CICERO Working Paper 2002:01

Mobile source pollution control in the United States and China

Fredric C. Menz

April 2002

CICERO
Center for International Climate
and Environmental Research
P.O. Box 1129 Blindern
N-0318 Oslo, Norway
Phone: +47 22 85 87 50
Fax: +47 22 85 87 51
E-mail: admin@cicero.uio.no
Web: www.cicero.uio.no

CICERO Senter for klimaforskning
P.B. 1129 Blindern, 0318 Oslo
Telefon: 22 85 87 50
Faks: 22 85 87 51
E-post: admin@cicero.uio.no
Nett: www.cicero.uio.no

Tittel: Mobile source pollution control in the United States and China

Forfatter(e): Fredric C. Menz
CICERO Working Paper 2002:01
26 sider

Finansieringskilde: CICERO, Norway-U.S. Fulbright Foundation
Prosjekt: Promoting sustainable road transportation in China: The greening of the automobile industry
Prosjektleder: Lin Gan
Kvalitetsansvarlig: Lin Gan

Nøkkelord: Utslipp fra mobile kilder, kontroll av utslipp fra mobile kilder, forurensingskontroll politikk, økonomiske virkemidler, USAs forurensingskontroll politikk, miljørelaterte skatter og avgifter, kinesisk forurensingskontroll politikk, transportforurensing, amerikanske luftforurensingstrender

Sammendrag:. Dette notatet tar for seg politiske virkemidler for å begrense utslipp fra mobile kilder, og muligheten for å kunne bruke denne politikken i Kina. Første del av notatet ser på USAs erfaringer med utslippskontroll fra mobile kilder siden slike reguleringer ble innført i "Clean Air Act" fra 1970. De viktigste punktene fra denne politikken og trender i utslippene fra mobile kilder i perioden 1970 til 2000 blir diskutert. Andre del av notatet diskuterer mulige politiske virkemidler som kan brukes for å kontrollere forurensing fra mobile kilder, fra tradisjonelle direkte reguleringer til markedsbaserte virkemidler. Erfaringer med bruk av økonomiske incentiver i USA og andre land vil også bli diskutert. Tredje del av dette notatet diskuterer hva USAs erfaringer med å kontrollere forurensing fra mobile kilder kan bety for Kina. Selv om markedsbaserte virkemidler kan være passende på mange områder av Kinas forurensingspolitikk, vil forskjeller i institusjonell struktur i Kina og USA antyde en gradvis innføring av slike virkemidler. Notatet avslutter med en konklusjon.

Språk: Engelsk

Rapporten kan bestilles fra:
CICERO Senter for klimaforskning
P.B. 1129 Blindern
0318 Oslo

Eller lastes ned fra:
http://www.cicero.uio.no

Title: Mobile source pollution control in the United States and China

Author(s): Fredric C. Menz
CICERO Working Paper 2002:01
26 pages

Financed by: CICERO, Norway-U.S. Fulbright Foundation
Project: Promoting sustainable road transportation in China: The greening of the automobile industry
Project manager: Lin Gan
Quality manager: Lin Gan

Keywords: mobile source pollution, vehicle pollution control, pollution control policies, economic instruments, U.S. pollution control policies, environmental-related taxes, Chinese pollution control policies, transport pollution, U.S. air pollution trends

Abstract: This paper reviews policies for the control of mobile source pollution and their potential application in China. The first section of the paper reviews the U.S. experience with mobile source pollution control since regulations were first established in the Clean Air Act of 1970. Highlights in the policy and trends in vehicle emissions over the 1970 to 2000 time period are discussed. The second section of the paper discusses the range of policy instruments that could be used to control vehicle pollution, ranging from traditional direct regulations to market-based instruments. Experiences with the use of economic incentives in the United States and elsewhere are also discussed. The third section of the paper discusses possible implications of the U.S. experience for controlling vehicle pollution in China. While market-based instruments might be particularly appropriate for use in several aspects of China's pollution control policies, important differences between the institutional structures in China and the United States suggest that they should be phased in gradually. The paper closes with concluding remarks.

Language of report: English

The report may be ordered from:
CICERO (Center for International Climate and Environmental Research – Oslo)
PO Box 1129 Blindern
0318 Oslo, NORWAY

Or be downloaded from:
http://www.cicero.uio.no

Contents

1 INTRODUCTION 1

2 THE U.S. EXPERIENCE WITH VEHICLE POLLUTION CONTROL 2

2.1 THE U.S. REGULATORY APPROACH 2
2.2 TRENDS IN MOBILE SOURCE EMISSIONS, 1970–1999 6
2.3 AN ASSESSMENT OF U.S. POLICY 9

3 POLICY DESIGN FOR MOBILE SOURCE POLLUTION CONTROL 12

3.1 THE RANGE OF POLICY INSTRUMENTS 12
3.2 ECONOMIC CONSIDERATIONS 14
3.3 ECONOMIC INCENTIVE POLICIES IN PRACTICE 16

4 CONTROLLING MOTOR VEHICLE POLLUTION IN CHINA 18

5 CONCLUSIONS 24

Acknowledgements

I would like to thank Camilla Bretteville, Lin Gan, and Lynn P. Nygaard for comments on an earlier version of this paper. This paper was completed while I was visiting Fulbright scholar at CICERO. Thanks to CICERO for hosting my visit and to the Norway-U.S. Fulbright Foundation for financial assistance.

1 Introduction

Since the 1970s, control of emissions from mobile sources has been a concern of U.S. air pollution control policy. Nonetheless, vehicle emissions continue to play an important role in causing air pollution problems at the local, regional, and national levels in the United States. Although pollution control standards for vehicles have become much more stringent over time, mobile source emissions, particularly from passenger vehicles, continue to be significant because of a combination of Americans' desire for larger cars, increases in vehicle-miles traveled, and economic growth. It is becoming increasingly clear that advances in technology will not be sufficient to overcome increasing environmental impacts from growing motor vehicle use worldwide and that current road transportation systems are not environmentally sustainable over the long term (OECD 2001a). Even with continued progress toward reducing discharges of conventional regional pollutants, transportation sources are now the fastest-growing source of global greenhouse-gas emissions. Thus, the control of mobile source emissions is a very important policy problem.

China faces similar, if not more critical, problems in attempting to control pollution from mobile sources. China's rapid economic growth and increase in living standards has led to greater demand for passenger cars to provide more convenient and flexible transportation. Like the United States and other developed countries, China's transportation policies tend to encourage the use of vehicles powered by fossil fuels. Increasing urbanization and the rising use of automobiles in China have led to numerous environmental problems, particularly in major cities such as Beijing, Guangzhou, and Shanghai (Kebin and Chang 2000). Although the energy and industrial sectors are currently the biggest contributors to urban air pollution in China, economic growth will undoubtedly increase demand for vehicles, transportation infrastructure, and services. The number of urban vehicles in China is expected to be from 13 to 22 times greater in 2020 than in the late 1990s, and this could have a major influence on air pollution in China's biggest cities (Stares and Zhi 1995, 50). To avoid continuing air quality problems, particularly in more densely populated regions, aggressive measures will be required to manage emissions from mobile sources.

For a number of reasons, designing and implementing policies to control vehicle pollution is particularly difficult. First, controlling mobile source pollution is fundamentally different than controlling stationary source pollution because the problem results from a large number of highly mobile sources, each of which emits a negligible amount of pollution. Second, the various types of policy measures for controlling mobile source pollution have not received the same attention as alternative policies for controlling stationary source pollution.

