Can the Environment Survive China's Craze for Automobiles?

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Introduction

China now desires the same vehicle systems that have given developed countries great mobility and convenience over the last century. Its vehicle population has been increasing rapidly and the auto industry has become an important sector in the country's overall economy. However, the rapid and continuous growth of China's vehicle population poses great challenges to China's energy security and environmental protection. A large transportation system in China based on gasoline and diesel fuels would dramatically increase China's dependence on oil imports and also increase the threat of global climate change. Were China to have as many vehicles per capita as the United States, over 900 million vehicles would be traveling its roads, which is 40 percent more than today's world total. And if China's per capita oil consumption matched the current U.S. rate, Chinese oil demand would exceed today's worldwide oil production by 18 percent. Clearly, this trend threatens to increase international tensions over oil.

Can the already seriously polluted environment survive the Chinese craze for automobiles? China is still in an early stage in structuring its automobile industry and transportation system. Can China attempt to follow a more sustainable path by addressing the needs of its people while promoting energy security and environmental well-being, avoiding the model of motorization of industrialized countries? China's decisions about the automobile industry will affect not only China but the rest of the world with respect to energy security, environmental protection, economic competitiveness, and climate change.

Drawing upon field research conducted from 2001 to 2003, this paper first presents an introduction of China's auto industry, then analyzes environmental impacts of vehicle emissions, evaluates government's efforts to reduce vehicle emissions, and finally discusses policy implications.

Development of China's Automotive Industry

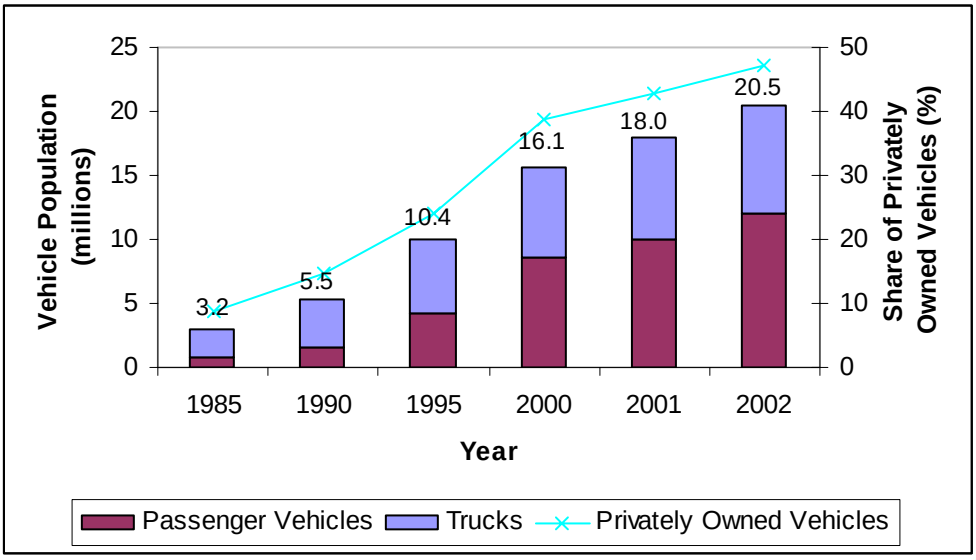
China's automotive industry started in the 1950s, but rapid development began in the 1990s. The value added of China's auto industry in 2002 was US$19.1 billion, 50 percent higher than the previous year, and accounting for 6% of all manufacturing value added (CAA & CATAC 2003). As of 2002, 33.5 million Chinese were employed in the automotive industry and directly related sectors; one out of 22 workers in China worked in these sectors. The auto industry has become the world's fourth largest vehicle producer, with exceptional high projected growth of 20-30 percent annually for the next 10 years. The auto sector's contribution to total GDP growth could be as high as 20%.[1]

1. Fastest Growing in Vehicle Population

China's vehicle population has been increasing dramatically (see Figure 1). The motor vehicle population of China in 2002 reached 20.5 million, increasing by 272 percent since 1990 (CAA & CATAC 2003). The annual growth rate of vehicles has averaged approximately 12 percent since 1990. Passenger vehicles (including cars and buses) grew faster than trucks, with average annual growth rate of 17 percent, or an increase of 641 percent since 1990.

[1] Deutsch Bank, Hong Kong. Report?

Figure 1 China's Vehicle Population



Source: CAA & CATAC 2003.

The rate of growth is even faster in major cities, such as in Beijing and Shanghai. The annual vehicle growth rate in Beijing has been about 17-20%. It took Beijing 48 years, from 1949 to February 1997, to reach one million vehicles, but only 6 and half years to reach two million vehicles (in August 2003). Just three years ago, experts predicted that Beijing would not reach 2 million vehicles until 2010. It is expected that Beijing will reach three million vehicles in about 3 years and 3.8 million vehicles by 2008.[2]

Much of the growth has occurred in privately owned vehicles. The share of privately owned vehicles increased from 8.9 percent in 1985 to 47 percent in 2002, and the share in large cities is even higher. In August 2003, of the 2 million registered vehicles in Beijing, 64% were privately owned. Of the 280,000 new vehicles registered in 2002, 90% were private cars. Beijing now has 19 private cars per 100 households.[3]

[2] Beijing Youth Daily, August 7, 2003, available at http://www.bjyouth.com/.
[3] *Beijing Youth Daily*, August 7, 2003.

The sustained rapid growth in vehicle population is mainly the result of rapid increases in purchasing power and falling prices of vehicles due to strong domestic competition. In 2003, China's GDP growth rate was 9.3 percent, and there was not a single month or hardly a single week that passed without news of price reductions.[4] Automobile prices fell by 15-20 percent in 2003 compared to 2002.[5] The institutional and fleet demand for automobiles was giving way to private demand and the automobile market was moving from a seller's to a buyer's market.[6] The severe acute respiratory syndrome (SARS) epidemic in China in April and May 2003 did not slow down car sales but actually prompted a consumer rush to purchase privately owned to avoid public transportation.[7]

2. Vehicle Production and Sales

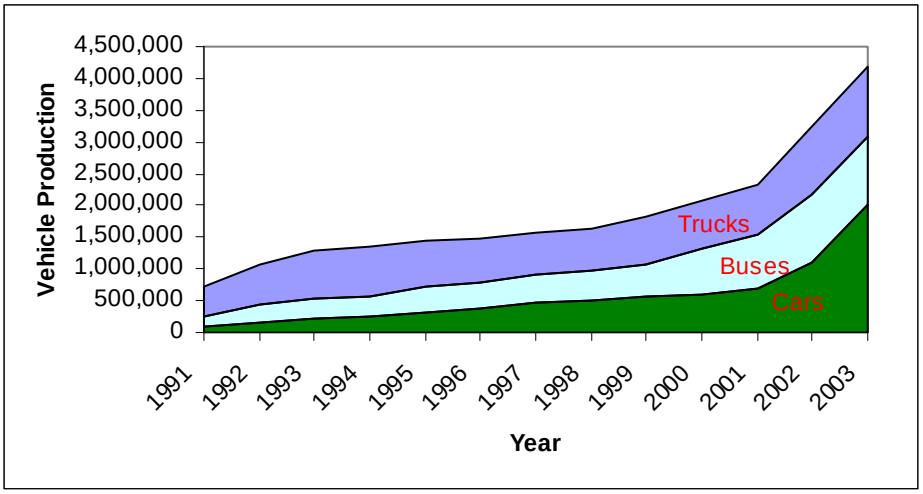
The automobile industry had 2401 vehicle-producing companies in 2002, 117 of which were original equipment manufacturing (OEM) enterprises capable of assembling vehicles (CAA & CATAC 2003). Major car companies are joint ventures with multinational companies; technology is partly or completely imported. Currently, 23 provinces (cities) in China have the capability to produce cars. The share of major vehicle-producing companies has expanded, while the production capability of most vehicle manufacturers remains small. Two of the 117 those OEMs have production capacity of more than 500,000 units, while 70 have less than 1,000 units of production capacity each year.

