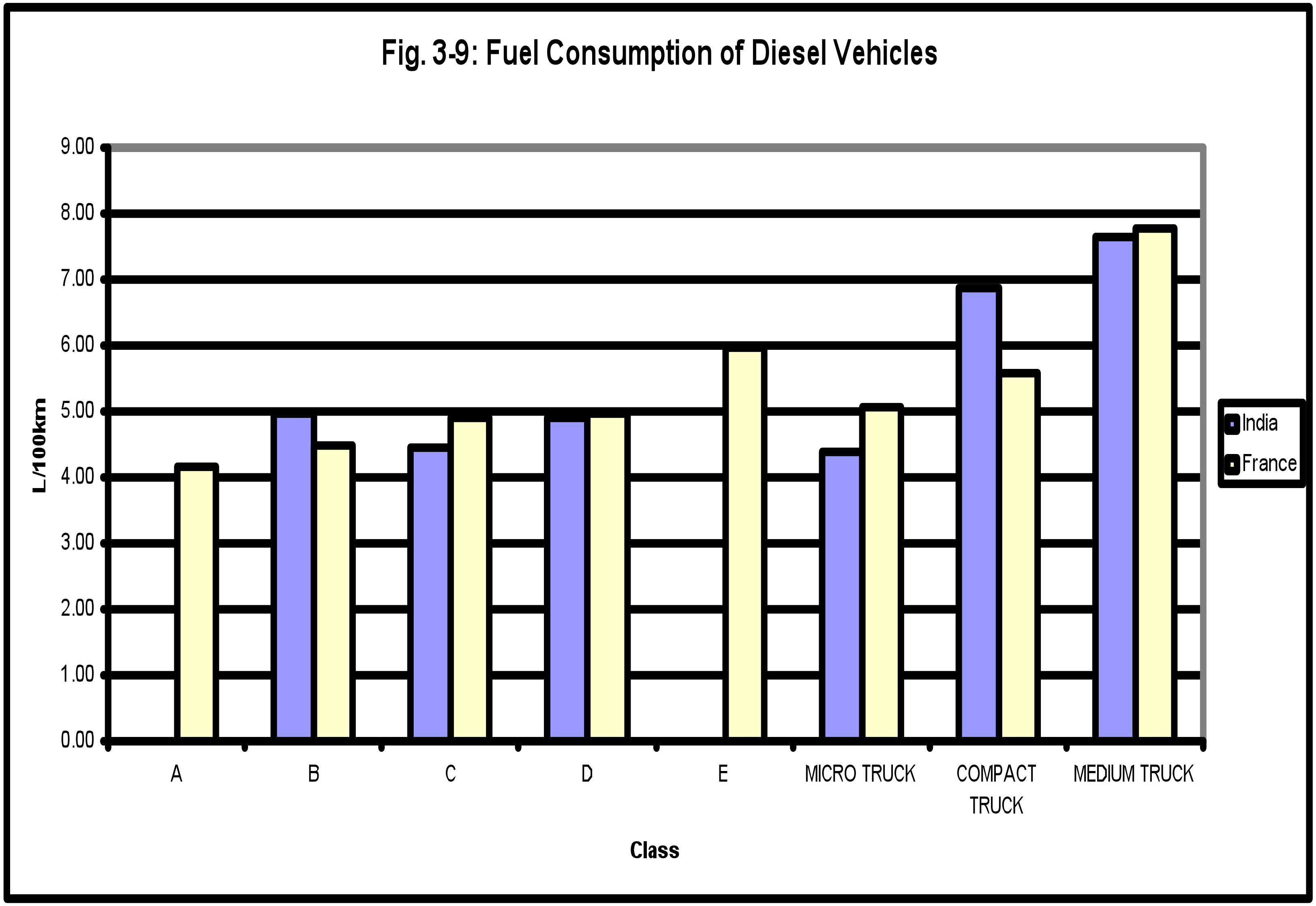


Fig. 3-9: Fuel Consumption of Diesel Vehicles
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
L/100km
A
B
C
D
E
MICRO TRUCK
COMPACT TRUCK
MEDIUM TRUCK
Class
India
France

3.4 DECOMPOSITION ANALYSIS

The average fuel consumption of the fleet is the market share weighted fuel consumption by market class. When comparing the average consumption difference between two country (A and B, respectively) fleets, we can write the difference as follows

$$FC_A - FC_B = \Sigma\ (FC_{Ai} * m_{Ai} - FC_{Bi} * m_{Bi})$$

$$= \Sigma\ (FC_{Ai} - FC_{Bi}) * m_{Ai} + FC_{Bi} * (m_{Ai} - m_{Bi})$$

Where m is the market share and subscript A and B refer to the country and subscript 'i' to the market class. The first term in the equation above is the difference in fuel consumption at the class level for each country where the products are comparable in terms of consumer attributes, and the difference can be attributed to technology differences. The second term is the contribution of mix of sizes sold to the overall difference. Since the sample for France had the lowest fuel consumption, we have used the fuel consumption at the size class level as the comparative gauge, and is country 'A' in all the following comparisons. As a result, the overall difference in fuel consumption is always a negative number.

The fuel consumption difference at the size class level can be further decomposed into the observable differences plus other differences attributable to technology differences that require detailed knowledge of individual vehicle technology characteristics. The major observable differences include

- diesel penetration
- differences in weight
- differences in performance (HP/WT)
- difference in automatic transmission penetration.

The penetration differences and differences in weight and performance were quantified in Section 3.3. The relationship to fuel consumption is also well known: diesel engines provide a 25 $\pm$ 2 percent reduction in fuel consumption, a 10 percent reduction in weight at constant performance provides a 6 $\pm$ 0.3 percent increase in fuel consumption, a 10 percent increase in (HP/WT) ratio results in a 2 $\pm$ 0.2 percent increase in fuel consumption while an automatic transmission imposes a fuel consumption penalty of 5 $\pm$ 1 percent relative to a manual transmission with the same number of gears. Any remaining difference can be attributed to fuel efficiency technologies used in one country but not the other. Of course, the small uncertainty band around each observable technology implies that small residuals on the order of 5% or less imply little or no difference in other technology between countries.

