Vehicle Ownership and Usage Charges

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January 2009

Abstract

We present a simple model to study the welfare effects of a shift from ownership to usage taxes for cars. We consider a model in which a single representative consumer derives utility from consuming two goods---consumption of motor vehicle kilometers, and an aggregate consumption good treated as numeraire. We characterize the optimal consumption of car kilometers by a representative car user and find that a shift from ownership towards usage taxes is not necessarily welfare-improving: while a revenue-neutral shift makes the representative car user worse off; a utility-neutral shift leads to a significant loss in revenue to the government. An empirical analysis based on Singapore data is also consistent with our theoretical results.

Keywords: transport externalities, fixed tax, usage tax, variabilization, representative consumer, consumer welfare, revenue loss.

JEL Classification: D01, H23, H31, R48.

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1. Introduction

Most of the industrialized world has experienced substantial increases in private motor vehicle ownership over the past two decades, resulting in rapid increases in total travel on the road. According to Stopher (2004), in the United States, by the year 2000, car ownership had exceeded an average of one car per licensed driver in many urban areas. The 2001 National Household Travel Survey (NHTS) data demonstrate a widespread prevalence of drivers and personal vehicles in the United States. According to the survey, nationwide, about 88 percent of persons 15 years or older are reported as drivers. While the mean number of vehicles owned or available to US households is 1.9 personal vehicles, on average those households have 1.8 drivers. Similar patterns are evident in many other countries around the world.

It is increasingly recognized that a mobile society incurs high social costs and causes negative externalities of various kinds, including traffic congestion, accidents and fatalities, pollution and noise annoyance, and other forms of environmental degradation.[1] Although these costs are large and pervasive, they are not actually reflected in the transportation prices paid by the persons whose traveling decisions give rise to these social costs. Consequently, faced with rising transportation demand and growing negative impacts, the urban areas of most countries have begun to use economic instruments like motor vehicle ownership and usage taxes to internalize transport externalities.

Of late, in many countries a popular prescription to solve externality problems linked to car use has been to replace ownership-related taxes to use-related taxes, also known as the "variabilization" of car taxation. Governments claim that such variabilization can better internalize the different externalities and are capable of increasing welfare. A well known example of vehicle usage taxation is the electronic road pricing in Singapore where a charge is levied for the use of the road at a certain time and place. Most recently, London has introduced congestion charging for the central area, in an effort to reduce central London's congestion levels. Following on the heels of that, many other cities around the world are now seriously considering similar congestion charging schemes.[2]

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[1] Delucchi (2003) summarizes estimates of the total social cost of motor vehicle pollution in the United States for 1990-1991. These include US 24-450 billion per year of health costs (including in the high-end a somewhat speculative US $154 billion of damages from road dust alone), US $4-27 billion per year of visibility costs and US $0.3-8 billion per year of climate change costs. The total social costs are in the range of US $38-547 billion per year. Some consider that the upper end of the cost range - over US $500 billion - is too high (see Delucchi et al., 2002), and that the total probably is of the order of US $100 billion. The range is of the order 1-10% of 1991 US GDP, with a best estimate of about 2%.

[2] New York City was actively considering the idea of charging drivers for entering the most heavily trafficked parts of Manhattan at the busiest times of the day. The government felt that by creating a financial incentive to carpool or use mass transit, congestion pricing could smooth the flow of traffic, reduce delays, improve air quality and raise the speed of crawling buses. According to the proposal, the 840,000 cars that enter Manhattan south of 60th Street on an average weekday could be subject to a $7 charge during peak hours. Vehicles starting and ending their trips

De Jong (1990), Van Dender (1996), Chia et al. (2001) and De Borger et al., (2004) have analyzed many important questions concerning the relative merits of fixed and variable transport taxes. This paper contributes to this growing literature by studying the welfare effects of a shift from ownership to usage taxes for cars.

We develop a model in which there exists a single representative consumer who derives utility from consuming two goods. The first good is consumption of motor vehicle kilometers, and the second good is an aggregate consumption good treated as numeraire. The individual can consume kilometers by traveling either by car or by public transport. We assume that, car owners travel exclusively by car and public transport users do not own a car. Consumers who own a car perceive some additional utility from simply owning or possessing the car. Also, consumers have a higher preference for a trip made by car, than if the same trip is made by public transport. We characterize the optimal consumption of car kilometers, by a representative car owner, and analyze the potential welfare effects, when ownership taxes on cars are replaced by usage taxes.

Our analysis leads to some interesting results. We find that a shift from ownership towards usage taxes is not welfare-improving: while a revenue-neutral shift makes the representative car user worse off; a utility-neutral shift leads to a significant loss in revenue to the government. An empirical analysis based on Singapore data, where the government in recent years has taken initiatives to reduce the Certificate of Entitlement (COE) or Vehicle Quota Premium on purchase of new cars and gradually increase Electronic Road Pricing (ERP) charges yields the same results. This obviously has some policy implications: rather than reducing ownership taxes or COEs, the Singapore government may be better off without any such reduction.

The structure of the paper is as follows. Section 2 presents the theoretical model. Section 3 studies government intervention through car taxes and analyzes the welfare effects of both a revenue-neutral and a utility-neutral shift from ownership to usage taxes for cars. Section 4 briefly outlines Singapore's transport demand management and vehicle taxation system and its problems. Section 5 investigates empirically the welfare implications of variabilization of car taxes based on Singapore data. Finally, Section 6 concludes.

2. The Model

We consider a model with a single representative consumer who derives utility from consuming two goods --- the first good k is consumption of motor vehicle kilometers, the second good x is a composite good treated as numeraire. Consumption of kilometers may be done by car k_c or by bus/public transport k_b. We assume that, car owners travel exclusively by car and bus users do not own a car, that is, we assume that, k is such that, $k_b = 0$ if $k_c > 0$ and $k_c = 0$ if $k_b > 0$ [3].

The preference of the representative consumer is given by the following utility function,

within that zone might pay a $4 charge (Chan, 2005). On April 7, 2008, after a closed-door meeting, the Democratic Conference of the State Assembly decided not to vote on the proposal.

[3] This assumption (car owners traveling exclusively by car), may be quite unrealistic in a European context, where a large fraction of public transport users (especially for commuting trips) actually do own a car.

$$U(k,x) = \begin{cases} k_c^{\theta_H}(x+\alpha) & \text{(for car)} \\ k_b^{\theta_L}x & \text{(for bus)} \end{cases} \tag{1}$$

where θ_H and θ_L are preference parameters with $0 < \theta_L < \theta_H < 1$. Since $\theta_H > \theta_L$, the representative consumer has a higher preference for consumption of car kilometers, than consumption of kilometers by bus. The term α, denotes the additional utility which a consumer receives from simply owning a car, that is, α is the reservation price at which a consumer is just indifferent between purchasing and not purchasing the car. [4]

We follow the neo-classical theory of consumer behavior and describe the decision problem of the representative consumer as maximizing utility under a given budget constraint.

3. Government intervention through car taxes

3.1 Fixed tax regime

When the government uses fixed taxes like purchase taxes as an instrument to regulate transport externalities, the utility maximization problem of a representative car user is as follows,

$$\underset{k_c, x}{Max} \quad k_c^{\theta_H}(x+\alpha), \ \text{s.t.}, \tag{2}$$

$$p_c k_c + x + F = m \tag{3}$$

where p_c is the variable price per car kilometer, m is the annual income of the representative car owner and F is the annual fixed tax on car ownership. The Lagrangian multiplier associated with the budget constraint is denoted by λ. Differentiating with respect to k_c, x and λ respectively, the first order conditions for the above maximization problem are as follows,

$$(x+\alpha)\theta_H k_c^{\theta_H - 1} = \lambda p_c \tag{4}$$

$$k_c^{\theta_H} = \lambda \tag{5}$$

$$p_c k_c + x + F = m \tag{6}$$

[4] Car ownership is perceived by many people, particularly in Asian countries, as a symbol of social status. Hence, car owners in our model receive utility not only from driving a car, but also from simply owning it.

