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VEHICLE USAGE AND FUEL EFFICIENCY FOR FUEL TAX POLICY MODIFICATION: THE CASE OF TAIWAN☆

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Abstract: This study uses Taiwan as an example to update the 1983 tax collection method by sampling vehicle usage and fuel efficiency to estimate the amount of fuel consumed. In this study, vehicles are classified by type, engine size, commercial/private use, domestic/imported, etc. As expected, fuel efficiency of small automobiles has improved during the past 20 years in Taiwan though there is no significant change perceived for trucks and buses. As for the vehicle usage, it is interesting to learn that certain size of small vehicles is popular on the market. The study reveals that fuel consumption of small automobiles can be fairly estimated by any available method but this is not the case for commercial vehicles, such as trucks and buses. Findings in the paper would provide references to some government which attempts to change its fuel tax collection method from plate to fuel consumption.

Key Words: Fuel tax, Collection, Consumption

1. INTRODUCTION

Fuel tax is the major revenue source of the Highway Pavement and Maintenance Fund. In order to ensure sufficient fund for maintaining highway service, government needs to constantly examine the efficiency of tax administration and the effectiveness of enforcement. This article therefore examines fuel tax structure from the policy perspective. The aim of the article is twofold. First, the paper discusses the vehicle tax collection method employed among International Energy Agency (IEA) member countries. In particular, the differences of fuel tax structure between America and Europe will be examined in the paper. Second, the article investigates fuel tax collection method as well as conducts a field survey in Taiwan.

This article is organized into five sections. After introduction, the section 2 discusses the worldwide fuel consumption trend. Section 3 describes transport energy efficiency and compares the differences of fuel tax structure between America and Europe. Section 4 investigates fuel tax collection method as well as conducts a field survey in Taiwan. Finally, section 5 concludes from survey data and proposes the use of fuel tax collection method based on fuel consumption in Taiwan.

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2. FUEL CONSUMPTION TREND IN THE WORLD

2.1 Changes in fuel consumption

It is well-known that the carbon dioxide (CO_2) emission produced by motor vehicle is a big threat to the environment since the continuing build-up of CO_2 greenhouse gases in the air contribute to the formation of global warming and the amount of CO_2 emitted from vehicles is approximately proportional to the amount of fossil fuel consumed. The CO_2-emission is produced when fuel is not burned completely in the engine and, therefore, the most effective way to reduce the emission is to burn less gasoline.

Figure 1 shows that the transportation sector not only represents about 55% of the oil consumed by the Organization for Economic Co-operation and Development (OECD) member countries in 2004 but also is the driving force for the increasing demand in oil among OECD countries. When other sectors of the economy, such as manufacturing and household, try to cut down their use in oil, the transport sector consumes an ever-increasing proportion.

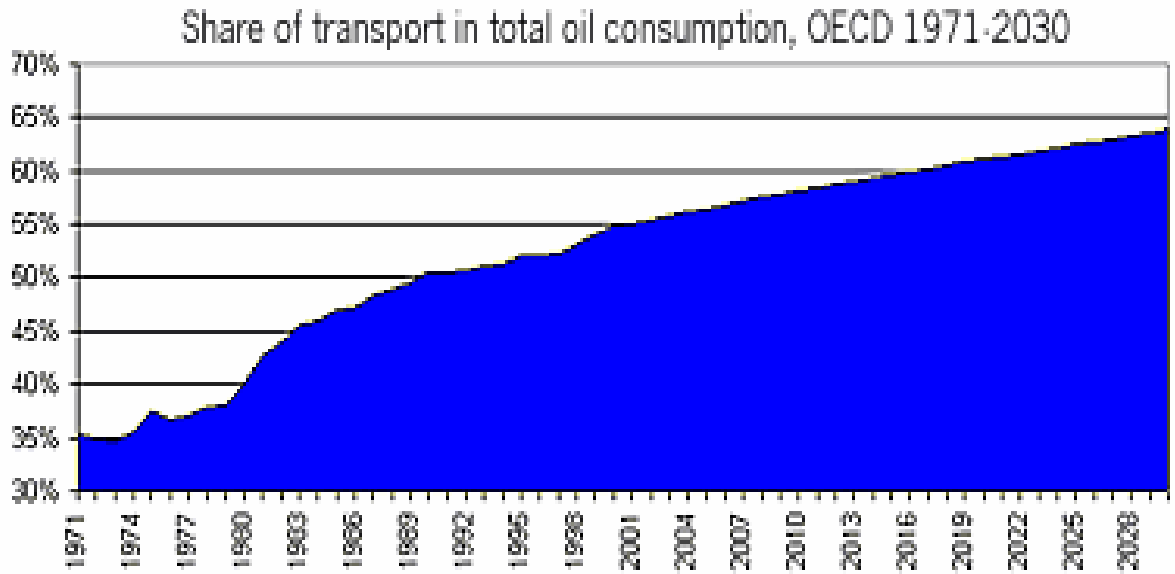

Figure 1. Share of Transport in Oil Consumption, OECD, 1971-2030
Source: World Energy Outlook, International Energy Agency, 2004, http://www.iea.org