The results of the market share analysis are summarized in the following table, with the US, China and India compared to France, with Delta FC in L/ 100km

Baseline: France	Delta FC Vehicle	Percent Vehicle	Delta FC Market	Percent Market	Total Delta FC
USA	-2.734	55.5	-2.253	44.5	-4.923
China	-2.081	97.7	-0.0485	2.3	-2.129
India	-0.3913	142.7	+0.117	-42.7	-0.274

The country specific issues are quite obvious – the difference between French and US consumption are split almost equally between vehicle related factors and mix of classes sold, whereas the differences between Chinese and French fuel consumption and Indian and French fuel consumption are almost completely vehicle related.

The detailed analysis of the vehicle related differences at the size class level are summarized in Table 3-1. The results decompose the percentage difference or reduction in fuel consumption into percentages associated with each of the factors described above. The results are in very good agreement with expectations based on industry structure and local conditions as described below.

Table 3-1: Decomposition Analysis of Vehicle Technology Effects

US	Diesel	Weight	HP/Curb Wt.	Trans	Other Tech	**FC_{fr}-FC_{us}**
A						0.000
B	-17.10%	2.74%	-6.17%	-4.00%	-2.26%	-1.810
C	-22.19%	-3.57%	-9.04%	-4.00%	-1.80%	-3.468
D	-24.16%	-7.38%	-8.11%	-3.20%	0.61%	-3.685
E	-23.98%	-5.31%	-9.62%	-3.00%	-0.07%	-4.383
MICRO TRUCK						
COMPACT TRUCK	-24.34%	-9.90%	-8.24%	-4.00%	-0.04%	-4.915
MEDIUM TRUCK	-25.00%	5.45%	-12.09%	-3.75%	2.48%	-3.809
LARGE TRUCK						

China	Diesel	Weight	HP/Curbwt	Trans	Other Tech	**FC_{fr}-FC_{Ch}**
A	-2.80%	4.59%	4.94%	0.00%	-33.79%	-1.715
B	-17.10%	5.25%	-3.71%	-0.50%	-8.73%	-1.630
C	-22.19%	5.63%	-4.58%	-1.50%	-7.91%	-2.232
D	-24.16%	-0.56%	-5.11%	-2.00%	-11.59%	-3.867
E	-23.98%	-5.30%	-4.55%	-3.00%	10.00%	-2.220
MICRO TRUCK	-22.58%	24.23%	-8.93%	0.00%	-12.16%	-1.250
COMPACT TRUCK	-24.34%	0.27%	-6.45%	-0.50%	0.78%	-2.450
MEDIUM TRUCK	1.25			0.05		0.000
LARGE TRUCK	1.20					0.000

India	Diesel	Weight	HP/Curbwt	Trans	Other Tech	**FC_{fr}-FC_{us}**
A	-2.80%	13.99%	2.54%	0.00%	-26.80%	-0.695
B	-10.10%	14.98%	-1.57%	-1.00%	-9.64%	-0.391
C	-11.26%	9.46%	-4.42%	-2.00%	4.29%	-0.207
D	0.84%	1.63%	-0.47%	-3.50%	4.43%	+0.143
E						
MICRO TRUCK	2.42%	42.88%	26.53%	0.00%	-53.94%	0.785
COMPACT TRUCK	0.66%	-8.58%	4.58%	-0.75%	-13.74%	-1.227
MEDIUM TRUCK	0%	4.71%	-5.44%	-1.50%	3.66%	0.110
LARGE TRUCK	1.11					0.000

Sum of the percentages difference in each row equals the total percentage FC difference

In the US, the differences in diesel penetration, vehicle performance, weight and use of automatic transmissions almost completely explain the difference in class specific fuel consumption between France and the US. Note that all of the differences allocated to other technology fall between ± 2.5%, i.e., they are not significant. Hence, an important conclusion is that outside of the diesel engine, **there are no significant differences in the use of fuel efficiency technology between France and the US.**

In China, we see that all of the classes (with one exception, Class E) have about 10% higher fuel consumption after adjusting for all other factors except technology. In class A, the differential rises to 33.8% but this largely explained by the fact that the Chinese class A market is very small and dominated by a few older models produced by small local manufacturers under license. Class E is dominated by imports with the Audi A6 being the best seller, and it features an advanced turbo-charged direct injection gasoline engine, explaining the positive fuel consumption offset of 10% relative to France. Hence **an important conclusion is that there is a technology opportunity of about 10% in most high sales volume classes in China, relative to the technology employed in France.**

In India the picture is more complex. There does appear to be a significant technology opportunity in Classes A, B, and compact trucks which account for about 78% of total sales. In classes C and D, the products are almost completely from international suppliers building the same product that they offer across the world, with the only compromise being some reduction in compression ratio or engine calibration to account for the local fuel quality, so that differences with France are small (<5%). **The significant finding is that there is substantial technology opportunity in the high sales volume segments in India, but this must be tempered by the fact the opportunities are in very cost sensitive segments.**

3.5 BOTTOM-UP ANALYSIS

In this section, we examine specific vehicles sold in India and China in segments where we identified large technology opportunity relative to similar vehicles sold in France, to verify the opportunities and examine the actual market limitations in these countries. We have focused on the highest sales volume models in each country by fuel type since diesel engines provide a substantial fuel economy advantage,

Table 3-2 compares the characteristics of the two or three highest sales volume cars in the A class. As shown below, all of the cars except the Hyundai Santro use 3 cylinder engines, but the French cars have fuel consumption <u>20 to 30 percent</u> lower than that of the Indian and Chinese cars, consistent with the findings of the decomposition analysis. Although some of the reasons include the use of modern high compression ratio low friction 4-valve engines, Variable valve timing and aerodynamic bodies, the very large difference is quite surprising and suggests that Indian and Chinese cars in this segment are poorly optimized for fuel economy. In particular, the Chinese cars are old design models sold as price leaders, as is the Maruti 800, and Indian and Chinese manufacturers may be offering the cheapest product possible in this segment at the expense of fuel economy. It should be noted that there is a very large price differential in Europe versus India and China for A class cars; for example, the Citroen C1 is listed at about Euro 9000, while the Maruti 800 lists for about Euro 3000, a factor of 300 percent! Hence, technology improvement may be difficult in this price sensitive segment.

Table 3-3 provides a similar comparison for Class B gasoline cars. In this case, the difference between India and European cars is quite small, but European cars are generally higher performance while offering similar levels of fuel economy. This suggests that Indian cars may have potential to improve by 5 to 10 %, since European cars have about 20 to 25 percent higher horsepower. The Chinese cars have significantly worse fuel consumption than their Indian and European counterparts and the local design Geely has fuel consumption levels almost 30% higher than similar vehicles in Europe and India. However, it should be noted that B-class cars are very dieselized in France, and the equivalent levels of fuel consumption are 4.4 to 4.5 L/100km.