Solving the first order conditions, we obtain the optimal annual consumption of car kilometers k_c and the composite good x in the fixed tax regime as follows,[5]

$$k_c^* = \frac{(m - F + \alpha)\theta_H}{(\theta_H + 1)p_c} \tag{7}$$

$$x^* = \frac{m - F - \alpha\theta_H}{(\theta_H + 1)} \tag{8}$$

The indirect utility associated with owning a car and paying a fixed tax for car ownership is given by,

$$v^F(p_c, 1, m) = \underset{k_c, x}{Max} \quad k_c^{\theta_H}(x + \alpha), \text{ s.t. } p_c k_c + x + F = m$$

Making use of equations (7) and (8), we get the indirect utility of the representative car owner in the fixed tax regime as follows,

$$v^F(p_c, 1, m) = \left[\frac{m - F + \alpha}{\theta_H + 1}\right]^{\theta_H + 1} \left[\frac{\theta_H}{p_c}\right]^{\theta_H} \tag{9}$$

3.2 Variabilization of car taxes

Having discussed the choice problem of a representative car owner under fixed tax regime, we now analyze the effects of variabilization of car taxes which is the main issue of this paper. As mentioned earlier, variabilization refers to shifting car taxes away from fixed towards variable taxes to counter drawbacks of fixed taxes and improve usage disincentives. Such variabilization is usually carried out by policymakers in a revenue-neutral way. Revenue-neutrality means that the total tax receipts remain constant after variabilization. In the following section, we consider the effects of a revenue-neutral shift from ownership to usage tax for cars.

3.3 Revenue-neutral shift from fixed to usage tax

In order to analyze the effects of a revenue-neutral shift from fixed to usage tax regime, we consider the case where, the fixed tax F, in equation (3) is replaced by a usage tax per kilometer t, in such a way that the total tax revenue collected by the government is the same under both taxes. When the representative car owner faces a usage tax per kilometer t (instead of a fixed tax F), his utility maximization problem is as follows,

[5] We assume that $m > \alpha \geq F$. So, we have $m - F + \alpha > 0$. Also, we assume that $m - F - \alpha\theta_H > 0$.

$$\underset{k_c, x}{Max} \quad k_c^{\theta_H}(x+\alpha), \;\; \text{s.t.}, \tag{10}$$

$$(p_c + t)k_c + x = m \tag{11}$$

where t is the usage tax per kilometer driven by the representative car user. Once again, setting up the Lagrangian (where λ is the Lagrangian multiplier), the first order conditions are as follows,

$$(x+\alpha)\theta_H k_C^{\theta_H - 1} = \lambda(p_c + t) \tag{12}$$

$$k_c^{\theta_H} = \lambda \tag{13}$$

$$(p_c + t)k_c + x = m \tag{14}$$

Solving the first order conditions, we obtain the optimal annual consumption of k_C and x, in the usage tax regime as follows,[6]

$$\hat{k}_C = \frac{(m+\alpha)\theta_H}{(\theta_H + 1)(p_C + t)} \tag{15}$$

$$\hat{x} = \frac{m - \alpha\theta_H}{(\theta_H + 1)} \tag{16}$$

The indirect utility associated with owning a car and paying a usage tax (per kilometer) is given by,

$$v^U(p_c, 1, m) = \underset{k_c, x}{Max} \quad k_c^{\theta_H}(x+\alpha), \;\; \text{s.t.} \;\; (p_c + t)k_c + x = m$$

Making use of equations (15) and (16), the indirect utility of the representative car owner, in the usage tax regime is given by,

[6] It is important to note that for transparency of analysis, we have used a simple Cobb Douglas utility function to denote the preference of a representative car user. Hence, in our analysis the consumption of the composite good x is independent of the consumption of car kilometers when there is a usage tax per kilometer driven by the car owner. However, this result will not hold if an alternative functional form, such as the CES utility function is used. In such a case, change in consumption of car kilometers k_C will depend on the elasticity of substitution between car kilometers and the composite good x.

$$v^U(p_c, 1, m) = \left[\frac{m+\alpha}{\theta_H+1}\right]^{\theta_H+1}\left[\frac{\theta_H}{p_C+t}\right]^{\theta_H} \tag{17}$$

The revenue raised by this usage tax t is $\hat{R} = t\hat{k}_c$. Since the objective of the government is to ensure that the total tax receipts remain constant, that is, the revenue raised under usage tax, is the same as that raised under fixed tax regime, we require that,

$$t\hat{k}_c = F$$

In order to analyze the effects of a revenue-neutral shift from fixed to usage tax, let us now calculate the optimal k_c and x under the fixed tax regime, when $F = t\hat{k}_c$. If $F = t\hat{k}_c$, then substituting for $\hat{k}_c$ from equation (15), we have,

$$F = \frac{t(m+\alpha)\theta_H}{(\theta_H+1)(p_C+t)} \tag{18}$$

Substituting for F, from equation (18), into equations (7) and (8), we get the optimal annual consumption of car kilometers k_C and the composite good x, under the fixed tax regime as follows,

$$k_c^* = \frac{(m+\alpha)\theta_H}{(\theta_H+1)(p_C+t)} + \frac{(m+\alpha)t\theta_H}{(\theta_H+1)^2(p_C+t)p_c} \tag{19}$$

$$x^* = \frac{m-\alpha\theta_H}{\theta_H+1} - \frac{t(m+\alpha)\theta_H}{(\theta_H+1)^2(p_C+t)} \tag{20}$$

3.4 Effects of a revenue-neutral shift from fixed to usage tax on car mileage, and utility of the representative car user

Proposition 1: The replacement of the fixed tax F by a revenue-neutral usage tax per kilometer t,

i) reduces the consumption of car kilometers k_c, that is, $\hat{k}_c < k_c^*$.

ii) increases the consumption of the composite good x, that is, $\hat{x} > x^*$.

iii) reduces the utility of the representative car user, that is, $v^U(p_C, 1, m) < v^F(p_c, 1, m)$.

Proof: When the fixed tax F is replaced by a revenue-neutral usage tax per kilometer t, the representative car user reduces his consumption of car kilometers k_c, and increases his consumption of the composite good x. Comparing equations (15) and (19), it is easy to see that, $\hat{k}_c < k_c^*$. Similarly, comparing equations (16) and (20), it can be seen that, $\hat{x} > x^*$.

The basic reason for this is that, whereas both the fixed and usage tax reduce the representative car user's income and produce income effect, the usage tax, in addition to the income effect, also raises the relative price of car kilometers and therefore causes substitution effect, thus forcing the car owner to consume less of the taxed car kilometers and more of the non-taxed composite good.

Consider now the budget constraint of the representative car owner, as given in equation (3), under the fixed tax regime. When $F = t\hat{k}_c$, the form of this budget constraint would be,

$$p_c k_c + x = m - t\hat{k}_c \tag{21}$$

This is a line with slope $-p_c$ that passes through the point $(\hat{k}_c, \hat{x})$ as shown in Figure 1[7]. Hence, the bundle $(\hat{k}_c, \hat{x})$ is an affordable choice for the car owner, under the fixed tax regime, but it is not an optimal choice for the car owner. At $(\hat{k}_c, \hat{x})$, the marginal rate of substitution (MRS) between the two goods is $-(p_c + t)$. But the fixed tax allows the car owner to trade at a rate of exchange of $-p_c$. Thus, the fixed tax budget line cuts the indifference curve at $(\hat{k}_c, \hat{x})$ as shown in Figure 1, which implies that there will be some point (k_c^*, x^*) on this budget line that will be preferred to $(\hat{k}_c, \hat{x})$. Hence, the car owner can achieve a higher level of utility from a fixed tax, than from a usage tax, even though they both generate the same revenue. The usage tax causes price distortion that reduces consumer welfare. The above result is also clear, from comparing equations (9) and (17). When $F = t\hat{k}_c$, it is easy to see that, $v^U(p_C, 1, m) < v^F(p_c, 1, m)$.

