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Fiscal Policy Instruments for Reducing Congestion and Atmospheric Emissions in the Transport Sector:

A Review

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Abstract

This paper reviews the literature on the fiscal policy instruments commonly used to reduce transport sector externalities. The findings show that congestion charges would reduce vehicle traffic by 9 to 12 percent and significantly improve environmental quality. The vehicle tax literature suggests that every 1 percent increase in vehicle taxes would reduce vehicle miles by 0.22 to 0.45 percent and CO_2 emissions by 0.19 percent. The fuel tax is the most common fiscal policy instrument; however its primary objective is to raise government revenues rather than to reduce emissions and traffic congestion. Although subsidizing public transportation is a common practice, reducing emissions has not been the primary objective of such subsidies. Nevertheless, it is shown that transport sector emissions would be higher in the absence of both public transportation subsidies and fuel taxation. Subsidies are also the main policy tool for the promotion of clean fuels and vehicles. Although some studies are very critical of biofuel subsidies, the literature is mostly supportive of clean vehicle subsidies

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Fiscal Policy Instruments for Reducing Congestion and Atmospheric Emissions in the Transport Sector: A Review [†]

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1. Introduction

Fiscal instruments are primarily price-based instruments that take advantage of market mechanisms and work through prices (Acutt and Dodgson, 1997). These instruments include: congestion charge or toll tax, emission and/or pollution tax or charge (e.g., carbon tax, sulfur tax), fuel tax (e.g., any excise tax on fuel or a BTU tax), vehicle tax (e.g., ownership, licensing or registration fee) and subsidies (e.g., subsidies for clean fuels, efficient vehicles, and public transportation). These instruments are expected to correct transport sector negative externalities through various means such as cutting travel demands, switching from private transportation to public transportation, substituting polluting fuels (e.g., petroleum products) with clean fuels (e.g., ethanol, hydrogen, compressed natural gas) and encouraging the public to use high-fuel economy vehicles.

Despite well-established theoretical foundations and a few examples of implementation, fiscal policies are associated with several issues that require further investigation before they are recommended for broader implementation. The most important issue is which fiscal policy instrument would be the most effective and under what conditions? Are these policies mutually exclusive? If not, what combination of these instruments would produce the best results? Answering these questions is crucial as hundreds of cities throughout the globe, mostly in developing countries, are severely suffering from the negative transport sector externalities and are currently seeking appropriate instruments to correct them. With these issues in mind, our goal is to review the following potential fiscal policy instruments: congestion charge; fuel tax; emission tax; vehicle tax and subsides, while trying to bring their comparative advantages to light[1].

[1] Note that there are other policy instruments, such as regulatory instruments (e.g., fuel economy standards, vehicle occupancy standards, high vehicle lanes), behavioral instruments (e.g., telecommuting, staggering work start times; promotion of multiple function trips) and infrastructure investment policies (e.g., bus rapid transit, metro etc.). This study focuses only on financial instruments for the sack of clarity and comparability of instruments considered. We leave reviews of other policy instruments for future studies.

Existing studies (e.g., Acutt and Dodgson, 1997), have reviewed alternative policy instruments used to reduce transport sector externalities. These studies however, focus only on their theoretical aspects and do not provide any quantitative information on the impacts of these policy instruments. To the contrary, our study discusses policy instruments that contain numerous examples of their actual implementation. The study first compares the different types of impacts the fiscal instruments have on vehicle mileage, congestion, emissions and welfare. Secondly, we compare fiscal policies that have been introduced throughout different parts of the world in terms of their ability to contain transport externalities, while providing some insight on how the same fiscal policy could produce different results in different geographical settings.

We find that the selection of fiscal policy instruments depends on several factors such as: type of problem (e.g., congestion vs. emissions), severity of problem, flexibility to achieve the goals, and cost of the policy instruments. Mega-cities with predominantly private vehicles and with severe congestion problems may prefer congestion charges. On the other hand, developing cities looking for additional government revenue sources with no serious congestion or emission problems might consider fuel taxes. Subsidies created for public transportation are a common and conventional phenomenon in all countries throughout the world, even though these subsidies are not intended to reduce emissions or congestions. However, the level of transport sector externalities might have been higher in the absence of subsidies to public transportation. Moreover, subsidies have played key roles in promoting clean fuels (e.g., biofuels in the United States) and are expected to play similar roles in promoting clean vehicles.

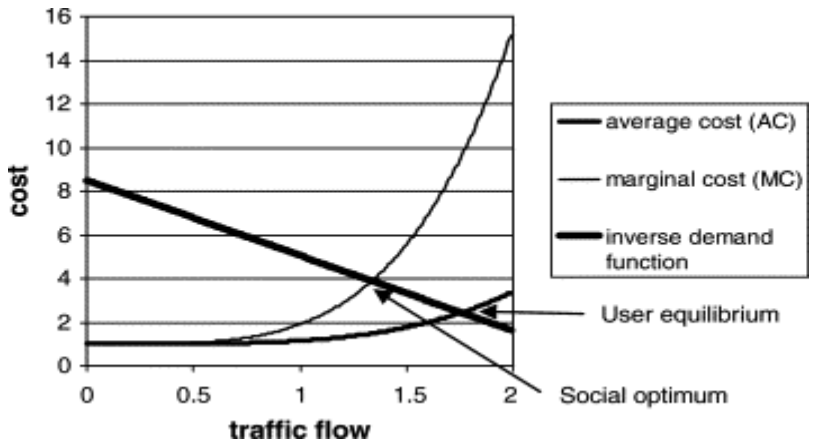
The paper is organized as follows: Section 2 discusses theory, real world examples, and impacts of congestion charge. Following is a brief review of fuel taxes including: fuel tax rates, revenue generation and environmental and economic impacts. Section 4 and 5 present, respectively, vehicle and emission taxes. In Section 6 we have an in-depth discussion of subsidies in public transportation, clean fuel and clean vehicles. Section 7 discusses parking charges. Section 8 highlights comparative pictures of the policy instruments being considered. Section 9 concludes.

2. Congestion Charges

The main principle of congestion pricing is to impose higher charges on travelers at times and places when road systems are congested. This reduces both social and environmental costs imposed by congestion through enhancing traffic flow and decreasing travel demands and emissions resulting from the idling and slowing of vehicles. Thus, congestion charges internalize the additional travel cost imposed by motorists on fellow travelers by altering their travel behavior (Sikow-Magny, 2003). This charge also encourages people to travel during off-peak hours, through non-congested routes or through other modes of transportation. It is considered an effective policy instrument in controlling vehicular emissions because it helps to reduce the number and duration of trips, alter routes, and offers decreases in speed variation (Daniel and Bekka, 2000). However, the willingness of motorists to pay congestion charges depends upon their level of income and their availability of alternative means of transportation (Sharp, 1966). Congestion pricing is theoretically well-established and implemented in practice throughout many urban centers, particularly in developed countries.

2.1 Theory of Congestion Charge

The theory of congestion pricing states that the charges imposed should equal the difference between the social marginal cost and the private cost for the flow, which will prevail only after imposing the charges (Jansson, 1969). Congestion charges are meant to internalize their external costs (Teubel, 1998). Pigou (1920) and Knight (1924) established a foundation to describe misallocation of resources resulting from free access to public roadways (see Figure 1). As illustrated in Figure 1, the average time taken for a motorist to travel a particular road segment increases with an increase in traffic flow. With the increased congestion, average speed decreases and average travel time increases for the driver. Thus, an increased travel time causes the average and the marginal travel costs to increase.



Source: Walters (1961)

Figure 1.The Pigou-Knight Analysis

Numerous studies (Vickery, 1969; Walters, 1961; Mohring and Harwitz, 1962; Kraus, 1981) persuaded Pigou to research the roles of taxation in an effort to internalize congestion externalities. Earlier studies (i.e., studies before nineties) focused mainly on reducing congestion (e.g., Walters 1961, Vickrey, 1963, Keeler and Small, 1977; Sullivan, 1983) whereas recent studies equally address both congestion and environmental pollution (Innes, 1995; Daniel and Bekka, 2000; Parry and Bento, 2002). These address the need and the effectiveness of taxation in correcting the misallocation of public resources associated with free access to public roads.

2.2 Congestion Charges in Practice

In order to reduce both the social and environmental costs associated with congestion, congestion charging systems have been adopted in various parts of the world with varying degree of success. Congestion charges that increase the cost of travel may convince motorists to alter their travel behavior, although some diversions of traffic may take place. The area licensing scheme (ALS), introduced by Singapore in 1975, is probably the first example of congestion pricing created to alter travel behavior. In this

system, only those cars with three or fewer people were charged. The charge ranged between $1.50 to $2.50 per day (Daniel and Bekka, 2000). In September 1998, after 23 years in operation, the ALS was replaced by an electronic version called the Electronic Road Pricing System (ERP), (Keong, 2002). In 2003, the city of London introduced a congestion charging scheme in which vehicles entering inside a 22-square km zone comprising core shopping, government, entertainment and business districts were required to pay a congestion charge of £5 between 7 AM and 18.30 PM on weekdays. The change has been increased to £8 since July of 2005 (Schmöcker et. al., 2005).

Table 1 presents congestion pricing schemes introduced in four countries: Singapore, Norway, the United States and the United Kingdom. Congestion charges are placed differently, by those who impose the schemes depending on the goals. In Singapore, the United States, and the United Kingdom, the primary objective behind road pricing is congestion relief, whereas in Norway, initially, it was designed to generate revenue (currently it is environmental quality and safety). In Singapore and the United Kingdom, motorists pay charges on a daily basis, unlike the United States and Norway where motorists pay a toll per passage. In Singapore, charges vary, depending on the peak and off-peak periods and are reviewed on quarterly basis (de Palma et. al., 2006)[2].

