Do policy incentives affect the environmental impact of private car use? Evidence from a sample of large cities*

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Abstract. In this paper, we study the effectiveness of tax incentives and the variation in vehicle user cost on the environmental impact of private motor vehicle use in OECD countries and in some non-OECD countries in Asia. We present a simple model of private motor vehicle stocks, miles travelled and CO_2 emission in relation to acquisition, ownership and fuel taxes, the overall user cost of cars, and income per capita. The user cost of cars is broken down into the acquisition, ownership and running cost. Each component is split into a tax segment and a resource cost segment. We developed our model by means of data from 68 large cities, among which 49 from OECD countries and 19 from non-OECD countries in Asia. The implications for sustainable development of the structural differences between these taxes in terms of the model outcomes are identified. Our results indicate that an incentive-based system that rewards higher environmental performance, such as differential tax rates by vehicle weight, would be effective.

JEL classification: D12, H23, H71, L92, R41

Key words: motor vehicle taxes, vehicle miles travelled, CO2 emission, consumer behaviour, incentives

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1 Introduction

Many countries have implemented measures to reduce greenhouse gas emissions and other environmental costs resulting from the transport sector. Energy consumption, CO_2 emission and other environmental impacts of the transport sector depend on the modal split in transportation, which in turn depends on the relative cost and convenience of each transport mode.

In this paper we focus on private motor vehicle use. Figure 1 shows the relationship between car density (the number of private cars per 1000 of the population) and per capita income. Figure 1 combines two samples: one sample of cities in Europe, North America and the Asia-Pacific region and one sample of the corresponding country information. The figure illustrates two points. First, the demand for private cars clearly increases with the level of development. Second, at each level of development there is considerable variation in car ownership. The latter variation is *inter alia* due to local geography, available infrastructure, private cost in use of motor vehicles, congestion levels and local regulations. We exploit the variation in these conditions across cities in this paper in order to identify the effect of the user cost of private cars and tax incentives on car ownership and use.

Figure 1 about here

The incidence of car ownership and vehicle miles travelled (VMT) are likely to be related, but the relationship is no necessarily a close one. This is illustrated in Figure 2. As car density increases, the average annual distance travelled per capita increases, but the variance increases too. A high rate of ownership is likely to reflect a low user cost and a high level of income. In some cities a high rate of vehicle ownership is accommodated by an extensive infrastructure that encourages car use. On the other hand, congestion may arise where the infrastructure is inadequate, leading to a relatively lower level of distance travelled. While Figure 2 depicts pooled data for 1990 and 2002 from a range of cities in North America, Europe and the Asia-Pacific region, the same relationship holds for more homogeneous subgroups of cities.

Given that GDP and other factors affect car ownership and that car ownership affects VMT, the question arises to what extent these relationships are modified by transportation and environmental policies. In this paper we analyse the responsiveness of demand to the user cost per kilometre in order to identify which tax policy might be effective for an improvement of environmental conditions.

Figure 2 about here

Our analysis is based on a study of large cities in Europe, USA, Canada and the Asia-Pacific region. Our data set includes 68 large cities, of which 49 are located in OECD countries (including Japan) and 19 from other Asian countries. Data are available for either 1990 or 2002, and in a few cases for both years.[1]

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[1] The cities and years are: Adelaide (1990); Amsterdam (1990); Auckland (1990); Bangkok (1990,2002); Beijing (1990,2002); Boston (1990); Brisbane (1990); Brussels (1990); Busan (2002); Calgary (1990); Canberra (1990); Chiba (2002); Chicago (1990); Chongqing (2002); Copenhagen (1990); Calcutta (2002); Deli (2002); Denver (1990); Detroit (1990); Edmonton (1990); Frankfurt (1990); Fukuoka (2002); Hamburg (1990); Hanoi (2002); Ho Chi Min City (2002); Hiroshima (2002); Hong Kong (1990,2002); Houston (1990); Jakarta (1990,2002); Kathmandu (2002); Kobe (2002); Kuala Lumpur (1990,2002); London (1990); Los Angeles (1990); Manila (1990,2002); Melbourne (1990); Montreal (1990); Mombai (2002); Munich (1990); Nagoya (2002); New York (1990); Osaka (2002); Ottawa (1990); Paris (1990); Perth (1990); Phoenix (1990); Portland (1990); Sacramento (1990); San Diego (1990); San Francisco (1990); Sapporo (2002); Seoul (1990,2002); Shanghai (2002); Singapore (1990,2002); Stockholm (1990); Surabaya (1990); Sydney (1990); Tienshin (2002); Tokyo (1990,2002); Toronto (1990); Urawa (2002); Vancouver (1990); Vienna (1990); Washington (1990); Wellington (1990); Winnipeg (1990); Yokohama (2002); Zurich (1990).

Tax incentives differ between regions, but they are in all cases aimed at reducing VMT, which may be expected to have the closest relationship with the environmental impact. However, we also consider CO2 emissions explicitly.

The population density, the number of passenger vehicles per 1000 people and the available public transport infrastructure are all expected to influence VMT and greenhouse gas emissions. The sample of Asian cities was selected by means of the following criteria: (1) A private car density of less than 200 passenger vehicles per 1000 people; (2) A population density of at least 150 people per ha; and (3) public transport expenditure of less than US$200 per capita annually.

The paper is organized as follows. The next section provides a brief survey of the literature on demand elasticities for car travel. Section 3 describes the data. In Section 4 we report on some simple regression models of the relationship between car use, pollution and tax incentives. In the final section we sum up and suggest how the tax structure can be improved, particularly in Asian countries.

2 Previous research and theoretical considerations

Urban areas in Asia are experiencing a considerable growth in the number of vehicles. Asian countries seem to have different vehicle usage compared with OECD countries because of a different land use, a different population density gradient in urban areas, etc. Although people may change their behaviour due to various reasons, the price elasticity of demand is the most important factor to take into account when considering tax incentives. Standard economic theory would suggest that an increase in the price of private motor vehicle transportation, e.g. to reduce congestion on urban motorways, will indeed reduce VMT, although the consumer may also change his or her driving behaviour by taking an alternative route or by driving at off-peak times. Consequently, the calculation of travel demand elasticities is complex and has yielded significantly different formulations in the literature.

Espey (1998) carried out a meta-analysis of a large number of estimates of the price elasticity of the demand for fuel in the US and other countries. She finds that elasticity estimates are sensitive to the inclusion or exclusion of some measure of vehicle ownership. Elasticities of demand do also appear to vary across countries. She also finds that gasoline demand appears to be getting more price-elastic and less income-elastic over time.