Table 3-2 A-class cars comparison

Make	Model	Engine	HP	Weight	FC		Comment
Maruti India	800	0.8L	37	650	5.75		2-valve, 8.7 CR, 4-spd trans.
Maruti India	Alto	0.8L	47	720	5.12		4-valve, 9.2 CR 5-spd trans.
Hyundai India	Santro	1.1L	67	854	5.52		3-valve, 10.1 CR 5-spd trans
Chery China	QQ3	0.8L	52	880	6.60		4-valve, 9.5CR 5-spd trans.
FAW China	Xiali	1.0L	53	845	6.50		2-valve, 9.5 CR 5-spd trans
Citroen France	C1	1.0L	68	865	4.50		4-valve 10.5 CR 5-spd trans
Toyota Europe	Aygo	1.0 L	68	865	4.60		4-valve 10.5 CR 5-spd trans

Table 3-3 B-class cars comparison

Make	Model	Engine	HP	Weight	FC		Comment
Maruti India	Swift	1.3L	87	980	5.82		4-valve, 9.0 CR, 5-spd trans.
Tata India	Indica	1.2L	64	1075	5.50		2-valve, 10.0 CR 5-spd trans.
Maruti India	Wagon R	1.1L	64	980	5.45		4-valve, 9.0 CR 5-spd trans
Geely China	Freedom	1.3L	86	1042	6.90		4-valve, 9.3CR 5-spd trans.
Shangai GMChina	Lova	1.2L	87	1105	6.07		4-valve, 10.5 CR 5-spd trans
Citroen France	C2	1.4L	88	1088	5.60		4-valve 11 CR 5-spd trans
Fiat Europe	Panda	1.2L	60	940	5.40		2-valve 9.8 CR 5-spd trans

Among C-class vehicles, international models dominate sales in China and to a lesser extent in India. The most popular models in this class (in order of decreasing sales) are the VW Jetta, Hyundai Elantra, Toyota Corolla, Buick Excelle, BYD F3 and Ford Focus, and five of the top six are international models. With the exception of the Toyota Corolla at 6.8 L/100km, all of the others are 7.3 to 7.6 L/100km range, with an average of 7.3 L/100km. Engine sizes are also relatively high at 1.64L average, while in India, the average engine size is a little smaller at 1.5L. Top sellers in India in order of decreasing sales are the Honda City, Tata Indigo and Maruti (Suzuki) SX4, and the smaller engine size and lower performance results in an average fuel economy of 5.95 L/100km. In France, the segment has very high diesel penetration and hardly any gasoline cars are sold, but the average gasoline vehicle has a fuel consumption of 6.55 L/100km and an average engine size of 1.62L, quite similar to China. Hence, Chinese vehicle fuel consumption in this segment is 10 percent higher than French consumption but the reasons are not obvious. The lower Indian fuel consumption is in line with the lower performance and weight of Indian vehicles in this class suggesting no technological differences with France.

The higher Chinese fuel consumption figures may be in part, related to the fuel economy reporting. For example, the Toyota Corolla in India is rated at 6.4 L/100km while the similar Chinese model is rated at 6.8 L/100km. Similarly the Honda Civic 1.5L is rated at 6 L/100km in India but at 6.9 L/100km in China. Unfortunately the percentage differences are not consistent across paired match comparisons of models across countries, but we caution the IEA that the Chinese fuel consumption ratings may have some adjustment for on-road conditions.

4. FORECASTS OF VEHICLE SALES AND FUEL ECONOMY AND POLICY CONCLUSIONS

4.1 OVERVIEW

There is substantial concern that the Chinese and Indian light vehicle fleets could grow enormously and that consumers could also continue to move to larger vehicles as incomes increase, offsetting technological improvements to fuel economy. Long range forecasts of vehicle sales, fleet size and fuel economy are quite difficult due to a number of unresolved factors that would have huge impacts on the ultimate outcome. These factors include the possibility of a peak in oil supply, significant actual climate impacts of global warming that result in unified government actions, and the extent of linkages between energy price and global economic growth, to name a few. By 2040, it is likely there may be critical energy supply shortages with resultant high energy prices that could lead to major economic downturns. The consideration of such long term issues is beyond the scope of this report, but we focus on the next 5 to 10 year period where such disruptions are less likely (but not impossible) and fuel economy regulations over the period known or under discussion. Products in the pipeline to 2015 are also known with some certainty so that technology and fuel economy changes can be forecast with more precision. The consideration of these issues makes it clear that all four countries are moving in different directions. The report also qualitatively examines how fuel prices ranging from $50 to $100 per barrel of crude will likely affect the forcasts relative to the $70 level today.

4.2 US MARKET TRENDS

Light vehicle sales (to 5 tons gross weight) in the US peaked at over 17.1 million in 2006, and have been sliding ever since. Current sales in 2009 are expected to be at 10 million units, and most observers expect only a modest recovery to 11.5 million units in 2010. There is talk that the era of 17+ million sales is permanently over. However, our analysis shows no cause for such pessimism. The current US light vehicle fleet (2008 data) shows a vehicle population of 136 million cars and about 90 million light trucks for a combined population of about 225 million vehicles. With the average lifetime of vehicles at about 14 years, the vehicle replacement rate alone requires average sales of 16.1 million vehicles. In recent years, the fleet may have over-expanded due to cheap credit for rental car fleets and there may be some short term shrinkage of fleet size, but in the longer term (2015+) we anticipate fleet size to return to over 225 million and sales to return to 16+ million on average, exceeding 17 million in good years. This scenario does not assume unusual economic growth, and US population growth of 1% per year seems likely to continue mostly due to immigration.

However, what has appeared to change significantly is the demand for very large vehicles. The large pickup, van and SUV market has declined significantly with market share declining from a high of almost 20 percent of sales (over 3 million vehicles) to about 14 percent in 2009. Many manufacturers are exiting the market and we expect the market for large passenger trucks to become quite small with future sales dominated by large (light commercial) pickup trucks. Another change is the market for A class and B class cars is reappearing and could grow from about 3% of sales to 5 or 6% even under a forecast of stable oil prices (at $70/bbl.) due to the appearance of several new models being introduced in this segment. The market share of the popular middle segment of the car and truck market seems relatively stable even through the oil price swings. The changes in market shares alone are likely to reduce fuel consumption by 3 to 4 percent. A return to low fuel prices with oil under $50/bbl. could reverse the market share changes with a similar reverse effect on fuel consumption.