[2] Note that the congestion charge and road pricing are used interchangeably in some literature. In this paper we have distinguished between the two and focus only on congestion charges, as the purpose of road pricing could be different from reducing traffic congestion (e.g., revenue generation etc.). We have not included road pricing literature in this paper.

Table 1. Characteristics of Four Real-World Urban Road-Pricing Schemes

	Singapore	**Norway** (Various Cities)	**US** (Various Cities)	**United Kingdom** (London)
	Area license & electronic road pricing	Toll rings	High occupancy toll (HOT) lanes	Area congestion pricing
Inception year	1975	1986	1995	2003
Objectives	ALS (1975–98): congestion relief RPS (1995–98): familiarize users with link pricing; ERP (1998-): control congestion by maintaining range of speeds	Initially revenue generation. Amendments to Road Acts now permit demand management to enhance environmental quality, safety	Congestion relief	Demand management: primarily congestion relief
Type(s) of tolling	ALS: inbound cordon. Paid daily RPS: linear. Per passage ERP: CBD cordons and linear. Per passage.	Inbound cordons. Per passage.	Link. Per passage.	Area licensing scheme. Includes parking on public roads. Paid daily
Tolled area or infrastructure	ALS: 7 km2 restricted zone	Toll rings successively added in Bergen, Oslo, Namsos Trondheim etc.	Five projects: SR-91 and I-15 in California, I-10 and US 290 in Texas, I-394 in Minneapolis-St Paul	21 km2 charge area around city centre.
Means of payment	ALS and RPS: paper licenses with manual enforcement ERP: in-Vehicle Units (IUs) and smart cards	Electronic and manual	Electronic	Manual payment by various means
Time variation	ALS: morning peak, extended to evening in 1989 and to inter-peak in 1994; RPS: morning peak; ERP: CBDs 7:30–10, 12–19; expressways: 7:30–9:30. Changes in 5 or 30-min. steps. Reviewed quarterly.	Variable tolls in Trondheim & Stavanger. Flat tolls elsewhere.	I-10, US 290: flat	Flat charge on weekdays except holidays, 7:00–18:30
Annual revenues	ERP: €35M (1998)	Oslo: €143M (2002)	Other 4 facilities: constant., SR-91: $32M (2004)	Charges: € 65M Enforcement: € 102M
Annual operating costs	ERP: €3.75M	Trondheim: €23M (2002)	SR-91: $21M (2004)	€130M

Source: de Palma et. al., (2006).

A congestion charge not only helps correct transport sector externalities, such as emissions and congestion, but also generates a significant amount of revenue. For example, annual revenues generated through congestion charges are much higher than the annual operating costs in Singapore and Norway (see Table 1).

2.3. Impacts of Congestion Charges

In addition to alleviating traffic congestion, a congestion charge has several impacts, such as reducing fuel consumption, and improving environmental quality and social welfare. In this section, we briefly highlight these impacts.

2.3.1 Impacts on Transportation Services

By definition, the primary objective of a congestion charge is to reduce traffic congestion. The congestion tax system introduced in London for example, led to the reduction in city-center traffic by 12%; of which 50-60% shifted to public transport (Transport for London, 2004). Rich and Nielsen (2007) estimate that annual reductions in car mileage in Copenhagen would be 7%, 6.5% and 3%, respectively, if congestion charges are introduced based on km charging, cordon and large toll ring systems. The reduction in congestion time would be approximately 2-3 times as high as that of car mileage. It is estimated that daily inbound traffic would be reduced by 5% in New York if a toll or a variable charge (like MTA) is introduced on the East River Bridge (Zupan et al., 2003). A London-type congestion charge would reduce daily traffic volume in the city by 9%; if a full variable pricing is introduced the reduction could reach 13% (Zupan et al., 2003).

2.3.2 Impacts on Environmental Quality

A congestion charge reduces congestion, and as a result, reduces fuel consumption and associated emissions from vehicles which help improve environmental quality. Existing studies have assessed the environmental impacts of either proposed or actually implemented congestion charges. For example, Prud'homme and Bocarejo (2005) estimate the total environmental benefits generated by the congestion charge, introduced in London, at 4.9 million euros per year. The ex-post evaluation of the quantified impacts

of the congestion charging scheme in London, conducted by Evans (2007) show that distance vehicles traveled across London were reduced by approximately 211 million per year with a £5 charge, and 237 million with an £8 charge. The value of CO_2 emissions saved was £2.3 million to £2.5 million with £5 and £8 charges. Rich and Nielson (2007) discuss the socio-economic assessment of proposed road user charging schemes in Copenhagen. They estimate that CO_2 emissions in Copenhagen can be reduced anywhere from 11, 500 tons to 154,000,000 tons annually, depending upon the type of congestion charge (see Table 2). They also find that the congestion charges, based on distance traveled (i.e., km charge) could reduce the highest amount of CO_2 compared to other types of congestion charges, such as large toll ring, and small toll ring.

Table 2. Annual Reductions in External Effects in 2005

External effect	Km charge	Cordon charge	Large toll ring	Small toll ring
Reduced CO_2 tonnage (×1000)	154,000	138,000	58,000	11,500
Reduced accidents (number)	330	155	298	100
Reduced noise (1000 SBT)	2.7	2.7	1.2	0.2
Reduced wear damage (million DKK)	12	11	4	1

Source: Rich and Nielsen (2007)

A congestion charge not only reduces traffic congestion, but also reduces carbon monoxide (CO) and volatile organic compound (VOC) emissions proportionately more than other types of emissions (Abbott et al., 1995; Acutt and Dodgson, 1997). Daniel and Bekka (1999) estimate the impacts of congestion pricing on emissions of CO, nitrogen oxide and hydro carbons for an actual metropolitan highway network calibrating Delaware's household travel demand, and highway traffic count data in EPA's mobile 5a model. They find that vehicle emissions could be reduced as much as 10% in aggregate and 30% in highly congested areas through the use of a congestion charge.

2.3.3 Impacts on Economy and Welfare

A large number of studies have analyzed the economic and welfare impacts of congestion charges (see e.g., Walters, 1961; Weitzman, 1974; Richardson, 1974; Arnott et. al., 1994; Parry and Bento, 2002; Santos and Rojey, 2004; Eliasson and Mattson, 2006). Whether or not a congestion charge improves welfare depends on several factors, including the definition of welfare itself. Studies conducted as early as the 1960s have showed that congestion charges can increase welfare (see e.g., Walters, 1961; Weitzman, 1974). This is because a congestion charge ensures a more efficient use of existing infrastructure while generating revenues, which then can be invested in the road and public transport system surplus (Eliasson and Mattson, 2006). However, the welfare of those who use the roadscan decline if the revenue generated from such charges is not returned to them (Glazer and Niskanen, 2000). Parry (2002) finds that, under ideal congestion pricing, a congestion tax imposed uniformly across freeway lanes can achieve more than 90% of the maximum efficiency gains.

Existing studies such as Richardson (1974) and Arnott et al. (1994) argue that congestion charging could be regressive because it benefits higher income groups that the value time gained, and believe it worth the charge and thus, the people with small economic margins are worse off. As congestion charges disproportionately impact the travel choice of lower income households, revenue redistribution is the key to acceptability of congestion charging schemes. Evans (1992) argues that low-income groups can benefit from congestion charges if the revenue generated is invested in public transportation. This is because low-income groups use public transportation more often than higher income groups, and thus will profit more from the revenues generated through congestion charging. There are several proposals (Goodwin, 1989; Small, 1992; Verhoef et. al., 1997) put forward to enhance acceptability of congestion-pricing schemes. Small (1992) proposes reimbursing the travelers as a group to offset the regressive taxes and using revenue to fund new transportation services. Verhoef et al. (1997) suggest considering the motorists' preference while recycling revenues generated through congestion charges to the economy (e.g., investment in new roads, reduction of

fuel taxes). Different schemes for recycling congestion tax revenues obviously have different implications for different travelers. Eliasson and Mattson (2006), for example, show that women and low-income groups benefit the most when the revenue is used for improving public transport. The net benefit will be equal for men, and women on average, and benefit high income groups if revenues are used for tax cuts. The distribution impacts of congestion pricing depends upon where different population groups live and work, their mode of transportation for commuting, and the ways in which revenues collected are allocated (Santos and Rojey, 2004). Parry and Bento (1999) show that the net effect of a revenue-neutral tax on congestion can stimulate labor force participation at the margin. De Borger and Mayeres, (2007) argue that the better welfare improvement is possible only when the government differentiates variable car taxes between periods to capture greater differences in congestion between peak and off-peak periods. De Palma et al. (2006) find that welfare gains tend to increase with an increase in proportion of a transport network that is priced. They argue that, in order to stop extensive traffic diversions in places where only a small fraction of transport network is tolled, charges need to be set at relatively low levels.

3. Fuel Taxes

A fuel tax is a levy on the consumption of fuel in proportion to its pre-tax price (Gupta and Mahler, 1994). Traditionally it is introduced for several purposes, such as to raise government revenue with low administrative costs; to conserve foreign exchange, and to generate revenue to finance road maintenance, etc. (Gupta and Mahler, 1994). Fuel tax can, however, act as a pricing instrument to correct transport sector externalities, such as congestion and environmental pollution (Acutt and Dodgson, 1997). In the short-run, a fuel tax results in an increase in fuel price, which in turn, discourages utilization of vehicles and thus over-consumption of fuel and release of emissions. In the long-run, fuel taxes also alter consumers' purchasing behavior, thereby causing them to switch to more fuel-efficient methods (Acutt and Dodgson, 1997). Unlike other taxes, the fuel tax is administratively simple and well-established in principle. The fuel tax considers externalities that are not directly priced (Ubbels, 2002).