A typical example of elasticities reported in a recent survey by Graham and Glaister (2002) is as follows. The elasticity of VMT with respect to the price of gasoline price may be about -0.16 in the short run and -0.3 in the long run. However, the elasticity of gasoline consumption with respect to gasoline price is -0.27 in the short run and -0.71 in the long run. It is clear from these estimates that an increase in the gasoline price leads to behavioural responses such that gasoline consumption is much more affected than car traffic. Graham and Glaister conclude that changes in gasoline prices are more likely to affect fuel consumption rather than road congestion.

Hansen and Huang (1997) found elasticities of 0.9 in California metropolitan areas for a 4 to 5-year time period. Income level is an essential decision factor, but it may not be the only factor to determine travel demand. In Eltony's estimates[2] of household gasoline demand in Canada from 1989-2000, 75% of households reduce their travel by car within 1 year after a fuel price increase[3]. Fifteen percent of households shifted from large vehicles to small vehicles. Ten percent of households switched from less fuel-efficient vehicles to more efficient vehicles. However, these papers focus on only private vehicles. These models focus on behavioural change on car usage. Their model did not take mode choice into account.

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[2] ELTONY, M., (1993) Transport gasoline demand in Canada. *Journal of Transport Economics and Policy*, Vol. 27, 193-208.

[3] During this period, the price of regular gasoline grew at 2.7% every year on average. Prices of other manufacturing goods grew at 3.6% on average.

Drollas' surveys (1984)[4] of gasoline elasticities for European countries in the 1980s found that people switched from gasoline to LPG or diesel-powered vehicles, or used a different mode of transport as gasoline prices increased. The author's results yield long run price elasticity estimates of approximately -0.6. Compared to the short run elasticity of -0.26, he finds that the gasoline price in the long run may be more elastic than that of the short run. These surveys limit only the economic component and impact on vehicle usage.

Relating to car stock, Drollas provides a vehicle stock adjustment model. The form of the vehicle stock estimation consists of income, the real price of gasoline, the real price of other transport services and the price of the vehicle. The model was estimated in the dynamic model and in log-linear form with endogenous and exogenous lags. The author found that gasoline demand may be inelastic in the short run. He found that elasticities for mode choice and fuel type are important in the long run[5].

Table 1 Elasticity survey about here

VMT seems to positively relate to car ownership. Car ownership seems to positively relate to GDP. This travel growth may be contrary to the hypothesis: travel demand is totally inelastic with respect to price. Travel growth may be attributed to not only fuel price, but also total overall vehicle costs.

Elasticity analysis between car costs and VMT has been performed in the US and Europe recently. U.S.DOT (1997) utilizes the elasticity of VMT with respect to total costs of -0.8 for a 5-year and -1.0 for a 20-year period[6]. According to several reviewers (SACTRA, 1999), the fuel price elasticities of vehicle kilometrage are around –0.15 in the short run and –0.3 in the long run. The elasticities of the Italian model are –0.2 for the short run and –0.5 for the long run, which are higher than those of previous surveys. The short-term effect in the Italian model has only mode choice. The long-term effect of the model includes destination and frequency choice.
De Jong and Gunn (2001)[7] also concluded that not only gasoline price, but also these 4 elements are important for model construction. De Jong and Gunn (2000) compared the elasticities by explaining structural differences of the three models. They reported mainly on the Netherland's National Model System (NMS), the Italian National Model System, the transport model for the Brussels region and the Norwegian National Model[8]. In their literature reviews, the impact of car cost on car trip is similar among the models both for the short run and long run. They are generally close to –0.2. In the European literature and the NMS, commuting and business travel is less sensitive to changes in fuel prices than travel for other purposes[9]. De Jong and Gunn also discussed the impact of car cost on travel distance. Since the NMS contains a destination choice effect, the long term elasticities of car kilometrage are bigger than that of the short term. If the fuel price increases, long distance destinations become less attractive. The average elasticities for long term for all source is –0.25. Hansen and Huang (1997) utilize population, personal income, density and gasoline price for impact on lane miles.

U.K.'s SACTRA (The Standing Advisory Committee on Trunk Road Assessment) (1994) concluded that income growth did not attribute solely to traffic growth. SACTRA argued

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4 DROLLAS, L., (1984). The demand for gasoline: future evidence. *Energy Economics,* Vol. 6. 1984.

5 GRAHAM, D.J., AND GLAISTER, S., 2000. The Demand for Automobile Fuel. A Survey of Elasticities. *Journal of Transport Economics and Policy*. Volume 36, Part 1,3.

6 NOLAND, R. B., AND COWART, W.A., 1999. Analysis of Metropolitan Highway capacity and the growth in vehicle miles of travel. In: Public Policy and Management Annual Research Conference, 79th Annual Meeting of the Transportation Research Board, Washington, DC. Washington DC: Transport Research Board.

7 DE JONG, G., and GUNN, H., 2001. Evidence on Car Cost and Time Elasticities of Travel Demand in Europe. *Journal of Transport Economics and Policy*. Volume 35, Part 2, 145.

8 DE JONG, G., and GUNN, H. Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe. *Journal of Transport Economics and Policy*. Volume 35, Part 2, May 2001,137-160.

9 DE JONG, G., and GUNN, H. Recent, 2001. Evidence on Car Cost and Time Elasticities of Travel Demand in Europe. *Journal of Transport Economics and Policy*. Volume 35, Part 2, 144.

that economic growth and highway capacity had an impact on traffic growth[10]. Elasticities were found between 0.5 and 0.9 for metropolitan data. Noland and Lem (2002) concluded that new transportation capacity tends to induce increase of travel in both a short run effect and a long run effect.

Each component of car costs may function differently as vehicle taxes have different reasons and history of introduction in each country. Here is our hypothesis: travel demand is not price inelastic including the tax component. We attempted to identify which component had the most significant effect on VMT. Are environmental taxes effective on VMT, CO_2 emissions and car stock control?

In the United States, the federal government offers consumers tax deductions ranging from $2,000-$50,000 towards incremental expenditure increase for the purchase or conversion of an approved clean fuel vehicle[11]. In a similar manner, the Japanese government reduces the acquisition tax for clean energy vehicles, such as electric or natural gas powered vehicles. Japan also offers a separate reduction in the acquisition tax for vehicles that meet certain emission targets. Figure 3 shows the tax incentives for low-emission vehicles in Japan. The number of low-emission vehicles significantly increased from 2000 to 2001.