[INSERT FIGURE 1 HERE]

The above result is synonymous with the standard text book result, that a consumer is always worse off facing an excise tax than an income tax that generates the same revenue. The intuition behind this result derives directly from the utility-maximization hypothesis --- an income tax leaves the individual free to decide how to allocate whatever final income he or she has. On the other hand, taxes on specific goods reduce a person's purchasing power and distort their choices because of the artificial prices incorporated in such schemes. Hence, general income taxes are to be preferred if efficiency is an important criteria in social policy.

[7] The way to check this is to plug $(\hat{k}_c, \hat{x})$ into the above constraint and see if it is satisfied, that is whether, $p_c\hat{k}_c + \hat{x} = m - t\hat{k}_c$. Substituting for $\hat{k}_c$ and $\hat{x}$ from equations (15) and (16) respectively, it is easy to see that the above constraint is indeed satisfied. This establishes that $(\hat{k}_c, \hat{x})$ lies on the fixed tax budget line.

3.5 Utility-neutral shift from fixed to usage tax

In this section, we consider the effects of a shift from ownership to usage tax, which is utility-neutral to the representative car user, that is, we consider the case where, the fixed tax F, in equation (3) is replaced by a usage tax per kilometer t, in such a way that the utility of the representative car owner is the same under both tax regimes. When the representative car owner faces a usage tax per kilometer t, his utility maximization problem is the same as in Section 3.3

Since the objective of the government is to ensure that the utility of the representative car owner under usage tax is the same as that under fixed tax regime, we require that, the usage tax per kilometer t is set such that,

$$v^U(p_C, 1, m) = v^F(p_c, 1, m)$$

In order to analyze the effects of a utility-neutral shift from fixed to usage tax, let us consider Figure 2.

3.6 Effects of a utility-neutral shift from fixed to usage tax on car mileage, and revenue generation

[INSERT FIGURE 2 HERE]

From Figure 2 we have the following,

Proposition 2: The replacement of the fixed tax F, by a utility-neutral usage tax per kilometer t,

i) reduces the consumption of car kilometers k_c, that is, $\hat{k}_c < k_c^*$.

ii) increases the consumption of the composite good x, that is, $\hat{x} > x^*$.

iii) leads to a fall in revenue, that is, $t\hat{k}_c < F$.

Proof: From Figure 2, it is easy to see that the representative car owner reduces his consumption of car kilometers, that is, $\hat{k}_c < k_c^*$, and increases his consumption of the composite good, that is, $\hat{x} > x^*$. Moreover, for utility to remain the same under both tax regimes, that is, for $v^U(p_C, 1, m) = v^F(p_c, 1, m)$, the government must set t in such a way that the cost to the car owner (and hence revenues to the government) is lower compared to the fixed tax regime. Hence, a utility-neutral shift from fixed to usage tax will lead to a fall in revenue collected by the government, that is, $t\hat{k}_c < F$.

Our results make it clear that, as a revenue-raising device, the usage tax per kilometer is a very poor substitute for the fixed tax and falls far short of it, as the government incurs significant revenue losses in the usage tax regime. Such revenue losses to the government may not be welfare improving, particularly when the revenues raised are either used for road or transport development or simply for the production of a public good which will benefit both car and non-car users.

It is worth noting from proposition 1 and 2 that a shift from fixed towards usage tax is not welfare-improving: while a revenue-neutral shift makes the car owner worse off, a utility-neutral shift leads to reduction in government revenue.

4. Vehicle taxation system in Singapore --- A discussion

In this section, we analyze the welfare effects of a shift from ownership to usage tax for cars, based on Singapore data. First, we briefly outline Singapore's transport demand management and vehicle taxation system and its problems. We also explain why the government is seeking to shift away from fixed towards usage tax for cars, and analyze empirically the potential welfare implications of the same.

4.1 Existing transport demand management and vehicle taxation system in Singapore

The spread of ownership and use of motor cars is strongly affected in all countries by panoply of government-controlled instruments, such as taxes and duties on vehicles and fuel, engine emission standards, land-use zoning and controls. The Singapore government has long had a reputation for innovative approaches to transport policy to restrict both the ownership and use of cars. As these measures have grown in coverage over the years, they have also come to account for a growing and ever larger share of government revenue. For example, throughout the late 1990s taxes and fees on purchase and ownership accounted for between 80 and 85% of total vehicle-related revenues (Barter, 2005).

Singapore experienced traffic congestion as early as the late 1960s, and measures such as road construction and traffic management eventually proved to be inadequate in a land-scarce island-state. Despite high import taxes, registration fees and road taxes, car ownership began to increase rapidly in the late 1980s as a result of high economic growth. Between 1980 and 1990, the number of persons per car fell from 16 to 11 (Chin, 2002). Rising incomes had neutralized the effects of fiscal instruments on car ownership. In 1990, Singapore pioneered the use of a vehicle quota system with auctions of rights to purchase a vehicle, to regulate the number of new cars on the road.

This Vehicle Quota System (VQS) involves the sale of a limited number of permits, known as Certificates of Entitlement (COEs), under a uniform-price auction twice every month.[8] By limiting the number of COEs available each month, the government essentially uses supply

[8] For more details on the Vehicle Quota System (VQS) in Singapore, please see, Phang et al., 1996, Phang and Asher, 1997, Chin and Smith, 1997, and Chu and Goh, 1997.

driven economics to limit the number of new vehicles on the road. Each new COE has a lifetime of 10 years after which a further COE must be purchased at prevailing prices or the vehicle must be scrapped or exported. As a result of taxes and levies on car ownership, like the COE, Additional Registration Fee (ARF), the Excise Duty (ED) and the annual road tax, a medium sized car with an Open Market Value (OMV) of S$20,000, sold for approximately S$80,000 in late 2004 (Barter, 2005).

As regards usage based taxes, the government introduced the Area Licensing Scheme (ALS) in 1975, to reduce traffic congestion in the city centre. It has been suggested that the ALS charges may have in practice been set too high, with congestion levels within the controlled area much lower than those outside (Willoughby, 2001). This manual cordon pricing scheme was later replaced by the Electronic Road Pricing (ERP) system in 1998, which is a form of congestion charging, with vehicles automatically charged time and location-specific point charges for passing a set of gantries ringing the city center and a number of other locations (Barter, 2005). The much greater flexibility of the ERP has made it possible to achieve fuller use of available road space, since such a system enables prices to be different for different short periods, and also to make changes in prices very easily in response to traffic changes. The LTA is also already considering the design of a second generation ERP which could permit distance based zonal charging, and would enable usage charges generally to be increased, and ownership charges reduced (May, 2004).

4.2 Reasons for the need to shift towards a more usage based vehicle taxation system

As a result of the existing vehicle taxation system discussed above, the negative externalities attributable to motorization, like congestion, pollution and road accidents, have clearly been far less in Singapore, than in most other cities of the world (Willoughby, 2001). However, problems do exist, in the existing vehicle taxation structure. As a result of tight ownership restraint measures (COE plus high upfront taxes), many people in Singapore cannot afford to own a car. Sometimes, the COEs were bid at astronomical levels, occasionally in excess of US$58,000 for luxury cars, leading to much frustration on the part of many unsuccessful aspiring new car owners (Goh, 2002).