According to Table 1, the oil demand for land transportation accounted for almost 80% of total oil used by the transportation industry in the IEA countries from 1973 to 1988. During the same period, as indicated by table 3, gasoline consumption only had increased by 16.9% while the number of registered vehicles had increased 57.9%. This clearly shows that either the fuel efficiency of automobiles had improved substantially or the incentive policies/programs to discourage the use of vehicle had been effective over these years. The result is confirmed by Table 3. Table 3 points out that the fuel consumption per vehicle in IEA countries had reduced by 25.9% in this period.

Table 1. IEA Oil Consumption in the Transportation Sector (Unit: million liters)

Year	Land Transportation	Shipping	Air	Rail	Non-specified Transportation	Total	Land Transportation Ratio
1973	511.9	83.7	75.2	22.6	0.4	693.8	73.78%
1979	595.0	86.3	83.6	22.0	0.5	787.4	75.57%
1980	576.2	86.1	83.1	21.0	0.5	767.0	75.12%
1981	576.0	79.2	79.3	20.3	0.5	755.2	76.27%
1982	575.8	68.5	79.2	18.6	0.5	742.6	77.54%
1983	588.1	63.0	80.6	16.3	0.5	748.4	78.58%
1984	597.3	65.7	88.5	17.4	0.6	769.5	77.62%
1985	603.1	67.9	92.1	16.4	0.6	780.1	77.31%
1986	623.1	70.0	97.7	15.8	0.6	807.2	77.19%
1987	646.6	69.0	101.5	16.0	0.6	833.6	77.57%
1988	675.5	71.3	106.4	17.0	0.6	870.7	77.58%

Source: International Energy Agency, Fuel Efficiency of Passenger Cars. OECD, Paris 1991.

2.2 The increase of vehicle population on the road

Within the transportation industry, the primary emphasis on reducing oil consumption has been to cut back fuel consumed by highway vehicles, particularly automobiles (Table 2). Therefore, it is reasonable to suggest that policies for reducing energy consumption, in particular the oil consumption, should focus on the transportation industry and automobiles within the sector.

Table 2. Number of Car Per Thousand Capita

Year	Taiwan	America	Japan	Britain	France	Germany	Italy	Canada	Korea	Hong Kong	China
1991	156	743	483	418	501	491	541	630	98	69	5
1992	174	746	495	401	506	489	584	623	119	75	6
1993	190	748	511	403	506	508	586	575	142	77	7
1994	205	755	520	380	518	516	567	594	166	79	7
1995	219	761	533	396	518	523	574	563	188	78	8
1996	232	773	547	398	524	529	580	568	210	76	9
1997	244	770	555	415	528	533	591	576	227	79	10
1998	248	820	560	419	543	538	608	581	226	80	10
1999	243	788	566	389	560	539	610	…	239	79	11
2000	251	…	573	…	574	548	…	…	256	78	12
2001	256	…	…	…	…	564	…	…	273	78	…
2002	263	…	…	…	…	571	…	…	293	78	…

Source: International Road Federation (IRF), 1992-2003. World Road Statistics. Annual Report

Table 3 points out the changes in consumption on the amount of gasoline and vehicles. The changes were marked differently on a regional basis from 1973 to 1988. Consumption rose 10.3% in North America while its fleet amplified 39.6%. It went up 42.6% in the Pacific Region, accompanied by a 103.3% boost in the fleet. The enlargement magnitude was 34.9% in Europe while the fleet grew 75.2%. Furthermore, annual average gasoline consumption per car in the IEA countries fell 25.9%, from 2,891 liters to 2,141 liters. The greatest decline occurred in the Pacific Region followed by Europe and North America regions.

Table 3. Changes in Consumption on the Amount of Global Gasoline and Vehicles from 1973 to 1988

Region	Total Gasoline Consumption Changes (%)	Vehicle Number Change (%)	Fuel Consumption Per Vehicle Change (%)
North America	+10.3	+39.6	-21.0
Pacific Region	+42.6	+103.3	-29.9
Europe	+34.9	+75.2	-23.0
IEA countries	+16.9	+57.9	-25.9

Source: International Energy Agency, Fuel Efficiency of Passenger Cars. OECD, Paris 1991.

