Motorization and energy consumption in large cities in the OECD and Asia – tax incentives and public transportation for greater fuel efficiency

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Abstract

With the advent of motorization, many national and local authorities have implemented measures to conserve energy. It is very important to achieve positive results through a positive incentive-based system that rewards higher environmental performance. This paper is an attempt to analyze impacts of vehicle-related taxes on passenger car and public transportation use in large cities in the OECD and Asia-Pacific region in order to save energy. We focus on expenditures for private vehicle maintenance, public transportation and vehicle-related taxes in order to evaluate energy consumption reduction from policy implementation. Our results show that the environmental objectives can be achieved more easily by a modal shift with the vehicle tax system.

Introduction

Many countries have implemented various measures to reduce emissions from the transport sector. One of the important measures is to give consumers incentive to reduce their energy consumption because consumer behaviour affects the modal split, which in turn influences emission from the transport sector. Figure 1[1] represents the number of private cars and income growth at the national and city levels. The number of private cars normally increases with income growth at the national level. However, it may vary by region, road infrastructure and population density at the city level. This is why we analysed demand responsiveness to expenditures for public transport, private car and vehicle taxes only in large cities, not at the national level.

People may change their behaviour due to price increases. In order to measure the impact of price increases, a lot of elasticity analyses have been made on fuel prices. Espey[2] examined 1 230 papers on fuel price elasticity analysis in the US from 1966 to 1997[3]. Studies on fuel price elasticity might yield different results to explain the various factors. Drollas' surveys[4] of gasoline elasticities for European countries in the 1980s found that people would switch from gasoline to LPG or diesel-powered vehicles, or use a different mode of transport as gasoline prices increased. The author's results yield long run price elasticity estimates of approximately -0.6. Comparing to the short run elasticity -0.26, he finds that gasoline price in the long run may be more elastic than that of the short run.

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2. Espey, M. "Watching the fuel gauge: an international model of automobile fuel economy". *Energy Economics.* Vol. 18, 1996. (93-106).
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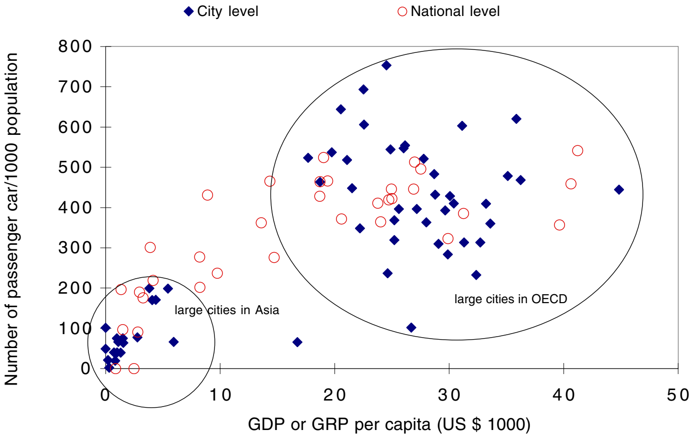

Figure 1. *Per capita income and the number of private cars in Europe, North America and the Asia-Pacific region.*

In Eltony's estimates[5] 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[6]. 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.

Jong[7] indicates that geographical differences influence the value of price elasticities of fuel and public transport in his comparison of North Europe, Belgium, the Netherlands and Italy. These models are made for traffic estimations in the future. Jong points out that the factor of "congestion feedback" makes the results different. With congestion feedback, car time increases and working hour would be reduced, it reduces car use.

Italian model has slightly the highest elasticity on the modal shift because the Italian model put priority on travel for long distance. It does not have to consider traffic congestion very much. Brussels' model has the lowest elasticity among three models due to including the traffic congestion feedback.

Espey analyses not only the role of fuel prices, but also of vehicle related taxation in changes of consumer patterns. The data set entails 8 countries: USA, Japan, France, Germany, the UK, Norway, Sweden and Denmark between 1975 and 1990. Espey estimates the fuel economy improved only by 0.94% as a result of changes in fuel prices, income or vehicle taxation at 6% in the first year. The author believes that acquisition and ownership taxes have important roles in improving fuel economy. Johansson and Schipper[8] also consider the effects of different taxation measures on fuel and travel demand. An important point of these papers is that fuel prices have a greater impact on energy consumption than vehicle related taxes. These studies show a slow rate of adaptation with little immediate effect.

