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Taxes and Traffic in Asian Cities: Ownership and use taxes on Autos in Singapore *

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Abstract

This paper presents a simple general equilibrium model involving trips from residential areas to a central business district, along with modal choice between cars and public transit. Using a calibrated numerical model, we investigate the relative merits of ownership and use taxes. The proposed model is used to evaluate traffic control policies in Singapore and can be used in other Asian countries. We compare full internalisation of congestion externalities to optimal tax outcomes for the different tax types. In our framework, use taxes restore Pareto optimality since congestion damage rises with more trips. Ownership taxes only partially internalise congestion externalities. However, in terms of revenue-raising ability, the marginal excess burdens in the neighbourhood of optimal taxes are typically lower for ownership taxes than use taxes.

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1. INTRODUCTION

Concern about increasing traffic congestion and its environmental and health consequences has been an important research agenda in the past decade. There is a growing realisation that based on current policies, transport trends are unsustainable. For the developed countries, many policy documents have advocated the need for pricing reforms – "prices have to be right in order to get transport right" (see EEC Green Paper 1995 and EU White paper 1999). In many Asian cities, traffic congestion has grown rapidly in recent years, threatening in some countries to become major impediment to development (Midgley 1994 and Forbes 1996). For example, Bangkok's "traffic disaster" has been infamous, and increasingly Beijing, Taipei, Jakarta, Manila and Seoul are referred too with similar labels (Dolven et al. 1997).

As traffic congestion worsens in major cities in Asia, one key element in the growing policy debate about how to respond is the choice of instrument to internalize the externalities associated with traffic.[1] As discussed in Madhaven (2000), the policy issues relating to urban transport are multi-faceted, involving air quality, congestion, infrastructure and safety. In this paper, we focus on congestion externality. Many years ago, Vickery (1969) and Walters (1961), and more recently by Button and Verhoef (1998) argue that traffic related externalities arise from travellers responding to the average congestion inflicted on them by all other travellers rather than to the marginal damage their own travel inflicts on other travellers. Typically, marginal damage exceeds average damage, and some form of transit related tax is therefore justified on externality correction grounds. The issue is the form the tax intervention should take.

No country has been more innovative in Asia in this field than Singapore which has long implemented vehicle congestion policies. Policy makers in Singapore were the first to experiment with fiscal and regulatory traffic control measures to restrict both the ownership and use of cars (see Chia and Phang 2001 for details). As these measures have grown in coverage over the years, they have come to account for a growing and ever larger share of

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[1] Others, for example, Bernick and Cervero (1996) suggest the development of efficient, environmentally friendly transit communities that hug metropolitan rail systems to reduce gridlock and spur growth in cities.

government revenue. Chia (1998) estimated that around 30% of tax and fee income of the government in Singapore comes from vehicle related sources. These begin mainly as ownership taxes with large tariffs on imported cars (in an otherwise free trade regime), continue with government issued certificates which must be bought when cars are acquired; annual registration taxes, gasoline taxes, transit taxes paid for entrance into the central business district, and other levies. In recent years there has been a policy shift towards motor vehicle taxes based on car use. As part of a motor vehicle tax rationalisation programme in 1998, ownership taxes have been lowered while use taxes in the form of new electronic road pricing have been increased. Arising from these changes, a pertinent issue is whether use taxes are superior to ownership taxes to internalise congestion externality.

There is little prior literature on the relative merits of ownership and use taxes in Asian cities.[2] At first sight, the choice between ownership and use taxes for internalizing congestion related externalities may seem straightforward. Marginal decisions to travel are directly affected by gasoline taxes, road pricing, and other road usage related instruments. Hence, ownership taxes affect the decision to acquire vehicles, but not their use once acquired. Hence, ownership taxes reduce the number of operating vehicles, use taxes their mileage driven. But in reality, the differences involved are more subtle. Use taxes can also be used to affect the composition of traffic through the day, while ownership taxes are more difficult (although not impossible) to use in this way.[3] Also, ownership taxes affect the size of vehicle purchased, and other characteristics.

In this paper, we use a general equilibrium model to compare the welfare effects of ownership and use taxes. Our model captures the transit between periphery areas and a city centre and also the modal choice between buses and cars. Congestion (and hence transit time)

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[2] De Jong (1990) used micro-simulation techniques to determine the impacts of changing the costs of both car ownership and car usage in a model with a non-linear household budget set arising from fixed and variable costs. His model, however, is a partial equilibrium model and does not capture congestion externalities. The issue of appropriate tax design, the subject of this paper, is thus not addressed by De Jong.