Regulations in most countries still rely primarily on new-vehicle emissions standards aimed at manufacturers, complemented by inspection programs for testing emissions of vehicles in use. This is striking since it is widely held that existing policies have been ineffective in controlling vehicle pollution – either by design or in practice – throughout the world. Third, the effect of current regulations on technological innovation in vehicle and fuel technologies is unclear. For example, it is not known whether regulations aimed at vehicle manufacturers are more effective than measures directed at users in providing incentives for adopting more environmentally friendly transportation products. Finally, the predominant role of the automobile in the modern lifestyle makes the control of mobile source pollution difficult for political reasons.

This paper reviews U.S. policies for controlling pollution from mobile sources and considers possible implications for the development of vehicle pollution policies in China. The next section of the paper reviews U.S. policy since 1970, analyzes trends in emissions of regional air pollutants, and evaluates key elements of the policy. The following section discusses various policy measures for controlling mobile source pollution and reviews the rationale for the use of economic incentives for pollution control. Examples of environmental-related economic incentives for mobile sources in the United States are then discussed. The next section of the paper considers the implications of this experience for China and makes policy recommendations.

2 The U.S. experience with vehicle pollution control

2.1 The U.S. regulatory approach

The approach used in the United States to control mobile source pollution relies on federal laws and regulations complemented by state initiatives and, more recently, joint efforts between the federal government and automakers to develop new technologies in vehicles and fuels. The framework legislation is the Clean Air Act of 1970, which is administered by the U.S. Environmental Protection Agency (EPA). Under this law, the federal government sets national air quality standards for carbon monoxide (CO), lead, nitrogen oxides (NO_x), ozone, particulate matter (PM), and sulfur dioxide (SO_2). The EPA monitors air quality and emissions of these pollutants on a regular basis. In addition, the Clean Air Act sets mandatory numerical standards for emissions of CO, hydrocarbons, and NO_x from new vehicles. Emissions performance standards for new vehicles are supplemented by emissions inspection and maintenance (I/M) programs for vehicles used in areas that are having difficulty meeting air quality standards.

Table 1 shows milestones in U.S. policy controlling mobile source emissions since 1970. Federal regulations have focused on controlling emissions from highway vehicles such as passenger cars, trucks, and buses, although off-road sources are now also regulated. The government also has used its authority to regulate lead and other fuel additives. A variety of technological specifications dealing with vehicles, fuels, and other components of the transportation system are also required in geographical areas not meeting federal air quality guidelines (nonattainment areas). In addition to federal government regulations, some states (most notably, California) have adopted stricter emissions standards for vehicles and/or developed transportation plans to reduce the number of vehicle-miles traveled in their jurisdictions. Over the years, as federal emissions standards for new vehicles have become more stringent and more requirements imposed on nonattainment areas in an effort to bring them into compliance with air quality standards, the EPA has introduced numerous flexibility provisions to reduce program costs.

Table 1. Milestones in U.S. Vehicle Emissions Control

1970	Clean Air Act establishes auto emissions standards.
1971	Charcoal canisters introduced to meet evaporative standards.
1973	EGR valves appear to meet NO_x standards.
1975	First catalytic converters appear for HC and CO. Unleaded gas appears for use.
1981	3-way catalysts with on-board computers and O_2 sensors appear.
1983	Inspection and maintenance programs established in 64 cities.
1990	Clean Air Act amendments set new tailpipe standards.
1993	Limits set on sulfur content of diesel fuel.
1994	Phase in begins of new vehicle standards and technologies.
1995	On-board diagnostic systems appear in new cars.
1998	Sales of 1999 model year vehicles meeting California standards begin in northeast.
2000	EPA allows averaging, banking, and trading for automakers to achieve NOx standards

Sources: USEPA 1994.

The 1970 Clean Air Act mandated emissions standards for new cars through a certification program and an associated enforcement program that includes assembly line testing of vehicles, warranty requirements, and recall provisions. The certification program requires that prototypes of new vehicles be tested for conformance with federal emissions performance standards before they can be manufactured or sold. Prototype vehicles from each engine family must pass emissions tests that simulate driving experiences over the useful life of the vehicle. The current performance standards for new light-duty cars and trucks are set in two tiers. The first refers to the first five years, or 50,000 miles of use, and the second establishes less stringent standards for the remainder of the vehicle's life (ten years, or 100,000 miles of use).[1]

Federal regulations include warranty provisions designed to insure that vehicles will meet emission standards not only at the time of purchase but over a vehicle's entire usable life. There are two sets of warranty provisions. The first holds manufacturers responsible for fixing any defects in a vehicle's emissions control equipment that could result in its failure to meet the standards during the vehicle's entire usable life. The second provision requires the manufacturer to bring any car that fails an emissions test within the first 24 months or 24,000 miles into conformance with the standards. After this period, the warranty is limited to replacement of devices (e.g., catalytic converters) for emissions control.

The Clean Air Act gives responsibility to the states to develop regulations to insure that ambient air quality standards are met within their jurisdictions. Amendments to the Act in 1977 recognized the existence of nonattainment areas and placed special requirements on local authorities to bring those areas into compliance. Since vehicle emissions were the source of air quality problems in many nonattainment areas, local authorities in those areas were required to take further actions to reduce mobile source emissions, including the establishment of I/M programs to test emissions from vehicles in use. Emissions testing programs typically involve regularly scheduled emissions measurements of CO, HC, and NO_x from passenger cars and light trucks and visual checks of pollution control equipment.[2] Vehicles that fail inspection must be re-inspected after repairs are made. Some states exempt extremely old vehicles and vehicles whose owners have low incomes.

Major revisions were made in 1990 to the Clean Air Act in an attempt to further reduce emissions of CO, HC, NO_x, and particulate matter from vehicles. Stricter standards were set for tailpipe emissions from all types of highway vehicles, and I/M programs were expanded to include more areas, allow for more stringent tests, and require residents in certain areas to have their cars repaired and re-tested for conformance with standards. Cars and light trucks will by 2004 be required to meet the same emissions standards, and gasoline and diesel-fueled vehicles must meet identical standards. For the first time, other states were

[1] The current exhaust emission standards are in USEPA 2000 and Sec. 202, Clean Air Act amendments of 1990, at www.epa.gov/oar/caa/caa202.txt.

[2] See USEPA 1999.

allowed to adopt California new-vehicle emissions standards. The diesel particulate standard for buses in urban areas was reduced by 60 percent, and the EPA was given authority to regulate emissions from off-road sources, including locomotives, construction equipment, and lawnmowers. In response to continuing air quality problems, some urban areas had to require the installation of vapor recovery systems on nozzles of gasoline pumps and the use of clean fuels in 30 percent of new vehicles purchased by centrally fueled fleets.

The 1990 amendments also established a "clean fuel" vehicles program. Certain nonattainment areas were required to establish programs for the adoption of clean fuel vehicles by centrally managed vehicle fleets. Fleet owners who surpass the requirements are awarded emissions credits that can be banked for future use or traded. California was given the authority to adopt a program to require automobile manufacturers to produce and sell a certain number of "clean" vehicles if they wished to sell cars in the state. In September 1990, the California Air Resources Board passed low-emissions vehicle (LEV) and zero-emissions vehicle (ZEV) regulations. The LEV regulation established increasingly strict emissions standards over time, starting in 1994, for conventional fuel vehicles. Manufacturers can produce and certify cars with different emissions levels (including those that meet federal standards), but to be in compliance the average emissions across the fleet (weighted by sales) must achieve the specified standards. The ZEV regulation requires that at least 10 percent of new car sales be zero-emitting vehicles by 2003, although partial ZEV credits are granted for extremely clean vehicles that are not pure ZEVs (California Air Resources Board 2001).