3.1 Fuel Tax Rates and Revenues

Table 3 compares fuel tax rates in Western Europe, Organization for Economic Co-operation and Development (OECD) countries and selected developing countries. In OECD countries, tax rates vary from 50 cents per liter in Switzerland to $1.03 per liter in Portugal. These tax rates are 5 to 10 times higher than that in the United States, where the average fuel tax was 10 cents per liter in 2005. Although the fuel tax is one of the policy instruments, it is not necessary that it always provides desired results. How effective a fuel tax would be depends on price elasticity, the fuel use, and other factors such as other policy instruments superseding the fuel tax (Bonnel, 1995). For example, despite low fuel taxes, private vehicle use is relatively smaller in Switzerland as compared to other European cities. Bern and Zurich have a lower rate of private car use than Lyon, Grenoble, Montpellier in France, Cardiff and Liverpool in Great Britain, Oslo in Norway, and Bologna and Milan in Italy where the fuel tax is among one of the highest in Western European countries. Other policy instruments, particularly, private car control measures over the past 20 years, are mainly responsible for decreased car use in Bern and Zurich (Bonnel, 1995).

It becomes evident from Table 3 that fuel tax rates in Western Europe are significantly higher than those in North America and other OECD countries. In most countries, fuel taxes provide more revenue than taxes on products such as tobacco and alcoholic beverages (Gupta and Mahler, 1994). In developing countries like Niger, Nicaragua, South Korea, and Côte d'Ivoire, fuel taxation accounts for more than 20% of total state revenue. The contribution of fuel tax toward governmental revenue is also fairly high in industrialized countries (See table 4). As in developing countries, fuel taxes in developed countries also account for substantial portions of state revenue. The fuel tax accounted for 10% of state revenue in the Netherlands, 12% percent in France, 17% percent in Spain, 17% in Japan, and 12% in the United States in 2004 (Metschies, 2005).

Table 3. Gasoline Taxes in Selected Countries in 2005

Country	Cents/liter	Country	Cents/liter
Western Europe		**Developing Countries**	
Portugal	103	Kenya	47
Netherlands	100	Malawi	50
United Kingdom	97	Mali	71
Belgium	94	Mauritius	29
Italy	90	Morocco	65
Germany	90	Niger	57
France	89	Nicaragua	24
Finland	85	Pakistan	17
Sweden	80	Panama	09
Norway	74	Senegal	65
Spain	72	Sri Lanka	27
Denmark	70	Turkey	99
Austria	68	India	42
Ireland	62	Ghana	04
Luxembourg	60	China	03
Switzerland	50	Brazil	39
Other OECD Countries		Albania	78
Japan	46	Colombia	27
New Zealand	42	Costa Rica	33
Australia	35	Bolivia	09
Canada	26	Chile	40
Mexico	21		
USA	10		

[a] expressed in purchasing power parity at 2000 constant price.
Source: IEA (2006) for OECD countries and Metschies (2005) for developing countries

Table 4. Fuel Tax Revenues as Part of Total State Revenues

Country	Percentage	Country	Percentage
Western Europe		**Developing Countries**	
Portugal	13	Kenya	9
Netherlands	10	Malawi	18
United Kingdom	14	Mali	10
Belgium	7	Mauritius	7
Italy	13	Morocco	11
Germany	8	Niger	20
France	12	Nicaragua	20
Finland	8	Pakistan	1
Sweden	6	Panama	2
Norway	8	Senegal	9
Spain	17	Turkey	18
Denmark	6	India	15
Austria	6	South Korea	33
Ireland	9	Brazil	5
Switzerland	7	Albania	24
Other OECD Countries		Côte d'Ivoire	20
Japan	17	Costa Rica	17
New Zealand	2	Eritrea	1
Australia	9	Chile	12
Canada	6		
Mexico	1		
USA	12		

Source: Metschies (2005)

3.2 Impacts of Fuel Tax on Travel Demand, Fuel Consumption and Emissions

Although the fuel tax is introduced mainly to generate government revenues, it could have significant impact toward the reduction of emissions and traffic congestion. A number of existing studies (e.g., Eltony, 1993; Hirota et al., 2003; Sterner, 2006) demonstrate how the fuel tax reduces travel demand, fuel consumption, and emissions. Employing an econometric model for household gasoline demand in Canadian provinces for 1969-1988, Elton (1993) finds that a 10% increase in the fuel price would cause 75% of households to reduce their vehicle travel within one year after the fuel price increase. As a result, 15% of households shifted from large to small vehicles, and 10% of households switched from less fuel-efficient to more efficient vehicles. Using the data from 68 large cities worldwide, Hirota et al. (2003) demonstrate that for every 1% increase in the fuel tax, vehicle miles traveled (VMT) could be reduced by 0.042%. Fuel taxes have played an important role in restraining growth in transport sector fuel consumption and associated carbon emissions in OECD countries. Sterner (2006) calculates that had the different OECD countries introduced a gasoline tax at the level of EU countries, such as Italy, the United Kingdom, and the Netherlands, gasoline consumption would have been reduced by 57% in the United States; 36% on average in Canada, Australia and New Zealand; 34% in Japan and 44% in the OECD as a whole. Since CO_2 emissions are directly linked with fuel consumption, this would translate into a substantial reduction in CO_2 emissions from the transport sector. Sterner also estimates that if all OECD countries had a low gasoline tax as does the United States, the total OECD gasoline consumption would have been 31% higher. These findings demonstrate the positive impacts of fuel taxes in fuel consumption and atmospheric emissions from the transport sector.

3.3. Fuel Tax Impacts on Welfare and Economy

Economic intuition suggests that a fuel tax will cause welfare loss unless the environmental quality improved by the tax acknowledges welfare measures. Much of the burden (i.e., welfare cost) are found to be born by low-income households. Nelson et al. (2003), for example, find that motorists in the lowest quartile in the Greater Washington metro area pay $141 million per year in gasoline taxes, yet still suffer from a negative travel-related welfare change. They argue that welfare loss among the lowest income groups, is mainly because they value travel time improvements less than higher-income travelers and suffer from increased crowding on transit networks under a gas tax policy. Using the econometrically-based multi-market simulation model, Bento et al. (2005) demonstrate a considerable heterogeneity regarding the impacts of a gas tax on the poorest households. They find that the distributional impacts of a gas tax increase on the households with annual income less than $25,000 is higher than for those households with incomes greater than $75,000 in the United States.

Some options exist designed to mitigate part, or even the whole losses of welfare caused by a fuel tax. Proost and Dander (2002), for example, show that if the revenue generated through gasoline taxes is recycled to cut labor taxes, it would improve the welfare effects. Parry and Bento (2002) find that the deadweight costs of the fuel taxes on labor force participation of those that are at the fringe can be reduced if the revenues collected through congestion taxes are used to reduce distortionary labor taxes.

Existing literature illustrates that government spending of fuel tax revenues further worsens the economic inefficiency. For example, Wiese, et al. (1995) show that with an increase in the allocation of motor-fuel tax revenue for the general use by the government, the absolute and relative burden of the lowest income household also increases, and the policy becomes more regressive.

Since an introduction of the fuel tax reduces welfare, a removal or a decrease of the fuel tax would alternately produce the opposite impact. Uri and Boyd (1998) show,

for example, that a reduction of 4.3 cents/gallon in the excise tax on gasoline and diesel fuel would result in an increase in welfare by approximately $3.59 billion in the United States although such a cut would lead to a decrease of $2.37 billion in state revenue.

There also exists some literature that finds fuel taxes progressive (Hughes, 1986, Casler and Rafiqui, 1993). Hughes (1986) shows that the net effects of taxes on petroleum are progressive in their distributional impacts and can be used to increase both equity and allocative efficiency. Casler and Rafiqui (1993) argue that taxes on transport fuel are far less regressive than they are perceived to be. Toeing follows the same line, Poterba (1991) argues gasoline tax to be far less regressive than conventional analyses suggest.

4. Vehicle Taxes

Depending upon the transportation policies adopted by countries or the local jurisdiction, a vehicle tax could be a non-recurrent payment in connection with its purchase and registration (e.g., turnover tax, registration tax, registration fees). Alternatively, it could be periodically charged to the vehicle as a tax on the ownership or tenure (e.g., vehicle tax, insurance tax) (Kunert and Kuhfeld, 2007). In addition to acquisition and ownership taxes, usage dependent taxes, fuel taxes, and value-added taxes are also imposed in many European and Asian countries. These taxes or charges may represent a significant burden on the acquisition and ownership of new vehicles by motorists. A vehicle tax can also be interpreted as a policy instrument designed to reduce emissions and congestion, discouraging use of private vehicles; moreover it could substitute private vehicles with public transportation services.

Several factors are taken into consideration while creating vehicle taxes. Analyzing vehicle related charges and taxes in twenty-seven European countries, Kunert and Kuhfeld (2007) find that a broad range of factors are taken into consideration while imposing vehicle related taxes and charges in Europe. In Denmark, ownership tax is based on the fuel economy, whereas in Germany, it depends on emission standards. In

Sweden and the Netherlands, vehicle gross weight and fuel type are the criteria used to impose vehicle ownership tax. Vehicle ownership tax in France and the United Kingdom is based on CO_2 emissions. In most European countries, vehicle ownership taxes depend on the engine model, the engine capacity, the fuel type, and the vehicle age or vehicle gross weight (Hirota et. al., 2003). In Asia, vehicle ownership tax includes road tax, the re-registration fee, and the rate often depends upon engine capacity. In Thailand and the Philippines, the vehicle ownership taxes are based on vehicle gross weight; while in Malaysia they are based on engine capacity (Hirota et. al., 2003).