Singaporeans will continue to want to own cars because of convenience, flexibility and social status. Increasingly, car ownership is being viewed as a necessity of middle and upper-middle income lifestyle. The proportion of people with aspirations to own a car is likely to grow over time, as education level rises and people start to benchmark their lifestyle options against global standards. The high ownership taxes on cars are hence thought to be a drastic curtailment of legitimate middle-class aspirations to own a car. Also, with many young Singaporeans aspiring to own a car, the impact of high ownership taxes on the ability to retain local talent is also a huge concern for policymakers.

Moreover, the government thinks that high ownership cost is a blunt tool for controlling traffic congestion. Ownership costs are considered blunt and unfair, in the sense that all motorists must pay them regardless of how much their particular usage patterns contribute to pollution, congestion and other negative impacts of motor vehicles. Also, according to them, high ownership costs have distorted usage patterns by encouraging car owners to drive frequently, since the car has already been paid for (ERC, 2002). For instance, among those who own cars, usage tends to be high. The mileage clocked by a car in Singapore averaged 20,000 kilometers per year in 2004 (LTA, 2005a), which is very high by international standards.[9] This is not entirely surprising, given that motorists see the usage charges as being relatively low compared to their sunk costs. Another reason for the high mileage is that most households in Singapore own one car (due to the ownership controls) compared to other countries, and hence the single car is used more often (ERC, 2002).

Due to the inefficiencies of high ownership taxes discussed above, the government is of the view that, the costs to consumers of such taxes may be higher than their benefits, in terms of reduced pollution and congestion. Hence, such taxes may not be satisfactory in the long-run.

4.3 Steps taken towards variabilization of car taxes

With the introduction of the ERP in 1998, the government has been slowly increasing usage charges, and gradually reducing taxes on ownership of cars, to achieve a better balance between ownership and usage costs. For instance, the Additional Registration Fee (ARF) has been progressively reduced in recent years from a high of 175% of the Open Market Value (OMV) to 110% currently (LTA, 2003a).[10] The government also reduced the excise duty on cars from 31% of OMV to the current 20% (Ministry of Finance, 2002). In the past, road taxes were fairly substantial, but they have been reduced with the introduction of ERP. The road tax for cars was typically lowered by 20% in 2002 (Ministry of Finance, 2002).[11] With the government releasing additional COEs from time to time from the quota year 2002, due to the success of ERP, the COE prices for cars reached an all time low of less than $10,000 in December 2005 and January 2006 (LTA, 2005b and 2006).

Further drop in COE prices and other fixed vehicle taxes are expected to continue for the foreseeable future. An easing of ownership controls means that, more Singaporeans will start owning cars. Hence, in order to prevent congestion from worsening unacceptably, the government is likely to expand the ERP system to keep the roads free flowing. Therefore, the government is slowly making the transition towards a more usage based vehicle tax structure for Singapore.

Taking the current system with high ownership taxes as the reference case, in the next section, we analyze the welfare effects of a complete replacement of COE premium on cars by a usage

[9] According to Barter 2005, Hong Kong's car usage rate is about 12,700 km, in Japan's large cities it is between 8000 and 10,500 km and in most European cities, it is less than 12,000 km per car. However, Oslo and Copenhagen, which also have high purchase taxes, also have high rates of car kilometre per car of about 17,000 km.

[10] For cars registered with COEs obtained from March 2008 tender exercises and onwards, the ARF is 100% of OMV (LTA, 2008).

[11] From July 1 2008, the road tax for cars, motorcycles, taxis and commercial vehicles was reduced by 15%. The reduction in road tax is in line with the Government's on-going approach of gradually shifting from vehicle ownership costs towards usage measures to manage congestion on roads (LTA, 2008)

tax per kilometer driven, and see if indeed, a substitution of ownership taxes on cars by usage taxes can reduce the deadweight loss if any, arising from high upfront fixed taxes.

5. Numerical illustration of variabilization of car taxes based on Singapore data

5.1 Reference equilibrium/COE regime

In this section, we use the theoretical model set out in Section 2 to investigate numerically, the impact of a shift from ownership to usage tax for a representative car user in Singapore. First, the reference/fixed tax equilibrium is constructed, so as to represent in a stylized way, the situation in Singapore in 2003, when the government used fixed taxes on car ownership, through the release of Certificate of Entitlement (COE) quotas, as one of the main instruments to control vehicle population in Singapore.

Table 1 summarizes demand and price information in the reference equilibrium, for a representative car user.

[INSERT TABLE 1 HERE]

The reference/fixed tax equilibrium is constructed under a number of implicit and explicit assumptions. First, all price, cost and demand data in Table 1 refer to average figures for car traffic, in 2003. The average annual mileage traveled by car [which is the optimal consumption of car kilometers k_c^*, by the representative car user, as given in equation (7)] is available from the Singapore Land Transport Statistics in Brief, 2004 (LTA, 2004a) and is estimated based on mileage survey of in-use cars conducted at mandatory periodic vehicle inspections by the LTA.

We estimate the variable price per car kilometer p_c, given in the budget constraint in equation (3) as the sum of money costs and time cost. The money cost per kilometer includes petrol, road pricing (ERP charges) and parking charges.[12] The time cost per kilometer is the value of time per hour multiplied by the average transit time per car kilometer. For value of travel time per hour, we rely on empirical studies on the value of travel time.[13] The value of time used is S$11.04 per hour.[14] The average transit time per car kilometer of 2.44 minutes is obtained from the

[12] The petrol charges are calculated based on the average fuel consumption of a medium sized car estimated by the LTA from the fuel efficiency of popular vehicle models and available in Singapore Land Transport Statistics in Brief, 2004 (LTA, 2004a). The ERP and parking charges are calculated based on the average ERP and parking charges paid per car per day and available from the 2004-2005 Annual Report of the LTA (LTA, 2005).

[13] Based on 1975 data, Wilson (1989) estimated the value of travel time in Singapore to range between 47%-49% of the wage rate. A study by Png et al. (1994), estimated the value of travel time in Singapore, for the morning peak period, to be 67% of the average gross wage rate per car. Yap (1993) estimated the value of travel time per car in Singapore, taking 48% of the weighted average wage rate of drivers and passengers. According to Small (1992), a reasonable average value of journey time is 50 per cent of the gross wage rate. Hence, for the purpose of our study, we assume that the value of travel time by car is 50% of the average wage rate of car owners.

[14] The generalized household income of S$9000 per month for the representative car user corresponds to the top 20% by household income distribution in the 2003 Household Expenditure Survey (Department of Statistics, 2005) findings. According to the HES (Household Expenditure Survey), for the highest quintile, the average number of working persons in a household in 2003 was two. Hence, the monthly income of the representative car owner is assumed to be approximately S$4500. Assuming that on average people work for 47 hours per week and given that

Household Interview Survey, 2004 (LTA, 2005a). The Household Interview Survey is a travel survey that LTA conducts periodically to monitor trends in transport behavior and travel characteristics.[15]

In 2003, the ownership or fixed costs for a medium sized car with an Open Market Value (OMV) of around S$20000 amounted to approximately the following over five years, assuming it is then exported (which is now typical). The purchase costs are the OMV of S$20000, the Additional Registration Fee or ARF (S$6500 assuming it is levied at 130% of OMV but with a 75% rebate after exporting at 5 years), the Excise Duty (S$4000, or 20% of OMV), road tax (about S$4750 over 5 years) and other overhead expenses including registration fee of S$140 (about S$10000).[16] Hence, the annual fixed costs of car ownership were around S$9050.

The most important time-of-purchase tax is the COE. This represents the fixed tax F, in the budget constraint in equation (3). In 2003, the fixed tax or COE was S$14500, assuming a 10-year COE price for a medium sized car of about S$29000, and a 50% rebate when exporting at 5 years.[17] Hence the annual fixed tax was around S$2900.