China's vehicle production capability rose dramatically in the 2000s. China produced around 2 million motor vehicles in 2000, ranking the 11th in the world. In 2003

[4] Lei Xing, 2003: A year of Record Growth for Car Output and Sales, *CBU-Auto*, January 15, 2004.
[5] Editor's Note, "2003: The Year of Falling Prices," *CBU-Auto* Vol.9, No. 41, December 18, 2003.
[6] Editor's Note, "2003: The Year of Falling Prices," *CBU-Auto* Vol.9, No. 41, December 18, 2003.
[7] Available at htt://www.sina.com.cn, May 10-20, 2003.

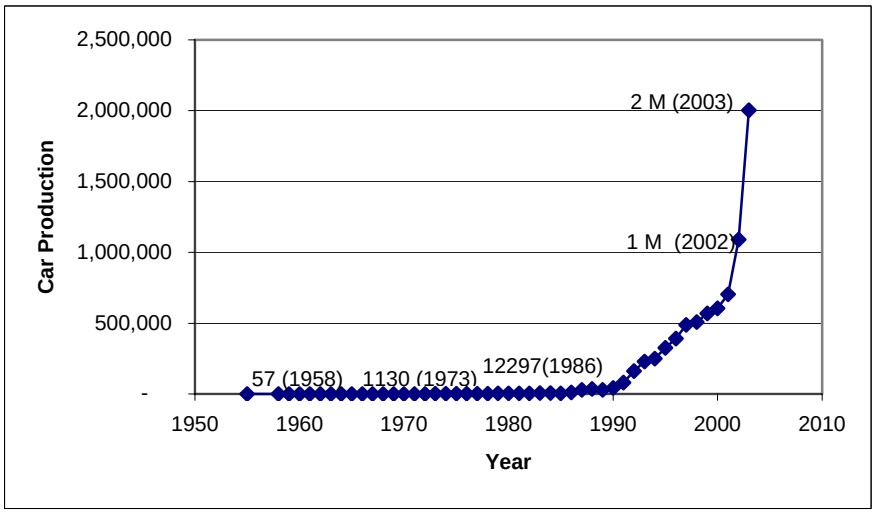
over 4.4 million vehicles were made, and China became the 4th largest vehicle producer in the world, following the U.S., Japan, and Germany.[8] Most of the increase was in passenger cars, which approached 50 percent of the country's total vehicle production in 2003 (See Figure 2). China produced 2.088 million cars in 2003, 84.4 percent more than the previous year (see Figure 3).[9]

Figure 2 Vehicle Production in China



Source: CAA & CATAC 2003; CBU-Auto, January 15, 2004.

Figure 3 Car Production in China



Source: CAA & CATAC 2003; CBU-Auto, January 15, 2004.

[8] China Business Update, 2003: A Year of Record Growth for Car Output and Sales, January 15, 2004.
[9] Editor's Note, "2003: The Year of Falling Prices," CBU-Auto Vol.9, No. 41, December 18, 2003.

3. Continuous Growth of China's Vehicle Production and Population

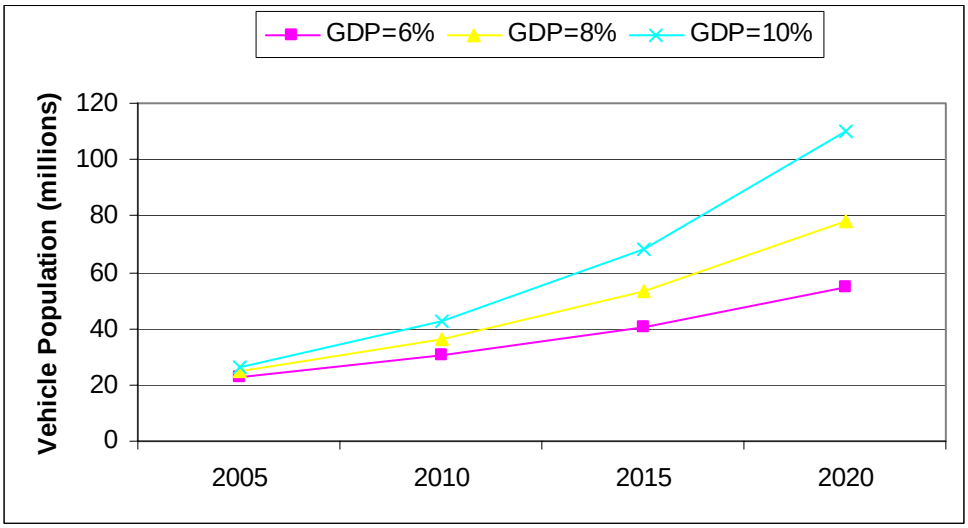
Even though China has experienced rapid growth in her vehicle population, the total number of vehicles in China remains a mere fraction of those in the United States or even other developing countries. China's vehicle ownership was 12 per 1000 people in 2003, much lower than the world average of 120 per 1000 people. The vehicle production and population will continue to grow rapidly with increasing purchasing power and falling vehicle prices. China's GDP growth rate is predicted to maintain rate of 7-8 percent annually over the next decade, so population who can afford to purchase vehicles will continue to increase. Even though currently China's GDP per capita is around US$900, GDP per capita reached US $4,000-5,000 in some developed coastal cities. Based on a survey conducted by the National Statistical Bureau's Urban Survey Team, about 150 million families in China, comprising a population of 500 million, are expected to buy automobiles in the coming 10 to 15 years.[10] Due to the high profits in the auto sector, some companies in other sectors, such as the household electric appliance sector and the tobacco sector, have begun to invest in vehicle production.