In some countries, such as Singapore, vehicle taxes have been used as the primary measure for discouraging private transportation and thereby reducing air pollution and congestion. Policies such as high vehicle ownership taxes, including the Additional Registration Fee (ARF), the Excise Duty and the annual Road Tax, and the Vehicle Quota System (VQS) have successfully contained congestion and other traffic externality problems in Singapore (Ang, 1996; Willoughby, 2000). These fiscal instruments significantly discouraged private vehicle ownership in the country during the 1970s and 1980s (Barter, 2005). Since 1990, the VQS has also been applied to discourage private vehicle ownership[3]. During 1990 - 2002, the VQS succeeded in bringing down the average annual motor vehicle population growth rate to 2.8% from 4.2% (Santos et. al., 2004). Similarly, a strong growth in the vehicle fleet, especially private cars and motorcycles, was successfully curbed through a registration tax (FTR) and an annual license fee (ALF) in Hong Kong (Khan, 2001).

4.1 Reductions in Vehicle Mileage, Fuel Consumption and Emissions

[3] VQS system requires new vehicle owners first to secure a 10-year Certificate of Entitlement (CoE). It is to be purchased through an open auction out of a quota pre-established by the government. The Quota Premium has risen steadily through 1994 and reached above US$27,000 equivalent for medium-sized cars and above US$45,000 for larger cars (Willoughby, 2001).

Car-related taxes play an important role in reducing over all VMT and CO_2 emissions. Hirota et al., (2003) using data from 68 large cities, 49 OECD countries and 19 non-OECD countries in Asia show that for every 1% increase in ownership tax, VMT decreases by 0.22% and for every 1% increase in acquisition tax, VMT decreases by 0.45%. However, for a 1% increase in acquisition and ownership taxes, CO_2 emissions decreased by 0.19% and 0.19% respectively. Although higher acquisition and ownership taxes discourage vehicle ownership, it might not if the acquisition and ownership taxes of used vehicles remain low. People may respond to higher taxes and fees by buying older, less fuel efficient models (Pritchard and DeBoer**,** 1995).

5. Emission Taxes[4]

An emission tax refers to a levy charged directly on effluents, or on a fuel in proportion to contents of emission causing elements of the fuel. For example, a NO_x (Oxides of Nitrogen) tax is charged based on the amount of NO_x released from a vehicle. A carbon tax, on the other hand, is levied for fuels in proportion to their carbon contents. Similarly, a sulfur tax is also levied for fuels based on their sulfur contents. In general, if the content of a fuel (e.g., carbon, sulfur) is primarily responsible for the emissions, the tax is based in proportion to that content. On the other hand, if the source of emissions is not only the content of the fuel, but also other factors, the emission charge is then directly applied to the emissions. For example, NO_x is released not only due to the oxidation of nitrogen present in a fuel (i.e., fuel NO_x), but also in the atmospheric nitrogen (i.e., thermal NO_x).

Three types of emission taxes are normally found either proposed or introduced in order to reduce transport sector emissions. These are: (i) taxes on local air pollutants such as suspended particulate matters (SPM), volatile organic compounds (VOCs), (ii) taxes

[4] Literature on emission taxes to reduce transport sector externalities is limited. There are two reasons behind this. First, in contrast to a stationary source, monitoring of emissions is expensive for mobile sources and hence the emission tax might not be the preferable instrument to reduce transport externalities. Secondly, emission taxes when applied to a fuel (e.g., carbon or sulfur taxes) might be interpreted as fuel taxes and included in the fuel tax category.

on local, as well as regional air pollutants, such as NOx, SOx (e.g., sulfur tax) and (iii) taxes on GHG emissions (e.g., carbon tax). The first types of taxes are not common. The second types of taxes are found introduced in a number of cities, such as Tokyo. Moreover, a reduction in the sulphur content of fuel is important not only to reduce SO_2 emissions, but also to improve the effectiveness of catalysts used to reduce NO_x (Sheffield et. al., 2001). Mobile sources are subject to the sulphur emissions charges in Japan. The Japanese government has levied sulphur emissions charges to compensate victims of SO_2 pollution-related diseases.

The carbon tax is the most widely discussed policy instrument in literature due to overwhelming interest by researchers on climate change. A carbon tax can be introduced uniformly to all types of energy consumers (e.g., households, industry, government etc.) and hence literature on carbon tax that is focuses specifically on the transport sector emissions is not common. Some studies (e.g., Timilsina & Shrestha, 2002) which provide information on the sectoral impacts of a carbon tax could shed light on its impacts on transport sector emissions. One should, however, be cautious while interpreting these results because the transport sector in most CGE models does not account for private transportation but for the household sector. Speck (1999) finds impacts of the carbon tax to be moderate based on the type of fuel (transport or heating) that is being taxed. Barker and Köhler (1998) argue that the taxation of transport fuels possesses, although weak, a progressive outcome for most European Union countries. They suggest that the overall weak regressive effect of carbon taxes is due to taxes on domestic energy used for heating.

6. Subsidies

A subsidy is a traditionally-used, and probably the most common, fiscal instrument in the transport sector, particularly in developing countries. A subsidy can be provided to public transportation (e.g., bus, railway and water transportation), clean fuels (e.g., ethanol, bio-diesel) and clean vehicles (e.g., fuel cell and hydrogen cars, CNG bus, etc.).

While subsidies for public transportation could reduce both emissions and congestion, subsidies for cleaner fuels and vehicles do not necessarily help reduce neither congestion nor the number of cars on the roads. However, clean fuel and vehicle subsidies can help reduce emissions in the transport sector.

6.1 Subsidies on Public Transportation

Switching to public transportation (e.g., rail, bus) from private transportation (e.g., car) is considered an effective policy instrument designed to reduce transport sector externalities, mainly congestion and emissions problems. Subsidies on public transportation could be the main fiscal instrument that triggers a change from one mode of transportation to another.

Public transportation has already been subsidized in many countries around the world for several reasons. For example, only 25% of the total capital and operating expenses in the United States and 50% in Europe are covered by fares for public transit (Brueckner, 1987). In developing countries, public transport subsidies are necessary mainly because drivers, in low-income households, can neither afford to own private vehicles, nor pay the actual fare if public transportation is not subsidized (Cropper and Bhattacharya, 2007). Public transportation subsidies can thus be interpreted as environmental policy instruments from two angles. First, existing subsidies could have contributed to both reducing emissions and congestion because some users of public transportation could have used private transportation and thus increased emissions or worsened congestion in the absence of such subsidies. For example, Cropper and Bhattacharya (2007) find that removal of the bus subsidy (i.e., a 30% increase in fares) would reduce bus commuters by 10-11% in Mumbai, India. Second, additional subsidies on purely environmental grounds could help reduce emissions and congestion by encouraging travelers to switch to public transportation from private transportation. Note that an increase in public transport subsidies would reduce fares of public transportation thereby increasing ridership (De Witte et. al., 2006). With increases in public transport ridership, there will be fewer cars on the roadways, which will result in the reduction in total atmospheric emissions from the transport sector (Acutt and Dodgson, 1997).

Subsidies in public transportation could have both short- and long-term effects. In the short-term these subsidies will help reduce the use of private vehicles as well as congestion and emissions. Whereas in the long-term, they could reduce ownership of private vehicles and further reduce the externalities. Based on evidence regarding the relationship between public transport generalized costs and car ownership, Goodwin (1992) argues that increased public transport subsidies coupled with better service quality will certainly result in the reduction of car ownership and increase the public transport demand .

6.2 Subsidies on Clean Fuel

Subsidies are key fiscal policy instruments designed to promote clean fuel, particularly the use of biofuels. Subsidies on biofuels are common practice in countries where their production is significant (e.g., Brazil, United States, and Germany). In India, sugar mills interested in setting up ethanol production facilities, receive subsidized loans for 40% of project costs from the government. Ethanol subsidies are directed towards consumers in Brazil. Sales taxes are lower for hydrous ethanol (containing water) and E25 (25 percent ethanol) than gasoline (Coyle, 2007). In the European Union, twenty one countries grant a tax exemption (full or partial) for each liter of biodiesel supplied on the market, whereas twenty countries grant tax exemptions on bioethanol (Kutas et. al., 2007). Biofuel subsidies are often justified on the basis of their alleged positive effects on climate, energy, and agricultural policy goals (Henke et. al., 2005).

There has been a tremendous growth in the Ethanol market in the United States in the past two decades from 550 millions gallon in 1984 (Rask, 1998) to 3,600 million gallons in 2004 (Shapouri and Gallagher, 2005). Along with increases in production, the number of ethanol producing plants has also increased. They increased from fewer than 20 in 1980 to more than 80 in 2004 (Shapouri and Gallagher, 2005). However, unlike in Brazil, where ethanol accounts for about 30% of gasoline demand, its share is only 2% of the total transport fuel demand in the United States (Fulton, et. al., 2004).

There are several major subsidies and incentives introduced by federal and state governments in the United States. The federal incentives include: Biodiesel Blenders tax credit, smaller producer tax credits Federal Bio-based products preferred procurement program, United States Department of Agriculture (USDA) Energy Systems and Energy Efficiency Improvements Program, and the USDA Value-Added Producer Grant Program. It is argued that without the existing federal and state subsidies, which average about $0.8 per gallon, ethanol production in the United States would not be economically viable (Saitone et al., 2007). The total cost of ethanol subsidized both by the federal and the state government was estimated to be $5.1 billion in 2006.

With changes in market conditions, the institutional structure surrounding ethanol has also changed substantially. Following Schumacher (2006), Tables 5(a) and 5(b) highlight the federal and state-level subsidies and other incentives for transportation of clean fuel in the United States.