Figure 3. Tax incentives for low emission vehicles in Japan about here

High population density, low passenger car ownership and high use of public transportation make Asian cities look environmentally friendly. One of the problems in Asia is the improvement of public transport service. Some Asian countries take users' income levels into account. The governments tend to subsidize fuel prices or maintain low public transportation fares.

Asian countries seem concerned about equity issues in their tax systems[12]. In the Philippines, the sales tax is lower for diesel vehicles than for gasoline vehicles. However, the Philippine government tries to provide as simple a tax system as possible. The government might reduce the tax level for each item and impose tax on broader items. In Thailand, the government introduced a VAT tax instead of the business tax because people felt the business tax was unfair. Malaysia has tax incentives for environmental consideration. For example, conversion kits for alternative fuel vehicles are exempt from import duties and sales tax. Among European countries, the UK has the highest fuel tax rate. However, the UK government uses this tax to reduce taxes on heating oil for low-income groups. In contrast, Italy has the highest tax on heating fuel while its fuel tax rate is not as high as that of the UK[13]. This kind of trade-off might be taken into account in Asian countries.

Tax levels in the four previously mentioned Asian countries also vary by engine capacity, vehicle gross weight and price. The existence of a vehicle taxation system based on engine capacity or vehicle weight would be a potential incentive to purchase or keep vehicles with smaller engine capacity or lighter weight. However, Thailand and the Philippines may have to reform their tax systems by vehicle age. Older vehicles are taxed at a lower level, which is controversial from an environmental perspective. According to the Polluter Pay Principle, older vehicles should be charged at a higher tax level. For example, Tokyo and some other prefectures in Japan charge a higher tax for older vehicles.

[10] NOLAND, R.B., AND LEM, L.L., 2002.A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research*, Part D 7, 1-26.
[11] http://www.fueleconomy.gov/feg/tax_hybrid.shtml
[12] The examples raised in this paper are not specifically Asian cities.
[13] OECD. Environmentally-related Taxes in OECD Countries. Issues and Strategies. Paris: OECD, 2001. p58.

In the Netherlands, the government reformed vehicle-related taxes for environmental objectives, but the total energy consumption since 1990 has been stable and not decreasing[14]. This is because car ownership has not decreased. The average vehicle gross weight of new cars increased by 1.9% annually from 1987 to 1991. Average engine capacity of new cars increased by 4% from 1985 to 1997. The government of the Netherlands plans to impose an acquisition tax (B.P.M) based on CO_2 emissions. The government expects 4% CO_2 reduction by this reform. The Danish government decided to reform the ownership tax system from a weight basis to a fuel-economy basis in 1997. Fuel-efficient vehicles are taxed at a lower rate. Since this action, the average fuel economy for new cars has been improved by 0.5 km/l for gasoline vehicles and by 2.3 km/1 for diesel vehicles. As a result, CO_2 emissions have been reduced from 183 g/km to 176 g/km. It is necessary to improve fuel economy by 2.4% each year in order to fulfil the voluntary agreement (140 g/km). In Denmark, the green tax system has imposed higher taxes on diesel vehicles.

These case studies on impacts of tax incentives indicate that consumer behaviour may not be strongly related to fuel economy. Consumers might still prefer other criteria. In further research, estimates should be made using cross section-time series.

Asian countries also provide incentives for clean fuel vehicles. For example, the Malaysian Department of Environment has been encouraging the use of natural gas in public service vehicles in urban areas, and the road tax is reduced for alternative fuel vehicles (50% off for monogas vehicles, 25% off for bi-fuel or dual fuel vehicles). According to the Malaysian DOE[15], 1540 vehicles (mostly taxis) have been converted to bi-fuel mode (petrol-natural gas) and 1000 monogas taxis are in service in Kuala Lumpur.

People will use different modes of transport to a destination. Each large city provides different types of transport so that people's decisions are affected by the circumstances. The full cost of each type of transport per kilometre seems appropriate to compare all type of mode with consideration of the different circumstances. The vehicle costs consist of vehicle maintenance, insurance, vehicle taxes, maintenance cost, fuel cost and other spending.

Energy price and circumstances such as the vehicle tax may affect consumer behaviors. The following equations assume that energy demand of passenger vehicle depends on vehicle user cost and vehicle related tax. The data on large cities are analyzed using a cross section approach. The data of our model was divided by city population. Then, the models were created using ordinary least squares (OLS). The equation for elasticity analysis is as follows. In this section, we will discuss impacts on the optimization problem. Under the budget constraint, a consumer maximizes his/her utility.

$$\max_{x_1, x_2} U(x_1, x_2) \quad \text{Eq 1}$$

$$\text{sub to } \; p_1 x_1 + p_2 x_2 = m \qquad \text{Eq 2}$$

U: Utility
p_1: Vehicle related tax for a private car per km (estimated)
p_2: Vehicle user costs except tax for a private car per km (estimated)
x_1: Vehicle Mileage Travel (VMT) per capita or CO_2 emissions
x_2: Car stock
m: Gross regional product per capita (USD PPP1990, 2000)

[14] Robert M. M. Van den Brink, Bert Van Wee. "Why has car-fleet specific fuel consumption not shown any decrease since 1990? Quantitative analysis of Dutch passenger car-fleet specific fuel consumption." Transportation Research Part D6 (2001) 75-93.
[15] Ishak Aminuddin. "Urban air quality management: Motor vehicle emission control in Malaysia." Clean Air Regional Workshop. Feb 12-14, 2001.