New fuel economy standards have also been proposed for 2016, with the fleet standard equivalent to 175 g/km CO_2 on the NEDC (250 g/mi. on the US test). Assuming diesel penetration stays small as evidenced by product plans, the standard is equivalent to a US test fuel consumption of 6.63 L/100km. However, the proposed standards also contain some “credits” for flexible fuel vehicles and air conditioner improvements, as well as banked credits for exceeding standards in 2010 to 2012 so the real fuel economy is only expected to be around 7.25 L/100km on the US test which is equal to 8.18 L/100km on the European test (NEDC). Hence, US fuel consumption will be significantly higher in 2016 than the French fuel consumption in 2008. This still represents a 20 percent reduction in fuel consumption from actual 2008 levels, which were significantly better than standards on a fleet-wide basis.

The technology improvements used to improve fuel consumption by 20% include the following:

- widespread use of direct injection (DI) gasoline engines with higher compression ratio
- phase out of older 2-valve engine designs and replacement with smaller 4 – valve high output engines
- replacement of V-8 and larger V-6 engines with V-6 or four cylinder turbocharged DI engines, respectively
- use of 6-speed automatics instead of 4 –speed units in larger cars and light trucks, and use of continuously variable transmissions in small cars.
- Replacement of engine driven accessories with electrical accessory drives.
- Body weight, tire rolling resistance and aerodynamic drag reduction
- Introduction of more hybrid models with market share expected to increase beyond 10 percent by 2015.

It appears that the 2016 standards can be met largely with improvements to conventional technology which are generally low cost, and only modestly increased levels of hybrid technology use will be required. However, both California and the EPA are contemplating more stringent standards for the 2017 to 2025 time frame which may force much higher levels of hybrid technology use with fewer conventional technology options to meet standards.

ICF analysis has shown that fuel prices will have little impact on the levels of new vehicle fuel economy attained in 2016 and 2020. At current gasoline prices of $2.50 to $3 per gallon (equivalent to crude at $70 to $80 per barrel), manufacturers will be hard pressed to meet the 2016 standard without the carry-forward credits from exceeding near term standards. Higher gasoline prices will not enable more technology in this time frame since the manufacturers are at the limit in terms of rate of change of technology for the next six years. In fact, higher gasoline prices at say $4 per gallon (equivalent to $125 crude) would cause some additional mix shift to smaller vehicles, and allow manufacturers some room to slow down the pace of technology introduction. Low gasoline prices will force manufacturers into additional efforts to control mix by cross subsidies between small and large vehicles and subsidies for hybrid technology, but standards will be limiting. Hence the fuel economy forecast for the US over the next decade will be relatively stable under a wide range of scenarios and will be standards driven rather than market driven.

4.3 FRENCH MARKET TRENDS

Like the US, light vehicle sales in France have declined this year following a relatively stable period of sales in the 2.4 to 2.8 million range. The French automotive market is also quite mature and sales are likely to stay in this same range in the 2012 to 2020 period after the end of the economic recession of 2009. However, the French market is unique among the major European markets by having 1) the smallest average vehicle size and engine size and 2) having a diesel penetration of 80+ percent. This has enabled the French new car fleet to be the only one in Europe to meet the "voluntary" CO2 target of 140 g/km in 2008 as per the European Commission's 1998 agreement with the European Automobile Manufacturers Association (the target date was subsequently delayed to 2012). The EC was considering much more stringent CO2 targets for the future and has settled on 130 g/km target to be phased in between 2012 and 2015, while a 95 g/km target has been set for 2020. The 'modalities' and 'aspects of implementation' of the 2020 standard will be reviewed by the Commission in early 2013. The 130 g/km target is 18% below the actual 2007 EC wide level of 158 g/km but is only 7 percent below the actual 2008 French emission levels.

Given the relatively small vehicle size and high diesel penetration levels of the French fleet, significant changes in the size mix and diesel penetration to decrease fuel consumption further are simply not possible. In fact, the recent run up in diesel prices in Europe caused diesel market share to decline in 2008/9 by about 5 percent on pan-European basis. However, the French fleet can meet the 2015 standard of 130 g/km without much problem, since a range of diesel engine technology improvements from improved fuel injection to downsizing/ down-speeding the engine and employing sequential twin turbochargers is expected to reduce diesel engine fuel consumption by 6 to 7 percent. Modest weight, rolling resistance and drag reduction coupled with accessory electrification can provide another 7 to 8 percent reduction. In addition, new "idle stop" technology that turns off the engine at idle and deceleration could provide another 3 to 4 percent improvement in fuel consumption on the NEDC test. Idle stop technology is becoming popular in Europe and is a low cost technology for cars with manual transmissions and without air-conditioning. Hence, a low cost path exists for the French fleet to reduce CO2 emissions by another 17 to 20 percent over the next decade.

The 2020 target requires a reduction of 32.15% from 2008 levels in France, which is substantially higher than the level available from conventional technology, and hence vehicle hybridization or electrification will be required. The German manufacturers have embraced hybrid technology which can provide an additional 18 to 20% fuel consumption reduction, but is a relatively high cost technology. ICF analysis of European product plans show that the majority of E class cars and a sizeable fraction of D class cars in Europe will use either gasoline hybrid or diesel hybrid technology, but its use in smaller vehicles may be far more limited. One interesting possibility is the all electric car (EV). Both the French auto-manufacturers and especially Renault have publicly stated their intent to introduce several EV models starting in 2011. The Renault EV plan includes urban commuter (low performance) 2-seaters, family vehicles and even an electric version of the Kangoo small utility vehicle. France may be more hospitable to EV models because

- battery costs (which drive the high cost of EV) scale with vehicle size, and small vehicles are more accepted in France

- vehicle accessories like air conditioning, which drain the battery quickly are less common in France
- the shorter commutes common in France may make EV models with a range of only 80 to 100 km before recharge more acceptable.
- France enjoys a milder climate than other parts of Europe which leads to less stress on the battery
- The reliance on nuclear power in France results in large GHG benefits for EV operating on off-peak electricity.