Table 5: Federal and State Level Subsidies on Clean Fuels in the United States

Table 5(a): Federal Level Subsidies

Subsidy	Description
Biodiesel Blender Tax Credit	Producers receive a tax credit of $1.00 per gallon of biodiesel produced from virgin oil, which could be either animal fats or oilseeds.
Smaller Producer Tax Credit	Producers with less than 60 million gallons of biodiesel or ethanol per annum can receive a tax credit of $0.10 per gallon for the first 15 million gallons of production, with a maximum tax credit being $1.5 million per year.
Alternative Fuel Infrastructure Tax credit	Tax credit is equal to 30% of the cost of alternative refueling property, maximum amount being $30,000 for businesses and $1000 for individuals using alterative fuels such as Biodiesel blends of B20 or more and ethanol blends of E85 or greater
USDA Renewal Energy Systems and Energy Efficiency Improvement Programs	Projects generating energy from renewal sources (including biodiesel and ethanol) can get grants of up to $500,000 and loan guarantees of up to $10,000,000. However, grant requests are limited to 25% and loan guarantees are limited to 50% of the total project costs.

Table 5 (b): State Level Subsidies

Subsidy	Description
Montana	
Biodiesel Production Facility Tax Credit	Tax credit equal to 15% of the cost to compensate for depreciation of equipments in the construction and facilities to be used for the production of biodiesel
Biodiesel Production Incentive	Producers receive $0.10 for each gallon of biodiesel produced that represents an increase over the previous year's production. However, this incentive is available only for the first three years of a production facility's operation and is scheduled to expire on July 1, 2010
Refund for taxes paid on biodiesel by a distributor or retailer	A refund of $0.02 per gallon is paid to the distributor and $0.01 to the retailer for the previous quarter, if biodiesel was produced entirely from ingredients produced in the state of Montana
Alternative Fuel Conversion Tax Credit	50% of the cost (up to $500) of converting vehicle that runs on fuel blended with a minimum of 85% methanol or ethanol
Idaho	
Biodiesel Production Tax Deduction Program	Tax deduction for distributors of biodiesel produced from oilseeds or animal fats. However, It is provided in the form of a reduced tax rate, $0.225 per gallon as opposed to $0.25 per gallon for petroleum and diesel and is not applied to more than 10% of the volume of biodiesel
Wyoming	
Ethanol Credit Program	A $0.40 per gallon credit for ethanol producers if 25% of their feedstock purchases are produced in Wyoming. However, there is a ceiling of $2 million per year for individual producers
North Dakota	
Biodiesel Tax Credit	A biodiesel tax credit of 10% per year up to five years for costs incurred to develop or modify a facility to produce or blend biodiesel. However, the amount received as a tax credit cannot exceed $50,000 per year and a cumulative maximum of $250, 000
Ethanol production incentive programs	Facilities that produce fewer than 15 million gallons receive a maximum of $900,000. The incentive, however, decreases once the facility exceeds the ceiling of 15 million gallons. After 15 million gallons, they qualify for a maximum of $450, 000.
Iowa	
Ethanol Infrastructure Cost-Share Program	Up to $325,000 for eligible facilities that convert or build infrastructure required to distribute E85 fuel. Retailers can claim an ethanol tax credit of $0.025 per gallon for every gallon of ethanol blended fuel that they sell in excess of 60% of their total volume
Illinois	
Clean school bus program	Rebates of up to 80% or maximum $4000 towards the purchase of alternative fuel vehicles. Sales or use tax exemption on biodiesel blends of 10% or more
Minnesota	
Ethanol production incentive program	A $0.20 per gallon incentive to ethanol producers; however, a producer cannot receive more than $3 million under this program

Some environmentalists and economists argue against the ethanol subsidy, citing its dire effects for both the economy and the environment (Stiglitz, 1998). Pimentel (2003) argues that subsidized ethanol production is not only environmentally deleterious, but also ethically questionable because corn production causes more total soil erosion than any other crop and also increases environmental degradation. Pimentel further argues that diverting human food resources to the costly inefficient production of fuel raises an ethical question as more than half of the world's population is malnourished.

6.3 Subsidies on Clean Vehicles

Subsidies or some form of financial incentives are necessary to encourage automobile buyers to purchase low carbon-emitting vehicles such as hybrid cars. In many countries, electric vehicles and vehicles fueled by alternate fuels are subsidized by the government. For example, Chinese cities such as Beijing, Shanghai Tianjin, Shenzhen, Xi’an, Chongqing and Changchun have begun a program called ‘National Clean Vehicle Action’ since 1999 to combat vehicular pollution and also to reduce oil dependency. This program was introduced to encourage the use of Compressed Natural Gas (CNG) and Liquid Petroleum Gas (LPG) in transport. Local governments provide financial support to this program. In 1998, the Shanghai Municipal Government provided 9 million Yuan and exempted import duty on equipment to build LPG stations (Zhao, 2006).

Subsidies can facilitate market penetration of High Efficiency Vehicles (HEV) such as hybrids. According to Maclean and Lave (2003), a hybrid vehicle needs to be driven for 14 years or 313,000 kilometers before customers begin to enjoy true financial benefits. In the United States and Japan, the governments offer consumer tax deductions for the purchase or conversion of an approved clean fuel vehicle. The federal government in the United States offers consumers tax deductions ranging from $2,000 to $50,000 towards incremental expenditure increases for the purchase or conversion of an approved clean fuel vehicle (Perkins, 1998). In Japan, a separate reduction in the acquisition tax for vehicles that meet certain emission targets exists (Hirota et. al., 2003). Like the United States and Japan, Malaysia also provides financial incentives to encourage the use of

clean fuel vehicles. The Malaysian government provides public service vehicles in urban areas using natural gas to ease the strain of road taxes: monogas vehicles receive a 50% discount and bi-fuel or dual fuel vehicles receive a 25% discount (Hirota et. al., 2003). In Finland, sales tax is lower for low-emission vehicles. In the Netherlands, although the car purchase tax is 45.2%, there are fixed allowances of 1,540 euros for LPG cars (Potter and Parkhurst, 2005).

There exists a consensus among existing studies that subsidies are necessary to promote clean vehicles. Rubin and Leiby (2002) argue that, without subsidies, no substantial hybrid penetration is possible; they estimate that a permanent subsidy of $1600 per vehicle would ensure a market share of hybrid vehicles at about 45%, while a $4000 subsidy could increase the share to 90% in the United States. Using the MARKAL model, Ichinohe and Endo (2006) show that the share of hybrid passenger cars in 2030 could be 62% and the peak total subsidy required to achieve that share would be $1.23 billion per year in 2020 to reduce energy related annual CO_2 emissions 8% below the 1990 level through 2030 in Japan. Based on a survey conducted to study the rebound and other possible affects of tax rebates among 367 buyers of the hybrid second-generation Toyota Prius car in Switzerland in the first 9 months after the market entry, Haan et. al. (2007) finds that the tax rebates incentives could lead to significant increases in sales in Swiss cantons having tax rebates. Similarly, Potoglou and Kanaroglou (2007), using the Nested Logit (NMNL) model, find that the reduced monetary costs, purchase tax reliefs and low emission rates are the factors that would encourage households to buy cleaner vehicles within the metropolitan area of Hamilton, Canada. Carlsson and Johansson-Stenman (2002) show that battery-powered cars cannot compete with conventional gasoline powered cars in the Swedish transport sector unless an unanticipated major breakthrough in battery technology occurs, thereby implying for a subsidy for electric vehicles. According to Funk and Rabl (1999), as the social cost of the Electric Vehicle (EV) is at least 50% more than that of gasoline-powered cars, the cost of air pollution associated with cars using gasoline alone is not enough to give the EV a clear advantage against all conventional cars.

7. Parking Charges

Parking charges can also be interpreted as an instrument to reduce transport sector externalities as it could discourage driving through increasing the costs of car use. Moreover, in areas where parking charges are levied, it could lead to an increase in the use of public transportation (Acutt and Dodgson, 1997). Feeney (1989) shows that an increased parking cost and decreased availability may have five major effects on motorists: (1) change their parking location, (2) change starting time of their journey, (3) change the mode used, (4) change trip destination and (5) abandon the trip altogether. Willson and Shoup (1990) estimate that an increase in parking charges for all employees in government offices in Ottawa, Canada not only led to a 20% reduction in single car trips, but also forced a model shift. Through simulation studies of five British cities, Dasgupta et al. (1994) demonstrate that doubling the parking charges reduces car share of central area trips by 13%, from 56% to 43%.

8. Policy Implications

8.1 Single or multiple policy instruments?

As there is no single policy that fits all prescriptions when it comes to designing appropriate fiscal instruments to combat transport sector externalities, many cities around the world, particularly in developing countries, are experiencing difficulty in trying to determine appropriate sets of policy instruments to reduce the transport sector externalities. Existing literature (e.g., Molina and Molina, 2004) suggests that urban air pollution originating from transport activities cannot be solved through one specific strategy; instead, it requires a mix of policy measures that best suit each city's specific circumstances. For example, as marginal decisions to travel are directly affected by a set of taxes and charges such as fuel taxes, road pricing, and other road usage related charges, imposition of fuel taxes alone may only account for some externalities but not all. Although fuel taxes, to some extent, can be justified as road use charges, they are

relatively blunt instruments and may not account for marginal congestion costs. In congested urban conditions, fuel consumption per km increases as a result of which marginal congestion costs can exceed fuel taxes by a factor of 20 or more (Newbery, 2001). Imposing vehicle ownership taxes may discourage car ownership, but not its use by motorists. In order to discourage both car ownership and usage, it may be necessary to implement car ownership taxes and other vehicle use related charges concurrently (Faiz et.al. 1990). Thus, a well-designed tax on vehicle ownership and use and on fuel consumption would be more affective than the introduction of these instruments in isolation

8.2 Which Policy Instruments and Where?

Some governments favor policy instruments which fulfill multiple objectives. For example, the New Zealand government favors a combination of energy taxes, fuel taxes and carbon taxes (Scrimgeour, et. al., 2005). However, some argue that fiscal policy instruments that directly address externalities would be the most efficient ones, for example, congestion tax or charge to reduce congestion or emission tax to reduce emissions. An energy tax could encourage energy conservation, reduce emissions and increase government revenues; however, an energy tax is always more costly than the emission tax if the primary objective of the tax is to reduce emissions (e.g., Goulder, 1995; Timilsina and Shrestha, 2007). This is because an energy tax is an indirect instrument and an emission tax is a direct instrument designed to reduce emissions.