To solve the optimization problem, we use a Lagrange multiplier λ which links $U(x_1, x_2)$ and $p_1x_1 + p_2x_2 = m$. This yields a Lagrange function ℓ .

$$\ell \equiv U(x_1, x_2) + \lambda[m - p_1x_1 - p_2x_2] \quad \text{Eq 3}$$

The first order condition is partial differential by λ

$$\left\{ \begin{array}{l} \frac{\partial L}{\partial x_1} = \frac{\partial u}{\partial x_1} - \lambda p_1 = 0 \\ \frac{\partial L}{\partial x_2} = \frac{\partial u}{\partial x_2} - \lambda p_2 = 0 \\ \frac{\partial L}{\partial \lambda} = m - p_1x_1 - p_2x_2 = 0 \end{array} \right\} \quad \text{Eq 4}$$

For econometric analysis, we formulate the models as follows: We use the first demand function in log form.

$$\left\{ \begin{array}{l} u_1(x_1, x_2) - \lambda p_1 = 0 \\ u_2(x_1, x_2) - \lambda p_2 = 0 \\ m - p_1x_1 - p_2x_2 = 0 \end{array} \right\} \longrightarrow \left\{ \begin{array}{l} x_1(p_1, p_2, m) \\ x_2(p_1, p_2, m) \\ \lambda(p_1, p_2, m) \end{array} \right\} \quad \text{Eq 5}$$

$$\log x_1 = \beta_1 + \beta_2 \log p_1 + \beta_3 \log p_2 + \beta_4 \log m + \varepsilon \quad \text{Eq 6}$$

Variables are re-defined as:
p_1: Vehicle related tax (Acquisition, ownership and fuel tax) for a private car per km
p_2: Vehicle user costs except tax for a private car per km
m: Gross regional product per capita (USD PPP1990, 2000)
x_1: Vehicle Mileage Travel (VMT) per capita or CO_2 emissions
x_2: Car stock
ε: *disturbance*

The model features vehicle mileage travel (VMT), CO_2 emissions and car stock as dependent variables. As per capita income increases, vehicle travel distance increases generally[16] [17]. First, elasticities are estimated for the OECD and Asian cites together for Eq 6. Secondly, elasticities are estimated in 2 stages. VMT and car stock are separately analyzed with directly related explanatory variables: VMT depends on car ownership (Eq7). Car ownership depends on income (Eq8).

$$\log x_1 = \beta_5 + \beta_6 \log p_5 + \beta_7 \log p_6 + \beta_8 \log p_7 + \beta_9 \log m + \varepsilon \quad \text{Eq 7}$$

[16] Kenworthy, Jeffry R. and Felix B. Laube. An International source book of Automobile Dependence in cities 1960-1990. Colorado; University Press of Colorado: 1999. The key variable is the expenditure by different population densities. In lower density areas, people often drive private cars and use little public transport.

[17] Noland., R. B. and Cowart, W.A. "Analysis of Metropolitan Highway capacity and the growth in vehicle miles of travel." TRB paper 001288. Accepted 24, 1999. 79th Annual Meeting of the Transportation Research Board. p.11.

$$\log x_2 = \beta_{10} + \beta_{11} \log p_8 \ + \beta_{12} \log m + \varepsilon \qquad \text{Eq 8}$$

Variables are re-defined as:

p_5: Vehicle user costs for a private car per km
p_6: Vehicle fuel tax for a private car per km
p_7: Vehicle ownership tax per km
p_8: Vehicle acquisition tax per km
m: Gross regional product per capita (USD PPP1990, 2000)
x_1: Vehicle Mileage Travel (VMT) per capita or CO_2 emissions
x_2: Car stock
ε: *disturbance*

3. Data description

The data on large cities was analyzed using the data of 1990 and 2000. It appears that acquisition taxes are generally based on car prices. Ownership taxes are imposed based on emissions, fuel economy, weight, or engine capacity in many countries. Fuel taxes differ by type of fuel. To compare by cross-section, we assume the vehicle characteristics shown at the top of the next page.

The vehicle related taxes are classified in three stages: acquisition, ownership and driving. In each stage, the following points are assumed for types of taxes, including environmental taxes. Tax reduction and its impact are introduced in the data interpretation.

The local currencies are converted into Purchasing Power Parity[18] in US$ in 1990 and 2000. In general, the tax in OECD countries may be for environmental concerns while many Asian countries use the tax to induce industrial development.

Assumptions: New passenger vehicle gasoline vehicle, domestic production 1 unit
Vehicle weight: 1100 kg, Engine capacity 1600cc, Fuel economy average for a new car in 1998 in each economy
Horse power 72HP, Vehicle price US$13000[19], Travel distance per year: 10,000 km/year, CO_2 emissions 196 g/km. The vehicle will be used for 10 years with one owner

VMT was estimated with the traffic volume (passenger-km) divided by city population. If the traffic volume at city label was not available, the traffic volume divided by national population was applied for each region. Since Asian cities have higher density than European and North America, VMT per capita is lower those of European and North American countries. The CO_2 emission data from the transport sector[20] is available only at the national level. The data was divided by population at the national level. Car stock (unit per 1000 people) was estimated from car ownership in city divided by city population, which multiplies 1000 people.

This is applied as the average fuel economy for new sales vehicles. Fuel economy for European countries is given data from the ECMT statistical data, which is converted in the 10/15 mode[21]. Fuel economy for the USA is the value of the CAFÉ standard (FTP mode), which is converted in the 10/15 mode. Fuel economy for Japan is given data from EDMC statistics. Fuel

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[18] International Monetary Fund. (Washington, DC)
[19] Since we assume the car price to be in dollars, we have to convert in local currency.
[20] IEA., 2002. *CO2 emissions from fuel combustion 1971-2000.* Paris; IEA.
[21] Some European countries dieselize car stock in order to reduce CO_2 emissions that improve average fuel economy.

economy data is used to estimate gasoline tax per km. Fuel economy for Asian countries is assumed as 8.73 km/l, which was estimated from total energy consumption in the case of China[22] and total car stock from the JARI database.

Vehicle user costs per km consist of the following costs in USD PPP 1990 and 2000. The following costs are included as vehicle user costs. After sum up these costs, it was divided by VMT.

1) Fuel cost without fuel tax
2) Annual maintenance and repair cost
3) Annual insurance cost

The fuel cost is estimated from the price of unleaded gasoline (in local currency/liter) divided by fuel economy. The annual maintenance and repair costs are often given data from various Automobile Association websites. They often provide costs per km, which are very useful. If this is not available, we use expenditure survey statistics. The expenditure surveys also provide vehicle user costs. In this case, the expenditure is divided by VMT.

Vehicle related taxes consist of acquisition, ownership tax and fuel tax. Import tariff was excluded. After sum up these costs, it was divided by VMT.

1) Acquisition tax
2) Ownership tax
3) Fuel tax

Many European countries impose Value Added Tax (VAT) on acquisition tax. VAT is based on the sales price. Since the vehicle price is related to income level, there may be the idea that "high income people have to pay more tax."[23] Denmark has the highest tax level. According to the Danish Ministry of Energy and Environment, this high tax level inhibits people from buying a car.[24] Many countries have a lower acquisition tax level for clean energy vehicles. The acquisition tax is determined based on fuel economy, emission level, gross vehicle weight (G.V.W.) and fuel type.