However the above studies don't include Asian countries or cities. In this paper, we focus on Europe, USA and Asia-Pacific regions at the large city level. This paper also considers whether similar policies can be applied in Asia-Pacific regions. Our data set includes 49 large cities, i.e., 40 from OECD including Japan and 9 from the rest of Asia[9].

The purpose of the tax incentive differs by region, but all involve reducing energy consumption. In order to compare the OECD and Asian regions, we focus on energy consumption reduction. We also include CO_2 reduction and exhaust emissions as additional information.

The population density, number of passenger vehicles per 1 000 people and public transport expenditure are variables which affect expenditure and transportation modes. The criteria for the Asian large city group are as follows:

- Private car density: less than 200 passenger vehicles per 1 000 people;
- Population density: at least 150 people per ha[10];
- Public transport expenditure: less than US$ 200 annually.

This paper is organized as follows. We begin by describing the vehicle tax structure. Following the tax information, expenditure for transportation, elasticities are estimated by econometric methodology. Comparing the results, we propose some points of improvement in tax structure in Asian countries.

Environmental incentives and the vehicle-related tax structure

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. In order to compare by cross-section, we make the assumptions of vehicle characteristics shown at the bottom of the page.

The vehicle related taxes are classified by three stages: acquisition, ownership and driving. In each stage, the following points are assumption 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[11] in US$ in 2000. In general, the tax in OECD countries may be for environmental concerns while many Asian countries use the tax to induce industrial development.

5. Eltony, M. "Transport gasoline demand in Canada." *Journal of Transport Economics and Policy*, Vol. 27, 1993. (193-208).
6. During this period, the price of regular gasoline grew at 2.7% every year in average. Prices of other manufacturing goods grew at 3.6% in average.
7. Gerard de Jong and Hugh Gunn. "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).
8. Johansson Olof., and Lee Schipper. "Measuring the long-run demand of cars." *Journal of Transport Economics and Policy*. September 1997. (277-292).
9. We include Japan in the group of OECD cities, not in the group of Asia.
10. Singapore and Kuala Lumpur was excluded for estimation because these cities have population density more than 100 people/ha.
11. International Monetary Fund. (Washington, DC).

Assumptions: New passenger vehicle gasoline vehicle, domestic production 1 unit.
Vehicle weight: 1 100 kg, Engine capacity 1 600 cc,
Fuel economy 12 km/liter (8.3/100 km).
Horse power 72 HP, Vehicle price US$ 13 000[12], 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.

Acquisition tax

OECD COUNTRIES

Types of taxes: VAT, registration fee, sales tax.

Tax level

Figure 2 shows tax levels for OECD countries. Many European countries impose Value Added Tax (VAT) on acquisition. VAT is based on the sales price. Since vehicle price seems to be related to income level, there may be the idea "the high income people have to pay more tax."[13] 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.[14] 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 (GVW) and fuel type.

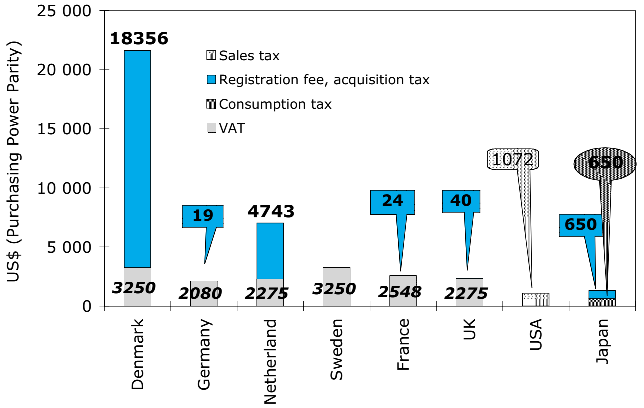

Figure 2. *Acquisition tax in OECD countries. Sources: ACEA tax guide 2001, official documents and websites in Japan and the USA.*

ASIAN COUNTRIES

Tax types: Sales tax, VAT, Interior tax, Surtax, Luxury tax.