The strong relationship between income and motorization provides a straightforward basis for projecting the future number of motor vehicles in China. Figure 4 displays vehicle population projections by the Chinese Academy of Engineering and the National Research Council (CAE & NRC 2003). Three different GDP growth rate—6, 8, and 10 percent—were used to produce different projections for China's vehicle population. The vehicle population is forecast to increase by a factor of approximately 4 by 2020 with the GDP growth rate of 8 percent. The Chinese government estimates that

[10] Beijing Times, March 12, 2003.

vehicle production will double and reach 8 million in 2010, and reach 12 million in 2020, when China will rank second in the world after the United States and account for 20 percent of global output.[11]

Figure 4 Prediction of Vehicle Population in China



Source: CAE & NRC 2003

Environmental Impacts of Vehicle Emissions

1. Air Quality in China

China's rapid industrialization, urbanization, and motorization have contributed greatly to China's urban air pollution. A report released in 1998 by the World Health Organization noted that of the ten most polluted cities in the world, seven can be found in China.[12] The main sources of urban air pollution change over time—coal smoke pollution due to industrialization during the 1970s, serious acid rain pollution in the 1980s, and vehicle pollution or a mix of vehicle pollution and coal smoke since the late 1990s (He, Huo, and Zhang 2002).

[11] China Development Forum, November 17, 2003, Beijing.
[12] China: Environmental Issues, July 2003, Energy Information Administration, available at http://www.eia.doe.gov/cabs/chinaenv.html.

Air quality in China has recently improved slightly with a recent increase in the percentage of cities meeting national air quality standards (level II) from 27% in 1998 to 44% in 2002 (see Table 1). Among major air pollutants in China, SO_2 and TSP[13] pollution has fallen or stabilized but nitrous oxides (NOx) pollution has become more serious in large cities. The reduction occurred due to smoke abatement and dust removal, after regulations requiring the use of briquettes and optimization of the residential fuel structure by using gas, electricity, and oil to replace coal in the late 1990s. Some non-point sources, such as soil, road particles, and construction dust, have become the major source of urban air particles. NOx concentration in some large cities such as Beijing, Shanghai, has increased gradually in the 1990s and some even exceeded national air quality standard level III, because of the increasing vehicle population (He, Huo and Zhang 2002).

Table 1 China Urban Air Quality in 1998~2002 (mg/m^3)

Year	1998	1999	2000	2001	2002
Total number of cities investigated	322	338	332	341	471
Share of cities reach National Standard Level II (%)	27.6	33.1	34.9	33.4	44.4
Shares of cities meeting Standards Level III but not Level II (%)	28.9	26.3	30.1	33.4	28.7
Shares of cities not meeting Standards Level III (%)	43.5	40.6	34.9	33.1	27.0
Average SO_2 Concentration	0.057	0.054	0.053	0.052	0.047
Average TSP Concentration	0.045	0.046	0.044	0.035	0.033
Average NO_x Concentration	0.284	0.264	0.263	0.272	0.254
Average PM_{10} Concentration				0.113	0.12

[13] The indicator TSP was change to PM_{10} in late 1990s due to concern over PM_{10}'s impact on human health.

Source: SEPA 2003.

2. Major Source of Urban Air Pollution

Motor vehicles have become China's major sources of air pollution, replacing industrial pollution. In a 2001 report, the World Bank noted that China had made strides in lowering industrial pollutants and coal-burning, but cautioned that vehicle-related pollution was rising (He, Huo, and Zhang 2002). For example, NOx emission in Beijing fell by 17% from 1988 to 2000, but increased by 7.1% in 2002 and increased again in 2003.[14]

On average, vehicles are currently contributing approximately 45 to 70 percent of the NOx emissions and about 50-80 percent of CO emissions in typical Chinese cities (see Table 2). The contribution from vehicle emission has increased over time. In 1996, in the downtown area of Shanghai, about 86% of carbon monoxide, 96% of HC, and 56% of NOx in the air were from automobile exhaust, and the shares increased to 87%, 97%, 74% respectively in 2002 (Lu and Qi 1999; Guo 2003).

Table 2 Contribution of Vehicle Emission to Air Pollution in Some Cities (2002)

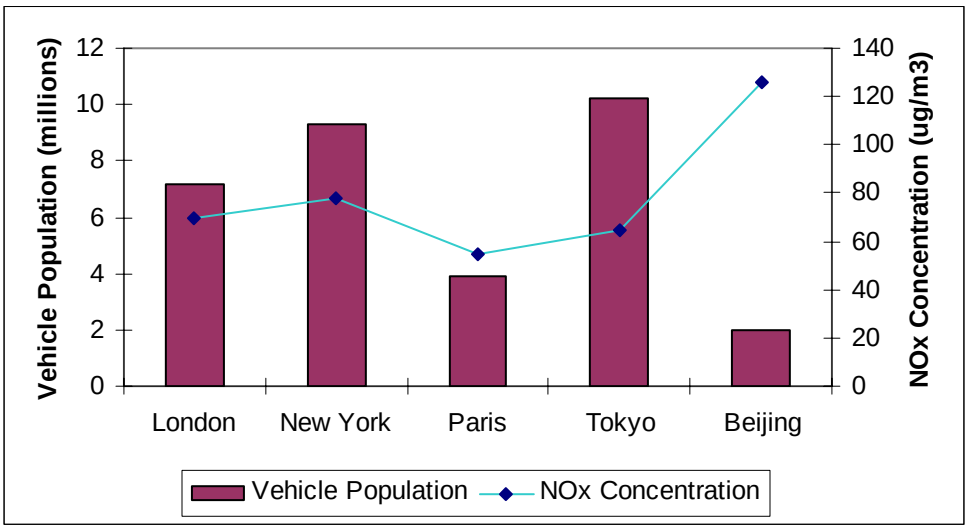
City	Vehicle Contribution Rate（%）		
	CO	HC	NO_x
Beijing	63.4	73.5	46
Shanghai	87	97	74
Chongqing	85.8	36.6	86.3
Xian	98.6	--	69.7
Qingdao	70	20	10
Wulumuqi	88.7	--	48.5
Tianjin	83	81	55
Chengdu	62	70	45
Guangzhou	84.1	--	25.7

Source: Guo, 2003. This table is based on survey conducted at the end of 2002 by National Clean Vehicle Office.

[14] http: //www.bjepb.gov.cn, September 26, 2003.

Although the number of automobiles is not a great compared to developed countries, because of old manufacturing technology, the long duration of vehicle use, less stringent emission control laws, serious traffic congestion, and bad maintenance of vehicles, pollution from automobile exhaust in China is very serious. Beijing has a low vehicle population but high pollution compared to other cities in the world (see Figure 5).

Figure 5 Comparison of Beijing with four big cities



Source:

Traffic congestion in large cities also exacerbated vehicle emissions. While the number of vehicles is increasing by 20% per year in Beijing, the road network is expanding by only 3-4% per year. The average driving speed on 11 main roads in Beijing is estimated to be only 12 km/h, roughly the same as riding a bicycle.[15] The generally lower traffic speeds and stop-go driving patterns not only increase the amount of fuel consumed, but also result in higher emissions per unit of distance traveled.

The resulting air pollution affects public health. Respiratory disease now accounts for one in four deaths in China, and the World Bank estimates that air pollution

[15] *Beijing Youth Daily*, August 7, 2003.

costs about 5% of China's GDP if one considers the health-care costs and lost productivity from those too ill to work.[16] Because of increased vehicle emissions, coughs and common colds in Shanghai have become more severe and it takes a longer time for people to recover.