[3] Some large cities, such as Mexico City, have attempted to restrict traffic by allowing car use on specified days in accordance with the end number of licence plates. Singapore also experimented with an "off-peak car" scheme which restricted car use to non-peak hours and weekends only, by lowering the fixed cost of owning such cars through various tax concessions (see Chia and Phang (2001) for details).

is an increasing function of car traffic density; and if more time is consumed in transit, less time is available for market production. Costs of transit involve ownership costs (acquisition costs amortised over time) and use costs (gasoline and fees). We assume a production function for city activity with labour as inputs

While use taxes can be set in this model so as to fully internalise the congestion externality, since car trips are the source of additional congestion, the tax must be set as an explicit transit fee per trip. An ownership tax cannot achieve full internalisation since it does not change the price of additional trips, which are the source of damage. Since, gasoline taxes apply only to the non-time variable inputs into trips; they also cannot achieve full internalization, if there is substitution between inputs (time and gasoline via speed driven).

Our simulations, based on Singapore data, show that use taxes can better internalize congestion externalities than ownership taxes, but that ownership taxes are more revenue efficient than use taxes since the marginal excess burden of raising a dollar of revenue from an ownership tax is smaller than that from a use tax. This is because ownership taxes tax away some of the surplus accruing to car users who do not switch to buses, since only a small percentage of people change from car to bus use under a tax. Unlike use taxes, some of the revenue raised is non-distortionary and hence while ownership taxes may not achieve full internalisation, they are typically more revenue efficient. Also, the optimum ownership tax rate is lower than the optimal use tax since the base is larger for the former than for the latter.

The paper is organised as follows. Section 2 describes the model used to compare ownership and use taxes. The implementation and calibration of the model using Singaporean data is given in Section 3. Section 4 reports and discusses the simulation results. Concluding remarks are offered in Section 5.

2. A TRAFFIC CONGESTION MODEL WITH OWNERSHIP AND USE TAX

We use a simple equilibrium model that captures both the fixed and variable costs of car use as well as modal choice between buses (public transit) and cars. In this model, taxes on ownership and/or use of cars will induce bus/car substitution, affect traffic density, and hence congestion.

On the demand side of the model, individuals have utility functions defined over trips and goods, and each individual faces a non-linear budget set, depending on whether he is a car owner or a public transit user. Individuals in the economy differ in income (but have the same preferences), so that with fixed costs of car ownership, individuals with low incomes use buses, while high-income individuals use cars. With this assumption, we are able to isolate the impacts of different tax types on the choice of mode. It is common in some models to treat transit as reflecting a required daily trip to work and hence model the number of trips as exogenous. We think of trips as referring to kilometres travelled, and so more demand for trips can reflect a larger distance travelled per trip.

We consider utility maximisation subject to a non-linear budget set. The non-linearity of the budget set comes about because of the fixed cost of car ownership and the difference in the relative price of trips by car and trips by bus. Individual's utility U is defined over trips (T), which include both work and pleasure trips, and a composite good (G). Trips may be taken on buses (T^b) or cars (T^c).

$$Max\ \ U = U(T, G) \tag{1}$$

$$\text{where } T = max\,(T^b,\ T^c) \quad \text{s.t. } T^b = 0 \text{ if } T^c > 0 \text{ and } T^c = 0 \text{ if } T^b > 0 \tag{2}$$

subject to the budget constraints,

$$Y \quad = P_g G + P_T^b\ T^b \tag{3}$$

$$Y - F = P_g G + P_T^c\ T^c \tag{4}$$

where Y is the household income, F is the fixed cost of car ownership, P_g is the price of the composite good G and P_T^b and P_T^c respectively represent the consumer price of trips by bus and car. The latter can be thought of as both time and gasoline costs.

We assume an exogenous individual distribution of income. Given prices of the two types of trips, we can derive the demand for goods using Roy's identity and taking derivatives of the indirect utility function. The indirect utility function for the bus regime, for example, defined as $V^{B}(Y_i, P_g, P_T^b)$ will yield a corresponding direct utility $U_i^B(G, T_i^b)$ for which the indifference curve is tangent to the budget set for individual *i*. Given the price of the two types of trips, a threshold income Y_S exists such that an individual with income Y_S will be indifferent between trips by car or bus; i.e., the indirect utilities under the two regimes are equalized.

$$V^{B}(Y_S, P_g, P_T^b) = V^{C}(Y_s - F, P_g, P_T^c) \tag{5}$$

Modal choice is affected by the relative prices of the two trip types and the size of the fixed cost of car ownership. The population is thus divided into two segments -- bus users whose incomes are below the threshold income Y_S and car users whose incomes are above Y_S. A commuter's willingness to pay for trips depends on the average variable cost of the mode they use, which includes the monetary operating cost and time cost. In the case of bus trips, the average variable cost is the fare and the time lost in transit. For car trips, this includes gas costs, tolls, vehicle operating costs and time costs.