Congestion and vehicle emission are the two major concerns with regard to transportation policy worldwide. Since motor vehicles are built on durable and heavy materials, they tend to make noise, vibrate at low speeds, and cost more to purchase and maintain. A 1997 German study estimated that 60~70 percent of cancers caused by urban pollution was due to PM_{10} found in diesel exhaust *(*Barnard, 1999). As the number of vehicles on the road grow rapidly, increases in transport activity without changing patterns is likely to create considerable social cost to society. Road congestion is a symptom of inadequate transport efficiency. Since congestion problem will damage the environment as well as incur health hazards, it is an important part of the external costs to road transportation. The problem is also indirectly related to the fuel efficiency issue. Gains in fuel efficiency will be partially offset by slow moving traffic flow which increases fuel consumption per vehicle-km.

Although most regulations worldwide require automakers to install catalytic converters on vehicles before they could sell cars on market, it is hard to control CO_2 emissions produced by vehicles. Accordingly, alternative ways to lower the CO_2-emission are to further improve fuel efficiency, to develop the technology for alternative fuel, and to reduce overall travel volume either by dropping vehicle population or average traveling distance per car (Johansson and Schipper, 1996)

3. TRANSPORTATION ENEREGY EFFICIENCY

3.1 The Origin of transportation energy efficiency

Transportation system efficiency and low energy consumption could be achieved by urban and land-use planning, modal mix design (e.g., cars, trucks, rail, air, etc.), behavioral and

operational management (e.g., occupancy of vehicles, driver behavior, and system characteristics), and vehicle efficiency and fuel choice. In particular, energy efficiency in the passenger transportation system could be attained through pricing and taxing schemes, technology improvements, and the overall system efficiency design. Apart from raising revenue, tax measure provides an incentive for energy efficiency. This is because people may choose to buy small rather than large automobiles, change their mobility habits, drive less, or take public transportation to meet their commuting needs. There are various types of vehicle tax measure, such as purchase tax, ownership and registration fees, fuel/carbon tax, road and congestion pricing, and parking fees.

The basic price, excluding all taxes paid by final consumers, comprises the price of crude oil, production/distribution costs (including taxes paid by producers/distributors), and the oil companies'/distributors' profit margins. All these components are relatively insignificant compared to the amount of tax paid by final consumers. (Sussams, 2000). Higher fuel price results in greater fuel conservation. The European and Japanese governments, for instance, impose high fuel taxes leading to high gasoline prices of approximately US$4 per gallon on the market which, in turn, creates a large demand for small and fuel-efficient vehicles. In the U.S., however, high fuel tax is unpopular among voters and hence it is very unlikely that politicians would support a significant increase in gasoline tax. (Anonymous, 2002)

3.2 The importance of vehicle tax revenue

Though governments have the obligation to provide "accessibility" to their people in order to meet their commuting needs is part of the social welfare concept, transportation infrastructure system requires expensive construction and maintenance inputs. Nonetheless, these inputs are paid from government's revenue which generates directly from taxpayers. In order to alleviate the burden on taxpayers as well as to maintain equality, a principle of "user-pay" pricing has been promoted recently by both scholars and officials.

On a free market, before a consumer purchases an automobile, that consumer would consider whether or not the price which is regarded as an internal cost meets the marginal cost of the automobile. If external cost such as air pollution and congestion is present, the price which a consumer pays for a gallon of gasoline must equal to the automobile's true cost. Nevertheless, it is rather difficult to add external cost in the production cost and then reflect in fuel price since external cost includes not only pollution cost but also social cost and it is almost impossible to figure out the "intangible" aspect of the social cost.

In principle, the taxation of road transport might be used to address each of the major form of social cost involved in vehicle use: environmental costs including global and local air pollution, noise and aesthetic losses (Button, 1993), congestion costs and accident costs imposed on other road users (Newbery, 1990), and the otherwise uncharged costs of using the public-provided road infrastructure (Newbery, 1988). It is desirable that the social cost should be reflected in the costs of road use faced by individual road user. The tax system may have often been unclear about 'which-if any-of' the various social costs are reflected in the high level of taxation on motor vehicles and vehicle fuels (Crawford and Smith, 1995).

Reno and Stowers (1995) suggested the following four criterions for designing a tax structure.