Rapid vehicle growth could also dramatically increase the threat of global climate change. China is the world's second largest emitter of greenhouse gases, after the United States. Even though China's energy use and greenhouse gas emissions per capita remain far below the levels found in richer countries, the increase in vehicle population will make the total emissions from China rise quickly. The International Energy Agency predicts that the increase in greenhouse gas emission from 2000 to 2030 in China alone will nearly equal the increase from the entire world.[17]

Efforts Adopted to Reduce Vehicle Emission Impacts

The Chinese government has started to pay attention to vehicle emissions since the late 1990s. Significant actions have included the phaseout of leaded gasoline and the introduction of European emission standards. In addition to controlling vehicle emissions through pollution control measures, China began to promote alternative fuel vehicles and supported R&D program for advanced clean vehicle technologies, such as electric battery vehicles, hybrid vehicles, and fuel cell vehicles.

1. Lead-free Gasoline Program

China's lead-free gasoline program was directed by the central government and supported by local governments. The unleaded gasoline program was implemented in three steps: a

[16] Ben Dolven, The Great Car Crush, Nov. 27, 2003.
[17] Keith Bradsher, China's Boom Adds to Global Warming Problem, *The New York Times*, October 22, 2003.

pilot program in Beijing, Shanghai, and Guangzhou, implementation in 47 cities in special economic zones and several important tourist cities, and a nationwide production phaseout by 1 January 2000.[18] By the end of June 2000, China phased out leaded gasoline use by all vehicles. The unleaded content in gasoline exceeded 99% with emission reductions of more than 1500 tons annually (SEPA, 2001).

China did this quickly, unlike many other countries. For example, it took the U.S. Environmental Protection Agency from 1970 to 1996 to phase out lead in gasoline (Lovei, 1996). The rapid move to unleaded gasoline demonstrates the strong leadership role the central government can play in pollution control. In contrast to other market economy countries, the Chinese central government still retains relatively strong administrative power due to the long history of the centrally planned system and China's authoritarian political system. China's national government can still play an important role in promoting issues that carry social and environmental benefits. The rapid move to unleaded gasoline was also made possible by the strong support of local governments. Great public pressure to deal with heavy air pollution in Beijing and Shanghai has provided political and economic incentives for local governments to move forward quickly. In addition, complete scientific preparation and international experience provided solid knowledge and information foundation for a quick change.

2. Vehicle Emission Control Programs

China adopted the European system for controlling emissions from new vehicles during the late 1990s. China required all new light duty vehicles sold after January 1, 2000 to meet the Euro I standards, and all new vehicles must meet the Euro II emission standards

[18] Interviews with an official in SEPA, July 2002, Beijing.

beginning July 1, 2004.[19] China's third phase emission standard for passenger and light vehicles, based on Euro III and IV emission standards, has been released to government departments and automakers for comments and suggestions.[20] It is expected that China will implement Euro III in 2008.

Some local government agencies, in particular in Beijing and Shanghai, have been proactive in controlling vehicle emissions. Beijing advanced the deadline for enforcing Euro I standards one year ahead of the national schedule and two years ahead for Euro II standards. Shanghai followed by implementing Euro II standards in 2003, one year earlier than national standards. Their decisions to implement Euro II standards came in the wake of public appeals for clean air and the soaring number of vehicles. It was estimated that Beijing will implement Euro III in 2005 and Euro IV in 2008 for the 2008 Beijing Olympic Games.[21] Shanghai may advance its Euro III schedule for the World Trade Expo in Shanghai in 2010.

Tax refund policies helped motivate auto manufacturers to comply with national standards ahead of national regulations. The State Administration of Taxation and the Ministry of Finance announced in July 2000 that the consumption tax for automobile manufacturers whose products satisfied the Euro II emission standard before 2004 would be decreased by 30 percent. The affected vehicles included sedans, sports utility vehicles, and mini-buses. The consumption tax is paid by manufacturers based on vehicle type and sale quantity. The major auto companies, such as First Auto Works, Dongfeng Motor Corp., and Shanghai Automotive Industry Corp., all applied for tax refunds for their

[19]For passenger cars, Euro I CO: 4.05 g/km, HC: 0.66, and NO_x: 0.49. Euro II CO: 3.28, HC: 0.34, and NO_x: 0.25. European is now at Euro III (CO: 2.30, HC: 0.20, and NO_x: 0.15). By 2005, they have to be at Euro IV (CO: 1.00, HC: 0.1, and NO_x:0.08).
[20] Available at http://www.zhb.gov.cn.
[21] Beijing Morning News, September 11, 2003.

vehicles meeting Euro II.[22] In 2004, the related government agencies cancelled the tax refund policies for vehicles meeting Euro II but issued a similar tax refund policy for vehicles meeting Euro III, which has no national schedule yet.

Inspection and maintenance (I/M) programs such as annual emissions testing, roadside inspection, scrapping of old vehicles, and refitting in-use vehicles have been adopted to reduce the emissions of in-use vehicles. Inspections are conducted by agencies authorized by local public security bureaus and the environmental protection bureaus (Li, 2002). I/M programs offer an inexpensive and effective way to ensure that vehicles meet emission standards. A car that is not in compliance with emission standards in an annual inspection or roadside inspection is not permitted to be driven on the road and the owner must install emission reduction equipment in the car. Beijing started to use environmental labels (green and yellow) to distinguish vehicles meeting different emission standards in 1999 and did not allow vehicles with yellow labels to run within the central city areas during certain time periods.[23]

Another major contributor to vehicle emissions is the use of vehicles exceeding their service life. In 1997, the State Environmental Protection Administration (SEPA) and other government agencies issued an amended Vehicle Elimination Standards on Scrapping Old Vehicles. It specifies that vehicles with emissions exceeding the national emission standards after repairs or the installation of a filtering device should be scrapped. However, due to different regional emission requirements, some in-use vehicles which were required to be scrapped in Beijing were instead sold to other cities or rural areas.

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[22] Interviews with managers and technicians at big 3 companies, July and August 2002, Changchun, Shanghai, and Beijing.

[23] http://www.bjepb.gov.cn, Explanation of restricting driving of high emission vehicles in central city areas, Beijing Auto Daily.

Emission control in both new and in-use vehicles helped slow emission increases, but there remain many problems. China's vehicle-emissions standards are about the same levels as those of India, the Philippines, and Indonesia, but lag those of most developed nations by nearly a decade.[24] Compared with the United States, China's current limits (Euro II) are 26% higher for carbon monoxide, and more than twice as high for hydrocarbons. The standards also have not been well implemented due to weak enforcement. It is very easy for vehicles to pass inspections because inspections are not very strict and some drivers just pay for an inspection license.[25] Also, there are no emission standards for farm vehicles and most vehicles do not have good emission control equipment.

3. Alternative Fuel Vehicle Program

In order to significantly lower pollution from vehicles and reduce oil dependency, in April 1999, twelve Chinese cities began participating in the program "National Clean Vehicle Action" that introduced alternative fuels, in particular compressed national gas (CNG) and liquefied petroleum gas (LPG). By 2002, the Ministry of Science and Technology had invested 50 million RMB (US$6.1 million), and local governments and enterprises had invested billions more RMB in the program (Zhang, 2002).