Tax level

Figure 3 shows the tax levels in Asian countries. Asian governments tend to design their tax structures to induce economic growth. The Thai and Malaysian tax structures for example, include incentives instrument for industrial development. The Philippines government has imposed lower tax rate on diesel vehicles than on gasoline vehicles. This might be favourable for commercial vehicles[15]. 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.

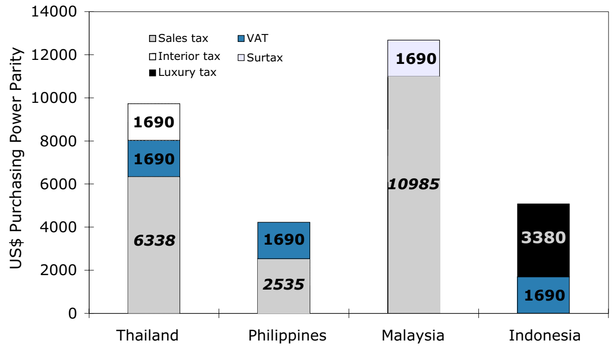

Figure 3. *Acquisition taxes in Asian countries .*
Sources: Official documents and websites from each country.

Ownership tax

JAPAN-EU

Tax types: Ownership tax, road tax, weight tax.
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 level

Figure 4 shows the ownership tax in EU and Japan. 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.

12. Since we take the assumption of the car price in dollars, we have to convert in local currency.
13. Working group of vehicle related tax_*A report of vehicle related*. Tokyo 2001. For the case of the US, New York tax system is applied in Figure 2.
14. Danish Ministry of Energy Environment, June 2000.
15. National Center for Transportation Studies. *A Research on Proper Automobile Usage Strategy towards Environmental Impact Abatement in Large Cities in Asia. Manila*, March 2000 (14).

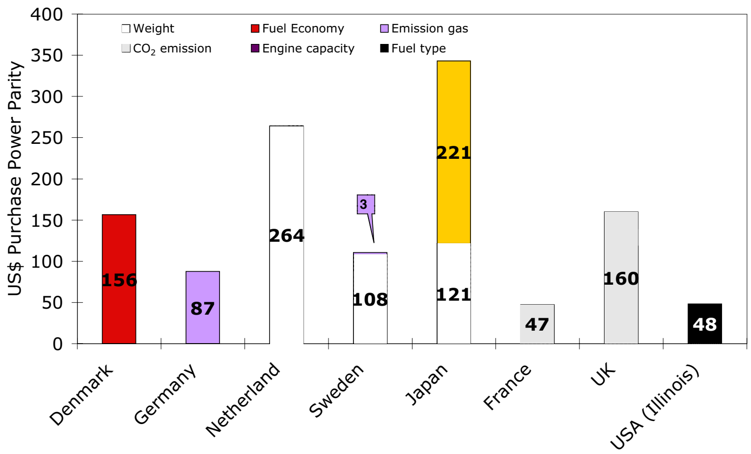

Figure 4. *Ownership tax in the EU and Japan. Sources: ACEA Tax guide 2000, JAMA.*

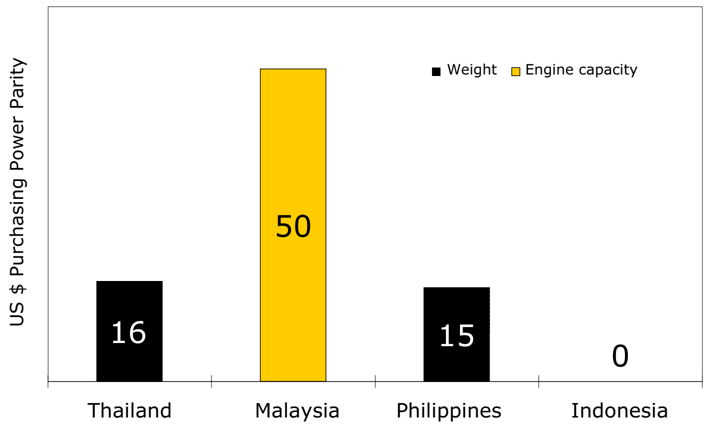

Figure 5. *Ownership tax in Asian countries. Sources: Official documents and websites from each country.*