The federal government and some states have also implemented regulations to require the use of newly developed cleaner fuels or to constrain the use of other fuels. Certain nonattainment areas are required to offer only "cleaner" gasoline for sale to motorists, including reformulated gasoline in certain ozone nonattainment areas to reduce emissions of hydrocarbons and toxic air pollutants and oxygenated gasoline in certain CO nonattainment areas.[3] For example, specially formulated fuel has been provided in Denver, Colorado, during the winter in an attempt to reduce its CO problem. The federal government prohibited the use of any fuel containing lead or lead additives after 1995 and has also set limits on the sulfur content of diesel fuels used in highway vehicles.

In addition to programs aimed at existing vehicles and fuels, there have been joint initiatives among U.S. automakers (General Motors, Ford, and DaimlerChrysler) and the federal government in response to stiffer federal emissions requirements and California

[3] Market-based incentives are being used to implement this requirement. Marketable credits are issued for fuels that exceed legal requirements, thus capping the amount that can be sold. The credits can be used by the recipient or transferred to another source in the same nonattainment area.

regulations. The *Partnership for a New Generation of Vehicles* was formed in 1993 to facilitate the development and production of fuel-efficient, low-emissions vehicles. The goal of the cooperative effort was to conceive and develop by the year 2004 a "marketable and affordable" vehicle with up to three times the fuel economy of existing mid-sized sedans (80 miles per gallon gasoline equivalent), with the assistance of $1.5 billion in government subsidies. In January and February 2000, each manufacturer introduced concept cars: the DaimlerChrysler ESX3, the Ford Prodigy, and the General Motors Precept. All three vehicles incorporate hybrid-electric power trains with small turbo-charged diesel fuel engines that shut down when the vehicle comes to rest (Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles 2001). In January 2002, the federal Department of Energy announced an alternative program aimed at more fundamental R & D with the long run goal of replacing the internal combustion engine with engines powered by fuel cells (Bannerjee 2002). Under the *FreedomCAR* program, automakers will also seek to develop new technologies applicable to both hybrid and fuel cell approaches, e.g. batteries and electronic components.

2.2 Trends in mobile source emissions, 1970–1999

Data on U.S. emissions of criteria pollutants from 1970 to 1999 are presented in Tables 2 and 3. Table 2 shows total emissions and emissions from transportation sources for the six criteria pollutants. Table 3 shows emissions by type of pollutant for specific categories of mobile sources. Nationwide emissions of all criteria pollutants except NO_x fell from 1970 to 1999, and emissions from transportation sources followed the same general pattern as overall emissions.[4] As of 1999, emissions from transportation sources accounted for 77 percent of CO emissions, 56 percent of NO_x emissions, and 47 percent of VOCs. The share of mobile source emissions relative to total nationwide emissions stayed relatively constant from 1970 to 1999 for CO and VOCs but rose for NO_x. On-road vehicles are the dominant source of emissions from the transport sector (Table 3). Light-duty gasoline-powered vehicles (cars and trucks) account for the predominant share of CO, NO_x, and VOC emissions from on-road vehicles, but their share of all criteria pollutants has been decreasing over time.

The decrease in lead emissions since 1970 has been particularly dramatic. The reduction resulted from the gradual phase out of lead in vehicle fuels in conjunction with the use of catalytic converters. Nationwide particulate (PM-10) emissions decreased by 75

[4] It should be noted that air quality measures for all criteria pollutants (including NO_x) improved over this time period. A principal reason for the discrepancy for NO_x is that air quality is monitored primarily in urban areas whereas emissions are based on nationwide estimates.

Table 2. U.S. national and transportation sector emissions trends, 1970-1999*

Pollutant		1970	1980	1990	1995	1999
Carbon Monoxide (CO)	Transportation	100,004	92,538	76,635	75,035	75,151
	Total	129,444	117,434	99,119	94,058	97,441
	Transportation share (percent)	77.26	78.80	77.32	79.78	77.12
Lead (Pb) –Tons	Transportation	181,698	64,706	1,197	564	536
	Total	220,869	74,153	4,975	3,929	4,199
	Transportation share (percent)	82.27	87.26	24.06	14.35	12.76
Particulate Matter (PM-10)	Transportation	786	786	838	756	753
	Total	12,325	6,258	3,340	3,165	3,045
	Transportation share (percent)	6.38	12.56	25.09	23.89	24.73
Nitrogen Oxides (NO_x)	Transportation	9,322	12,150	12,014	13,085	14,105
	Total	20,928	24,384	24,170	25,051	25,393
	Transportation share (percent)	44.54	49.83	49.71	52.23	55.55
Sulfur Dioxide (SO_2)	Transportation	494	697	1,476	1,311	1,299
	Total	31,161	25,905	23,678	19,188	18,687
	Transportation share (percent)	1.59	2.69	6.23	6.83	6.95
Volatile Organic Compounds (VOCs)	Transportation	14,849	11,291	8,988	8,515	8,529
	Total	30,982	26,336	21,053	20,918	18,145
	Transportation share (percent)	47.93	42.87	42.69	40.71	47.00

* Annual emissions, in thousands of short tons, except lead (long tons)
Source: USEPA 2002b.

percent over the time period, but the amount coming from transportation sources remained relatively constant because of the increased use of diesel engines, particularly in non-road uses (Table 3). Particulate matter includes both coarse (PM-10) particulates emitted directly into the atmosphere and fine (PM-2.5) particles, formed in the atmosphere from primary gaseous emissions such as sulfates and nitrates. While reductions in PM-10 emissions have been significant, there is increasing concern about PM-2.5 levels because of their health effects. Transportation sources account for a small share of total SO_x emissions, but emissions from vehicles increased from 1970 to 1999, largely due to increased emissions from non-road vehicles.

Table 3. U.S. transportation sector emissions trends, by category, 1970–1999*

		CO	Pb	PM	NOx	SOx	VOC
Light-duty gasoline autos							
	1970	64,031	142,918	225	4,158	132	9,193
	1980	53,561	47,184	120	4,421	159	5,907
	1990	34,996	314	57	3,013	129	3,692
	1995	29,787	14	55	3,043	126	3,029
	1999	27,382	24	58	2,859	137	2,911
Light-duty gasoline trucks							
	1970	16,570	22,683	70	1,278	40	2,770
	1980	16,137	11,671	55	1,408	50	2,059
	1990	17,118	100	37	1,552	19	2,016
	1995	19,434	5	41	1,991	93	2,135
	1999	16,115	7	46	1,638	91	1,722
Heavy-duty gasoline vehicles							
	1970	6,712	6,361	13	278	8	743
	1980	7,189	1,646	15	300	10	611
	1990	5,029	7	10	306	10	405
	1995	4,103	-	9	330	11	325
	1999	4,262	1	12	459	17	375
Diesel-powered vehicles							
	1970	721	-	136	1,676	231	266
	1980	1,139	-	208	2,493	303	402
	1990	1,233	-	225	2,340	352	331
	1995	1,447	-	185	2,591	82	326
	1999	2,217	-	186	3,635	118	289
Non-road vehicles							
	1970	11,970	9,737	220	1,931	83	1,878
	1980	14,489	4,205	398	3,529	175	2,312
	1990	18,191	776	489	4,804	916	2,545
	1995	20,244	544	456	5,128	999	2,699
	1999	25,162	515	458	5,515	936	3,232

* Thousands of short tons, except lead (long tons)
Source: USEPA 2002b.

Total emissions of CO decreased by 25 percent from 1970 to 1999, and the share from transportation sources remained relatively constant. Most of the reduction in mobile source CO emissions over the time period came from automobiles. Light-duty passenger car CO emissions decreased by 57 percent, while CO emissions from non-road vehicles increased by 110 percent. Vehicle CO emissions comprised 52 percent of the nationwide total in 1999, while emissions from non-road uses contributed 25 percent of nationwide emissions (Table 3). High concentrations of CO generally occur in areas with heavy traffic congestion such as cities, where automobile exhaust contributes 95 percent of all CO emissions in the United States (USEPA 2001a).