Acquisition tax includes sales tax, VAT, Interior tax, Surtax, Luxury tax in the Asian region. Asian governments tend to design their tax structures to induce economic growth. The Thai and Malaysian tax structures for example, include incentives instrumental for industrial development. The Philippines government has imposed a lower tax rate on diesel vehicles than on gasoline vehicles. This might be favorable for commercial vehicles[25]. In Indonesia, the tax system has not been used very much as an instrument for economic growth because Indonesia has various resources. Only the Malaysian government provides incentives for natural gas vehicles.

Ownership tax includes ownership tax, road tax, and weight tax in OECD countries. In European countries, the ownership tax depends on engine model, engine capacity, fuel type, and vehicle age or vehicle gross weight. According to the Polluter Pays Principle, vehicles with more stringent emission standards are taxed at a lower level. Tax levels differ by vehicle characteristics in many countries. Danish ownership tax depends on fuel economy, while in Germany it is based on emission standards. The UK and France impose the tax based on CO_2 emissions. In the UK, the road tax used to be one rate for all car types, but the UK government imposed a VED (passenger road tax) with 4 categories based on CO_2 emission levels. The French government ownership tax depends on vehicle age and the region where it is registered. In the Netherlands and Sweden, the ownership tax is based on vehicle gross weight and fuel type. Japan's tax is the highest among these 7 countries. In the US, all states have a registration fee as

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[22] IEA Energy balances of Non-OECD countries, 1992 and 2002.
[23] Working group of vehicle-related tax. *A vehicle-related report.* Tokyo 2001.（73）For the US, the New York tax system is applied in Fig. 2
[24] Danish Ministry of Energy Environment June 2000.
[25] National Center for Transportation Studies. Research on Proper Automobile Usage Strategy towards Environmental Impact Abatement in Large Cities in Asia. Manila, March 2000. (14)

the ownership tax. It varies by state from US $8 to US $2892 per year depending on vehicle size/weight, private/contract carrier, farm/non farm, etc. . Most states and local governments also have property tax, sales tax and operator's licence. They vary from state to state[26].

Asian ownership tax includes road tax, and the re-registration fee. In Malaysia, the ownership tax depends on engine capacity. In Thailand and the Philippines, it depends on vehicle gross weight. According to official documents from 1999, ownership tax did not exist in Indonesia in 1999. The Malaysian tax level is the highest among these 4 countries. In the Philippines and Thailand, older vehicles are taxed less.

These costs above were sum up as private transport costs in order to compare to Kenworthy data[27]. Our estimates (Hirota estimates) have higher value than the data of Kenworthy (millennieum). Probably tax values and USD PPP in our data cause these higher estimations (Figure 4-7). The coefficients of acquisition tax result in relatively higher than the other taxes in the results of econometrics analysis.

Figure 4 about here
Figure 5 about here
Figure 6 about here
Figure 7 about here

4. Results

Table 2 and Table 3 show the correlations on VMT, CO_2 and car stock. Each estimated value is evaluated for its significance at the 5% (*) and 1% (**) levels.

VMT is negatively correlated with vehicle user costs, and the taxes. VMT is positively correlated with income per capita. According to previous studies, VMT, or car use (km), is reduced by 0.16% for every 1% increase in fuel cost/tax for a short term. It is reduced 0.19-0.55% for every 1% increase of fuel cost/tax for a long term. Our results show that VMT decreases by 0.042% for every 1% increase for fuel tax income, which is lower than the literature survey. In our study, VMT decreases by 0.453% for every 1% increase in acquisition tax, decreases by 0.216% for every 1% increase of ownership tax. Acquisition tax results in the most influential tax for VMT change.

CO_2 emissions are negatively correlated with vehicle related taxes.CO_2 emissions are positively correlated with vehicle user costs. Our results show that CO_2 emissions increase from 0.042 for every 1% increase in vehicle user cost. The emissions decreased by 0.191% for every 1% increase in acquisition taxes. CO_2 emissions are decreased by 0.187% for every 1% increase in ownership taxes. The emissions decreased by 0.195% for every 1% increase in fuel taxes.

Car stock is negatively correlated with vehicle related taxes.Car stock is positively correlated with income per capita. Our results show that Car stock increases from 0.346% for every 1% increase in income. Car stock decreases by 0.267% for every 1% increase in acquisition taxes. Car stock decreases by 0.157% for every 1% increase in ownership taxes. Car stock decreases by 0.077% for every 1% increase in fuel taxes. Car stock decreases by 0.015% for every 1% increase in user costs.

Table 2: Table 2 VMT, CO_2 and Car stock demand elasticity about here

[26] International Road Federation (IRF). World Road Statistics 2002. Switzerland: IRF, 2002. (248)
[27] KENWORTHY, J. AND LAUBE, F.B. (1999). *The Millennium cities database for sustainable transport*. [CD-ROM]. UNION INTERNATIONALE DES TRANSPORT PUBLICS (UITP)

Table 3 show the results of Eq.7 and Eq.8 These equations how cause (explanatory variables) and effects (dependent variables) relationship. Fuel tax and ownership taxes aim at reducing VMT and CO_2 in general. Acquisition tax aims at reducing car stock.

VMT and CO_2 are negatively correlated with fuel and ownership taxes. VMT and CO_2 are positively correlated with income. Car stock is negatively correlated with acquisition taxes. Car stock is positively correlated with income. Our results show that VMT increased by 0.326% for every 1% increase in income per capita. CO_2 increased by 0.400% for every 1% increase in fuel tax. VMT increased by 0.326% for every 1% increase in income per capita. CO_2 decreased by 0.238 % for every 1% increase in fuel tax. VMT decreased by 0.458% for every 1% increase in ownership. CO_2 decreased by 0.285% for every 1% increase in ownership. CO_2 decreased by 0.238 % for every 1% increase in fuel tax. Car stock decreases by 0.018% for every 1% increase in acquisition taxes. Car stock is increased by 0.789% for every 1% increase in income.

Table 3 VAT, CO2 and Car stock demand elasticity by tax stage about here

People often rush into the cheapest gas station for just a few cents, but it is not really rational decision on total vehicle related costs. If there is more data availability on cost per km for drivers, their behaviour could be more rational than these days. These results indicate also relationship between vehicle tax design and environmental policy.