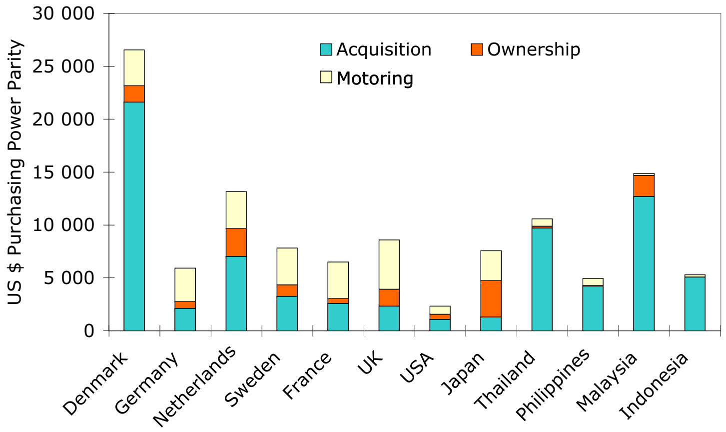

Figure 6. *Total vehicle related taxes.*

ASIAN OWNERSHIP TAX

Types of taxes: Road tax, re-registration fee.

Tax level

Figure 5 shows the ownership tax in Asian countries. In Malaysia, the ownership tax depends on engine capacity. In Thailand and the Philippines, it depends on vehicle gross weight. According to official documents 1999, the 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.

Total tax including fuel tax in 10 years

Fuel Tax types: Fuel tax in general, carbon tax and CO_2 tax.

Tax level by fuel type

Some countries offer lower taxes and prices for alternative fuels. GTL in France and LPG in Belgium are taxed less than gasoline and diesel oil. Sweden has given disincentive for diesel fuel by imposing a heavier CO2 tax on diesel fuel than gasoline. In OECD countries, many vehicle taxes and fuel taxes have been redesigned to better reflect their environmental purpose. Finland, Sweden and Denmark have shifted from energy taxes to “carbon taxes” that could reduce CO2 emissions. In Denmark, a tax rebate of 0.1 DKK/litre is granted for light diesel oil but not for normal diesel oil.

Figure 6 shows the total tax which includes acquisition, ownership and motoring taxes. The proportion of acquisition tax is the highest in each country.

Methodology and data description of the models

Energy price and circumstances such as public transport may affect the consumer behaviours. The following equations assume that energy demand of passenger vehicle depends on vehicle related expenditure, vehicle related tax and public transport expenditure. 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:

$$\log X = \beta_1 + \beta_2 \log VehExp_r + \beta_3 \log Tax_r + \varepsilon \qquad (Eq1)$$

$$\log X = \beta_1 + \beta_2 \log VehExp_r + \beta_4 \log PubExp_r + \varepsilon \qquad (Eq2)$$

$$\log X_p = \beta_1 + \beta_2 \log VehExp_r + \beta_3 \log Tax_r + \beta_4 \log PubExp_r + \varepsilon \qquad (Eq3)$$

Variables are defined as:
X: Total energy consumption of private cars per large city (MJ)or CO_2 emissions per city population (kg/large city population)
VehExp: Expenditure for private vehicle maintenance (US$/large city population)
Tax: Expenditures for vehicle-related taxes (US$/unit per large city)
PubExp: expenditure for public transport (US$/large city population)
r: region I
ε: disturbance

The model features energy consumption from private cars and CO_2 emissions as dependent variables. There was no significant difference between the results of total energy consumption and total CO_2 emissions. The key variable is the expenditure by different population densities. In lower density areas, people often drive private cars and use little public transport[16]. As per capita income increases, vehicle travel distance increases generally[17]. First, elasticities are estimated for the OECD and Asian cites together for Eq1, Eq2 and Eq3. Secondly, elasticities are estimated separately between OECD large cities and Asian large cities (except Japan) for the three equations.

The data on public transport and private vehicle expenditure are estimated from "Journey to Work[18] (%)", commuting expenses (%) and Gross Domestic Product or Gross Regional Product (US$ 1990). The data on vehicle related taxes comes from original official documents of Asian countries, the Association des Constructeurs Européens d'Automobiles (ACEA) tax guide and Japan Automobile Manufactures Association (JAMA) reports. The tax levels following the assumption for the comparison are converted into Purchasing Power Parity in US dollars in 2000.