CNG and LPG vehicles and stations increased rapidly in some demonstration cities. By the end of 2002, the number of CNG and LPG vehicles increased to 153,000 and refueling stations reached 486 for 12 demonstration cities. Eight other cities joined the program and had 12,500 CNG and LPG vehicles by 2002. A large number of urban buses and taxis in Beijing and Shanghai have been converted to use CNG and LPG.

[24] In compared, Euro I was put into effect in Europe in 1992, Euro II in 1996, Euro III in 2000, and Euro IV is planned to be implemented in 2005.
[25] Interview with a SEPA official, July 2002, Beijing.

More than 80 percent of taxis in Shanghai and 50 percent of buses in Beijing can use CNG/LPG vehicles (Hou, et al, 2002). However, the CNG/LPG technology is relatively primitive. The majority of China's alternative vehicles are retrofitted, and only 16 percent were new vehicles that were manufactured to use LPG and CNG by 2002 (Zhang, 2002).

China has also promoted ethanol-based and methanol-based fuel vehicles on a pilot basis in several cities.[26] China is demonstrating ethanol-based fuel vehicles in five cities in Henan, Jilin, and Heilongjiang, areas rich in corn production, a move designed to create a new market for surplus grain and to reduce consumption of petroleum. Three plants producing denatured fuel ethanol from corn are being constructed. The demonstration of methanol-fueled vehicles is occurring in Taiyuan, the capital city of Shanxi Province, which is rich in coal resources. Ninety-two methanol-fueled mini-buses have been used for several years in Taiyuan, and one methanol engine was approved for production. Shanxi plans to have as many as 5,000 on the roads in the next five years.[27]

Problems also have arisen in the process of moving to alternative fuel vehicles. First, progress in promoting alternative fuel use has been very limited. AFVs accounted for only 0.65 percent of the total vehicle population in China in 2002. The current Clean Vehicle Action Program focuses on a niche market—taxis and buses; there is no AFV market for individual consumers. The ethanol demonstration in Henan has not been effective because of the high cost of ethanol fuel, lower fuel efficiency, and insufficient availability of fuel refueling stations.[28] In addition, the AFV program has focused on the number of clean vehicles rather than the actual use of alternative fuels. This led cities to

[26] Ethanol is an alcohol-based alternative fuel produced by fermenting and distilling starch crops that have been converted into simple sugars. Methanol can also be used to make MTBE, an oxygenate which is blended with gasoline to enhance octane and create cleaner burning fuel.
[27] China uses methanol for cleaner fuel, *People's Daily*, October 11, 2001.
[28] Interview with an official from MOST, July 2002, Beijing.

pay more attention to the number of vehicles retrofitted to use LPG or CNG, but ignore whether the changed vehicles actually used LPG or CNG.

Second, the experience of these demonstration cities shows that simple conversion to LPG or CNG does not necessarily mean "cleaner" vehicles. The extent of clean versus cleaner vehicles depends on emission levels, which are not only influenced by what kind of fuel vehicles use but also on the emission control technology.[29] Currently around 84% of LPG and CNG vehicles (in particular taxis) are retrofitted with low emission control technology, some cannot even meet Euro I emission standards. In addition, some taxi drivers with LPG-gasoline dual fuel cars (in particular in Beijing) do not use LPG at all. Research conducted by Tsinghua University and SEPA on motor vehicle pollution control in Beijing found that the environmental improvements from alternative fuel programs is not obvious (Fu and Yuan, 2001).

Third, insufficient availability of refueling infrastructure for AFVs slowed down AFV development. The program did not pay attention to the availability of high-quality gas and the construction of gas stations at the early stage of program implementation.[30] The high cost of building LPG or CNG stations is a barrier to infrastructure development. Government provided subsidies for initial AFV retrofitting and infrastructure construction, but there are no taxation benefits or other economic incentives for consumers to use AFVs.

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[29] LPG or CNG fueled vehicles have three levels of technologies. The first generation technology can improve emission levels compared to same technology of traditional gasoline vehicles but not much and the vehicles cannot meet the Euro I standard. The 2nd generation technology uses electronic control-mixing chamber, and equipped with closed loop control and TWC equipment, which can meet Euro II. The 3rd generation technology adopts electronic injection (EPI), matching closed loop control and dedicated TWC equipment. Almost all are dedicated vehicles and they can meet Euro III or Euro IV standards.

[30] Interviews with officials in the Clean Vehicle Action Office, Beijing, July 2002.

4. Electric Vehicle R&D Program

The Chinese government started to support R&D on electric vehicles in the early 1990s, and initiated a comprehensive electric vehicle program under the 863 National High-Tech R&D Program for China's Tenth Five-Year Plan period (2001-2005). Through this program, the Chinese government aims to help China leapfrog over conventional vehicle technology and enhance the ability of China's auto industry to compete internationally. The national government has provided 880 million yuan, or U.S.$106 million (Cropper, 2002). The program focuses on promoting three kinds of clean vehicle technologies: commercialization of battery electric vehicles, large-scale production of hybrid vehicles, and R&D on fuel cell prototypes.

This program emphasizes industrialization and major auto producers are leading R&D on electric vehicles.[31] The Shanghai Automotive Industry Corp. plans to have a fuel cell prototype by 2005 based on its Santana 2000 model.[32] Beijing, Wuhan, Weihai, and Tianjin are listed as demonstration cities for battery electric vehicles and Beijing will test 20 battery electric buses in 2004 and will establish a 1,000 battery electric bus fleet for the 2008 Olympic Games.[33]

The move to clean vehicle technology has also created interests among international auto giants and international funding organizations. A fuel cell concept vehicle, the Phoenix, was developed in 2002 by the Pan Asia Automotive Technology

[31] Xu Guanhua, Speech at the National 863 High-Tech R&D Program for Electric Vehicles, September 21, 2001.
[32] See http://www.automarket.net, August 12, 2002.
[33] See http://www.chinafcb.org.

Center, a joint venture of GM and Shanghai Automotive Industry Corporation.[34] With U.S.$12 million from the Global Environmental Fund, the United National Development Programs and other funds from the Chinese national and municipal governments, and private sectors in China, Beijing and Shanghai will purchase and operate six fuel cell buses each from 2006 to 2007. This project aims to demonstrate the technical and commercial viability of a small fleet of fuel cell buses and accumulate knowledge and experience to allow for cost-reduction and application of fuel cell buses in ten cities in 2007-2015.

Some are skeptical about the program and are not sure whether China can really catch up to the world-level advanced technology because China still faces a large gap in R&D on advanced clean vehicle technology in comparison to industrialized countries.[35] Some developed countries and auto giants have already spent billions of dollars in R&D on fuel cell vehicle technology. About 150,000 hybrid vehicles have been sold worldwide since Toyota and Honda introduced hybrids in the late 1990s.[36] The huge production cost of electric vehicles and low R&D capability in auto technology are barriers to the development of fuel cell vehicles in China.