(1) Simplicity and effectiveness: such as the number of taxpayers, compliance cost, potential

of tax evasion and administrative costs.
(2) Equity: equity evaluations are most commonly made with regard to vehicle class, income group, and geographic area.
(3) Economic efficiency: including the impact of congestion on other users, not just on trip makers. Congestion pricing and road damage pricing would charge the marginal cost of travel, or at least move in that direction.
(4) Political implement ability: The potential for political support and implement ability must be judgmentally estimated by management.

These criterions are built upon the observation that taxpayers would normally support increasing user taxes/fees if these taxes/fees are used to improve transportation system.

3.3 Types of motor vehicle tax

Vehicle tax in the United State includes current fuel tax, tax on alternative fuel, registration fee, vehicle sales tax, annual vehicle miles of travel (VMT) fee, emission fee, congestion pricing, and pavement-damage fee/weight-distance tax. While vehicle tax in Europe includes sales tax on new vehicles, recurrent annual charge, tax treatment of company cars/commuting expense, fuel tax, special fuel tax, road-use-charges, and tolls.

Among various vehicle tax types, fuel consumption and environment pollution are highly correlated. With the subjects of economy, energy, and environment are becoming more important, fuel efficiency has been emphasized recently. Moreover, due to improved vehicle design, fuel consumption and motor vehicle tax have become important subjects. In particular, the overuse of various modern vehicles has damaged seriously to our environment. The environmental concern can be divided into two parts: first, pollution subject includes air pollution, noise pollution, and ecological crisis and, second, natural resource consumption consists of energy consumption and impact on land resource.

3.4 Demand on fuel

The amount of oil consumed by private passenger cars is mainly determined by three primary factors: vehicle population, fuel efficiency, and average annual driving distance. Other factors such as mode, speed, driving behavior, vehicle maintenance, climate, road condition, and congestion have a great influence on oil consumption as well.

Change in fuel price is one of the main factors affecting fuel efficiency and consumption. Taxes on gasoline and diesel fuel influence fuel consumption, especially when they are high, as in Europe. (Nonetheless, most governments of IEA member countries employ vehicle fuel tax in order to collect budget revenue rather than to encourage fuel efficiency). Fuel tax also affects consumer decisions on whether or not to buy cars. Differences in average fuel efficiency of passenger car fleets in IEA countries stem from many factors, such as the structure and age of vehicle population, variations in technology improvements in fuel efficiency, driving behaviors and car maintenance, and differences in the use (travel) of the existing fleet. In addition, there is a correlation between levels of fuel tax and the degrees of fuel efficiency of the car fleets. For instance, the United States, where gasoline price and tax have always been the lowest among IEA countries, the average passenger car fleet consumed the highest amount of fuel. A similar relationship can be observed in Australia and Canada.

Some interesting differences between taxes on gasoline and diesel affect patterns of fuel used for road transportation. Most IEA countries favor diesel fuel, with tax on diesel being lower than those on gasoline. Austria, Canada, Japan, the United Kingdom, and Turkey have a neutral taxation structure. Only Australia, Switzerland, and the United State have higher taxes on diesel than on gasoline. The lowest tax on diesel is in Norway, where the pump price of diesel is one third that of gasoline. Even though countries like Denmark, Italy, Netherlands, and Norway have low diesel price, they have the highest gasoline price. Since motor vehicle fuel tax is primarily used for revenue collection, low diesel tax is normally offset by higher gasoline tax.

Such situation exists in almost all IEA member countries, as shown in Table 4, but the tax computation method varies significantly. For instance, countries like Denmark, Netherlands, Sweden, and Turkey use annual car registration fee on vehicle weight; on the other hand, countries like Australia, Japan, and Switzerland use a combination of engine size and vehicle weight. Furthermore, countries like Belgium, Greece, Italy, and Spain compute car ownership fee based on cylinder capacity and fiscal horsepower.

Table 4. Vehicle Tax Base

Countries	Cylinder Capacity	Fiscal Horsepower	Weight	Fixed Rate	Other
Australia	X	--	X	--	--
Austria	X	--	--	--	--
Canada	--	--	--	--	X
Demark	--	--	X	--	--
Western Germany	X	--	--	--	X
Greece	X	X	--	--	--
Ireland	X	--	--	--	--
Italy	X	X	--	--	--
Japan	X	--	X	--	--
Norway	--	--	--	X	--
Spain	X	X	--	--	--
Sweden	--	--	X	--	--
Switzerland	X	--	X	--	--
Turkey	--	--	X	--	X
United Kingdom	--	--	--	X	--
United State	--	--	--	--	X

Source：International Energy Agency, Fuel Efficiency of Passenger Cars. OECD, Paris 1991.