From 1970 to 1999, total NO_x emissions increased by 21 percent, while NO_x emissions from mobile sources increased by 51 percent. The share of mobile source emissions relative to total NO_x emissions increased steadily over the time period, accounting for 45 percent of total emissions in 1970 and 56 percent in 1999. It is noteworthy, however, that NO_x emissions from light-duty gasoline automobiles and trucks decreased by 17 percent from 1970 to 1999 despite an increase in the number of miles traveled by these vehicles. Most of the increase in NO_x emissions came from non-road engines (primarily construction and recreation equipment) and diesel vehicles. EPA issued a rule in 1998 that required 22 states and the District of Columbia to revise their implementation plans to further reduce NO_x emissions by taking advantage of newer, cleaner control strategies. The rule did not mandate how the reductions are to be achieved, but gives each affected state a NOx emissions target. The goal of this program is to reduce total emissions of NO_x by 1.2 million tons in the affected states by 2007.

2.3 An assessment of U.S. policy

There has been criticism in the United States of the command and control regime of controlling mobile source pollution since 1970, particularly among economists who view the program as being considerably more costly than necessary. The costs could be too high either because the standards themselves are too stringent, resulting in program costs exceeding benefits, or because the methods used for pollution abatement are not minimum-cost methods. A number of economic incentive measures for controlling vehicle pollution were introduced during the 1990s in an effort to allow ambient emissions standards and air quality standards to be met more cost-effectively. An important finding from the U.S. experience is that economic incentives and flexibility mechanisms can play a role in mobile source pollution control policy, albeit an indirect one.

U.S. policy on controlling mobile source pollution has evolved since the Clean Air Act of 1970, but the effort is still focused largely on emissions performance standards that must be met before a new vehicle can be sold. One of the arguments for focusing on the point where vehicles are produced is that it is less costly to administer a program aimed at a few manufacturers than program directed at motorists. It has also been argued that setting stringent controls at the point of manufacture provides incentives for the development of cleaner technologies. On the other hand, factory-controlled emissions performance diminishes during normal usage, and drivers ultimately make the decision of which vehicle to drive as well as when, how, and where it is driven. Thus, even if strict new-vehicle performance standards are in place, motorists must bear at least partial responsibility for controlling pollution by maintaining the emissions performance of in-use vehicles.

New-car emissions standards were initially set in 1970 at extremely stringent levels to be achieved over a relatively short time period. Manufacturers were required to reduce new-car CO and HC emissions by 90 percent and NO_x emissions by a comparable amount by 1975. This caused problems by setting an infeasible compliance schedule for both manufacturers to meet mandated emissions standards and localities to meet ambient air quality standards.[5] Even if manufacturers could have met the emissions standards quickly, they applied only to new cars that comprise a small portion of the entire fleet. Thus it was impossible for localities to meet the ambient standards until well after the legal deadline. The problem continued for a number of years and included legal challenges involving the EPA, states, and environmental organizations. The impasse was finally resolved when deadlines for compliance with the emissions standards were subsequently extended in 1997 when the Clean Air Act was revised.

Focusing on emissions from new vehicles only partially addresses the mobile source pollution problem because new vehicles comprise just a portion of the entire fleet. Tighter new vehicle standards also increase their costs relative to older vehicles. This provides an incentive to drive older vehicles longer and causes emissions reductions to occur more slowly than if the program targeted both new and in-use sources (Gruensprecht 1982). The problem is being dealt with primarily by holding manufacturers responsible for maintaining a vehicle's emissions performance over a longer time period. However, until emissions from all vehicles are treated uniformly, the problem will remain. Emissions testing (i.e., I/M) programs are required only in nonattainment areas and have not been very successful even there. An important finding of numerous studies is that emissions tend to be concentrated in a relatively small number of gross emitters.[6] Since I/M programs usually test every vehicle rather than

[5] Local areas were using new-car emission standards to comply with ambient air quality standards. For an account of this experience, see Tietenberg 2001, 320).

[6] For example, a National Academy of Sciences study found that typically less than 10% of the fleet contributes more than 50 percent of emissions for a given pollutant (National Academy of Sciences 2001, 4-5).

concentrating on those likely to be high emitters, too many resources are devoted to inspecting relatively "clean" vehicles. The cost-effectiveness of emissions testing programs could be considerably enhanced if older vehicles and those with malfunctioning emissions controls were the primary target of these programs. The use of remote-sensing devices, more sophisticated on-board diagnostic systems, and non-scheduled inspections have also been suggested as ways to enhance the effectiveness of testing programs.

It can be argued, however, that the problems with U.S. emissions testing programs are not entirely technical. Under the current approach, motorists bear most of the responsibility and costs for maintaining the emissions performance of vehicles, but have little incentive to insure that emissions from their vehicle are controlled. Drivers bear the time and travel costs of taking the vehicle to a test facility, the expense of diagnosing emissions test failures, and the cost of re-testing those that need to be repaired. They also bear the costs of repairs to pollution control equipment – except warranty repairs – to bring a vehicle into compliance. The incentive to avoid repairs is greatest for those with the dirtiest vehicles. Alternative liability assignments might be more effective, including emissions-related charges to vehicle users, extending liability for emissions performance of in-use vehicles to the manufacturer, or subsidizing repairs to nonconforming ones.

Another problem with mobile source emissions standards relates to their uniformity. First, they are uniform across geographic areas, with the exception of California and some other states. Since the effect of emissions on ambient air quality depends on the number of vehicles, the composition of the fleet, driving patterns, meteorological conditions, and other factors, uniform standards are unlikely to be efficient. Vehicle emissions will be over-controlled in regions with unusually low benefits (or high costs), while they will be under-controlled in areas with unusually high benefits (or low costs). It would be more efficient if emissions in a given area were determined by the marginal costs and benefits of reducing pollution in that area. The region could be a state like California or any other geographic entity with particular air quality problems.[7] Second, until recently emissions standards were applied uniformly to every vehicle produced rather than to classes or types of vehicles. This raises the costs for manufacturers of complying with emissions standards. There could be substantial cost savings – without reducing benefits – if manufacturers were allowed to meet standards by averaging emissions across all new vehicles. In February 2000, the EPA

[7] In fact, because of its unique situation, California has imposed different vehicle emissions standards than national standards and several other states have recently followed suit. Cars registered in these states must meet more stringent emissions standards and often subject to more in-use emissions testing than in other states.

announced new standards for tailpipe emissions of NO_x but manufacturers are allowed to average emissions across vehicles to comply with the new standard.

3 Policy design for mobile source pollution control

3.1 The range of policy instruments

Table 4 shows a range of policy measures that can be used for controlling mobile source pollution from traditional direct regulations to measures that encourage voluntary efforts to reduce pollution. Possible regulatory instruments range from outright prohibition of an activity (or product) to voluntary agreements that request polluters to curtail a harmful activity. The table also shows for each instrument an example of a specific policy measure used in the United States for mobile source pollution control. For example, new vehicles must be fitted with a certain type of pollution control equipment (instrument three) and meet an emissions performance standard without specifying a particular technology (instrument four). Allowing emissions standards to be met across categories of vehicles or by trading emissions reduction credits among sources is an example of instrument five. Performance standards may refer to inputs (e.g., limits on the sulfur content of diesel fuels used in vehicles) or outputs (e.g., limits on the output of emissions). Likewise, charges or tradable allowances may apply to inputs (e.g., environment-related fuel taxes or transferable lead credits) or directly to emissions of the pollutant.