However, battery costs are very high currently and in the near term (2010-2012) costs of a Lithium-ion battery pack (not cell) will be in excess of Euro 700 per kWh of storage capacity. A small a or B class vehicle needs about 8 to 10 kWh of stored energy for a 80km range and 22 to 24 kWh for a 160 km range. The vehicle cost of the EV without the battery is similar to that of a conventional petrol car, and hence the EV retail price premium will be about Euro 9000 for a small car with 80 km range, and about Euro 22,000 for a small car with 160 km range. At current costs, EVs do not make economic sense. According to battery experts, battery costs could fall to Euro 300/ kWh by 2020, and EV motor costs could also be reduced by 30+ percent over the period, so that the retail price premium could be below Euro 3500 for a 80 km range vehicle by 2020. Over the life of the vehicle of 10 years/ 100,000km, a petrol vehicle rated at 5L/ 100km would use 5000 litres, which would cost about Euro 7000 at E1.40 per litre. In contrast, lifecycle electricity costs would be lower than E 2000 and the short range EV could be economical on a lifecycle cost basis.

Given the EV advantage in France relative to other countries, we forecast that the EV market could grow rapidly in the post-2015 time frame, especially if government subsidies promote the EV in the near term. One scenario that will allow France to meet the 2020 target of 95 g/km is an EV penetration level of 15 to 20%, a 10 to 12 percent penetration of hybrids in larger vehicles, combined with low cost conventional technology improvements to conventional petrol/ diesel vehicles.

4.4 SALES GROWTH IN INDIA AND CHINA

As noted in Section 4.1, China has been experiencing sales growth rates of 20 to 30 percent year-on-year since the beginning of the decade. Indian growth rates have been lower at 10 to 12 percent, but assumptions of the continuation of these growth rates, especially in China, raise the specter of enormous annual sales by 2020. Even at the bottom end of the range of rates exhibited by Chinese vehicle sales, a 2020 sales rate of 50 million units per year is implied, which is comparable to total world sales in 2009! Hence, a literature search of possible sales at "saturation rates" of vehicle ownership in China and India was included in this study.

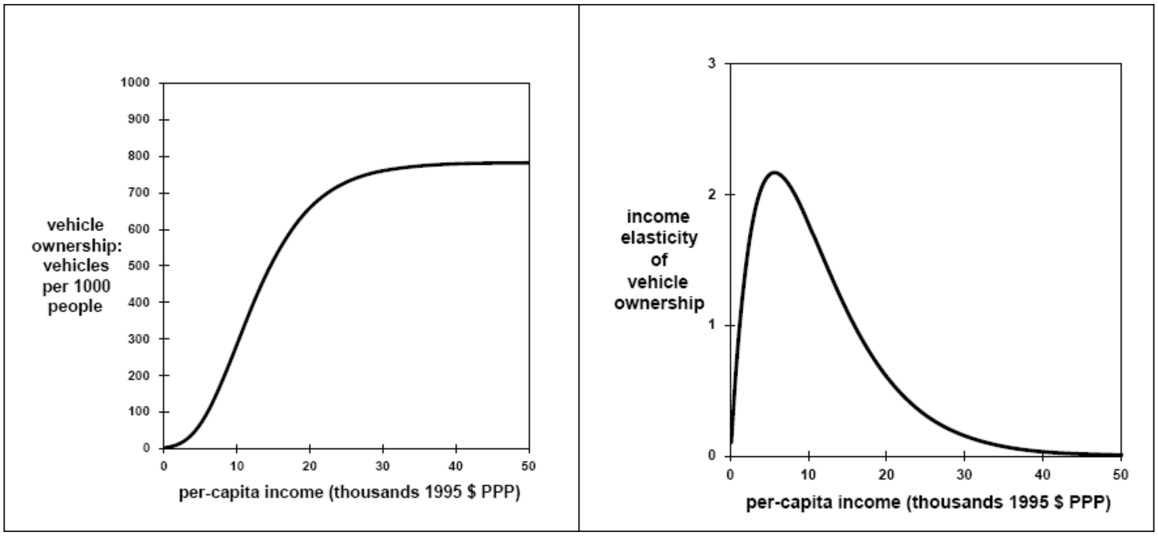
The development of vehicle ownership follows a non-linear functional form with significant similarities between countries and time periods. Several studies have shown that vehicle ownership rates can be reasonably modeled if projections of per capita GDP are available. Those studies use a Gompertz function, which was developed specifically to characterize demand as a function of income. The form of the Gompertz function is as follows:

$$V_i = V^* \times e^{\alpha e^{\beta (GDP_i)}}$$

Where V_i is the vehicle ownership rate (vehicles per 1000 people) in year i, V^* is the saturation level for the particular geographic area in consideration (also in vehicles per 1000 people), GDP_i is per capital income in year i, and the parameters α and β determine the shape of the curve. The nature of the curve implies that the elasticity with respect to income is not constant, but peaks and then declines as a function of income.

$$\eta_i = \alpha\beta(GDP_i)e^{\beta(GDP_i)}$$

The figures below show the form of the relationship between income and vehicle ownership and the relationship between income and income elasticity.



Illustrative Gompertz vehicle ownership function and corresponding income elasticity (from Dargay et al)

Selecting the proper values for V^*, α, and β is clearly critical to projecting vehicle ownership for a given level of income for a particular country or region. There are several studies that attempt to do just that – in this review the focus is on three: one developed by the Argonne National Laboratory that focuses specifically on China (Wang et al., 2007), one that attempts to develop estimate for 45 countries independently (Dargay et al., 2007), and one from Goldman Sachs that focuses on the BRIC nations (Brazil, Russia, India and China) (Wilson et al., 2004).

The saturation rate, V^*, is a function primarily of population density (it is also a function of the extent of the road network though most studies seem to make the implicit assumption that as per capita GDP increases so to does the road network such that it is not a limiting factor except for as the road network is itself also a function of population density). The Dargay, et al., study used population projections divided by land area to develop sautration levels. This raises a peculiarity for China however, as a substantial region of the country is essentially uninhabitable and the population tends to be concentrated (as the authors explicity note). They estimate a value of 683 vhicles per 1000 population where Dargay assumes a saturation rate for China equavalent to that of India, in comaprison to the current level of about 850 in the US.

Similarlly, the Wilson et al study did not vary saturation rates between India and China, but assumed the two would be roughly equivalent and estimated an ultimate ownership rate of about 600. The Wang et al piece does not provide an estimate for India, but includes low, mid and high growth scenarios for China of 400, 500 and 600 respectively. Wang et al's estiamtes are lower than the others, but presumably this is because Wang includes consideration of Chinese scrappage policy (whereas the other studies do not mention this). Wang shows survival rates by vehicle age with dramatic dropoffs at 15 years, reflecting Chinese regulations that vehicles be scrapped after either 400,000 km or 10 years with a 5 year allowable extension (for most passenger highway vehicles). It is not clear, however, if this regulatory policy is to be continued over the long run.