Recommendations

1. Limiting privately-owned vehicles is not a practical approach, but vehicle use can be reduced

[34] Available at http://www.gm.com/company/gmability/environment/products/fuel_cells/phoenix_fuelcell_earthday_042202.html.
[35] Interviews with auto manufacturers, June-August, 2002, China.
[36] Hakim, D., "Hybrid Cars Are Catching On," *New York Times*, January 28, 2003.

It is argued that China should limit privately owned vehicle population in order to avoid going through the same path of developed countries in vehicle development. However, the growing importance of the booming automotive industry to the national economy, as well as to local governments' fiscal revenues and employment, naturally lead policy-makers to think twice before adopting such an approach. There is little sign that the Chinese government is ready to limit the growth of its car market. In fact, the nation has invested enormous economic capital and designed national policies for this sector in order to stimulate demand and promote economic growth. Driving has become a middle-class status symbol, and demand for vehicles has inevitably increased along with income growth and falling car prices. As General Motors Chairman and CEO Rick Wagoner put it in November 2003: "The Chinese are car crazy."[37]

Shanghai is the only city in China that limits the use of vehicles by restricting ly registered vehicles since 2000. The city limits the number of license plates it issues and prices them at auction. Both the number of plates and the price for a license has been increasing. In 2003 Shanghai issued 53,068 licenses and each license cost 35,000-40,000 yuan ($4,225-$4,830). As a result, the number of locally registered cars in Shanghai is less than that in Beijing; vehicle numbers remain below 1.4 million although some residents may go to nearby cities to buy their cars.[38] However, even with limits on licensing, Shanghai's privately owned vehicles increased from 7,000 to 200,000 over the past 4 years.[39] Shanghai's mayor announced in July 2003 that Shanghai would gradually loosen restrictions on the purchase of private vehicles in the long run but further restrict the use of cars in downtown areas.

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[37] Ben Dolven, The Great Car Crush, Nov. 27, 2003
[38] Beijingers Go Car Crazy, China Daily, available at http://english.peopledaily.com.cn, August 6, 2003.
[39] Jiefang Daily, http://www.sina.com.cn, Feb 11, 2004.

Beijing failed to follow such model due to strong opposition from industry and consumers. In September of 2003, the Beijing municipal government proposed to limit privately owned vehicles by charging license fees as one of ten measures to deal with serious traffic congestion in Beijing.[40] This proposal met strong opposition from the automobile industry and consumers, leading to heated debates on websites and in newspapers. On one website, more than 60% of those responding opposed this proposal.[41] In late October, the Beijing municipal government cancelled the proposal and promised to continue to encourage private vehicle consumption. Similar discussions also occurred in other cities, such as in Guanzhou and Chengdu, but none have moved forward.

Limiting personal ownership of private vehicles is not a practical approach at this moment, but vehicle use can still be reduced. Compared to other large cities in the world, the central problem in Chinese cities is not the number of vehicles but the number of vehicles in use everyday. I conducted a simple calculation comparing the number of vehicle population and the number of vehicles in use based on fuel consumption. Assuming fuel efficiencies are the same, in 2001, the usage of China's vehicles are 6.15 times of those in the U.S., 2.49 times of those in Japan and 3.31 times of those in France. Based on these numbers, the number of vehicles on the road in Beijing is almost the same as in New York but more than that in Tokyo even though New York and Tokyo have much higher vehicle populations. The major reasons for such differences include better and convenient public transportation systems and high parking fees for downtown areas

[40] Ten Measures for Beijing's Traffic Congestion, available at http://cn.news.yahoo.com/030924/83/1t6ez.html, September 24, 2003.
[41] see http://auto.sina.com.cn.

in those other cities. Beijing and Shenzhen have recently proposed charging higher fees for downtown parking.[42]

2. Public Transportation

Most large cities depend on the public transit system to restrict car use, for example, 90 and 80 percent of people in Hong Kong and Washington, D.C. take public transit for working and shopping. For a long time, China's city transportation heavily relied on buses and bicycles. However, due to the rise in automobiles, commuters in large cities such as Beijing and Shanghai have increasingly depended on taxis and private cars. The share of individuals using the public transit system in Beijing fell to 24% percent in the 2000s from 70% in the 1970s.[43] The bicycle population in urban China decreased from 182.1 per hundred households in 1998 to 142.7 in 2002.[44] The percentage of people who bike to work in Beijing has decreased to 20% from 60% ten years ago.

The inconvenience and slowness of the public transit system is a barrier to greater use of public transportation systems. Beijing has three metro lines, with a total length of 100 km and fewer than 100 stations, while New York has 30 metro lines, with a total length of 411 km and 468 stations.[45] Beijing's population is about 13.6 million, while New York's is 19.1 million. Beijing's public transit is highly dependent on ground buses, which contributes to serious traffic congestion. By the end of 2002, Beijing had 21049 buses with 739 routes, accounting for 75% of Beijing's public transit system. Due to bad urban planning and because there is no right of way for public transit vehicles, public

[42] *Nanfang Urban Daily*, http://www.sina.com.cn, January 19, 2004; http://english.peopledaily.com.cn,
[43] http://house.sina.com.cn, January 16, 2004.
[44] Disappearing Bicycles, *Xinhua Net*, Dec. 9, 2003,
[45] Chong Gang, http://www.qiche.com.cn, April 11, 2003.

buses are among the slowest traffic mode and even become the reason for traffic congestion.

Major cities such as Beijing and Shanghai made great efforts to build elevated ring roads and urban expressways and metro systems to enhance the city's public transit capacity and to reduce traffic congestion. In addition, local governments began to encourage private investment in transportation infrastructure as a means of financing operations and expanding new and existing facilities. Beijing has proposed selecting private investors for urban road infrastructure through a bidding format, in return for 25 years of operating rights. Beijing's 2008 Olympics and Shanghai's 2010 World Exposition are creating high pressure for Beijing and Shanghai to build better public transit systems. Beijing will invest 35 billion yuan (US$4.2 billion) in 2004 and build a 130km-length new highway, 11 rapid road projects, 28 projects for urban road construction and 2 transfer stations.[46] It also will invest180 billion yuan (US$21.7 billion) on traffic improvement before 2008.

Bus rapid transit (BRT) was developed in the United States and is viewed as perhaps the most important transportation initiative because it can achieve the capacity and economic development potential of rail, but at a fraction of the cost and with low emissions(e.g., Sperling and Clausen 2002; Vincent 2003). Rail lines in urban areas cost over $100 million per mile in developing countries, whereas BRT costs less than one-tenth as much (Sperling and Clausen 2002). BRT achieves high speed by operating with exclusive rights-of-way, fast loading and unloading by elevating platforms to the same level as the bus floor, and collecting fares off board. BRT also has frequent and all day service and with intelligent transportation system technology. It is regarded as a cost-

[46] China News Network, http://finance.sina.com.cn, Feb 3, 2004.

effective transit alternative to help improve air quality and reduce congestion. A successful example of bus rapid transit in a developing country was in Curitiba, Brazil (Sperling and Clausen 2002). A growing number of cities around the world, such as Quito, San Paulo, Nagoya, Ottawa, Pittsburgh, are using BRT. With the support from the Energy Foundation and local governments, Beijing, Shanghai, Xian, Chengdu, Kunming are conducting a pilot BRT program.