A distinction is often made between traditional command and control (CAC) regulations and market-based instruments (MBIs), but this distinction can be blurred in practice. CAC regulations generally refer to specific directives placed on polluters (the first four instruments in the table). In their purest form, CAC regulations direct polluters what to do and how to do it, abatement options are uniform, and emissions reductions are not transferable among sources. An example is the set of technological requirements mandated for ozone nonattainment areas, including vapor recovery systems in gasoline pump nozzles and the use of clean fuels in new vehicles purchased by centrally fueled fleets. However, cost savings can be achieved by providing sources flexibility in meeting pollution standards. For example, "tradable performance standards" achieve cost savings by allowing sources to trade emissions reduction credits earned by reducing emissions beyond mandated standards. By coupling flexibility with rigid emissions standards, the standards can be met more cost-effectively.

Table 4. Pollution control instruments for mobile sources

	Examples
Traditional direct measures	
1. Prohibition of processes, inputs, activities or products	Prohibition of lead in motor fuels
2. Waste disposal regulations	Requirements that solvents, used oils, or other products be recycled; charges for disposal of tires
3. Specific technological requirements	Vehicles must be equipped with on-board oxygen sensors or vapor-recovery systems
4. Emissions standards, technology-based or performance-based	Emissions standards for fuel refiners; new-car emissions standards
Economic incentive measures	
5. Transferable emissions reduction credits	Credits for scrapped vehicles; transferable allowances for fuel refiners; credits to engine manufacturers for exceeding emissions standards
6. Pollution charges	Vehicle registration fees based on emissions potential; environmental-related taxes on fuels
7. Subsidies	Federal government-automaker program to produce clean vehicles
8. Take-back or refund systems	Refundable deposits for lead-acid automotive batteries
9. Legal liability provisions	Making drivers responsible for ongoing emissions testing
Other policy measures	
10. Provision of information	Emissions or fuel economy information for new vehicles
11. Voluntary agreements	Pre-1970 agreements with automakers to reduce emissions from new vehicles

In contrast to traditional regulations, MBIs are more flexible and make use of financial instruments and market signals to provide incentives for sources to reduce emissions. Examples include transferable discharge permits, emissions charges, subsidies for private abatement activities, deposit-refund systems, and other provisions making emitters liable for pollution. Economic incentives can be directly applied to emissions or indirectly applied to inputs to an activity that causes pollution. Well-designed economic incentives encourage individual sources to undertake pollution abatement efforts that satisfy both their own interests and public policy goals. Other measures include changes in legal liability provisions, provision of information to users, and voluntary agreements. Information about vehicle mileage, emissions, and other characteristics is a public good and can be provided by environmental authorities, nongovernmental organizations, and consumer groups. Much of this information is now available on the internet.[8] Voluntary agreements urge, rather than require, individual economic agents (individuals or firms) to alter their behavior and cause less harm to the environment.

3.2 Economic considerations

Economic efficiency in pollution control is achieved when the marginal cost of pollution control is equal to the marginal damage caused by the pollution of each source. If the value of damages from pollution is known and emissions from different sources have the same impact on environmental quality, then setting a charge equal to marginal damages will automatically insure that the environmental target will be met at minimum cost. Even if environmental targets are set on political grounds rather than at the economically efficient level, economic instruments can still be used to attain the environmental target at minimum cost. This is the rationale for the use of transferable emissions allowances to control the problem of acid rain in the United States and the flexibility mechanisms for controlling greenhouse gas emissions in the Kyoto Protocol.

The reasoning behind this argument is that total abatement costs will be at their minimum level when pollution control responsibility is allocated so that marginal abatement costs are equalized among the sources. This result could be achieved by the use of either a uniform pollution charge facing all emitters or by issuing transferable emissions allowances equal to the pollution target. With an emissions charge, all sources face the same charge per unit of discharge and can choose to continue emitting and pay the charge or control their emissions to avoid the charge. Sources will reduce their discharges until the marginal abatement cost is equal to the emissions tax in order to minimize their costs. Since all sources face the same charge per unit of emissions, there is an incentive to control discharges until their marginal abatement costs are the same. Total abatement costs will be minimized because sources with low abatement costs will reduce their emissions by more than those with high abatement costs.

A similar result can be achieved with transferable emissions allowances. The transfer of emissions quotas from sources with relatively high abatement costs to those with low abatement costs achieves efficient allocation of abatement responsibility. A form of emissions trading occurs when an entity is allowed to average discharges internally across

[8] Examples include the EPA's *Green Vehicles Guide* (USEPA 2002c), the ACEEE's environmental guide to cars and trucks (American Council for an Energy-Efficient Economy 2002), and the U.S. Department of Energy/EPA internet site with information on fuel economy, GHG emissions, air pollution ratings, and safety information for new and used cars and trucks (US Department of Energy and US Environmental Protection Agency 2002).

different sources. For example, new-vehicle emissions standards would be more flexible and provide opportunities for cost savings if manufacturers were allowed to average emissions across their entire fleet of vehicles, between new and in-use vehicles, etc. Since they would not be required to control emissions uniformly across vehicles or vehicle classes, they could choose to achieve greater discharge reductions from low abatement cost sources. This flexibility would allow the overall pollution control target to be met more cost-effectively than if a uniform discharge standard were applied to all sources.

Incentive measures for controlling mobile source pollution should encourage motorists to buy "cleaner" vehicles, purchase cleaner fuels, install pollution control equipment, travel fewer miles, buy more fuel-efficient vehicles, or alter their driving patterns in ways to reduce environmental damages. Motorists would be expected to meet pollution requirements by choosing different amounts of these abatement methods based on their relative cost. Efficient emissions reductions for mobile sources would occur if (1) motorists were required to pay charges equal to the marginal damage of their emissions, and (2) an economic instrument such as an emissions charge could be applied directly to a vehicle's actual emissions.[9] This would be a per-unit charge varying by time, place, and mix of emissions in order to reflect their environmental impact. If continuous monitoring of emissions were not feasible, an approximate result could be achieved if charges were based on estimated emissions for the type of vehicle, mileage driven, location, etc. A tax could be administered through local vehicle inspection programs and based on the emissions rate and number of miles actually traveled for each vehicle. Thus, the charge would be based on the total discharges (actual or estimated) from a specific vehicle during a given period of time and could be varied to reflect differences in the severity of regional air-quality problems.

A second-best result could be achieved through indirect taxes on fuels and vehicles, differentiated according to pollution characteristics. For example, charges for vehicles could be differentiated by weight, engine type, or other characteristics. These policies are not as effective as taxing emissions directly because a tax on a product creates an incentive to curtail use of the product but not to abate emissions directly. A tax on the pollutant characteristics of an input such as a tax on the sulfur content of diesel fuel can shift demand toward fuels with less sulfur content but will not create incentives to abate sulfur emissions by other possibly more efficient methods (such as the installation of better technological methods to control sulfur emissions).

[9] It is theoretically feasible to duplicate the outcome of emissions tax with a very complicated tax on gasoline, but attributes of vehicles such as engine size and pollution control equipment must be identifiable at the pump (Fullerton and. West 2002).

While fuel taxes can be used when it is difficult to levy charges directly on emissions, their environmental effectiveness – the extent to which an increase in a fuel taxes causes a decrease in pollution – depends on the quantitative reduction in fuel use in response to increased fuel prices, or the price elasticity of demand. While the demand for motor fuels is typically inelastic, demand for a particular type of fuel is more responsive to price changes because of the greater availability of substitutes. Thus, even if overall fuel use may decline only modestly as fuel taxes increase, taxes can encourage motorists to substitute among different fuels. For example, diesel fuel is typically taxed at a lower rate than gasoline in virtually all European countries and the tax differential has been a factor in causing the use of diesel fuel in road transport to increase from 15 percent of the total fuel used in 1970 to 32 percent in 1999 (OECD 2001b, 34).