Selection of fiscal instruments to reduce transport sector externalities within cities depends upon the specific situation of the city. Kingham et al. (1999), for example, cautioned the use of fuel taxes alone to reduce transport. They argue that, although fuel taxes could be effective in terms of smoothing traffic flows, reducing congestion and emissions, an increasing fuel prices, they will have limited impact if not accompanied by alternative modes of incentives. More specifically, in a city where a public transport system is weak, a fuel tax does not necessarily result in switching to public transportation from private transportation. Hence, a fiscal policy instrument which works in one country

may not necessarily work in others with a different socioeconomic and cultural context. For example, policy instruments, like Area Licensing Scheme (ALS) which was viewed as very successful in Singapore, might not work in countries like India or Indonesia. Although this policy is easy to comprehend and relatively cheaper to enforce in developed countries like Singapore and the United States, it might be expensive because of socio-economic and political settings in developing countries (Chin, 1996). In low-income countries with low administrative capacities, an instrument with smaller or no monitoring costs (e.g., fuel tax, emission tax) would be more effective than those requiring large monitoring or administrative and compliance costs (Gwilliam and Shalizi, 1996).

Some existing studies, such as Michaelis and Davidson (1996), Acutt and Dodgson (1997), Sterner (2006) argue that fuel taxes tend to be the most effective ones when it comes to reducing CO_2 emissions. This is true only when the fuel tax is designed in proportion to the carbon contents of the fuel used. If the fuel tax is designed based on its heat content or refinery gate price, it would not be effective to reduce emissions; instead, it would be effective to generate revenues. Newbery (2001) suggests that fiscal taxes on road transport fuels are the most important energy taxes that can be justified as a second-best mechanism for charging for road use and environmental damage.

8.3 Basis for a Policy Instrument: Efficiency or Equity?

Fiscal policy instruments are normally compared based on their overall economic or welfare effects. However, there is no consensus in the literature on the basis at which the instruments are compared. What should be the basis for the comparison of policy instruments: efficiency or equity? Or any other criteria such as implementation, administration and compliance costs? Using the model of a discrete choice of vehicle bundle and the continuous choice of vehicle-miles-traveled, West (2004), demonstrates that taxes on vehicle engine size, which is the basis for vehicle ownership taxes in many countries, or subsidies to new vehicles are significantly more regressive than gas or mileage taxes. This implies the use of efficiency as a yardstick for comparing the

instruments. On the other hand, Aasness and Larsen (2003) argue that some environmental taxes levied on specific consumer goods lead to a more equal distribution than others. They state that a differentiated, empirically-based tax system may attain both environmental targets and distributional goals. Following the equity argument, lower taxes on bus rides, bicycles, and mopeds, whereas higher taxes on air flights, taxis, and automobiles have positive environmental effects as well as inequality reduction potential.

Taxes (e.g., congestion changes, emission taxes) have a greater potential to reduce emissions and congestion, however, one of the major challenges facing implementation of these instruments is how to ensure that transportation costs to low-income travelers are not disproportionately high. Faiz et al. (1990) suggests that it is not easy to establish economically-justified and socially-acceptable motor vehicle control measures in developing countries because the magnitude of the problem and its consequences are not yet well understood. According to the equity principle, in developing countries where low income households cannot afford private vehicles, the wealthy should bear a relatively larger share of the tax burden than the poor. On the contrary, in high-income countries, where fuel use for road transportation is not a luxury good, ability to pay the principle does not hold true (Rietveld and Van Woudenberg, 2005). Jacobsen et al. (2003) find that higher taxes on private transport (registration duty and petrol tax) would be one way to balance the distributional impact of other environmental taxes.

8.4 Are Policy Instruments Introduced in Developed Countries Applicable to Developing Countries?

As the severity of the impact of air pollution increases, assimilative capacity of the environment, public attitudes, and degree of urbanization, transportation systems, and economic conditions, developing countries are confronted with the daunting task of answering a very basic question: What strategies should be adopted, how soon, and at what cost? (Faiz et.al.1990). Although developing cities have taken steps towards vehicle use restrictions, new technologies, privatization, transit management, transit service

innovation, and transportation pricing, very few, however, have taken concrete steps towards actually solving the problem (Gakenheimer, 1999).

Existing literature (e.g., Kathuria, 2002a) points out that it is extremely important to discourage ownership of private vehicles in developing countries. With rapid population growth, growth in disposable income, and out-migration of rural population, the cities in developing worlds are going to witness rapid surges in urban transportation demands. Between 370 and 600 new vehicles are being registered every day in Delhi, India. In an advent of such a rise in the number of vehicles, improvement in air quality is an illusive dream (Kathuria, 2002a).

As many large cities in the developing world are the centers of education, research, and innovation, the decline in mobility significantly damages the roles that they play. Thirty-five percent of Bangkok's gross city product is lost in congestion (Gakenheimer, 1999). He argues that countries in the developing world need to resort to assertive policies of congestion pricing and various kinds of ownership/use charges. In Bangkok and Kuala Lumpur, area licensing schemes resembling Singapore's have been repeatedly proposed. Although assertive policies of pricing have not appeared on a long-term basis in the lower income countries, with the passage of time and growth of the congestion problem, it may become a real possibility.

According to Eskeland and Jimenez (1992), price-based instruments are superior and provide greater certainty in reducing transport sector externalities. In developing countries, where the buses and taxis account for the greater percentage of public transportation, market-based solutions such as fiscal incentives can prompt car owners to convert their vehicles to run on alternative fuels such as LPG, CNG, or alcohol. Faiz etal. (1990) argues that higher taxes and license fees on the use of old, polluting vehicles can discourage the ownership of polluting vehicle fuels. Musgrave and Musgrave (1989) recommend the fuel tax because of the low enforcement costs and because user fraud is difficult to accomplish. However, even though the fuel tax is administratively simple to implement and targets most important emissions effectively, it is not sufficient enough to

base the entire policy framework for emission reductions (Johnstone and Karousakis, 1999).

There is a rapid growth in the number of motor vehicles in much of the developing world. In most countries, the growth is taking place at more than 10% a year and the doubles within 7 years (Gakenheimer, 1999). Thus, relying on single instruments, specifically command and control instruments (CAC), may be insufficient in controlling emissions from transport sectors in developing countries. Using the ambient air pollution data collected from the busiest intersection in Delhi, India, Kathuria (2002a) empirically demonstrates that CAC measures have not led to concomitant improvement in ambient air quality in the city.

Eskeland and Jimenez (1992) argue that, although there are no rigorous studies of pollution control in developing countries, there exists convincing casual evidence that regulations to protect the environment are ineffective or unnecessarily costly. The developing countries that have heavily relied on regulatory measures, containing vehicular emission through CAC instruments might be an uphill task. With the rapid increase in the number of vehicles, unless the enforcement standards are made more stringent, a regulatory approach based on emissions standards alone is bound to result in greater pollution (Kathuria, 2001b).

As there is no certainty about where the growth of motorization in developing countries will attenuate, its rapid growth shall continue for years to come. In order to avoid high economic and social impacts costs, Gakenheimer, (1999) suggest that actions to confront costs must be high yield ones. Faiz et al. (1990) argue that the promising way to control the increase in vehicle emissions within developing countries is through traffic management, and with administratively simple policy measures. It is not very difficult to formulate and implement policy instruments geared at changing vehicle use and fuel consumption patterns.

9. Concluding Remarks

This study presents a review of various types of fiscal policy instruments used to reduce transport sector externalities, particularly traffic congestion and atmospheric emissions. Four tax instruments: congestion charge, fuel tax, vehicle tax, and emission tax and three subsidy policies: subsidies on public transport, clean fuels and clean vehicles are discussed in terms of their theoretical basis and examples of their introduction in practice. Their impacts, particularly, on transport demand, vehicular pollution and economics and welfare are reviewed.

Our study finds that, although there is rich literature on policy instruments written to reduce transport sector externalities, implementation of these policies are limited to a few cities, such as Singapore, London, New York and Stockholm. Research on the congestion charge began in the early half of the 20th century with the pioneering works of Arthur Pigou, but it was not introduced in practice until the mid seventies in Singapore. Congestion charges seem to produce desired impacts in reducing vehicle mileages and also reducing vehicle emissions, to some extent. However, whether or not a congestion charge improves welfare is still debatable as some studies find welfare improving, whereas others find the opposite. It tends to depend on various factors such as the of networks charged, revenue neutrality of the tax, population groups that are being charged for using networks, the mode of transportation used for commuting, and the ways in which revenues collected are ultimately allocated. Besides the congestion charge, vehicle taxes are seen as playing a successful role in containing private vehicles in some cities, such as Singapore and Hong Kong.

Fuel taxes are not found to have been introduced to reduce transport sector externalities, instead they have been primarily aimed at raising government revenues. It is estimated that fuel taxes contribute as much as 20% of total government revenues in some countries, such as, Niger, Nicaragua, South Korea and Côte d'Ivoire. Still, fuel taxes are interpreted as policy instruments used to reduce transport sector externalities

because the level of the externalities would be higher than in the scenario without such taxes.