3. Great Potential to Reduce Emissions from Conventional Vehicles

Reducing emission from each individual vehicle is another way to reduce total vehicle emissions. America's experience with vehicle emission control over the past decades shows that an effort to control conventional vehicle emissions is necessary and can be cost-effective. The history of automotive emission regulations reveals remarkable success in reducing the emissions of CO, HC, and NOx from new automobiles. With Federal standards for exhaust emissions in effect for decades in the U.S., both HC and CO have been reduced by 96 percent in passenger cars since the 1960s, and NOx emissions have been cut 76 percent in cars over the same period (Ross et al 1995). Similar reductions have occurred for light trucks. During the same period, the "real-world" g/mile emissions of CO and HC were reduced by roughly 75%. Even though vehicle miles traveled were increased by about a factor of 2, total automotive emissions still declined by roughly 50% nationwide. This is a very important achievement.

Powerful new technologies made these reductions possible. Most noteworthy are the catalytic converter and closed-lope engine controls; the latter includes sensors before and after the engine proper, and computer analysis of the information leading to real-time

control of fuel injection, with the principal objective being to maintain the right chemical balance of fuel and air.

As discussed above, China's current emission standards are far behind the levels of developed countries. There is great potential for China to reduce its vehicle emission levels. Technologies that can meet international emission standards are available to multinational companies, which are the technology providers for China's joint ventures. Fords believe that there is no technology difficulty for it to meet high emission standards even approaching "zero" emissions.[47] Currently China's car price is higher than the international level and joint ventures enjoy high profit margins. Joint venture companies have the capability to produce cleaner vehicles even while maintaining or lowering current price levels. An MIT study concluded that in the next decade, improved conventional technologies will be the cost-effective choice of Chinese consumers (Drake 2002). The greatest challenge of moving to stricter emission standards is compliance by small domestic car companies.

China's policies in this area are moving in the right direction. The Chinese government is preparing to impose minimum fuel economy standards on new cars based on vehicle's weight for the first time to save on fuel consumption and reduce dependence on oil imports. China recently introduced guidelines that would require the national car fleet to be 15%-20% more fuel-efficient than the current U.S. fleet by 2008—with particularly tough restrictions on sports utility vehicles. In addition, the American standards are fleet averages while the Chinese standards are minimums for each vehicle.

4. Fuel quality is the key to meet emission standards

[47] Interview with Ford researchers, January 23, 2004, Ford Headquarter, Dearborn.

Meeting emission regulations requires both vehicle emission control technologies and high quality fuel. Experts believe that fuel quality is the key to meeting emission standards in China (Walsh 2003; He 2003). Current gasoline quality in China cannot meet the requirements of strict emission control, due to relatively high benzene, olefin and sulfur content. Sulfur in fuels damages the pollutant discharge control system and electronic sensor system in automotive vehicles. The performance of the catalytic converter in reducing CO, HC, and NOx emission also is closely linked to the sulfur in gasoline. With regard to diesel vehicles, the problem may be even more severe as high sulfur fuels can preclude the use of advanced PM and NOx control technologies because they are poisoned by sulfur.

In China, the current standard sulfur level for gasoline is 800ppm, compared to 500 ppm required by Euro II, and 150 ppm for Euro III. In Europe, sulfur content will be reduced to 50ppm by 2005, and further reduced to 10ppm in the future; in the United States, it will soon reach 30 ppm (Walsh 2003). China's sulfur content standard in diesel oil is 2,000ppm, while Euro III requires 350 ppm and Euro V 10 ppm.

High olefin content reflects the fact that China's refineries use catalytic cracking in their secondary processing equipment. More than 80 percent of the country's gasoline is made through such a process, which results in high content of olefin and the high content of aromatics. Given the limited ability of China's refining infrastructure to handle and process high-sulfur crude oil from countries in the Middle East, China will increase its imports of lower sulfur crude oils from countries such as Indonesia, Malaysia, Libya or from the North Sea.

The Energy Foundation recently funded a study to examine what needs to be done with China's refineries to increase fuel quality. The study showed that refinery modifications are possible at reasonable cost, and can provide the fuel that China's future vehicles will need. Converting fuels to meet Euro II standards across the country by 2005 is feasible at a relatively low cost of less than $0.01 per gallon for gasoline and less than $0.02 per gallon for diesel. The incremental cost per gallon of converting to Euro III beyond Euro II is $0.0029 and $0.0012 (Walsh 2003).

Government policy is necessary to encourage industries to improve transportation fuel quality. First, fuel quality standards and a monitoring system should be established based on the coordination of relevant agencies. Second, the government should set up a schedule for fuel quality improvement and standards, which can provide a clear timetable for enterprises to formulate their technology development strategies. Third, some economic incentive policies such as taxation policies should be established to give enterprises additional motivation to improve fuel quality. German and Hong Kong both used taxation policy to improve their fuel quality within a short time (He 2003). Finally, enforcement of standards should be strengthened to verify fuel quality during the fuel distribution process.

5. Farm Vehicles—weak point in China's vehicle emission control

China's output of farm vehicles in 2002 reached 2.59 million units, according to statistics from the Farm Vehicle Industry Association.[48] In Beijing, there are about 200,000 farm vehicles, accounting for one-tenth of all vehicles. Beijing had 4,731 registered tri-cars (small three-wheeled cargo vehicles used in rural areas) in 1996, and this figure jumped

[48] *CBU-Auto*, Vol. 4, No. 8, March 6, 2003.

nearly 10 times by 2002 to 44,945 tri-cars.[49] These vehicles are the basis for millions of small businesses that transport farm products to local markets and that move construction materials and locally manufactured products; they also serve as the principal mode of motorized travel in rural areas.

There are no emission standards for farm vehicles and most vehicles do not have emission control measures. Many farm vehicles are old; for example, over 81% of walking tractors have been used for 10 years or more. Less than 10% of these vehicles have regular maintenance for air, fuel and oil filters. As for Beijing, it is estimated that only 18% of the 200,000 agricultural vehicles and tractors in rural Beijing meet the municipality's emission standards.[50] Particulate emissions from farm vehicles, many of which have only single-cylinder diesel motors, are 6 to 10 times the level of a gasoline automobile. Given this proportion, particulates emitted from these farm vehicles equal the emissions from all other vehicles driving in Beijing.

It will be much more difficult to control farm vehicle emissions than car emissions, given lower farmer income and limited awareness of emission control. Developing innovative cleaner vehicles for rural use should be given high priority. Vehicle emissions from farm vehicles are not highly visible to high level leaders, but their effects on air quality is huge. The government should include farm vehicles in its emission control systems.