Results

Table 1 shows the correlations between energy consumption and expenditure (*Eq1 - Eq3).* Each estimated value is evaluated for its significance at the 5% (*) and 1% (**) levels. Energy consumption is negatively correlated with vehicle-related taxes and/or expenditure for public transportation. Energy consumption is positively correlated with expenditure for private vehicle maintenance.

According to previous studies, energy consumption is reduced at 0.1-0.5% for every 1% increase in energy price. Our results show that energy consumption increases by 0.306-0.759% when private car maintenance expenditure increase by 1%. This expenditure is estimated by income level per capita multiplies by proportion of private car spending in income level. Car expenditure can be interpreted as cost per trip multiplying by number of trip. This value affects the positive relationship between energy consumption and energy demand.

Energy consumption decreases by 0.234% for every 1% increase in vehicle related taxes without consideration of public transport expenditure *(Eq1).* Energy consumption decreases by at 0.149% for every 1% increases in public transport expenditure without consideration of vehicle-related taxes *(Eq2).* Total energy consumption is reduced by 0.325% (0.186% for every 1% increase in vehicle-related taxes and 0.139% for every 1% increase in public transportation expenditure) *(Eq3).* Since Eq3 has the highest percentage of environmental improvement among the three equations. It indicates that we need several complementary measures to reduce energy consumption. For further development of this study, it would be interesting to model between vehicle-related taxes and public transport expenditures.

Table 2 shows the correlations between CO_2 emissions and expenditure (*Eq1 - Eq3).* Each estimated value is evaluated for its significance at the 5% level (*) and 1% (**) levels. CO_2 emissions are negatively correlated with vehicle-related taxes and/or the public transportation expenditure. CO_2 emissions are positively correlated with expenditure for private vehicle maintenance.

Table 1. Energy demand elasticity.

	Eq 1	Eq 2	Eq 3
Private car expenditure β_2	0.306 (2.629)**	0.759 (15.313)**	0.423 (4.402)**
vehicle related tax β_3	-0.234 (-2.465)*	---	-0.186 (-2.490)*
Public transport Expenditure β_4	---	-0.149 (-2.399)*	-0.139 (-3.592)**
Constant β_1	3.275 (16.876)**	2.688 (19.788)**	2.13 (11.452)**
Adjusted R^2	0.919	0.908	0.951

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

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.
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18. Newman, Peter and Jeffrey Kenworthy. *Sustainablility and cities.* Washington, D.C. Island Press, 1999.(345-347).

Table 2. CO_2 emission elasticity.

	Eq 1	Eq 2	Eq 3
Private car expenditure β_2	0.286 (2.553)*	0.602 (17.440)**	0.385 (3.868)**
Vehicle related tax β_3	-0.228 (-2.502)*	---	-0.188 (-2.420)*
Public transport expenditure β_4	---	-0.145 (-3.837)**	-0.118 (-2.950)**
Constant β_1	2.226 (11.943)**	2.016 (20.747)**	2.275 (14.505)**
Adjusted R^2	0.915	0.927	0.943

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

According to previous studies, CO_2 emissions increase by 0.2-0.6% for every 1% increase in private car expenditure. This value of expenditure estimated also affects the positive relationship between energy consumption and CO_2 emissions. Our results show that CO_2 emissions increased by 0.286-0.602% for every 1% increase in private car expenditure because expenditure also includes cost per trip multiplying by number of trip. The emissions decreased by 0.228% for every 1% increase in vehicle taxes without consideration of public transport (*Eq1*). CO_2 emissions decreased by 0.145% for every 1% increase in public transport expenditure without consideration of vehicle related taxes (*Eq2*). CO_2 emissions will be reduced at 0.306% (0.188% for every 1% increase of vehicle related taxes and 0.118% for every 1% increase of public transport expenditure) in total (*Eq3*). These results show also the similar indication as that of energy demand elasticity.