1) Most taxes and user costs are negatively related to VMT, CO_2 and car stock. If tax is imposed for environmental reasons, it is effective in general.
2) With respect to income and tax, we find the strong relationship in acquisition and income in Table 2 and Table 3 is the higher than those of ownership tax or fuel tax.
3) VMT and Car stock depend on acquisition tax most and gasoline tax least among the vehicle taxes in the Table 2. However CO_2 emissions depend on acquisition most and ownership least. CO_2 tax in gasoline in Northern European countries may raise the coefficient of fuel tax.
4) The coefficient of acquisition is higher than those of the other taxes, possibly because acquisition tax imposes a very high level on car stock control. If our estimation is true, acquisition would change CO_2 and VMT most.
5) VMT per capita is another important variable for acquisition tax or ownership tax per km. VMT mainly depends on city population, density, accessibility to public transport and other geographical conditions. More VMT increase, cost per km is reduced. Higher acquisition and ownership tax could be able to reduce "Rebound effect".
6) Fuel tax per km depends on fuel efficiency (km/liter). Improvement of fuel economy affects the tax per km.
7) Vehicle user costs do not have significant relationship neither VMT, CO_2 and car stock.
8) In Table 3, the coefficients of ownership are higher than those of fuel taxes. It may means that ownership may affect more than gasoline taxes.
9) When we sum the coefficients in each equation, CO2, VMT and car stock may change more than just one type of tax. It means that combination of environmental tax in acquisition, ownership and fuel tax would be more effective.

5.Conclusion

This paper discussed the incentives regarding vehicle-related taxes in large cities. It also estimated energy demand and CO_2 reduction using econometric methodology at the city level. Our elasticity analysis indicates that the most effective way to reduce emission is to implement tax measures in high density area. When the model was applied to OECD cities and Asian cities separately, the value of coefficients looked fine for OECD cities. One possible reason for this improvement is that OECD countries have more environmental incentives for vehicle-related taxes. However, it still takes time to make people in OECD countries more environmentally conscious because the total energy consumption and total CO_2 emission are increasing there.

As motorization proceeds, all Asian economies must work to conserve energy saving, and reduce emissions and CO_2, while maintaining economic growth. Some countries have also achieved environmental results through negative reinforcement (i.e. tax policies which discourage certain behaviour). The more environmentally friendly vehicles have a lower tax. Many countries have achieved positive results through a positive incentive-based system that rewards higher environmental performance. This system has helped to achieve the environmental objectives, while promoting economic growth in many Asian economies.

Another way to reduce emissions is to tie vehicle taxes to vehicle age so that newer vehicles with better emissions controls are taxed less than older vehicles that are more likely to produce higher levels of emissions. This would reverse the practice common in many OECD countries. This type of incentive would help to introduce the rapid increase of clean/fuel efficient vehicles, clean fuels, alternative fuels and overall vehicle replacement.

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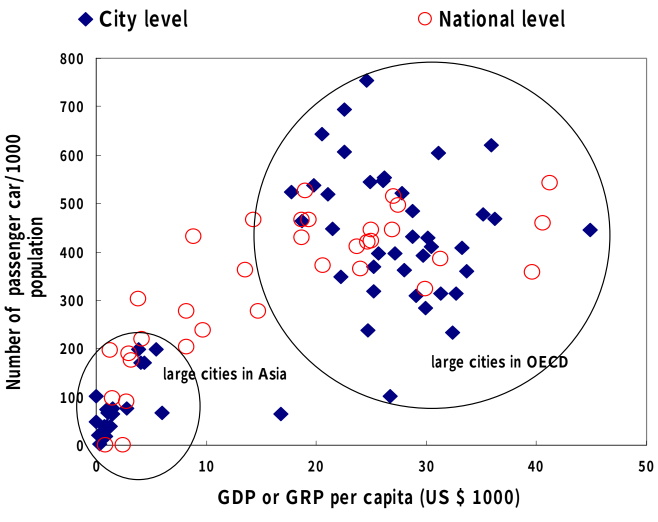


Figure 1 Per capita income and the number of private cars in Europe, North America and the Asia-Pacific region

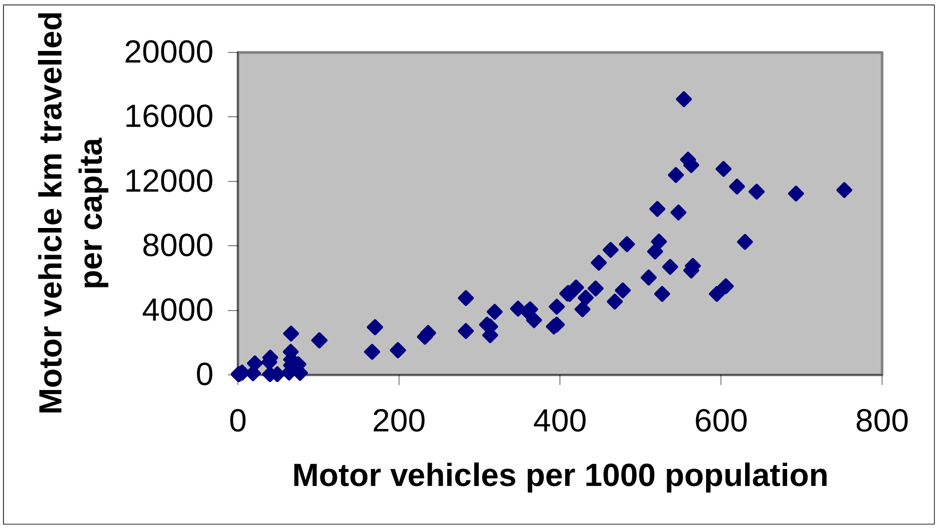
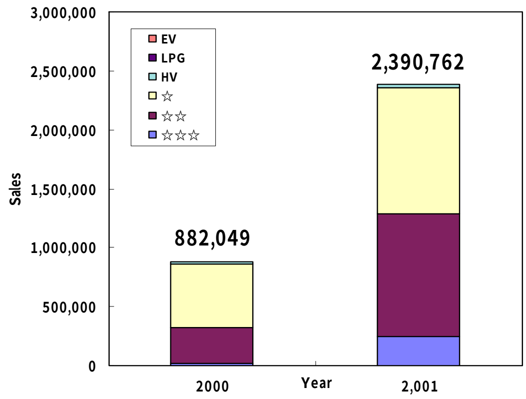


Figure 2 Private cars per 1000 population and vehicle km travelled per capita in large cities (1990 and 2002)



☆ 75% emission reduction from 2000 emission standards: motor vehicle tax 50% off
☆☆ 50% emission reduction from 2000 emission standards: motor vehicle tax 25% off
☆☆☆ 25% emission reduction from 2000 emission standards: motor vehicle tax 13% off