The result with environmental-related fuel taxation could be improved if it were supplemented by charges on vehicles reflecting their emission levels. This could be a tax levied at the time of purchase and/or periodically (e.g., quarterly or annually) based on both mileage and emissions. It could be administered through existing inspection programs and based on both emissions performance and miles driven for the vehicle. A combination of charges that even more closely approximates a direct emissions tax would include (1) a charge on new cars based on emissions performance, (2) an additional periodic registration fee according to where the vehicle is registered (e.g., higher in areas not in compliance with air quality standards), and (3) an additional periodic charge based on emissions performance. A system of vehicle taxes to reflect emissions levels should provide incentives for motorists to choose "cleaner" vehicles and for R&D activities to find new abatement technologies. Vehicle taxes have the important advantage of being able to influence both in-use and new vehicles. Differentiating annual registration fees by vehicle age can create a financial incentive to retire older vehicles earlier.

3.3 Economic incentive policies in practice

Although the basic principle of regulating environmental externalities through taxation has been known for some time, economic instruments have received very little use compared to direct regulations, particularly in controlling mobile source pollution. Motor vehicle emissions are not taxed directly anywhere in the world. While taxes on fuels and vehicles are used extensively, it is only recently that countries have begun to design these taxes to reflect potential environmental damages.[10] While economic incentive measures have been

[10] See OECD 2001b and USEPA 2001b for a review of the use of economic incentives and environmental taxes in OECD countries and the United States, respectively.

incorporated in regulations aimed at vehicle manufacturers and fuel refiners to allow them to meet mandated standards more cost-effectively, these measures do not directly control mobile source emissions.

The United States has implemented a number of policies to allow greater flexibility and reduce the costs for manufacturers to meet mandated performance standards. Increased emphasis has been placed these hybrid programs during the 1990s to allow more stringent standards to be met more cost-effectively. For example, emissions standards for new heavy-duty engines for trucks and buses were reduced in 1998 and will be reduced further in 2004. Manufacturers can comply with the standards by averaging (A), banking (B), and trading (T) emissions. The ABT program gives emissions credits to manufacturers who lower their engines' emissions beyond the performance standard. The credits are based on the reduction in lifetime emissions compared to an engine that exactly meets the standard. Manufacturers can use the credits to offset excess emissions from current-year engines (averaging), save them for future use (banking), or sell them to other manufacturers (trading). This approach has been extended to emissions performance standards for other types of vehicles including automobiles and light trucks, locomotives, outboard motors for boats, and lawnmowers (USEPA 2001b). Another example is in California, which requires that 10 percent of each manufacturer's fleet be zero-emissions vehicles (ZEVs) by 2003, but manufacturers can obtain ZEV credits for clean vehicles that are not pure ZEVs.

Market-incentive measures have also been introduced by the EPA and some states to accelerate the retirement of older, high-emitting vehicles. In one version of this program, vehicles not in conformance with emissions standards can either be repaired and brought into compliance or sold and scrapped. If the scrapped car is sold, the purchaser (often a stationary source) is given emissions reduction credits based on the remaining life of the car and the estimated number of miles it would have been driven (USEPA 1997). Other versions of the program either pay owners a fixed amount to retire an old vehicle or provide a credit for the purchase of a new, less-polluting vehicle. Congress is also considering proposals to subsidize the purchase of new high-mileage, less-polluting electric/gasoline hybrid cars. Subsidies may be required since production of these vehicles has not reached a sufficient level to make their prices competitive with comparable gasoline automobiles.

Most of the existing environmental-based economic measures for mobile sources take the form of taxes or registration fees on vehicles and fuels. In 1995, about 90 percent of the revenue from pollution-related taxes in OECD countries came from fees on gasoline, diesel fuel, and vehicles (OECD 2001b, 55). Tax rates on fuels can be differentiated according to their technical characteristics to reflect pollution impacts. In the United States, the federal tax is higher for diesel fuel than for gasoline and lower for special fuels such as ethanol, methanol, and liquefied natural gas, and a few state governments also differentiate fuel taxes by pollution characteristics. Several European countries also differentiate fuel taxes based on pollution characteristics (though most countries tax on-road diesel fuel at a lower rate than gasoline). Denmark's gasoline tax is lower in stations with vapor recovery systems, while Finland taxes reformulated gasoline at a lower rate than conventional gasoline. Norway has a special sulfur tax on diesel fuel, and Sweden and the United Kingdom vary the tax rate on motor fuels depending on their sulfur content. Finland, Norway, and Sweden have implemented an additional CO_2 tax based on the carbon content of motor fuels.

Vehicle sales taxes and registration fees are sometimes differentiated according to their emissions characteristics.[11] The United States imposes an additional one-time "gas guzzler" tax ranging from $1,000 to $7,700 per vehicle based on fuel consumption rates for inefficient passenger cars and sport utility vehicles. In Austria, the one-time registration tax (expressed as a percentage of the purchase price) for passenger cars depends on its fuel efficiency and is greater for a diesel auto than for a petrol auto that achieves the same mileage. Several European countries differentiate annual passenger car registration fees or usage taxes according to environmental impacts as well. For example, Denmark imposes an annual tax on passenger cars based on fuel efficiency. In Austria, Germany, and Norway, the annual registration fee depends on the environmental class of the vehicle as determined by European Union classification standards. The annual vehicle tax in Germany depends on cylinder capacity, engine power, and emissions rates, with low-pollution and low-fuel consumption vehicles taxes at lower rates. There is evidence that the differential tax has achieved environmental objectives: from July 1997 to January 2000, the stock of high-emissions cars decreased from 6.9 million to 3 million while the number meeting the tighter EURO 2, 3, and 4 emissions standards increased from 6.2 million to nearly 16 million (OECD 2001b, 104).

4 Controlling motor vehicle pollution in China

China has taken some important steps toward reducing air pollution since its first air pollution law went into effect in 1987. Nonetheless, ambient air quality standards for SO_2, NO_x, and TSP – the major the major pollutants that are monitored – were not being met in 67 percent of more than 300 cities as of 1999 (Policy Research Center for Environment and Economy,

[11] Some states in the United States differentiate vehicle registration fees according to a vehicle's weight, engine size, and/or number of axles, but these factors do not necessarily reflect a vehicle's environmental impact.

China National Environmental Monitoring Center, and Chinese Research Academy of Environmental Sciences 2001, 5, hereafter PRCEE et al). National NO_x air quality standards are currently exceeded across large areas, including high traffic areas in cities like Beijing, Shanghai, and Wuhan, where concentrations of NO_x show a clear increasing trend. Motor vehicle emissions are a major source of pollution problems in major cities and account for 45 to 60 percent of NO_x emissions and about 85 percent of CO emissions in typical Chinese cities (Walsh 2000, 29).

Like other countries, China has made greatest progress in controlling industrial pollution, which is most amenable to traditional regulatory approaches (World Bank 2001, 102). The policy on vehicle pollution control in China is quite similar to policies elsewhere, although it is in a much earlier stage of development and not enforced as effectively as it is in Europe and the United States. Like other countries, China places greater emphasis on manufacturers than motorists, and while there is interest in applying economic incentive measures, they are not widely used. Key components of China's strategy to control motor vehicle emissions include emissions standards for all categories of new vehicles, phasing out leaded gasoline, promotion of cleaner fuels, and establishing inspection and maintenance programs for vehicles under use (Walsh 2000). There has also been a policy in place since 1985 to discard old vehicles, with specific targets for the number of vehicles to be retired each year.