Since α in the utility function in equation (2), represents the reserve price of the car user, and buyers of new cars in Singapore bid for the right to own and use a car for 10 years, by specifying the maximum amount they are willing to pay for the COE (known as the reserve price), and since most of the successful bids are higher than the COE price, we assume the value of α to be on average 6% higher than the COE price.[18]

The generalized household income of the representative car user is assumed to be S$9000 per month. According to the Report of the Committee on the Fare Review Mechanism 2005, published by the Ministry of Transport Singapore (MOT, 2005), the majority of households which have no access to private transport (including car, motorcycle and other vehicles), have a monthly income corresponding to the bottom 60% by household income distribution.[19] Hence, the population of Singapore divides into two segments, public transport or bus users who belong to the bottom 60% and car users who belong to the top 40%, by household income distribution.

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there are 4.3333 (= 52/12) weeks in a month, the total number of working hours in a month is 203.66 hours. Hence, the average wage rate per hour for a representative car owner is around S$22.09. The value of travel time is taken to be 50% of the average wage rate.

[15] A total of 35,000 persons were interviewed in the 2004 survey. According to the survey, the average door-to-door journey time by car for an average journey distance of 10.9 km is 26.7 minutes.

[16] The fixed costs are calculated based on the Vehicle Tax Structure for private cars published by the Land Transport Authority of Singapore (LTA, 2003a).

[17] The COE premium for a medium sized car for the year 2003 was based on the Vehicle Quota Tender Results for 2003 published by the Land Transport Authority of Singapore (LTA, 2003).

[18] At the close of the COE auction, successful bidders pay the Quota Premium, which is the highest unsuccessful reserve price plus S$1, to get the COE (May, 2004). We take α to be on average 6% more than the COE price, because evidence from the Vehicle Quota Tender results published by the LTA suggest that in general most of the successful bids are 2.5-10% higher than the Quota Premium/COE price.

[19] The report was based on data from LTA's 1997 Household Interview Survey (HIS).

According to the 2003 Household Expenditure Survey (conducted by the Singapore Department of Statistics, 2005), the average household income of households in the fourth quintile (60th -- 80th percentile group) was S$5309, and that of the highest 20% (80th -- 100th percentile group) was S$12792 in 2003. Hence, the generalized household income of the representative car user (or average household income of a car user in Singapore) is assumed to be S$9000 per month. Thus, m in budget constraint (3) represents annual net household income, after deduction of annual fixed costs of car ownership, estimated earlier.

The above estimates of m, F, α, p_c and k_c^* allow us to compute the value of the preference parameter θ_H in the utility function from equation (7). We obtain the calibrated value of θ_H to be 0.133. We then solve for the optimum consumption of the numeraire using equation (8). We also calculate the indirect utility of the representative car user under the reference/fixed tax equilibrium using equation (9).

5.2 Effects of a revenue-neutral shift from COE to ERP regime[20]

In this section, we consider the effects of a shift from COE/fixed tax, to a revenue-neutral usage tax per kilometer/ERP regime. This policy assumes special significance, because of the recent initiatives of the Singapore government to transition towards a more usage based vehicle tax structure for Singapore. Table 2 summarizes the effects of a shift from COE to ERP, on the consumption of car kilometers, the composite good and utility of the representative car owner.

[INSERT TABLE 2 HERE]

From Table 2, it can be seen that our numerical results are consistent with the theoretical findings. When the COE premium on cars F, is replaced by a variable tax per car kilometer t, the representative car user reduces his consumption of car kilometers by around 22% and increases his consumption of the numeraire by around 3%. Moreover, in order for the net tax receipts to be the same in both the regimes, we find that the variable price per car kilometer has to be increased by around 32% in the ERP regime (the variable price per car kilometer in the ERP regime is 0.76 cents).

From Table 2, it can also be seen that the representative car user is worse off under the ERP regime: his utility falls compared to the COE regime. As discussed earlier, a variable tax causes distortion in the relative prices of the two goods, and hence reduces consumer welfare. Such a welfare loss may also result in the car owner being taxed off the road and switching to public transport.

[20] Since it may be feasible to collect a usage tax per kilometer driven through the ERP system in Singapore, we interchangeably say "usage tax per kilometer" or "ERP".

5.3 Effects of a utility-neutral shift from COE to ERP regime

The results of a utility-neutral shift from COE to ERP regime, in terms of demand structure and revenues raised are summarized in Table 3.

[INSERT TABLE 3 HERE]

From Table 3, it is clear that, the representative car owner reduces his consumption of car kilometers by approximately 19% and increases his consumption of the composite good by around 3%.

The most important result however pertains to revenue-productivity. Table 3 reports results on the revenues raised by the government from the representative car owner, both in the reference equilibrium and in the ERP regime. We find that in order for the representative car owner to yield the same utility from both the regimes, the government has to bear a significant loss in revenue. We find that revenues raised in the ERP regime from the representative car user are only 90% of those raised in the COE regime. It seems likely that a revenue-neutral implementation of variabilization of car taxes, which would result in loss in welfare of car users, may not have public acceptability in Singapore. This implies that a utility-neutral shift from COE to ERP is the likely option for the policymakers in Singapore.

However, the loss in revenue to the government as a result of such a shift has important policy implications. Motor vehicle related taxes and levies have proven to be highly revenue-productive in Singapore. Revenue from the sale of Certificate of Entitlement Quotas (COEs) is substantial. Most of the revenue from car ownership in Singapore comes mainly from the sale of COEs. For example, in the late 1990s the revenue from the sale of COEs accounted for about 52% of the total revenue from ownership taxes and fees (based on data cited in Chin, 2002). Also such revenue loss to the government may not be welfare improving, particularly when the revenues raised are used either for road or transport development or simply in the production of a public good which will benefit both car and non-car users, as is done in Singapore.

Therefore, since the sale of COEs is an important source of revenue to the government, we would like to estimate in the next section, the aggregate revenue loss to the government, as a result of a utility-neutral shift from COE to ERP system.

5.4 Aggregate revenue loss to the government as a result of a utility-neutral shift from COE to ERP regime

For simplicity of analysis, we have focused so far, on the case of a single representative car user. However, as discussed earlier, according to the Report of the Committee on the Fare Review Mechanism (MOT, 2005), the population of car users in Singapore is heterogeneous depending upon the level of household income.

In this context, it is reasonable to assume that revenue loss to the government as a result of a utility-neutral shift from COE to ERP may be dependent on the income of the car user. For instance, when household income is lower, an increase in variable price per car kilometer, may lead to a greater fall in kilometers consumed by the car user, due to income effect. On the contrary, when household income is higher, an increase in variable price per car kilometer may lead to only a small decrease in kilometers driven, that is, the loss in revenue to the government may be lower, in the case of higher income households and vice versa. Therefore, we can define revenue loss L, as a function of the household income of the car user, that is $L = g(m)$.

In order to compute total revenue loss to the government, we assume that the annual household income of car users is distributed over an interval $[\underline{m}, \overline{m}], \underline{m} > 0$, according to a density function $f(m)$. Then the expected value of revenue loss to the government, can be estimated as follows,

$$\int_{\underline{m}}^{\overline{m}} g(m)f(m)dm \qquad (22)$$

According to the 2003 Household Expenditure Survey (Department of Statistics, 2005) findings, the top 40% of households by income distribution in Singapore had a monthly income ranging from \$4000 to \$10000 and over. While the income range of \$4000 – \$6999 corresponds to the fourth quintile (60th – 80th percentile group), the income range of \$7000 – \$10000 and over, corresponds to the top 20% by household income distribution in the 2003 HES findings. The proportion of households with cars was 49.9% and 77.3% for the fourth quintile and highest 20% respectively.[21]

For the purpose of numerical estimation of revenue loss, we divide the income range of \$4000 to \$10000 and over, into the following subintervals, [\$4000, \$4999], [\$5000, \$5999], [\$6000, \$6999], [\$7000, \$9999] and \$10000 and over. We calculate the average revenue loss to the government under each subinterval, taking a representative car owner for each interval. For example, for the subinterval [\$4000, \$4999], we calculate the average revenue loss to the government by considering the choice problem of a car user with a monthly household income of \$4500 (the average income of a car user belonging to that sub-interval). Once we estimate revenue loss L, for each subinterval, we calculate the aggregate revenue loss to the government, using the information that the proportion of households with cars is 49.9% and 77.3% for the fourth quintile and highest 20% respectively.[22]

As mentioned earlier, to calculate revenue loss L under each subinterval, we consider the choice problem of a representative car user under each subinterval. To do so, we use the

[21] It is important to note that there will be no increase in the proportion of car users, since consumer welfare remains the same, when there is a shift from COE to ERP regime.