For the parameters α and β, each study created a compilation of historical data to fit the Gompertz function. Dargay et al calculated a common α-value and allowed β to vary for each country in their 45-country panel. Wilson et al used panel data from a 25 country sample to create a pooled data set, calculating a global α and β which they then applied uniformly to both India and China. Since this study also uses a uniform V^*, the resulting discrepencies between Indian and Chinese ownership rates in their projection are attributable soley to GDP and population projections. Wang et al appear to calculate values differentiated by region for the Gompertz function. Their curve fits are shown in Figure 4-1 (which also illustrates nicely the differences in saturation levels by region as a function of population density). The curves appear to justify much lower saturation rates than thos calculated by Dargay, et al., and Wislon, et. al., and our own evaluation suggests the 400 to 500 range as more appropraite from Asian data.

GDP and population projections for each study differ as well. Wang et al used official government (Chinese) targets (per capita GDP of $10,000 by 2050), supplemented with academic resources. Wilson et al used projections from Goldman Sachs sources for GDP and population growth for India and China (for which the basis of those projections are not clear). Dargay et al is not clear as to the source of their GDP and population projections, but include values for 2030 and average annual growth rates in their paper.

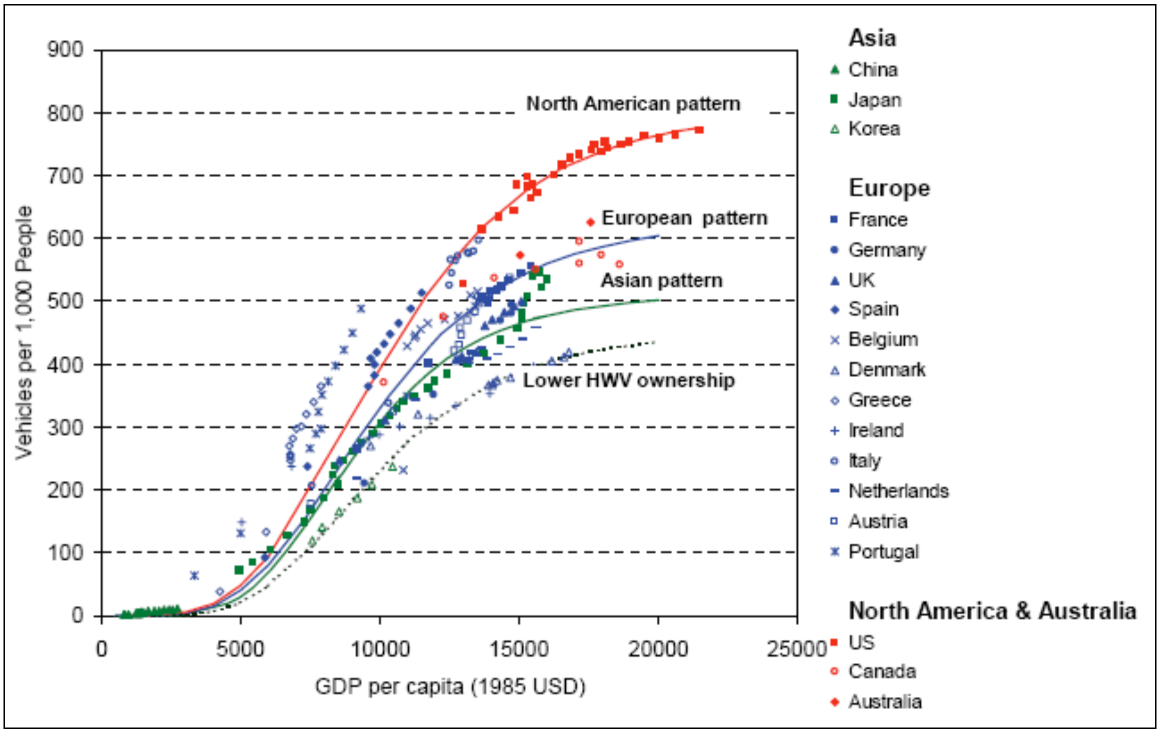


Fig 4-1: Example of Gompertz fit to observed vehicle ownership patterns (from Wang et al)

One clear commonality that comes out from all three studies however is that China is at the "sweet spot" for growth of ownership rates (using the Wilson et. al., language). Both countries are very near the start of the upward turn at the bottom of the S-curve, but Wilson et al suggests that India may be around 10 to 15 years behind China in terms of reaching peak rates of growth, but calculates higher total vehicle total for India over the long run (2050), peaking near 12% per year over the 2030-2035 timeframe. If the ultimate ownership is around 400 per 1000 population, this suggests a total vehicle population of 600 million vehicles in India and China for a population of 1.5 billion in each country. Due to the lower annual travel of vehicles, typical vehicle life is in the 20 to 25 year range, suggesting an ultimate sales rate of 25 to 30 million units annually. Of course, other factors such as oil supply peaking may intervene well before these rates are reached and actual levels may be far below levels indicated by this type of analysis which assumes no vehicle or fuel supply restraints. At current growth rates, Chinese sales will reach this level before 2020. Indian sales will not reach this level until 2030 at growth rates around 10 percent. Hence, like Wilson, et. al, we conclude that current Chinese growth rates must fall quick to less than 10 percent by 2017, whereas Indian growth rates can continue at 10 to 12 percent to 2020. Our sales estimates for light duty vehicles in 2020 are about 17 to 18 million/ year in China and 5.5 to 6 million per year in India. Our analysis of the country situations are based on this sales level for 2020.

4.5 CHINESE MARKET

The Chinese market has been moving towards larger vehicles for the last 7 to 8 years and A class vehicles are now a very small segment of the market. The average vehicle is now larger than the average French vehicle, and many observers see this trend continuing as incomes rise. Luxury vehicles, which accounted for just one percent of the market 8 years, ago accounted for 2.5 percent of the market in 2008. SUV models in the large/ luxury segment are also increasing. Sales in the C, D and E segments as well as the compact SUV segment have risen much faster than sales in the A and B segment. The E segment in particular is dominated by luxury European brands with the Japanese entering this segment only recently with the Lexus and Infiniti brands. The Chinese E-segment is so large in absolute sales that this is the most important market for sales volume leader, Audi, outside of Germany.