It must be noted that high tax on new car purchase could have a negative impact on the fuel efficiency of the car fleet. It can impede consumers from buying new and more efficient cars and thus raise the average age of car fleets. Older cars use more energy and greatly contribute to the environmental effects of high tax on car ownership. In May 1989, Greek government

enacted a law which introduced an incentive program to encourage the purchase of new and cleaner cars equipped with catalytic converters and used lead-free gasoline. For such a program, it offers an average reduction of 15% of purchase tax on new cars.

3.5 Differences between American and European fuel tax structure

The United States, with much lower fuel prices than those in Western Europe, actually has the highest energy consumption and the lowest fuel efficiency in passenger cars. Other factors such as geography, population distribution, and Corporate Average Fuel Economy (CAFE) standards[1] also contribute to this phenomenon. It is clear that there is a negative relationship between fuel price and vehicle population in Western Europe (IEA, 1997).

Due to factors such as the concept of "big is safe" and low gasoline price/tax, large size vehicles are more popular in the United States than in Europe. As shown in Table 5, the U.S. gasoline tax is only one-sixth to one-ninth as high as it is in Europe, despite a significant increase in the U.S. recently.

Table 5. Vehicle Fuel Tax (Unit: dollars per gallon)

Nation	Regular Gasoline	Premium Gasoline	Diesel Fuel
France	3.27	3.49	2.10
Germany	2.69	3.34	1.73
United Kingdom	3.35	3.74	3.42
United States	0.42	0.43	0.48

Source: Tele-Drop Company, 1999. Lundberg Survey. Energy Détente.

In Denmark, fuel tax has been implemented at a high level because of fiscal and environmental objectives. Thus, in 1984, tax including VAT made up 41% of the oil price facing consumers, whereas in 1995, it was 64% (Petersen and Togeby, 2001).

In the near future, car can be manufactured to be more energy efficient and diverse through a whole range of technology improvements. These improvements include engine, lighter construction material, transmission system, tires, aerodynamic structure, and alternative fuel technology (Kenworthy and Laube, 1999).

Most American drivers spend about US$1,200 per year on gasoline. That is US$100 per month or US$25 per week. Moreover, they paid about US$300 a year for fuel tax. Gasoline is so cheap because federal and state taxes are low—they are about 40 cents a gallon compared to US$2.50 a gallon in Western Europe (McElroy, 2003).

Table 6 points out that the US city has the highest vehicle concentration ratio in the world, followed by Australia, Canada, Europe, and Asia. Moreover, the U.S. cities use over 8 times more energy in private passenger cars than the developing Asian cities and have leaded nearly the same amount over the wealthy Asian cities. In comparison to its nearest rival, the Australian cities, the U.S. cities still consume 1.7 times more energy. When contrasted with

[1] CAFÉ standards were enacted in 1975 in response to the 1973 Arab Oil Embargo, which caused a shortage in fuel supply and a surge in gasoline price.

their North American neighbor, the Canadian cities, the U.S. cities' appetite for oil is only too apparent—the U.S. cities use 1.8 times more fuel per person to meet both inter/intra-cities transportation demand, even though both Canada and the U.S. are very close with regard to the levels of standard of living (Kenworthy and Laube, 1999).

Table 6. Cities Transportation Characteristic in 1990

City	Vehicle-Mile per capita	Private passenger energy usage (MJ/capita)	Energy-use per-car (MJ/pass, km)
America	11155	55807	3.51
Austria	6571	33562	3.12
Canada	6551	30893	3.45
European	4519	17218	2.62
Wealthy Asia	1487	7268	3.02
Developing Asia	1848	6819	1.81

Source: Kenworthy and Laube, 1999.

Tanishita et al. (2003) design a model to calculate the amount of fuel consumed by vehicles based on the interaction of car ownership, usage, and travel speed. The model predicts that, given the current fuel consumption trend in Japan, the Japanese would increase their fuel consumption by about 41% in the year 2010. Tanishita et al. further carried out an impact analysis regarding the relationship between motor vehicle taxes and fuel consumption. The analysis concludes the following: first, a fuel tax is more effective than either a car acquisition or ownership tax; second, a subsidy for mass transit (rail) is effective; third, a tax break or incentive is an effective means to induce automakers to improve fuel efficiency; and fourth, taxes have their limitations on lessening fuel consumption. Nevertheless, revenue generated from fuel tax in UK and France is now used for general purpose, while it is used for both road and public transportation in the U.S. and Germany.