[22] According to the Economic Review Committee 2002, most households in Singapore own only one car, due to the ownership controls. Hence, for the purpose of our analysis we assume that, there is only one car per household.

theoretical model set out in Section 2. Our analysis is similar to the case of the representative car user, discussed in Section 5.1.

5.5 Aggregate revenue loss: Numerical results

The results of a utility-neutral shift from COE to ERP regime, in terms of demand structure and revenues raised, for each of the subintervals of household income are summarized in Table 4.

[INSERT TABLE 4 HERE]

As can be seen from Table 4, revenue loss to the government is a decreasing function of the income of the car user. For instance, from Table 4, it can be seen that, while revenue loss to the government in the case of a car user with a household income in the range of [$4000, $4999] is around 20%, loss in revenue in the case of a car user with a household income in the range of $10000 and over, is around 6%.

According to the HES findings of 2003, 49.9% of households corresponding to the income range of [$4000, $6999], and 77.3% of households corresponding to the income range of $7000 ─$10000 and over, own a car.[23] Based on this, our results show that if the government were to adopt a policy of complete replacement of COE premium on cars by a usage tax per kilometer driven, then the total loss in revenue would be approximately 12%, based on 2003 COE prices.

Since the COE prices are subject to fluctuations in demand conditions, supply quota and speculative expectations of buyers, and vary from year to year, we have also carried out a sensitivity analysis by computing the total revenue loss to the government, as a result of a shift from COE to ERP regime, for the year 2004 when the COE was approximately equal to S$2500 per year for a car owner (with a medium sized car). The results are shown in table 5. For 2004 COE prices, we estimate the total loss in revenue to the government as a result of a shift from COE to ERP to be around 10%.

[INSERT TABLE 5 HERE]

It has been argued that the implementation of road pricing will increase the importance of motor vehicle taxes as a revenue-raising device in Singapore, since revenue would grow at a

[23] The data for the number of households in each subinterval of household income is obtained from the Household Expenditure Survey (HES) Report 2003 (Singapore Department of Statistics, 2005).

faster rate under ERP (Chia 1998, Phang and Asher, 1997). However, it can be seen that the current policy of the Singapore government to variabilize motor vehicle taxes will actually not be revenue-productive; it would lead to a significant loss in revenue to the government.

6. Conclusions

In this paper we present a simple model to study the welfare effects of a shift from ownership to usage taxes for cars. Conventional wisdom would suggest that replacement of fixed taxes by usage taxes would reduce the deadweight loss arising from high upfront fixed taxes, and would increase welfare. However, it is worth noting from our results that a shift from fixed towards usage tax is not welfare-improving: while a revenue-neutral shift makes the representative car user worse off; a utility-neutral shift leads to a significant loss in revenue to the government.

An empirical analysis based on Singapore data, where the government in recent years has taken initiatives to reduce the COE premium on cars and gradually increase ERP charges yields the same results. In this context, if the government were to adopt a policy of utility-neutral replacement of COE premium on cars by a usage tax per kilometer driven, then our results indicate that the total loss in revenue would be approximately 10-12%.[24]

It is worthwhile to note, however, that overall social welfare will also depend upon the environmental benefits which arise from a shift from COE to ERP, in terms of reduction in traffic congestion, air pollution etc. If such environmental benefits which accrue to both car and non-car owners more than offset the loss in welfare, then a shift from COE to ERP would indeed be welfare improving.

Our analysis takes a clear partial equilibrium point of view: our model does not capture the effect of environmental benefits (like lower traffic congestion) on labor productivity. Moreover, our paper also does not explicitly model the effect of revenue recycling and other revenue redistributive schemes on consumer welfare. These are left as issues for future research in this area.

[24] The loss may be higher if other purchase taxes like the Additional Registration Fee (ARF) and Excise Duty (ED) are also variabilized.

Reference

Barter, Paul, 2005, “A Vehicle Quota Integrated with Road Usage Pricing: A Mechanism to Complete the Phase-Out of High Fixed Vehicle Taxes in Singapore,” Transport Policy, 12, 525-36.

Chan, Sewell, 2005, “Driving in Manhattan? You Pay, Under One Idea,” The New York Times (newspaper), November 11, 2005, Accessed via http://nytimes.com.

Chia, Ngee-Choon, 1998, “The Significance of Motor Vehicle Taxes in the Revenue System,” Asia-Pacific Tax Bulletin, 4, 275-89.

Chia, Ngee-Choon, Albert KC Tsui and John Whalley, 2001, “Ownership and Use Taxes as Congestion Correcting Instruments,” NBER Working Paper No.8278 (Cambridge: National Bureau of Economic Research).

Chia, Ngee-Choon and Sock-Yong Phang, 2001, “Motor Vehicle Taxes as an Environmental Management Instrument: The Case of Singapore,” Environmental Economics and Policy Studies, 4, 67-93.

Chin, Anthony, 2002, “Urban Growth and a Sustainable Environment: Land Transportation Initiatives and Traffic Congestion,” In Koh Ai Tee et al., eds., Singapore Economy in the 21st Century Issues and Strategies, McGraw-Hill, Singapore, 222-37.

Chin, Anthony and Peter Smith, 1997, “Automobile Ownership and Government Policy: The Economics of Singapore's Vehicle Quota Scheme,” Transportation Research, 31, 129-40.

Chu, S. and Mark Goh, 1997, “The Price of Car Ownership in Singapore: An Empirical Assessment of the COE Scheme,” International Journal of Transport Economics, 24, 457-72.

De Borger, Bruno, and Inge Mayeres, 2004, “Taxation of Car Ownership, Car Use and Public Transport: Insights Derived from a Discrete Choice Numerical Optimization Model,” CES Working Paper No.13 (KU Leuven, Belgium: Centre for Economic Studies).

De Jong, G.C., 1990, “An Indirect Utility Model of Car Ownership and Private Car Use,” European Economic Review, 34, 971-85.

Delucchi, Mark, 2003, “Environmental Externalities of Motor Vehicle Use,” In D.A. Hensher and K.J. Button, eds., Handbook of Transport and the Environment, Elsevier, London, 429-49.

ERC, 2002, “Restructuring the Tax System for Growth and Job Creation,” Recommendations by the Economic Review Committee Sub-Committee on Policies Related to Taxation, the CPF System, Wages and Land, Report to the Singapore Parliament, Accessed online via http://www.channelnewsasia.com.

Goh, Mark, 2002, “Congestion Management and Electronic Road Pricing in Singapore,” Journal of Transport Geography, 10, 29-38.

Land Transport Authority Singapore, 1996, “World Class Land Transport System,” Government White Paper, Presented to the Parliament of Singapore, Accessed online via http://www.lta.gov.sg/corp_info/doc/white%20paper.pdf.

Land Transport Authority Singapore, 2003, “Vehicle Quota Tender Results 2003,” Accessed via http://www.lta.gov.sg/corp_info/doc/COE_result_2003.pdf.

Land Transport Authority Singapore, 2003a, “Vehicle Tax Structure for Private Cars,” Accessed online via http://www.lta.gov.sg.