The emission tax is an area where literature has rapidly grown over the past 25 years, however, the focus is mainly on carbon tax due to overwhelming interests by researchers on climate change. Besides the carbon tax, sulfur tax and NOx tax are also proposed, however, emission taxes are rarely used to reduce transport sector emissions because of monitoring costs.

Three types of subsidies are discussed in the literature and are also introduced in practice: subsidies for public transportation, clean fuel and vehicles. Subsidies on public transportation are traditional practices both in developed and developing countries. Public transportation subsidies are not originally intended to reduce emissions. They are actually meant to cover operating costs of public transportation. Nevertheless, public transportation subsidies can be interpreted as instruments to reduce the transport sector externalities as the level of externalities would be higher in the absence such subsidies. Subsidies have been used as primary incentives to promote clean fuels, particularly biofuels. Biofuels subsidies are provided either producers (e.g., ethanol producers in the United States) or consumers (e.g., Brazil). However, it is not clear what type of subsidy (producer or consumer or mixed) would be the most effective. Moreover, some studies criticize that biofuel subsidies, particularly in the developed countries, are not environmentally and ethically justifiable. Subsidies for cleaner vehicles (e.g., electric vehicles, hybrid vehicles, CNG buses) are becoming popular in many countries, such as China, India, the United States and Japan. Unlike subsidies for biofuels, no existing studies are arguing against clean vehicle subsidies.

Existing literature also highlights a number of factors to be considered while designing fiscal policy instruments to reduce transport sector externalities, particularly if fiscal policy instruments already introduced in industrialized countries can be replicated in developing countries. These factors include, among others, efficiency, equity, existing transportation system and institutional capacity.

References

Aasness, J. and Larsen, E. R., (2003). Distributional Effects of Environmental Taxes on Transportation, *Journal of Consumer Policy, 26: 279–300.*

Acutt, M. Z. and Dodgson, J. S., (1997). Controlling the environmental impacts of transport: Matching instruments to objectives. *Transportation Research Part D: Transport and Environment, 2: 1, 17-33.*

Ang, B.W., (1996). Urban transportation management and energy savings: the case of Singapore. *International Journal of Vehicle Design, 17: 1, 1–12.*

Arnott, R., de Palma, A. and Lindsey, R. (1994). The welfare effects of congestion tolls with heterogeneous commuters. *Journal of Transport Economics and Policy, 28, 139–161.*

Barker, T. and Köhler, J. (1998). Equity and Ecotax reform in the EU: Achieving a 10%, Reduction in CO_2 Emissions Using Excise Duties. *Environmental Fiscal Reform Working Paper No. 10, University of Cambridge, Cambridge.*

Bento, A. M., Goulder, L.H., Henry, E., Jacobsen, M. R., Von Haefen, R. H., (2005). Distributional and Efficiency Impacts of Gasoline Taxes: An Econometrically Based Multi-Market Study. *The American Economic Review, 95, 2, 282-287.*

Brueckner, J. K., (1987). Chapter 20 The structure of urban equilibria: A unified treatment of the muth-mills model. *Handbook of Regional and Urban Economics, 2, 821-845.*

Bonnel, P., (1995). Urban car policy in Europe. *Transport Policy, 2: 2, 83-95.*

Casler, S.D. and Rafiqui, A., (1993). Evaluating fuel tax equity: direct and indirect distributional effects. *National Tax Journal, 46, 197-205.*

Chin, A.T.H., (1996). Containing Air Pollution ad Traffic Congestion: Transport Policy and the Environment in Singapore. *Atmospheric Environment, 30: 5, 787-801.*

Cropper, M. L. and Bhattacharya, S., (2007). Public Transport Subsidies and Affordability in Mumbai, India. *World Bank Policy Research Working Paper No. 4395.*

Coyle, W., (2007). The Future of Biofuels: A global perspectives. *Amber Waves, 5, 5, p 24.*

Daniel, J. I. and Bekka, K., (1999). The Environmental Impact of Highway Congestion Pricing. *Journal of Urban Economics, 47:2, 180-215.*

Dasgupta, M., Oldfield, R., Sharman, K. and Webster, V., (1994). Impact of transport policies in five cities. *Transport Research Laboratory Project Report PR107, TRL, Crowthome, Department of the Environment and Department of Transport.*

De Borger, B. and Mayeres, I., (2007). Optimal taxation of car ownership, car use and public transport: Insights derived from a discrete choice numerical optimization model. *European Economic Review, 51: 5, 1177-1204.*

De Palma, A., Lindsey, R., and Proost, S., (2006). Research challenges in modeling urban road pricing: An overview. *Transport Policy, 13: 2, 97-105.*

De Witte, A., Macharis, C., Lannoy, P., Polain, C., Steenberghen, T., Van de Walle, S., (2006). The impact of "free" public transport: The case of Brussels. *Transportation Research Part A: Policy and Practice, 40: 8, 671-689.*

Eliasson, J. and Mattsson, L., (2006). Equity effects of congestion pricing: quantitative methodology and a case study for Stockholm. *Transportation Research A, 40: 7, 602–620.*

Eltony, M., (1993). Transport gasoline demand in Canada. *Journal of Transport Economics and Policy, 27, 193-208.*

Eskeland, G. S. and Jimenez, E., (1992). Policy Instruments for Pollution Control in Developing Countries. *The World Bank Research Observer, 7: 2, 145-169.*

Evans, A. W., (1992). Road congestion pricing: when is it a good policy? *Journal of Transport Economics and Policy, 26,* 213-243.

Evans, R. (2007). Central London Congestion Charging Scheme: ex-post evaluation of the quantified impacts of the original scheme. Prepared for Congestion Charging Modeling and Evaluation Team, Transport for London.

Faiz, A., Sinha, K., Walsh, M., and Varma, A., (1990). Automotive Air Pollution: Issues and Options for Developing Countries. *Working Paper 492, Infrastructure and Urban Development Department, The World Bank, Washington DC.*

Feeney, B.P., (1989). A review of the impact of parking policy measures on travel demand. *Transportation Planning and Technology, 13, 229–244.*

Felder, S. and Van Nieuwkoop, R., (1996). Revenue recycling of a CO_2 tax: Results from a general equilibrium model for Switzerland. *Annals of Operations Research, 68.*

Funk, K. and Rabl, A., (1999). Electric versus conventional vehicles: social costs and benefits in France. *Transportation Research Part D, 4: 397-411.*

Gakenheimer, R., (1999). Urban mobility in the developing world. *Transportation Research Part A, 33, 671-689.*

Glazer, A. and Niskanen, E., (2000). Which consumers benefit from congestion tolls? *Journal of Transport Economics and Policy, 34, 43-54.*

Goodwin, P. B., (1992). A review of new demand elasticities with special reference to short and long run effects of price changes, *Journal of Transport Economics and Policy*, 26, pp. 155–163.

Goulder L.H., (1995) Environmental taxation and the "double dividend": a reader's guide. International Tax and Public Finance 2: 157-183.

Gupta, S., and Mahler, W., (1994). Taxation of Petroleum Products: Theory and Practice. *International Monetary Fund Working Paper WP/94/32, Washington, D.C.*

Gwilliam, K. M. and Shalizi, Z. M., (1996). Road Funds, User Charges and Taxes. *Transport Division Discussion Paper No 18930. The World Bank, Washington DC.*

Haan, P.D., Peters, A. and Scholz, R.W., (2007). Reducing Energy consumption in road transport through hybrid vehicles: investigation of rebound effects, and possible effects of tax rebates. *Journal of Cleaner Production, 15: 1076-1084.*

Hirota, K., Poot, J., Minato, K., (2003). Do policy incentives affect the environmental impact of private car use? Evidence from a sample of large cities. *Paper prepared for the 43rd Congress of the European Regional Science Association, Jyväskylä, Finland 27-30 August 2003.*

Ichinohe, M. and Endo, E., (2006). Analysis of the vehicle mix in the passenger-car sector in Japan for CO_2 emissions reduction by a MARKAL model. *Applied Energy, 83: 1047-1061*.

Innes, J., (1995). Planning Theory's Emerging Paradigm: Communicative Action and Interactive Practice. *Journal of Planning Education and Research, 14:183-189.*

International Energy Agency (IEA), (2006). Energy prices and taxes. In: Quarterly statistics 2006. OECD, Paris.

Jansson, J. O., (1969). Optimal Congestion Tolls for Car Commuters. A Note on Current Theory. *Journal of Transport Economics and Policy, 3: 3, 300.*

Jacobsen, H. K., Birr-Pedersen, K., Wier, M., (2003). Distributional Implications of Environmental Taxation in Denmark, *Fiscal Studies, 4: 4, 477-499.*

Johnstone, N. and Karousakis, K., (1999). Economic incentives to reduce pollution from road transport: the case for vehicle characteristics taxes. *Transport Policy, 6, 2, 99-108.*

Kathuria, V., (2002a). Vehicular pollution control in Delhi. *Transportation Research Part D, 7, 373–387.*

Kathuria, V., (2002b). Vehicular Pollution Control in Delhi: Need for Integrated Approach. *Economic and Political Weekly,* Available at <http://www.beijer.kva.se/publications/pdf-archive/Disc144.pdf.>

Keong, C. K. (2002). Road Pricing: Singapore's Experience. Prepared for the third seminar of the IMPRINT-EUROPE Thematic Network: "Implementing Reform on Transport Pricing: Constraints and solutions: learning from best practice", Brussels, 23rd - 24th October, 2002.

Khan, A.M., (2001). Reducing Traffic Density: The Experience of Hong Kong and Singapore, *Journal of Urban Technology, 8:1, 69 – 87.*

Kingham, S., Dickinson, J., Copsey, S., (1999). Travel habits, attitudes and perceptions of Matra BAe Dynamics employees. Report (Ref # SEEC-04-1999-03) prepared for Matra BAe Dynamics.