4. FUEL TAX STRUCTURE IN TAIWAN

4.1 Current situation

With rapid progress on economic development, the fast growing of vehicle population has caused serious traffic problems in Taiwan. This phenomenon has a tremendous impact on Taiwan's transportation policy which includes issues like fuel consumption, CO_2-emission control, and vehicle growth management. The phenomenon also has impacted on the budget concern for the road transportation system since people now utilities roads more and it is expensive to construct and maintain roads.

Generally speaking, factors which affects the amount of fuel consumed can be divided into five categories in Taiwan; that is, vehicle factor (e.g. weight, engine design, cylinder size, transmission system, tire, and heating operation mode), traffic factor (e.g. travel speed and frequency/duration of stopping), road factor (e.g. pavement situation, geometry design, gradient and curve), weather factor (e.g. temperature, wind velocity, sunny or rainy), and driving factor (e.g. driving behavior, loaded equipment on vehicle while driving). When speed is stable, the relationship between speed and fuel consumption is stable too. Vehicle uses the

most fuel when its speed is around 40~60 kilometers per hour. And if the speed is not stable, such as during acceleration or deceleration, it will use more fuel. Moreover, when a car runs into traffic jam or red light, it will increase fuel consumption.

The growing use of fossil fuel due to economic development has resulted in speedy increase in CO_2 emissions. Sustainable economic development, energy consumption, and environment concerns (3-E) recently have received a lot of attentions in Taiwan. Fuel tax plays an important role to solve the 3-E problems. Fuel-based policies, i.e. minimum required fuel efficiency policy and fuel tax, could effective manage both fuel and traffic issues. Sound fuel tax policies are well compared to the effects of external transportation policies (e.g. full external cost pricing, cordon pricing, and parking fee). The government can exercise laws to regulate technologies for emission control and fuel efficiency. Accordingly, it is likely to employ fuel tax incentives to encourage people driving more efficiently.

4.2 Review of Taiwan fuel tax literature

Ho (1987) developed a consumption regression model for both gasoline and diesel fuels, using the collected data from 1975 to 1986. The following regressions make use of Ho's model and Table 7 compared fuel tax by vehicle plate and fuel consumption.

$$\ln GAS = -8.8774 + 0.4491 \ln AU + 0.6541 \ln GDP$$
$$(2.207) \qquad (1.569)$$

$R^2 = 0.989 \qquad F = 593.539$

Where: GAS is gasoline consumption per kilometer
AU is the number of car, light truck, and motorcycle
GDP is the gross domestic product

$$\ln DES = -15.013 + 1.934 \ln BU$$
$$(16.437)$$

$R^2 = 0.953 \qquad F = 270.182$

Where: DES is diesel fuel consumption per kilometer
BU is the number of passenger car and heavy truck

Table 7. Comparison of Fuel Tax by Vehicle Plate and Fuel Consumption

Evaluation criterion	**Vehicle Plate**		**Fuel Consumption**	
	Evaluation results	Statement	Evaluation results	Statement
Equitable and reasonable	Bad	Disregard to both fuel and driving mileages, the same class of vehicles must pay the same amount of tax. It is not fair to vehicle owners.	Good	Tax is paid by actual fuel mileage. If vehicle owner uses more fuel, he/she must pay more tax.
Easy to levy	Good	The procedure of levy is simple. Human resource and material to levy are limited. The procedure for users to pay tax is convenient.	Bad	The procedure of levy is more complex. It demands more human resource to process the procedure.

Financial status	Bad	Easy to estimate the total amount of tax that would be collected, but tax computation method is difficult to update. Stable status but no room to improve.	Good	It could eliminate tax avoidance. More room to flexibly update tax rate to improve financial status.

4.3 Fuel tax analysis

In Taiwan, road authority relies on fuel tax as one source to fund road improvement, maintenance and safety management. Fuel tax has been roughly collected proportional to road usage for all kinds of vehicles, so it could be viewed as a user charge. At present, fuel tax is levied by vehicle unit which is calculated according to the exhibit of various vehicles' fuel consumptions. Besides, vehicle fuel consumption is based on travel miles to multiply the fuel efficiency. Yearly travel mile is estimated by travel mile per day to multiply 30 days a month and the average monthly usage frequency. But the calculation list of average travel mile and average fuel consumption has been used since 1983. It is necessary to update to reflect the travel and technology changes in the past 20 years.