6. Hybrid vehicles should be promoted by government policies and programs

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle, resulting in

[49] Beijing Environment, Science and Technology Update-3-21-03.
[50] *Beijing Youth Daily*, February 10, 2003.

twice the fuel economy of conventional vehicles and lower emissions compared to conventional vehicles. This combination offers the extended range and rapid refueling that consumers expect from a conventional vehicle, with a significant portion of the energy and environmental benefits of an electric vehicle. There is no need for new infrastructure and it is relatively less expensive. The inherent flexibility of HEVs will allow them to be used in a wide range of applications, from personal transportation to commercial hauling. The recharging system from braking energy during stop-and-go low speed urban driving saves energy; this makes hybrids or partial hybrids of greater value for fuel economy. China has more buses than in any other country; with over 500,000, it has more than eight times the number in the United States. If these fleets were to be converted to hybrid vehicles, China's transportation system could be a model for the world.

Although China has begun research and development on the use of hydrogen as a transportation fuel, the transition to hydrogen cannot occur quickly. Conventional gasoline vehicle technology is very difficult to replace because of large sunk investments in vehicle production facilities and an extensive gasoline infrastructure. The incremental benefits of hydrogen to consumers will likely be small relative to “conventional technology” vehicles and fuels, even when the public good benefits such as cleaner air and energy security are greater. Hydrogen is inherently expensive to transport, store, and distribute—all significant disadvantages for a transportation fuel. Furthermore, the introduction of hydrogen requires the simultaneous deployment of hydrogen vehicles and development of a hydrogen infrastructure (Melaina 2003). A hydrogen refueling infrastructure would be capital intensive in absolute terms, although estimates have suggested that per vehicle costs could

be as low as $300-$700 per vehicle once economies of scale and production have been attained (Ogden et al, 1999). The cars themselves will most likely be expensive, at least initially, and especially if they are fuel cell vehicles. For these and other reasons, it is not reasonable to expect significant commercialization of hydrogen vehicles in the near future in China.

7. Economic incentive policies for both consumers and manufacturers are necessary

The high cost of advanced cleaner vehicles makes it difficult for these vehicles to be competitive with traditional automobiles. At the same time solely relying on regulatory measures cannot resolve all enforcement problems. Partnership between government and industry and market-based incentive policies are all necessary measures to get auto manufacturers to become actively involved in the move to cleaner vehicles instead of passively following national regulations. The consumption tax reduction policy for vehicles that meet environmental standards ahead of national regulations and the partnership of government and industry in R&D on advanced vehicle technologies are good initial examples of such cooperation. However, such policies are still rare in China. There is no preferential tax incentive for alternative fuel vehicles and sustaining economic incentive policies for infrastructure construction for alternative fuel vehicles.

Competitive pressure due to WTO accession and the opportunity to "leapfrog" technologically in the auto industry are motivations for auto manufacturers to move to cleaner vehicle technology. In China, General Motors is very active in promoting R&D on fuel cell vehicles; Volkswagen is lobbying to switch from gasoline to diesel engines to improve fuel efficiency; while Toyota is attempting to promote hybrid vehicles by supporting policy and standards preparation in China. The Chinese government should

establish incentives for those companies, and make China be their test ground for new vehicles.

China's price for gasoline and diesel is among the lowest in the world, about 30 percent of the gasoline price in France. China still has no taxes on transportation fuel, while more than seventy percent of the cost of gasoline in France, Germany, and the United Kingdom are due to taxes (Davis and Diegel 2003). Consumers in China are very sensitive to fuel economy. Qixue Institute conducted a survey to investigate factors affecting car purchasing in Beijing, Shanghai, and Shenzhen.[51] The survey finds that most buyers in China list vehicle price and fuel economy as the major factors affecting their decisions on which kind of cars to purchase. A fuel tax seems an obvious first step in reducing gasoline and diesel use by vehicles.

However, political factors can be a large barrier to its implementation. China's efforts to levy a tax on fuel consumption to replace road tolls and fees while encouraging fuel efficiency have not been successful. A tax on fuel was included in the Amendments to the Highway Law, which was passed by the National People's Congress in November 1999. The fuel tax was viewed as the key element of the central government's revenue reform policy by transforming the myriad of locally collected fees into centrally controlled tax revenues, and was therefore opposed by local governments.[52] Conflicting interests also occur in different ministries on how the tax should be fine-tuned to reduce unexpected and undesirable financial burdens on users, especially those who frequently use vehicles, e.g., taxi drivers, and farmers who use gasoline or diesel for pumping for crop irrigation.

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[51] The survey report was available at http://www.sina.com.cn, September 22, 2003.
[52] "China will not start Fuel Tax in Near Future," *People's Daily*, May 3, 2002,

Most consumers are first-time buyers of vehicles. Consumer education and training in advance are critical since many Chinese consumers have not formed habits of using traditional vehicles. This provides a great opportunity for China to establish a market for cleaner vehicles since the private vehicle market has just started. If China misses this opportunity, China could face the same consumer preference challenges as developed countries.

Conclusions

China will continue to motorize rapidly but measures must be taken to reduce the environmental impacts posed by motorization. The government will need to play a central role in guiding the direction of a greening motorization path by providing regulations and supporting policies. Efforts to control conventional vehicle emissions are necessary and can be cost-effective. Current available vehicle emission control technology can reduce vehicle emission greatly and have the potential to approach "zero" in the future based on the U.S. experience with vehicle emission control. The government should issue emission standards to encourage local governments and industries to move quickly to catch up with European and American standards. Farmer vehicles and motorcycles should be included in China's vehicle emission control system. Effective enforcement is critical for ensuring that vehicles comply with emission standards.

Fuel quality is one key to meeting emission standards. High sulfur content makes it difficult to meet higher emission standards. It is economically feasible for China's refineries to provide higher quality fuel based on current research findings. Government should support the efforts to increase fuel quality by advancing fuel regulations and

economic incentives. A fuel tax and strict enforcement of emissions and fuel efficiency standards can help reduce emissions.

The importance of automobiles to the national economy prevents the government from limiting the car market. The growth of privately owned vehicles is inevitable along with income increases and falling car prices. Restricting privately owned vehicles thus is not a practical approach but vehicle use can be reduced. A convenient and fast public transportation system can help reduce the use of cars. The bus rapid transit system should be promoted by local governments because it can meet the capacity and economic development potential of rail, but at a fraction of the cost and with low emissions.

Hybrid vehicles should be promoted by government policies and regulations as a transitional technology because there is no need for new infrastructure and is relatively less expensive. Both hybrid and hydrogen vehicles are more expensive than conventional vehicles under current available technologies. Economic incentive policies for both consumers and manufacturers are necessary to promote cleaner vehicles. This could also attract multinationals to use China as a testing ground for innovative cleaner vehicles. A new and thriving market for cleaner vehicles can be established through education and training of consumers before they form the same habits as in developed countries.

Overall, a consistent and integrated sustainable transportation policy should be adopted to balance short- and long-term goals to move towards cleaner vehicles. A transition to hydrogen vehicles will not occur quickly and its development should be viewed as a long-term goal due to huge cost and infrastructure requirements. The introduction of hydrogen fuel would be best supported by a range of near-term policy

strategies, such as carrying out basic R&D, improving vehicle fuel economy, and raising public awareness.

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