The Chinese government has been concerned about this trend to larger and more powerful vehicles and has taken two steps to control this trend in the future. First, it has imposed fuel economy standards that are more stringent for heavier vehicles than lighter vehicles. Second, it has lowered the tax rate on vehicles with engines smaller than 1.6L from 3 percent to 1 percent, while increasing taxes on vehicles with engines over 3L from 15% to 25%. The recent implosion of the stock market and the global recession has also contributed to controlling this trend in 2009 but this effect may be short lived as markets bounce back. Hence, some observers forecast a near term resurgence of the B-segment, but longer term, it does appear that the market shares of the D and E segment can increase from 16 to 20 percent and 2.5 to 5 percent, respectively. It is not clear if there is any significant market for the A segment in China. One Chinese manufacturer commented that it could produce a very cheap A segment car like the Tata Nano but there was no market in China for such a vehicle.

The Chinese fuel economy standards have been imposed by weight class and separate standards apply to automatic and manual transmission vehicles. The standards were first imposed in 2005 and tightened in 2008, and are applicable as an efficiency floor in that all vehicles must meet standards with no manufacturer averaging. The standards and the 2008 actual Chinese vehicle fuel consumption are shown in Figure 4-2. The 2005 standards affected few vehicles since the targets for smaller vehicles were all set above 8L/ 100km for automatic transmission vehicles and were set at over 11L/100km for 1500 kg curb weight vehicles. The typical midsize US car, for example, has a curb weight of about 1500kg and has fuel economy levels of about 8L/ 100km or lower on the US cycle and 9L/100km on the Chinese test. The standards for 2008 were lowered by 1L per 100 km at the lightest end and by almost 2L/100km at the heaviest end but the standard for a 1500 kg vehicle is still 10.5 L/100 km. Thus, it appears that standards are not a binding constraint on most Chinese vehicles at this point. Standards will be made more stringent in 2012 and perhaps in successive four year periods. As noted, Chinese vehicles have a 10 percent technology opportunity compared with French and US vehicles, but most 2008 vehicles were well below fuel consumption requirements as shown in Figure 4-2. It is not clear if government policy intends standards to be technology forcing, or to simply prevent the sales of the highest fuel consumption vehicles in any weight class. Our forecast is that Chinese standards will not be a binding constraint over the next decade unless there are fuel supply disruptions.

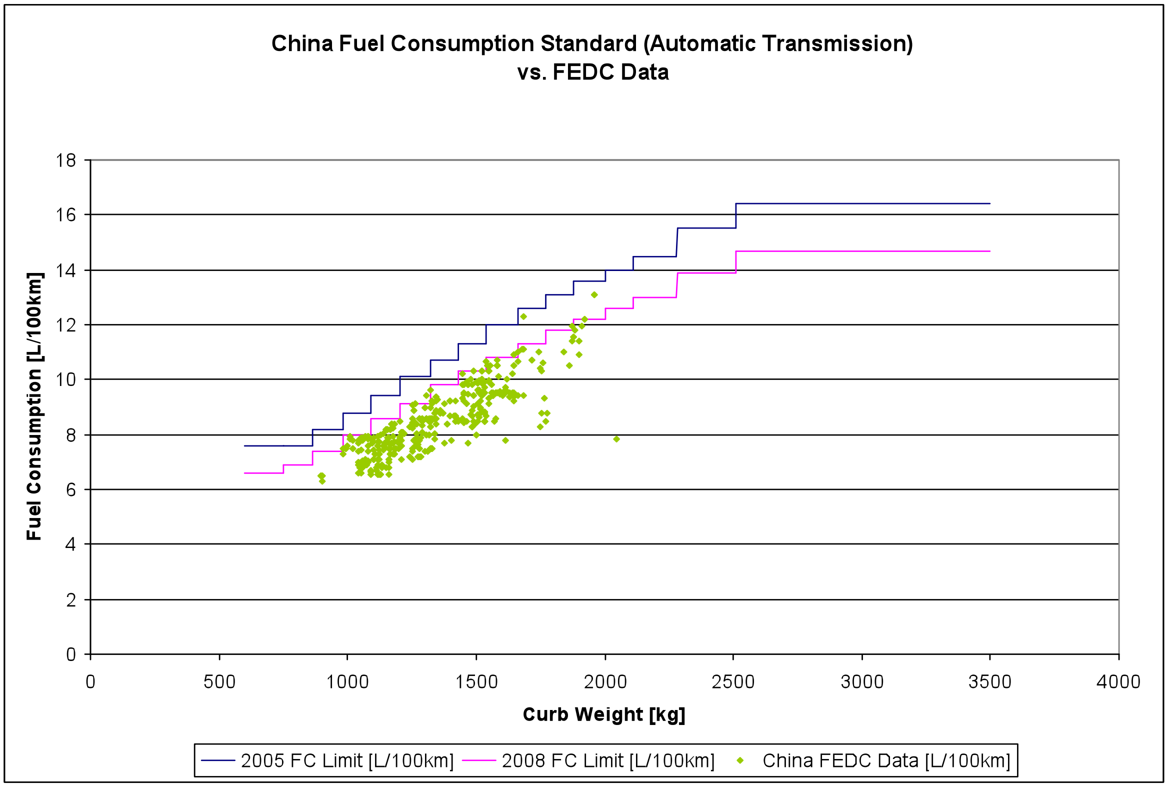
Our forecast for China is that conventional technology improvements will keep pace with developed country technology with a lag time of 4 to 5 years so that the 10 percent technology opportunity will be captured and the technology developments to 2015 will occur in China by 2020 for a reduction in fuel consumption of about 20 percent at the class level by 2020 relative to 2008. However, China is unlikely to follow in any major way with hybrid technology due to the high cost in a very cost sensitive market. The Chinese government is also trying to position China as a leader in EV technology, promoting both battery manufacturers and EVs with significant subsidies. The current subsidies are in the $5000 range but this is much too small to overcome the high first cost of the EV in China, and EV sales are well below announced targets. We do not anticipate that EV sales will have a large market share (>5%) even by 2020 in China, but major growth could occur in the post-2020 time frame.