According to the regulation of vehicle fuel tax, it charges NT$2.50 for a liter of gasoline fuel and NT$1.50 for a liter of diesel fuel. The price of gasoline is about NT$22 per liter and about NT$18 per liter of diesel. Therefore the Taiwan fuel tax levy ratio (2.5/22=0.114, 1.5/18=0.083) is lower than many developed countries, as shown in Table 5, even though Taiwan is not an oil producing country. As for the distribution of fuel tax, 10% is used for administration, with 2% for the levying procedure and 8% is for safety management. For the rest 90% where 25% is used to maintain highway service and 75% is for both new road construction and bridge construction/maintenance.

4.4 Fuel tax collection method

In order to learn the average fuel consumption for various vehicles, the study conducted a wide-range survey to calculate fuel consumption levels of various vehicles and compare the calculations with the 1983 fuel consumption formula.

Levying fuel tax by actual fuel consumption can facilitate equality and economic development, decrease fuel consumption, and lower social cost. On the other hand, it can bring more traffic loads to local roads, lessen the collectable fuel tax for those low travel mileage vehicles, and encourage unlawful oil market development.

To sum up, fuel tax based on fuel consumption could lessen the amount of fuels consumed in Taiwan. In order to promote the "user-pay" concept, the Ministry of Transportation and Communication has collected fuel tax by estimated fuel consumption since 1983. And, in order to simplify the levying procedure, the Transportation department now attempts to levy fuel tax directly from oil importers or manufacturers. Where or not this tax burden would be totally transferred to consumers is remained to be seen. But before the new procedure is put in place, the government would probably be interested to study a reasonable tax ratio.

Hwang researched the levy and distribution method of vehicle fuel tax in Taiwan and built a multi-exponent regression model in 1992. The research results are as follows:

1. Multi-exponent regression model of car fuel tax calculated by vehicle amount

   $VGASR=E^{4.44640506}V^{0.64235893}D_{61}^{0.26377236}D_{64}^{0.84288078}VD_{76}^{0.51316648}$

   Where: V is heavy vehicle amount by the end of the every year
   D_{61} and D_{64} (dummy variables) are the adjusted fee ratio in 1972 and 1975.
   VD_{76} is the calculated standard of adjusted consumption of heavy vehicle in 1985.
2. Multi-exponent regression model of car fuel tax calculated by fuel consumption

   $OGASR=e^{7.63633131}GAL^{0.62747436}DIL^{0.37329532}D61^{0.25021874}D64^{0.40432445}$

   Where: GAL is car fuel consumption
   DIL is diesel fuel consumption
   D_{61} and D_{64} (dummy variable) are adjusted fee ratio for 1972 and 1975

The research reveals that the fuel tax revenue collected from actual fuel consumption will be 8%~35% more than the revenue collected from vehicle plate. In addition, the Taiwan government employs different levy standards between gasoline and diesel. The fuel tax for diesel is 40% cheaper than that of gasoline—the tax rate per liter for gasoline is NT$2.50 while it is NT$1.50 for diesel. Though this comparison might be biased since diesel vehicles are more fuel efficient than gasoline vehicles. Hence, it would be fair to set a higher tax rate for diesel. The same reasoning was perceived by the Senators and the House of Representatives in the United States in 1965. Both senators and house representatives proposed that the diesel tax for large truck should be 45% higher than that of gasoline. In general, it would be more reasonable to set a diesel tax rate that is 33% higher because diesel vehicles travel much farther and cause more serious damage to roads than gasoline vehicles. Unfortunately, the tax rates are set in the opposite direction in Taiwan and many other developed nations

4.5 Field survey research

The vehicle fuel consumption tax rates (per plate) were established by the Ministry of Transportation and Communication in 1983. Since these rates are quite old and outdated, it is not reasonable to keep using them. Moreover, it is often a discussion whether or not the rates are too high or too low among politicians. Accordingly, this paper applied many methods to research the structure and fairness of fuel tax for all kinds of vehicles in Taiwan. The results are presented as follows.

4.5.1 Data source and research method

The Taiwan government taxes four types of vehicles: bus, automobile, truck, and motorcycle. The tax rates are different based on the level of fuel exhaust amount and the purpose of usage, i.e. commercial or private. In order to analyze travel mileages, the paper collected vehicle exhaust amount of these four vehicle types.

4.5.2 Results

Based on the collected vehicle travel data and field survey, Table 8 presents the average annual driving kilometers for all kinds of vehicles in Taiwan.