Figure 3. Tax incentives for low emission vehicles in Japan

Table 1　Elasticity survey

Impact in % Influence Factor (change in 1%)	Fuel cost／Fuel tax		Acquisition cost/tax		Ownership cost/tax		Driving cost/time/distance	
	Short term	Long term	Short term	Long term	Short term	Long term	Short term	Long term
Car stock		-0.3[a] -0.15/-0.41[b] -0.2/-0.4[c] -0.2/-0.1[d] -0.18/0.36[e] -0.18/0.36[j] **-0.03**[V]	-0.38[i] -0.09/-0.24[f]	-0.89[g] - 0.4/-1.6[g] -0.253[h] -0.77/-0.6[i] -0.28/-0.57[e] -0.22/-0.31[f]		-0.081[h] -0.08/-0.04[d]		
Fuel consumption	-0.27/-0.28[a] -0.1[f] -0.23[f] -0.5/0.6[l] -0.26[k]	-0.71/-0.84[a] -0.702[h] -0.77[f] -0.86[k]		-0.529[h]		-0.055[h] -0.16/-0.02[d]		
Car use (km)	-0.16[a]	-0.33/-0.29[a] -0.262[h] -0.55/-0.05[i] -0.3[k] **-0.23**[V] **-0.19**[w]		-0.287[h]		0.062[h] -0.04/0.8[d]	0.3/0.6[o]	0.3/0.7[p] 0.5/0.9[p] 0.7/1.0[o] 0.8/1.0[q] 0.3[q] 0.3/0.5[r] 0.559[s] 0.8/1.1[t] 0.29[u]
Public transport (km)	0.18[m] 0.37[n]	0.34[a] 0.18[m] 0.24[n]					2.78[m] 0.43[n]	1.24[m] 0.16[n]
Car maintenance	-0.26（1 car in a household）[b] -0.33（2 cars in a household）[b]							
Income	0.39[f] 0.48[k]	1.17[f] 1.21[k]						

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a Goodwin (1992) Average value of previous studies
b Hensher (1987) No differentiation for short either long run.　Data on vehicle maintenance from Annual household expenditure survey 1990
c Tanner (1981-83) No differentiation for short and long run.
d Johansson et al. (1996) Estimated value. The total of acquisition and ownership taxes are applied for the Ownership elasticity.
e Dargay (1998) Acquisition costs and fuel costs are estimated by income group.
f OECD (2001) Vehicle price elasticity impacts on public transport.　Fuel demand elasticity: OECD data (1960-1985)

Cost composition in %

Cost level per km (Tax, expenditure)

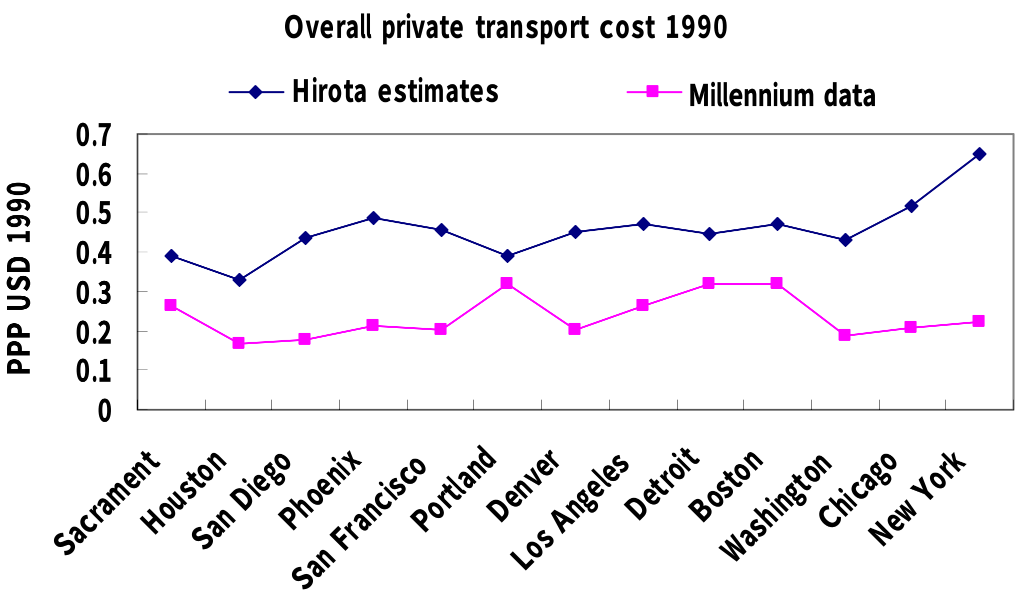

Figure 4 Overall private transport cost (North America)

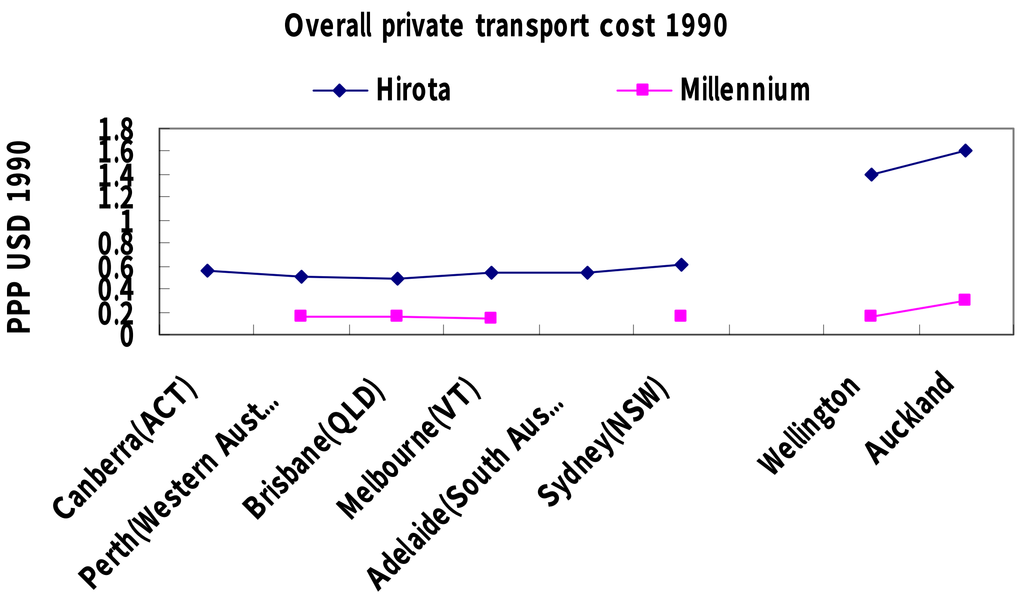

Figure 5 Overall private transport cost (Pacific)