Knight, F., (1924). Some fallacies in the interpretation of social cost. Quarterly Journal of Economics, 38. Reprinted in The Ethics of Competition and Other Essays. Allen and Unwin, London.

Kraus, M. C., (1981). Scale Economies Analysis for Urban Highway Networks. *Journal of Urban Economics, 9,1, 1-22.*

Kunert, U. and Kuhfeld, H., (2007).The diverse structures of passenger car taxation in Europe and the EU Commissions proposal for reform. *Transport Policy, 14: 4, 306-316.*

Kutas, G. Lindberg, C. and Steenblik, R., (2007). Biofuels-At What Cost? Government support for ethanol and biodiesel in the European Union. The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD) Geneva, Switzerland.

Maclean, H.L. and Lave, L. B., (2003). Life Cycle Assessment of Automobile/Fuel Options. *Environmental Science and Technology, 37: 5445-5452.*

Metschies, G. P., (2005). International Fuel Prices. 4th Edition – 172 Countries, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH Postfach 5180, 65726, Eschborn.

Mohring, H. D. and Harwitz, M., (1962). Highway Benefits: An Analytical Framework. Northwestern University Press, Evanston, Illinois.

Molina, M. J. and Molina, L.T., (2004). Critical Review: Megacities and Atmospheric Pollution. *J. Air Waste Manage. Assoc, 54, 6, 644-680.*

Musgrave, R.A. and Musgrave, P., (1989). Public Finance in Theory and Practice. McGraw-Hill, New York.

Nelson, P., Gillingham, K., and Safirova, E., (2003). Revving up the Tax Engine: Gas Taxes and the DC Metro Area's Transportation Dilemma. Urban Complexities Issue Brief 03-05, Resources for the Future 1616 P Street, NW, Washington, D.C.

Newbery, D.M., (2001). Harmonizing Energy Taxes in the EU. Paper prepared for conference *Tax Policy in the European Union* organized by OCFEB, Erasmus University, and held in the Ministry of Finance, The Hague, 17-19 October 2001.

Parry, I. W. H. and Bento, A., (2002). Estimating the Welfare Effect of Congestion Taxes: The Critical Importance of Other Distortions within the Transport System. *Journal of Urban Economics, 51, 2, 339-365.*

Parry, I.W. H., Williams, R.C., and Goulder, L.H., (1999). When can carbon abatement policies increase welfare? The fundamental role of distorted factor markets. *Journal of Environmental Economics and Management***,** 37**,** 52–84.

Perkins, S., (1998). Focus on transport emissions needed if Kyoto CO_2 targets are to be met. *Oil & Gas Journal, 96, 3, 36–38.*

Pigou, A. C., (1920). The Economics of Welfare, first edition, Macmillan Company, London.

Pimentel, D., (2003). Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts are Negative. *Natural Resources Research, 12: 2,127-134.*

Pritchard, T. and DeBoer, L., (1995). The Effects of Taxes and Insurance Costs on Automobile Registrations in the United States, *Public Finance Quarterly*, *23:283-304.*

Potoglou, D. and Kanaroglou, P.S., (2007). Household demand and willingness to pay for clean vehicles. *Ransport Research Part D, 12, 264-274.*

Potter, S. and Parkhurst, G., (2005). Transport Policy and Transport Tax Reform. *Public Money and Management, Volume 25, Issue 3, Page 171-178.*

Prud'homme, R. and Bocarejo, J. P., (2005). The London congestion charge: a tentative economic appraisal. *Transport Policy, 12, 3, 279-287.*

Proost S. and Van Dender, K., (2002). Methodology and structure of the urban model. In De Borger B., Proost, S. (eds.), *Reforming Transport Pricing in the European Union: A Modelling Approach*, Edward Elgar, Cheltenham, pp. 135-169.

Rask, K. N., (1998). Clean air and renewable fuels: the market for fuel ethanol in the US from 1984 to 1993. *Energy Economics, 20, 3, 325-345.*

Rich, J. and Nielsen, O. A., (2007). A socio-economic assessment of proposed road user charging schemes in Copenhagen. *Transport Policy, 14, 4, 330-345.*

Richardson, H.W., (1974). A note on the distributional effects of road pricing. *Journal of Transport Economics and Policy, 8, 82–85.*

Rietveld, P. and Van Woudenberg, S., (2005). Why fuel prices differ. *Energy Economics, 27, 79– 92.*

Rubin, J. and Leiby, Y., (2002). Transition Modeling: A Comparison of Alternative Fuel and Hybrid Vehicles. Joint Statistical Meetings. 11 – August 15, 2002, New York City.

Saitone, T.L., Sexton, R.J., Sexton, S.E., (2007). The Effects of Market Power on the Size and Distribution of Benefits from the Ethanol Subsidy. Agricultural Issues Center University of California.

Santos, G., Li, W.W., and Koh, W, T. H., (2004). Transport Policies in Singapore. *Research in Transportation Economics, 9, 209-235.*

Santos, G. and Rojey, L., (2004). Distributional impacts of road pricing: the truth behind the myth. *Transportation, 31, 21–42.*

Schmöcker, J.D., Fonzone, A., Quddus, M., and Bell, M.G.H. (2006). Changes in the frequency of shopping trips in response to a congestion charge. *Transport Policy,13,3, 217-228.*

Schrank, D. and Lomax, T., (2005). The 2005 Urban Mobility Report. Texas A&M University: Texas Transportation Institute.

Schumacher, J., (2006). Oilseed, Biodiesel, and Ethanol Subsidies & Renewal Energy Mandates: US Federal & Selected State Initiatives. Agricultural Marketing Policy Paper No. 16.

Scrimgeour, F., Oxley, L., and Fatai, K., (2005). Reducing carbon emissions? The relative effectiveness of different types of environmental tax: the case of New Zealand. *Environmental Modelling & Software, 20, 1439–1448.*

Shapouri, H., and Gallagher, P., (2005). USDA's 2002 Ethanol Cost-of-Production Survey. Agricultural Economic Report Number 845, United States Department of Agriculture.

Sharp, C., (1966). Congestion and Welfare-An Examination of the Case for a Congestion Tax. *The Economic Journal, 76: 304, 806-817.*

Sheffield, J., Dais, W., Lowe, W., Lett, D., McGill, R., (2001). Assessment of the Potential to Reduce Emissions from Road Transport through the use of Alternative Vehicles and Fuels in the Great Smoky Mountains Regions. Report Number: JIEE 2001-01, Joint Institute for Energy & Environment.

Sikow-Magny, C., (2003). Efficient pricing in transport—overview of European commission's transport research program. Acceptability of Transport Pricing Strategies eds. J. Schade and B. Schlag, pp. 13–26. Elsevier, Amsterdam.

Small, K., (1992). Using the revenues from congestion pricing. *Transportation, 19, 359–382.*

Shapouri, H., and Gallagher, P. (2005). USDA's 2002 Ethanol Cost-of-Production Survey. Agricultural Economic Report Number 845, United States Department of Agriculture.

Speck, S. (1999). Energy and carbon taxes and their distributional implications. *Energy Policy, 27, 659–667.*

Sterner, T., (2007). Fuel taxes: An important instrument for climate policy. *Energy Policy, 35, 6, 3194-3202.*

Stiglitz, J., (1998). Distinguished Lecture on Economics in Government: The Private Uses of Public Interests: Incentives and Institutions. *The Journal of Economic Perspectives, 12, 2, 3-22.*

Teubel, U., (1998). The welfare effects and distributional impacts of road user charges on commuters: An empirical analysis of Dresden, ERSA conference papers , 98, p37, European Regional Science Association.

Timilsina, G.R. and Shrestha, R.M., (2007). Alternative Tax Instruments for CO2 Emission Reduction and Effects of Revenue Recycling Schemes, *Energy Studies Review, 15, 1, 19-48.*

Ubbels, B., (2002). The Economics of Transport Pricing, In: *Colloquium Vervoersplanologisch Speurwerk: De kunst van het verleiden?*, Delft, CVS, pp. 201-219.

Uri, N. D. and Boyd, R., (1998). Aggregate Impacts of the Proposed Reduction in the Motor Fuels Excise Tax in the US. *Energy Economics, 20, 3, 309-323.*

Vickrey, W. S., (1969). Congestion Theory and Transport Investment. *American Economic Review, 59, 2, 251-60.*

Verhoef, E.T., Nijkamp, P. and Rietveld, P., (1997) . The social feasibility of road pricing: a case study for the Randstad area. *Journal of Transport Economics and Policy, 31, 3, 255–276.*

Walters, A. A ., (1961). The Theory& Measurement of Private & Social Cost of Highway Congestion. *Econometrica, 29, 4, 676-699.*

Wiese, A.M., Rose, A. and Schluter, G., (1995). Motor-fuel taxes and household welfare: an applied general equilibrium analysis. *Land Economics, 71, 229–243.*

Weitzman, M. L., (1974). Free access vs. private ownership as alternative systems for managing common property. *Journal of Economic Theory, 8, 225-234.*

West, S. E., (2004). Distributional effects of alternative vehicle pollution control policies. *Journal of Public Economics, 88, 735-757.*

Willoughby, C., (2000) Singapore's Experience in Managing Motorization, and its Relevance to Other Countries, Discussion PaperTWU-43, The World Bank, Washington DC.

Zhao, J., (2006). Whither the Car? China's Automobile Industry and Cleaner Vehicle Technologies. *Development and Change, 37, 1, 121–144.*

Zupan, J.M. and Perrotta, A.F., (2003). An Exploration of Motor Vehicle Congestion Pricing in New York. Regional Plan Association, New York. Accessed from <http://www.rpa.org/pdf/RPA_Congestion_Pricing_NY.pdf>