While China has the advantage of learning from the 30-year experience with motor vehicle pollution control policies in the United States, the results of specific policy measures may not be directly transferable since they were developed within an institutional context specific to the United States. China is at a different stage in its economic development and has considerably less experience implementing and enforcing pollution control regulations than the United States. In addition, there are important differences in the legal system and the nature of relationships between economic entities and the state. Nonetheless, China's current approach to controlling vehicle pollution is modeled after policies developed elsewhere, particularly in the United States, so it is likely that China may experience similar difficulties in controlling vehicle emissions.

Like other countries, a major component of China's mobile source pollution control policy is mandatory emissions standards for new vehicles. While China's emissions standards are scheduled to become more stringent over time, experiences elsewhere have shown that strict technological requirements on new vehicles would not be sufficient even if they could be strictly enforced. Poor vehicle maintenance is a leading cause of mobile source pollution problems in China (Walsh 2000, 30). Like other countries, the problem is due to a combination of improperly maintained pollution control equipment, ineffective emissions testing and repair programs, and lack of incentives to motorists to reduce vehicle discharges. The situation in China is compounded because emissions levels for vehicles currently used in China are comparable with the emissions levels that existed in Europe and the United States in the 1960s and 1970s (Kebin and Chang 2000, 38).

The situation could be improved if users of mobile sources were given incentives to control emissions since they are ultimately responsible for discharges from vehicles. A more user-oriented approach to controlling emissions from motor vehicles would provide incentives to individual motorists to reduce discharges and encourage the development of more environmentally-friendly products and processes. The incentives could take the form of pollution charges based on vehicle emissions (actual or estimated) or subsidies to purchase more fuel-efficient and less-polluting automobiles. Fuel taxes should also be differentiated to encourage the use of alternative fuels. While basing pollution charges on actual emissions would be ideal, a second-best policy would combine fuel taxes differentiated by pollution characteristics with vehicle taxes reflecting emissions characteristics.[12]

Taxing vehicles, whether at the time of purchase or through periodic registration fees, has the important advantage of being able to influence both in-use vehicles and new vehicles. Vehicle taxes should reflect the emissions characteristics of the vehicle – engine size, fuel type, fuel efficiency, and gross weight of the vehicle – and vary according to where it is registered. A system of differentiated vehicle taxes can be used to eliminate the bias against retiring older cars and also provide incentives for the development of cleaner vehicles and new pollution control technologies. Used in conjunction with taxes on fuels differentiated according to environmental characteristics, this policy would be less costly to implement, administer, and enforce than a program aimed more directly at vehicle emissions. Taxes to reflect actual or potential pollution costs create incentives to search for new and lower-cost abatement technologies. For example, diesel fuels tend to result in greater amounts of particulates and sulfur oxides than gasoline and this should be reflected in the taxes on diesel fuel.

Providing information to motorists about environmental characteristics of vehicles such as emissions rates and fuel economy (instrument 10, Table 4) should also be a key component of China's vehicle pollution control policy. This is a critical role for government in any economy because information is a public good and may not be provided through

[12] The extensive road construction program currently under development in China might make it practical to use remote-sensing devices in an intelligent transportation system to control discharges from vehicles.

market channels. This may be a particularly important role for environmental authorities in China since the motor vehicle industry is not yet well-developed. As the vehicle market develops, private sources of such information may tend to emerge. In the United States, the government provides information about vehicles' fuel economy, air pollution, and safety (e.g., USEPA 2002c), and vehicle manufacturers are required to display this information on window stickers on all new vehicles. Private market sources also rate vehicles according to various characteristics. With newly-emerging markets in China, this type of information is less available than in more advanced market economies, so the government can play a particularly important role in assisting motorists to make more informed vehicle purchases.

Another issue is whether vehicle emissions standards should be uniform across all regions in China. Because the environmental impact of a vehicle depends on when and where it is driven, there is a strong case for allowing vehicle emissions to vary across regions. Emissions standards might need to be more stringent in highly populated urban areas or other areas that would not otherwise be able to meet air quality standards. While uniform emissions standards reduce costs to vehicle manufacturers, they would only be consistent with meeting uniform ambient air quality standards if all of the factors determining vehicle emissions and air quality were identical everywhere. This is clearly not the case in large urban areas or where there are unusual geographic or weather conditions. Unless uniform emissions standards were set at a level sufficiently stringent to achieve ambient air quality standards under all circumstances, it would be necessary to take additional measures to control vehicle emissions in the most sensitive receptor areas.

In the United States, certain regions would not be able to achieve ambient air quality standards without enacting more stringent policies than the federal standards. A similar situation exists in China. However, given the division of responsibility among national and municipal government levels in setting environmental policies in China, major cities like Beijing and Shanghai can exert a significant effect on both manufacturers and motorists through their pollution control policies. Beijing, in particular, has taken aggressive efforts to control vehicle pollution, including phasing in new-car emissions standards ahead of the national schedule, requiring car manufacturers in China to retrofit all vehicles sold in Beijing from 1995 to 1998 with pollution control technology to meet Euro 1 standards, and retrofitting taxis and buses to use natural gas rather than diesel fuel (Walsh 2000). Such actions can have a powerful effect on market developments, such as developing cleaner vehicles and fuels, in a manner similar to the effect that California's more stringent policies have had in the United States. Economic incentive measures can be used to help meet more stringent standards in particular areas. For example, vehicle manufacturers and fuel refiners could be given pollution credits for exceeding clean vehicle or clean fuel requirements. This would allow stricter standards to be met at lower cost and provide continuing incentives to seek out new, lower-cost production methods and technologies to conform to regulations.

During the 1990s, there has been greater emphasis in China on using economic incentives to achieve environmental objectives, including a pilot SO_2 trading project in two medium-sized cities (Dudek et al 2001, Sun 2001). Nonetheless, applying prices and market principles to environmental services will necessarily take time to evolve as China moves gradually toward a more market-based economy. Even in the United States, the use of economic incentives took time to develop. For example, credits for reducing air pollution discharges beyond mandated performance standards were first introduced in the mid-1970's to allow averaging of emissions across entities (offsets) or individual sources within a single entity (bubbles). However, it was 1995 before emissions trading was implemented as part of a pollution control program to control acidic deposition, as mandated by Title IV of the 1990 Clean Air Act Amendments.

Important institutional requirements must be met for any environmental regulation to be effective, but this is particularly true for economic instruments such as emissions trading. Emissions allowances are intangible property rights, and legal institutions must be able to insure the integrity of the emissions trading system. Rights and responsibilities must be clear to all parties and enforced by courts. The transparency of the U.S. sulfur dioxide emissions trading program has also been important. Information on the allocation of allowances, emissions data, allowance transactions, and permit requirements are all available for public review.[13] The institutional requirements for implementing emission charges and pollution-related fuel and vehicle taxes are less stringent but still require administration and enforcement to achieve their goals.

China may be able to implement limited forms of emissions trading in mobile source pollution control. The most obvious applications would be to complement existing regulations that encourage scrapping of old high-emitting vehicles and to allow vehicle manufacturers and refineries to meet mandated performance standards more cost-effectively. While these programs do not put an overall ceiling on discharges, they provide a continuing incentive to seek less costly methods to reduce emissions beyond mandated standards. The program could at first be limited to internal trading within a single economic entity to allow greater flexibility in meeting pollution control standards. The credits would allow the entity to average emissions across a certain type of product (e.g., automobiles produced) or across a

[13] See USEPA 2002a.

number of discharge points (e.g., plants within a manufacturing firm). The program could be expanded to allow credits to be banked for future use or traded to other entities. This would involve relatively limited numbers of bilateral or intra-firm trades rather than extensive inter-firm trading on a well-organized exchange.