Table 8. Average Annual Traveling Distance for All Types of Vehicles (unit: kilometer per year)

Fuel exhaust amount	Town bus		Microbus		Truck		Motorcycle
	Commercial	Private	Commercial	Private	Commercial	Private	
50 c.c.	---	---	---	---	---	---	5,308
51~125 c.c.	---	---	---	---	---	---	6,838
126~250 c.c.	---	---	---	---	---	---	4,996
601~1,200 c.c.	---	---	1,886	4,167	9,004	15,066	---
1,201~1,800 c.c.	---	---	49,589	13,670	12,998	15,644	---
1,800~2,400 c.c.	---	---	53,858	11,031	16,526	19,031	---
2,401~3,000 c.c.	13,819	18,716	75,352	10,970	21,312	22,001	---
3,001~3,600 c.c.	34,868	21,241	---	15,066	33,479	35,953	---
3,600~4,200 c.c.	41,032	20,470	---	14,813	38,974	43,313	---
4,201~4,800 c.c.	37,159	11,153	---	16,364	41,439	39,876	---
4,801~5,400 c.c.	---	15,563	---	16,040	59,353	52,246	---
5,401~6,000 c.c.	51,580	37,595	---	15,908	22,944	16,547	---
6,001~6,600 c.c.	42,472	27,791	---	15,908	61,573	60,174	---
6,601~7,200 c.c.	59,992	10,554	---	25,459	59,759	53,817	---
7,201~8,000 c.c.	59,029	18,615	---	24,303	57,660	45,250	---
8,001~9,000 c.c.	40,454	48,940	---	32,049	20,846	45,280	---
9,001~10,000 c.c.	47,734	24,151	---	---	57,214	60,742	---
10,001~11,000 c.c.	**119,416**	29,535	---	---	32,840	74,389	---
11,001~12,000 c.c.	**88,249**	31,208	---	---	65,862	66,187	---
12,001~13,000 c.c.	46,659	87,813	---	---	75,342	68,691	---
13,001~14,000 c.c.	64,676	28,754	---	---	33,918	49,823	---
14,001 above	65,883	27,223	---	---	62,668	59,647	---

Source: Directorate of General of Highway.

Table 8 indicates that the fuel consumption normally increases with the increase of exhaust amount and the tax rates for commercial vehicles are higher than that of private vehicles because commercial vehicles travel much further and hence consume more fuels than that of private vehicles. The table further points out that vehicle has certain popular size which travel more than average and the fuel consumption for a bus is higher than that of a truck for the same exhaust amount but current fuel tax rates are not reflecting the situation since tax rates for trucks are higher than that of buses.

The research also finds that there exists a negative relationship between vehicle exhaust amount and fuel efficiency in private vehicles. Thus different fuel efficiency measurements should be used for different vehicles and some modifications needs to be put in place in order to update the 1983 fuel tax formula. As for travel mileage and fuel consumption, both have a positive relationship with vehicle exhaust amount though this relationship is not obvious. Some type of vehicles has a low travel mileage even it has large exhaust amount. Furthermore, the government applied same standard to various vehicle types and this is not fair from the usage efficiency perspective. It is therefore recommended that the standard should be modified in order to reflect current situation.

In addition, four suggestions are proposed in the paper, and they are as follows:
(1) Strengthen the regular travel mileage check at the time of inspection,
(2) Tax formula of travel mileage should be modified constantly according to current situation or completely change the collection method from vehicle plate to fuel consumption.
(3) Establish a systematic database to track vehicle travel mileage and fuel efficiency.

To sum up the results of the research, fuel consumption level is not the same as in 1983 and the level changes frequently because of technology improvements or behavior change. Investigation results of various items find that there is an apparent standard bias existing in Taiwan since the usage condition of vehicles is different and is not according to the exhaust amount assumed by government. It tells that vehicle characteristics, user behaviors, and travel conditions do not have the same pattern among different vehicles of different exhaust amounts.

Table 8 only represents the average amount of vehicles and does not fit with equal principle in vehicle class with higher or lower exhaust amount. Therefore, the research offers a modified exhibit list and it could be further validated to levy fuel tax. But the better approach is to levy fuel tax by amount of fuel consumed.

5. CONCLUSION

The study of vehicle growth and fuel consumption trend provides people a new way to think that sustainable fuel use and tax revenue are achievable by simultaneously putting ecological, economic, and social imperatives into consideration. An empirical study based on Taiwan shows that fuel tax collection based on fuel consumption would be beneficial to all relevant parties. Nonetheless, this collection method still has some problems need to be resolved. For example, simplify the tax computation method and the potential to lessen tax revenue. It is helpful that the assessments in this study can help lead to a sustainable society in regard of environmental and economic benefits with necessary and not controversial interests.

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