In our model, we also estimate elasticities for OECD and Asian large cities. In OECD large cities, energy demand can be reduced by 0.430% (0.319% by increasing vehicle tax at the 1% and 0.111% by increasing public transport expenditure 1%). CO_2 emissions can be reduced by 0.394% (0.296% by increasing vehicle tax at the 1% and 0.098% by increasing public transport expenditure at the 1%). All the estimated coefficients for OECD large cities are significant at the 1% level of t statistics. The coefficients focusing on only OECD data results in improvement of energy consumption and CO_2 reduction. We did not get significant values for Asian large cites due to the small sample size (n =9[19]).

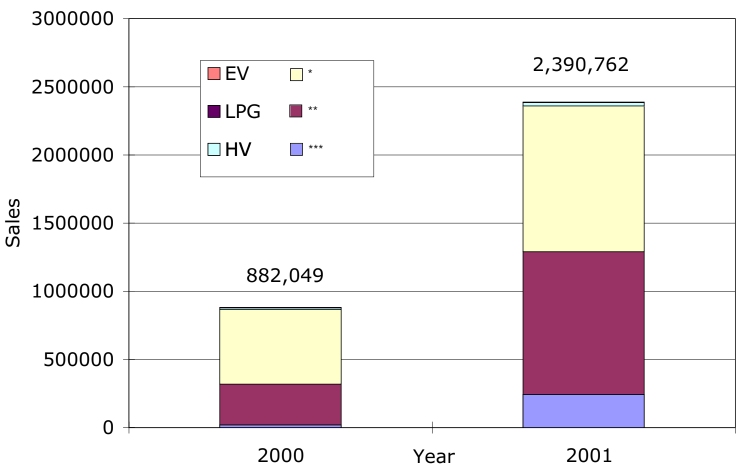

Figure 7. *Tax incentives for low emission vehicles in Japan.*

**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.*

Data interpretation

OECD COUNTRIES

In the United States, the federal government offers consumers tax deductions ranging from US$ 2 000-50 000 towards incremental expenditure increase for the purchase or conversion of an approved clean fuel vehicle[20]. 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 7 shows the tax incentives for low emission vehicles in Japan. The number of low-emission vehicles significantly increased from 2000 to 2001.

In the Netherlands, the government reformed vehicle-related taxes for environmental objectives, but the total energy consumption since 1990 has been stable not decreasing[21]. This is because car ownership has not decreased. The average vehicle gross weight of new cars has been increasing by 1.9% annually from 1987 to 1991. Average engine capacity of new cars has been increasing by 4% from 1985 to 1997. The government of the Netherlands plan to impose an acquisition tax (B.P.M) based on CO_2 emissions. The government expects 4% of CO_2 reduction by this reform. The Danish government decided to reform 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 of impacts of tax incentives indicate that consumer behaviour may not be strongly related to fuel economy. Consumer might still prefer other criteria. In fur-

19. Kuala Lumpur, Singapore, Bangkok, Seoul, Jakarta, Manila, Surabaya, Hongkong and Beijing. Tokyo is included in the OECD large cities.
20. http://www.fueleconomy.gov/feg/tax_hybrid.shtml.
21. 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.

ther research, estimates should be made using cross section-time series.

ASIA

High population density, low passenger car ownership and high use of public transportation make Asian cities seem to be environmental friendly. One of the problems in Asia is 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 to be concerned about equity issues in their tax systems[22]. In the Philippines, the sales tax is lower for diesel vehicles than for gasoline vehicles. However, the Philippine government tries to provide as simple tax system as possible. The government might reduce tax level for each item and impose tax on broader items. In Thailand, the Government introduced a VAT tax instead of the business tax. It was 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[23]. 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 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 the tax system by vehicle age. Older vehicles are taxed level at lower, 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.

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[24], 1 540 vehicles (mostly taxis) have been converted to bi-fuel mode (petrol-natural gas) and 1 000 monogas taxis are in service in Kuala Lumpur.

Conclusion

In this paper we have discussed the incentives regarding vehicle-related taxes and access to public transportation in large cities. We also estimate energy demand and CO_2 reduction in econometric methodology at the city level. Our elasticity analysis indicates that the most effective way to reduce emission is to implement tax measures in conjunction with public transport policy. When the model was applied to OECD cities and Asian cities separately, the value of coefficients looks fine for OECD cities. One possible reason of 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 total energy consumption and total CO_2 emission seem to be 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 behaviours). 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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