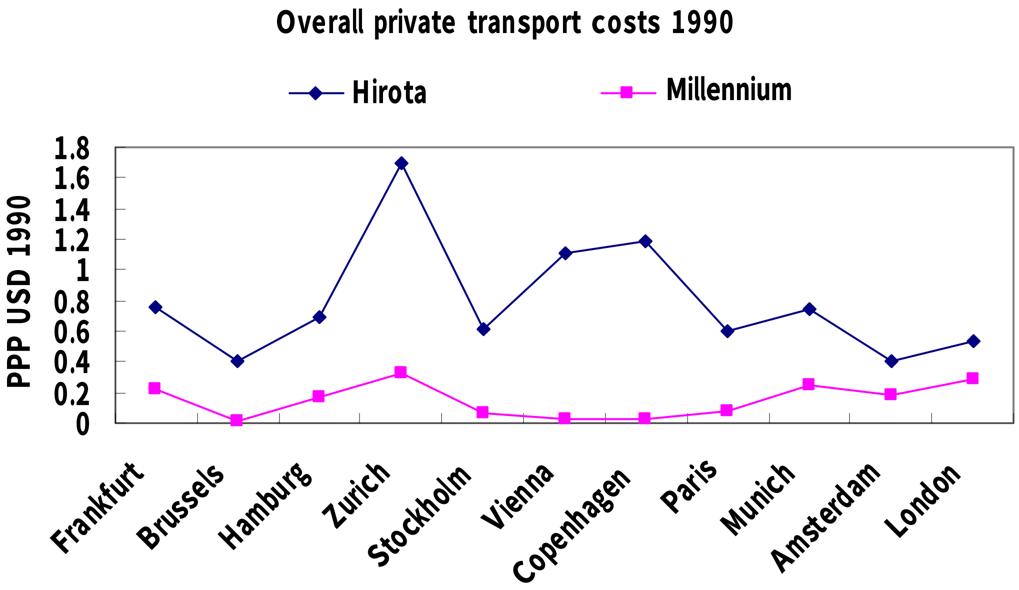

Figure 6 Overall private transport cost (Europe)

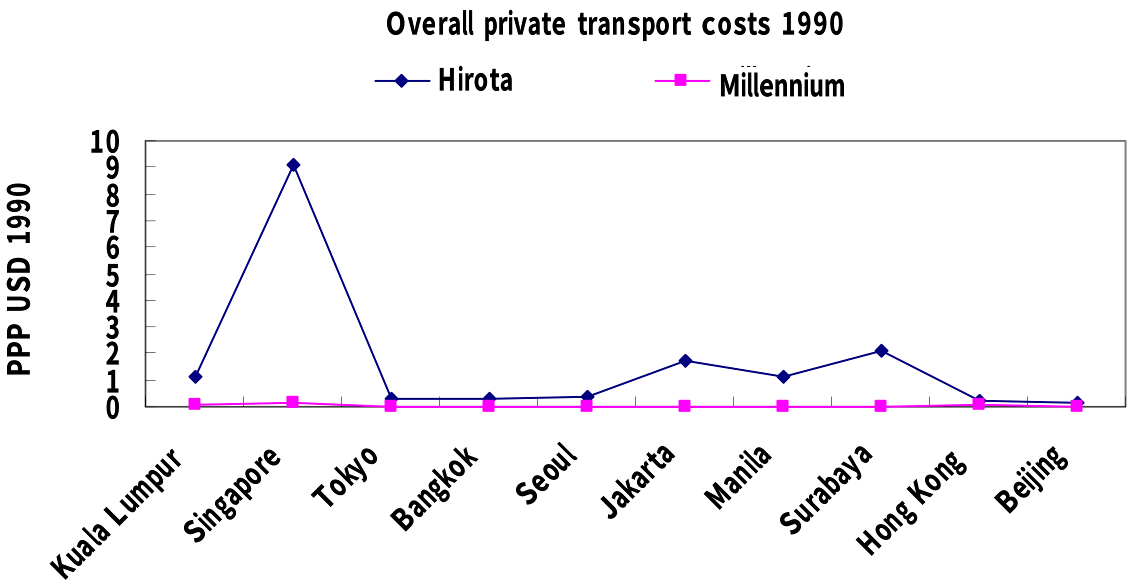

Figure 7 Overall private transport cost (Asia)

Table 2 VMT, CO_2 and Car stock demand elasticity

	VMT	CO_2	Car stock
Constant β_1	2.235 (6.008)**	1.159 (3.172)**	0.461 (1.329)
Acquisition tax per km β_{2a}	-0.453 (-8.491)**	-0.191 (-3.562)**	-0.267 (-5.376)**
Ownership tax per km β_{2o}	-0.216 (-4.638)**	-0.187 (-4.229)**	-0.157 (-3.614)**
Fuel tax per km β_{2f}	-0.042 (-0.499)	-0.195 (-2.474)*	-0.077 (-0.981)
Vehicle user cost per km β_3	-0.273 (-0.797)	0.042 (1.313)	-0.015 (-0.496)
Income per capita β_4	0.159 (2.103)*	0.332 (4.489)**	0.346 (4.898)**
Adjusted R^2	0.727	0.758	0.757

( ): t value *significant at the 5% ** significant at the 1%
---: no consideration

Table 3 VAT, CO2 and Car stock demand elasticity by tax stage

	VMT	CO_2		Car stock
Constant β_5	0.148 (0.259)	0.705 (1.888)	Constant β_{10}	-0.929 (2.468)*
User cost β_6	0.019 (0.401)	0.058 (1.676)	Acquisition tax per km β_{11}	-0.018 (-2.219)*
Fuel tax per km β_7	-0.154 (-1.276)*	-0.238 (-2.789)**	---	---
Ownership per km β_8	-0.458 (-8.520)**	-0.285 (-7.584)**	---	---
Income β_9	0.326 (3.086)**	0.400 (5.123)**	Income β_4	0.789 (8.695)**
Adjusted R^2	0.636	0.712	Adjusted R^2	0.631

( ): t value *significant at the 5% ** significant at the 1%
---: no consideration