Programs like these may be particularly suitable for use in China because they can be used in conjunction with traditional regulatory standards. For example, vehicle manufacturers or importers might be allowed some form of averaging within their fleet or given credits for exceeding emissions standards for certain vehicles. Even greater cost savings could be achieved if emissions trading were allowed among vehicle manufacturers (or importers). The commodity that would be traded is estimated emissions reductions over the useful life of the vehicle, and manufacturers would earn emissions reduction credits for lowering their engines' emissions beyond the performance standard. The credits could be used by the source to offset excess emission reductions from current-year standards, transferable to other sources, or banked for possible future use. While this program would not represent a significant departure from traditional approaches, it would extend China's ongoing (experimental) efforts with economic incentives such as emissions fees and emissions trading for industrial pollution management. By allowing pollution standards to be met more cost-effectively, standards can be more stringent than they might otherwise be.

Regardless of the specific policies, all require government authority to establish and administer the regulations, measure and monitor performance, and enforce compliance. While it is clear that the government of China has the authority to establish regulations, a recent evaluation of China's vehicle pollution control laws concludes that, while important changes to regulations have been recently made, they have not been effectively enforced (PRCEE et al 2001, 65). The problem may be partly related to the early stage of development of the environmental legal system in China. However, in addition to improving the operational aspects and enforcement of the program, such as testing procedures for new vehicles and inspection and maintenance requirements for vehicles in use, it is important that the liabilities and responsibilities for controlling pollution from motor vehicles be made clear. Once the legal liabilities are clarified, incentive mechanisms can be employed to allow environmental goals to be met more effectively.

5 Conclusions

The Chinese government has encouraged the use of private automobiles as part of an economic development strategy. For this strategy to be sustainable, however, it is important that the environmental implications of increased motor vehicle use be considered. There are important weaknesses in existing policies to control vehicle pollution in China, and further steps will need to be taken to control vehicle pollution if China is to meet ambient air quality standards. Rather than employing traditional regulatory approaches, the government should focus on making motorists accountable for the full costs of using motor vehicles. Economic incentive measures could be gradually introduced to complement existing regulations. The government should also ensure that information is provided to motorists about fuel economy, emissions, and other environmental characteristics of vehicles. Based on the U.S. experience, environmental authorities in China should place particular emphasis on (1) clarifying liability arrangements for maintaining emissions performance of vehicles under use, (2) extending emissions controls to all mobile sources, including non-road sources, (3) introducing flexibility provisions to allow standards to be met cost-effectively, and (4) encouraging local environmental protection bureaus to adopt economic incentive measures to achieve local environmental targets.

Economic incentives will become more appealing as abatement levels become more ambitious and people become more aware of the increasing costs of environmental protection. While economic incentive measures allow environmental objectives to be achieved at lower cost than traditional regulatory methods, they should be phased in over time in China so as to be compatible with China's political, economic and legal system. Incremental improvements building on the existing regulatory system – such as the early U.S. experience with emissions credits – may be the most appropriate way to reach the ultimate goal of managing pollution efficiently. Instruments such as emissions trading must be developed within a specific institutional context, but require transparency and an effective legal system to insure the integrity of the program.

Literature

American Council for an Energy-Efficient Economy. 2002. *ACEEE's Green Book Online: The Environmental Guide to Cars and Trucks*. http://www.greenercars.com/

Banerjee, Neela, with Danny Hakim. 2002. "U.S. Ends Car Plan on Gas Efficiency: Looks to Fuel Cells," *New York Times*, January 9.

California Air Resources Board. 2001. *Zero Emission Vehicle Program Changes*, Fact Sheet.

Dan Dudek, Ma Zhong, Jianyu Zhang, Guojun Song, and Shuqin Liu. 2001. "Total Emission Control of Major Pollutants in China," *China Environment Series*, Issue 4. The Woodrow Wilson Center, Washington D.C.

Fullerton, Don and Sarah E. West. 2002. "Can Taxes on Cars and on Gasoline Mimic an Unavailable Tax on Emissions?" *Journal of Environmental Economics and Management,* 43 (1), 135-57.

Gruenspurecht, Howard K. 1982. "Differentiated Regulation: The Case of Automobile Emission Standards." *American Economic Review* 72 (May), 328-31.

Kebin He and Cheng Chang. 2000. "Present and Future Pollution from Urban Transport in China." *China Environment Series*, Issue 3, 38-50, The Woodrow Wilson Center, Washington D.C.

National Academy of Sciences. 2001. *Evaluating Vehicle Emissions Inspection and Maintenance Programs.* National Academy Press, Washington D.C.

OECD. 2001a. *Conference on Environmentally Sustainable Transport: futures, strategies and best practices*, 4-6 October 2000, Vienna, Austria (Synthesis Report). Organization for Economic Cooperation and Development, Paris.

OECD. 2001b. *Environmentally Related Taxes in OECD Countries, Issues and Strategie*s. Paris.

PRCEE (Policy Research Center for Environment and Economy), China National Environmental Monitoring Center, and Chinese Research Academy of Environmental Sciences. 2001. *New Countermeasures for Air Pollution Control in China*, Final Report. Beijing.

Standing Committee to Review the Research Program of the Partnership for a New Generation of Vehicles. 2001. Seventh Report. National Academy Press, Washington, D.C.

Stares, Stephen, and Liu Zhi. 1996. "Motorization in Chinese Cities: Issues and Actions," *China's Urban Transportation Development Strategy: Proceedings of a Symposium in Beijing*, November 8-10, 1995, Discussion Paper No. 352. The World Bank, Washington, D.C.

Sun Changjin. 2001. "Paying for the Environment in China: The Growing Role of the Market." *China Environment Series*, Issue 4, 32-42, The Woodrow Wilson Center, Washington D.C.

Tietenberg, Tom. 2001. *Environmental Economics and Policy*, Third Edition. Addison Wesley Longman, Boston, MA.

US Department of Energy and US Environmental Protection Agency. 2002. http://www.fueleconomy.gov/

USEPA. 1994. *Milestones in Auto Emissions Control*, Office of Mobile Sources, Fact Sheet OMS-12. Washington, D.C.

USEPA. 1997. *Environmental Fact Sheet: Accelerated Vehicle Retirement Programs.* Office of Air and Radiation, Office of Mobile Sources. Washington, D.C.

USEPA. 1999. *Major Elements of Operating I/M Programs*, EPA 420-B-99-008. Office of Mobile Sources, Washington, D.C.

USEPA. 2000. Office of Transportation and Air Quality, EPA420-B-00-001, Washington, D.C.

USEPA. 2001a. *Latest Findings on National Air Quality: 2000 Status and Trends*. Office of Air Quality Planning and Standards, Research Triangle Park, NC, 2001. www.epa.gov/airtrends

USEPA. 2001b. *The U.S. Experience with Economic Incentives for Protecting the Environment*, EPA-240-R-01-001. Office of Policy, Economics, and Innovation. Washington, D.C.

USEPA. 2002a. *Clean Air Market Programs.* http://www.epa.gov/airmarkets/progsregs/index.html.

USEPA. 2002b. National Emission Inventory. *Air Pollutant Emission Trends.* Office of Air Quality Planning and Standards, Washington, D.C. http://www.epa.gov/ttn/chief/trends/index.html

USEPA. 2002c. *Green Vehicle Guide*. http://www.epa.gov/greenvehicles/index.htm

Walsh, Michael P. 2000. "Transportation and the Environment in China." *China Environment Series*, Issue 3, 28-37, The Woodrow Wilson Center, Washington D.C.

World Bank. 2001. *China: Air, Land, and Water. Environmental Policies for a New Millennium.* Washington D.C.