Land Transport Authority Singapore, 2004a, “Singapore Land Transport Statistics in Brief 2004,” Accessed online via http://www.lta.gov.sg.

Land Transport Authority Singapore, 2004b, “Vehicle Quota Tender Results 2004,” Accessed via http://www.lta.gov.sg/corp_info/doc/COE_result_2004.pdf.

Land Transport Authority Singapore, 2005, “Annual Report of the LTA 04/05,” Accessed online via http://www.lta.gov.sg/corp_info/doc/annual_report.pdf.

Land Transport Authority Singapore, 2005a, “Singapore Land Transport Statistics in Brief 2005,” Accessed online via http://www.lta.gov.sg.

Land Transport Authority Singapore, 2005b, “Vehicle Quota Tender Results 2005,” Accessed via http://www.lta.gov.sg/corp_info/doc/COE_result_2005.pdf.

Land Transport Authority Singapore, 2006, “Vehicle Quota Tender Results 2006,” Accessed via http://www.lta.gov.sg/corp_info/doc/COE_result_2006.pdf.

Land Transport Authority Singapore, 2008, “Vehicle Tax Structure for Private Cars,” Accessed online via http://www.lta.gov.sg.

May, A.D., 2004, “Singapore: The Development of a World Class Transport System,” Transport Reviews, 24, 79-101.

Ministry of Finance Singapore, 2002, “Fiscal Year 2002 Budget: Part III: Tax and Fee Changes,” Accessed via http://www.mof.gov.sg/budget_2002/part3.html.

Ministry of Transport Singapore, 2005, “Report of the Committee on the Fare Review Mechanism,” Accessed online via http://www.mot.gov.sg.

National Household Travel Survey, 2001, Accessed online via http://www.bts.gov.

Phang, Sock-Yong and Mukul G. Asher, 1997, “Recent Developments in Singapore's Motor Vehicle Policies,” Journal of Transport Economics and Policy, 31, 211-20.

Phang, Sock-Yong, Wing-Keung Wong and Ngee-Choon Chia, 1996, “Singapore's Experience with Car Quotas: Issues and Policy Processes,” Transport Policy, 3, 145-53.

Png, G.H., P. Olszewski and A.P.G. Menon, 1994, “Estimation of the Value of Travel Time of Motorists,” Journal of the Institution of Engineers, 34, 9-13.

Proost, Stef and Kurt Van Dender, 1998 "Variabilization of Car Taxes and Externalities," In K.J. Button and Erik T. Verhoef, eds., Road Pricing, Traffic Congestion and the Environment, Edward Elgar, UK, 136-49.

Singapore Department of Statistics, 2001, "Singapore Census of Population 2000, Mode of Transport," Accessed online via http://www.singstat.gov.sg.

Singapore Department of Statistics, 2005, Report on the Household Expenditure Survey 2002/03, SNP Corporation Ltd, Singapore.

Small, Kenneth, 1992, Urban Transportation Economics, Harwood Academic Publishers, UK, 36-47.

Stopher, Peter, 2004, "Reducing Road Congestion: A Reality Check," Transport Policy, 11, 117-31.

Toh, Rex, 1992, "Experimental Measures to Curb Road Congestion in Singapore: Pricing and Quotas," Logistics and Transportation Review, 28, 289-317.

Van Dender, Kurt, 1996, "A Dynamic Partial Equilibrium Model for Passenger Car Transport," Msc. Paper, Economics Department, KULeuven.

Willoughby, C., 2001, "Singapore's Motorization Policies 1960-2000," Transport Policy, 8, 125-39.

Wilson, Paul, 1988, "Welfare Effects of Congestion Pricing in Singapore," Transportation, 15, 191-210.

Yap, K.L., 1993, "Factors Affecting Congestion Costs in the CBD of Singapore," Journal of the IES, 33, 39-46.

Revenue-neutral shift from fixed to usage tax[25]

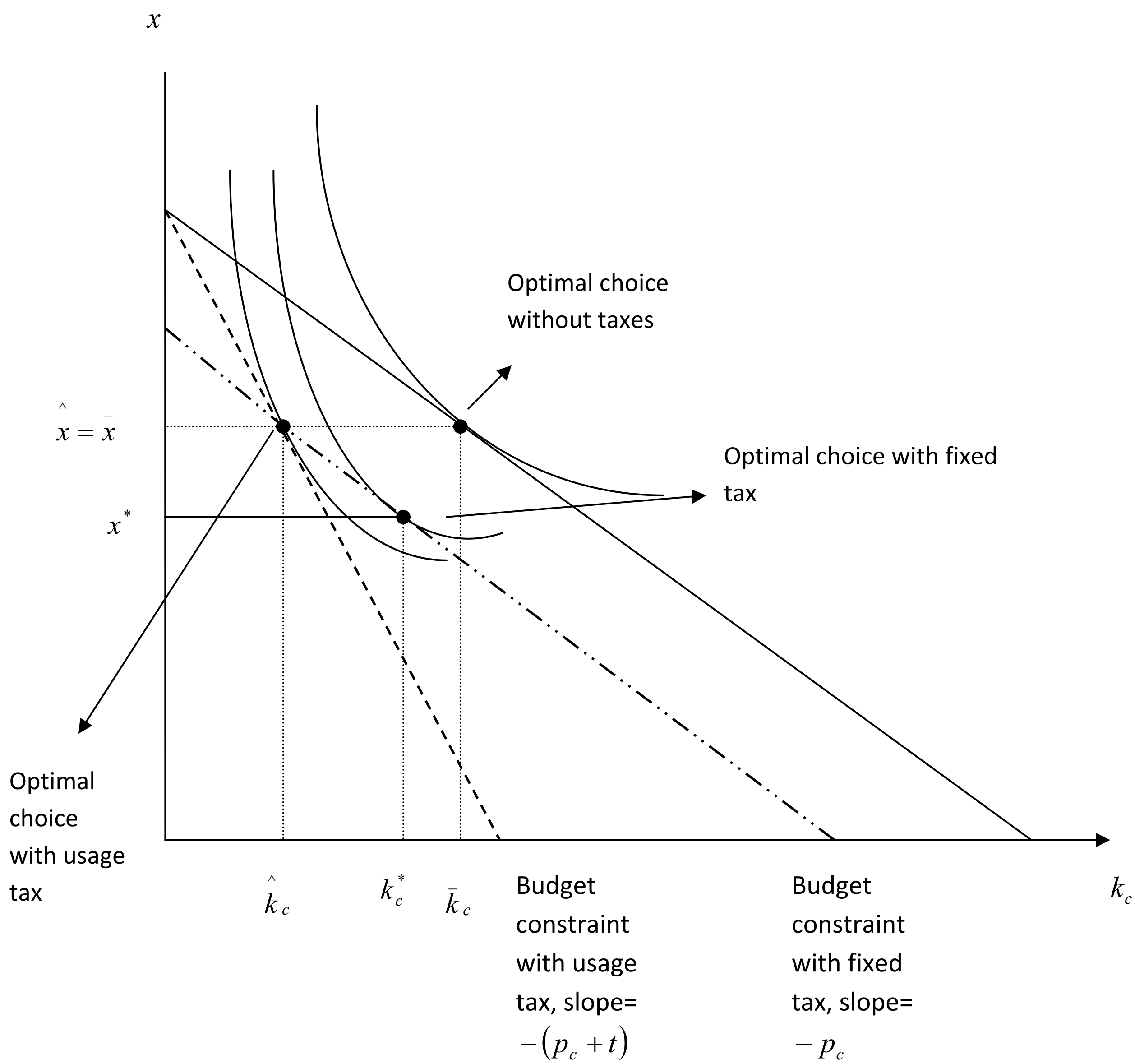

Figure 1

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[25] ($\bar{k}_c$, $\bar{x}$) is the optimal choice of the consumer when there are no ownership or usage taxes.