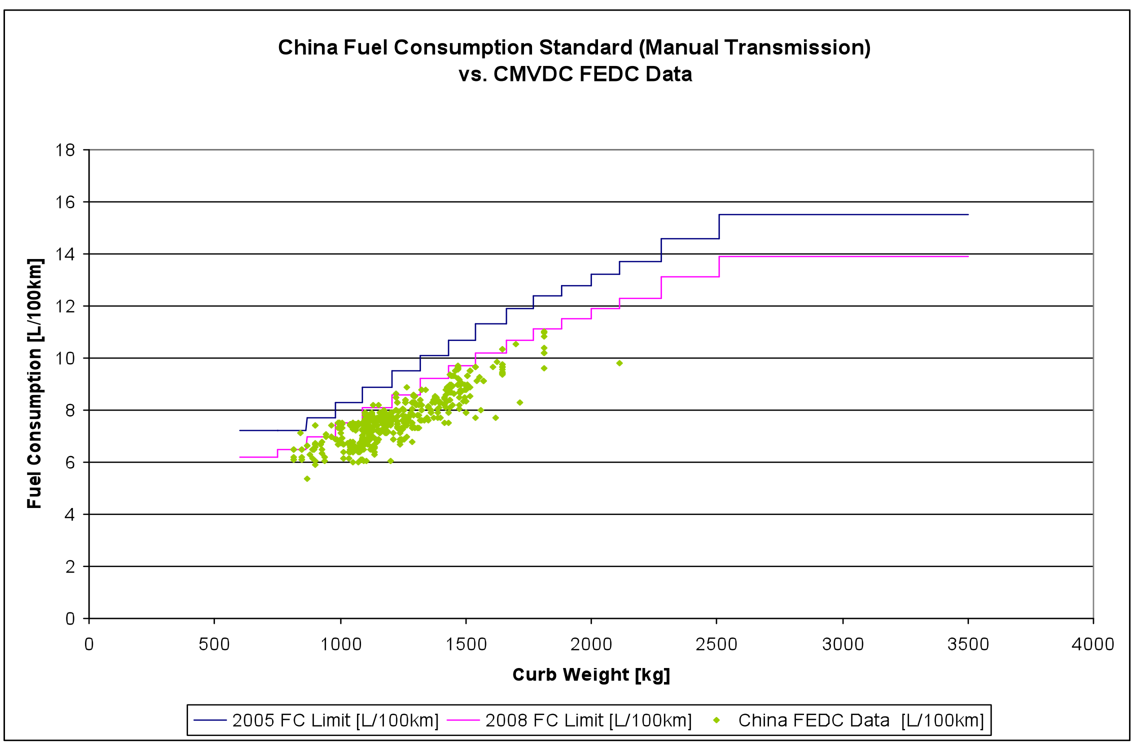
Fleet upsizing may negate only 4 to 5 percent of the benefits if the new taxes act as a deterrent to the recent trend towards large and luxury vehicles. Fuel price increases can have modest effects on size mix sold, but the retail fuel market is often insulated from price shocks in China. Hence we forecast a fuel consumption reduction of about 15 to 16 percent from 2008 to 2020 under stable crude prices of $70/bbl, and about 20 percent under rising crude prices to $100/bbl.

4.6 INDIAN MARKET

The Indian market has been growing at about 10 percent a year except in 2008 – 2009 period and we expect growth to resume next year at the 10 percent rate and continue at about his rate for the 2010 to 2020 period. India has one of the smallest vehicle size mixes of any major country, but in the 2002 to 2007 period, the sizes mix trended away from the entry level A class to the B and C classes. However, the introduction of the Tata Nano a sub- A class car, suggests a major growth in the very small vehicle market. The Nano was introduced in the market in mid-2009, and sales in 2010 for this model alone will account for about 10 percent of the total Indian light vehicle market. Other manufacturers including market leader Maruti and Ford are planning products in this segment that could be introduced in the 2012 to 2014 time frame. It is anticipated that the A class market could account for 1.2 million of the 2.8 million vehicle market implied by a 10 percent growth rate from 2009 to 2015, or a 43 percent market share, up from about 26 percent in 2008.

From the perspective of efficiency, these new models are quite significant due to their potential high fuel efficiency. The Tata Nano has been certified at 4.24 L/100km (4.55


China Fuel Consumption Standard (Automatic Transmission)
vs. FEDC Data
Fuel Consumption [L/100km]
18
16
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
3000
3500
4000
Curb Weight [kg]
2005 FC Limit [L/100km]
2008 FC Limit [L/100km]
China FEDC Data [L/100km]


China Fuel Consumption Standard (Manual Transmission)
vs. CMVDC FEDC Data
Fuel Consumption [L/100km]
18
16
14
12
10
8
6
4
2
0
0
500
1000
1500
2000
2500
3000
3500
4000
Curb Weight [kg]
2005 FC Limit [L/100km]
2008 FC Limit [L/100km]
China FEDC Data [L/100km]

L/100km in the city and 3.85 L/ 100km highway) which is a consumption rate 28% lower than the 2008 average of 5.86 L/100 km. Even if fuel efficiency improvements in other classes are minimal, the fleet average fuel consumption will be reduced to about 4.9 L/100km from the current 5.86 L/100km estimated for 2008, a 16.4% reduction. Larger reductions could occur if the other classes also aggressively adopt technology to compete with the low priced (and low profit) sub A class cars.

Two significant unknowns for the Indian market are the state of fuel economy regulations and the future of the light duty diesel. The Indian government agreed in principle to adopt fuel economy standards in 2007 but there has been almost no action on standards for the last 3 years. Internationally, India has also been resisting mandatory GHG emission cuts, and the government appears to not require standards to be technology forcing. We do not expect that fuel economy standards, even if promulgated, will have much of an effect on the car industry, given the very high level of efficiency without standards. Second, the large subsidy for diesel fuel to assist commercial trucking has made light duty diesels popular and current market share already exceeds 20 percent and may increase more in the B-class and larger segments. Many NGOs are complaining about the diesel fuel subsidy being harnessed by rich car owners, and it is possible that light duty diesel vehicles may be taxed extra to offset the fuel subsidy. This could reduce diesel penetration, but the effect on average fuel consumption will be to increase it by a maximum of 4 to 5 % relative to the 2008 baseline if diesel penetration goes to zero.

In summary, we expect the average fuel consumption of the vehicle fleet to drop by at least 16 percent in 2015 relative to 2008, driven largely by the anticipated popularity of very cheap sub A class cars. By 2020, the net reduction in fuel consumption could be around 20% or more due to both the mix shift and modest technology improvements to all vehicles. We do not anticipate that fuel economy standards will be a major driver of actual fleet fuel consumption in India to 2020.