Utility-neutral shift from fixed to usage tax

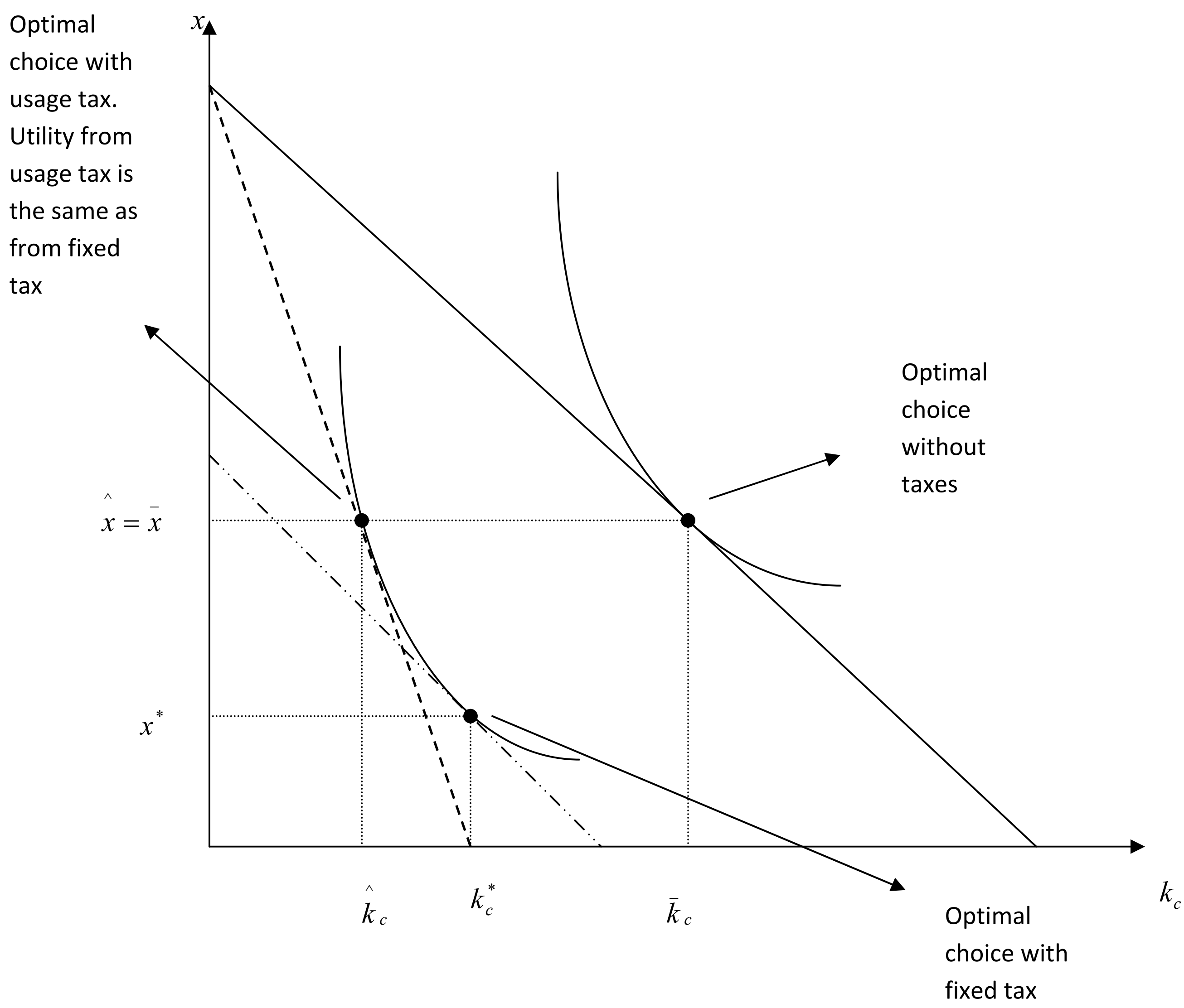

Figure 2

The Reference Equilibrium/COE regime (Year 2003)

	Reference equilibrium
Annual Kilometers traveled per car	20,171
Petrol consumption per car (litres per 100km) (for a medium sized car)	8.3
Travel time by car (minutes per kilometer)	2.44
Variable price per car kilometer (dollars)	0.58
Ownership and fixed costs (dollars per car per year) (for a medium sized car)	9050
Fixed Tax (COE) (dollars per car per year) (medium sized car)	2900
Utility function: α (reserve price for car ownership) (dollars per car per year)	3074
Utility function: preference parameter, θ_H	0.133
Generalized household income of car user (dollars per month)	9,000

Table 1

Effects of a revenue-neutral shift from COE to ERP on demand and utility of a representative car user

	Reference equilibrium/COE regime	Usage tax equilibrium/ERP regime Percentage change w.r.t. reference equilibrium
Annual kilometers traveled by the representative car user	20171	−21.86%
Annual consumption of the numeraire (dollars)	84351	+3.03%
Variable price per car kilometer (dollars)	0.58	+31.72%

	Reference equilibrium	Usage tax equilibrium/ERP regime
Indirect utility of the representative car user	3.2938×10^{5}	3.2801×10^{5}

Table 2

Effects of a utility-neutral shift from COE to ERP on revenue, demand and utility of a representative car user

	Reference equilibrium/COE regime	Usage tax equilibrium/ERP regime Percentage change w.r.t. reference equilibrium
Annual kilometers traveled by the representative car user	20171	−19.37%
Annual consumption of the numeraire (dollars)	84351	+3.03%
Variable price per car kilometer (dollars)	0.58	+27.66%
Revenue raised by the government (dollars/year)	2900	−10%

	Reference equilibrium	Usage tax equilibrium/ERP regime
Indirect utility of the representative car user	3.2938×10^5	3.2938×10^5

Table 3

Year 2003

Effects of a utility-neutral shift from COE to ERP on demand and revenue, by household income distribution

	Usage tax equilibrium/ERP regime Percentage change w.r.t. reference equilibrium/COE regime[26]				
	\$4000–\$4,999	\$5,000–\$5,999	\$6,000–\$6,999	\$7,000–\$9,999	\$10,000 and over
Annual kilometers traveled by the car user	–37%	–31%	–26%	–20%	–12%
Annual consumption of the numeraire (dollars)	+7%	+5%	+4%	+3%	+2%
Variable price per car kilometer (dollars)	+69%	+52%	+42%	+30%	+15%
Revenue raised by the government (dollars per year)[27]	–20%	–16%	–14%	–11%	–6%

Aggregate revenue raised by the government under ERP regime (Percentage change w.r.t. COE regime): –12.26%

Table 4

[26] The results are average values for each of the subintervals of household income.

[27] The fixed tax/COE in the reference equilibrium is equal to S\$2900 per year for a car owner.

Year 2004

Effects of a utility-neutral shift from COE to ERP on demand and revenue, by household income distribution

	Usage tax equilibrium/ERP regime Percentage change w.r.t. reference equilibrium/COE regime[28]				
	\$4000–\$4,999	\$5,000–\$5,999	\$6,000–\$6,999	\$7,000–\$9,999	\$10,000 and over
Annual kilometers traveled by the car user	–31%	–26%	–22%	–17%	–10%
Annual consumption of the numeraire (dollars)	+6%	+5%	+4%	+3%	+1%
Variable price per car kilometer (dollars)	+54%	+41%	+33%	+24%	+12%
Revenue raised by the government (dollars per year)[29]	–17%	–14%	–11%	–9%	–5%

Aggregate revenue raised by the government under ERP regime (Percentage change w.r.t. COE regime): –10.16%

Table 5

[28] The results are average values for each of the subintervals of household income.

[29] The fixed tax/COE in the reference equilibrium is equal to S\$2500 per year for a car owner.