We assume fixed traffic infrastructure and fixed locations for households and firms. All trips are thus from home to the central business district and back, so that as more commuters use the road, congestion occurs. Let *D* be the total congestion damage from bus users (D^b) and car users (D^c). This damage results in longer transit times, and, for convenience, we denominate it in terms of labour units and relate it to the number of individuals taking bus and trips, which is collinear with the number of each trip, i.e.,

$$D = D^b + D^c \tag{6}$$

$$D^b = \gamma_b N_b^{\lambda_b} \qquad \lambda_b > 1 \tag{7}$$

$$D^c = \gamma_c N_c^{\lambda_c} \qquad \lambda_c > 1 \tag{8}$$

where γ_b , λ_b , γ_c and λ_c are the parameters for the congestion damage function for bus and car users respectively. We assume λ_b and λ_c exceed unity, so that marginal exceeds average damage.

Assuming that car users are solo drivers and buses have a larger capacity, there is a relationship between the number of car (N_c) and bus commuters (N_b) given by,

$$N_b = \theta N_c \qquad \theta > 1 \tag{9}$$

The average congestion damage (or average transit time cost) can thus be expressed in terms of N_c .

$$AD = [\gamma_b(\theta N_c)^{\lambda_b} + \gamma_c N_c^{\lambda_c}] / [(1+\theta)] N_c \tag{10}$$

In deciding the mode of transport, we assume commuters only consider the marginal private cost of their trip. Marginal private costs are given by average congestion damage plus the monetary cost of the transportation mode, comprising fares, gas and non-congestion time costs. These can be represented as follows:

$$P_T^b = AVC^b = P^b + AD \tag{11}$$

$$P_T^c = AVC^c = P^c + AD \tag{12}$$

where P^b, P^c respectively represent the non-congestion costs of trips by bus and car.

Each commuter ignores the incremental increase in damage arising from his use of the mode, that is, the external congestion cost imposed on other commuters. This cost is the additional time that a commuter imposes on others through increased congestion. This external cost, or marginal damage *MD*, can be found by taking the derivative of equation (6) with respect to N_c, i.e.

$$MD = \theta^{\lambda_b} \gamma_b \lambda_b N_c^{\lambda_b - 1} + \gamma_c \lambda \; N_c^{\lambda_c - 1} \tag{13}$$

To close the model, each household is assumed to have a fixed endowment of time, $\overline{T}$, which can be allocated to market labour supply T^w, or time spent in transit, T^T, i.e.

$$\overline{T} = T^w + T^T \tag{14}$$

Market labour supply depends on time spent on transit, which in turn depends on the number of car and bus commuters. The time spent on transit T^T is an increasing function of N_c. The time available for labour supply for car and bus users is:

$$T_b^w = \overline{T} - D^b \tag{15}$$

$$T_c^w = \overline{T} - D^c \tag{16}$$

Labour supply is used in the production of *G*, which is a simple constant marginal product of labour production function, i.e.,

$$G = \beta(T_b^w + T_c^w) \tag{17}$$

In such an economy, the market outcome is not Pareto optimal since the marginal damage inflicted on others is not considered in an individual's modal choice decision. Individual workers when making their transit decisions take into account the average damage they face, rather than the marginal damage they inflict on all other workers in transit. Gains are thus possible through an internalization tax, which results in workers making the socially appropriate transit decision. In the present case, the issue is whether such internalization is best achieved via a tax on car usage, a tax on vehicle ownership, or some combination of both. A Pigouvian tax, which internalizes the externality, needs to be set to correct the wedge between the marginal social cost and the private variable cost of trips, so as to create the appropriate incentives. In the next section, we use numerical simulation methods to compare the efficiency of ownership and use taxes in both maximising overall welfare and raising revenue.

3. NUMERICAL COMPUTATIONS OF THE IMPACTS OF OPTIMAL OWNERSHIP AND USE TAXES

We used the structure set out in Section 2 to investigate numerically the impacts of ownership and use taxes based on Singaporean data. We assume a Gamma distribution of individual wage rates to incorporate the heterogeneity of household incomes in the model. Since the amount of time available for market labour supply is endogenously determined in this structure, the time available for work becomes endogenous. In other words, household income becomes dependent on wage rates. For convenience, we assume Cobb-Douglas household utility functions, for which the corresponding indirect utility functions for the bus and car regimes are given by:

$$V^B = \ln(wT_b^w) - \alpha\ln(P_s) - (1-\alpha)\ln(P_T^b) \tag{18}$$

and

$$V^C = \ln(wT_c^w - F) - \alpha\ln(P_s) - (1-\alpha)\ln(P_T^c) \tag{19}$$

where F is the fixed cost of car ownership.

This allows us to equate V^B and V^C to calculate a critical value of w^* at which that the population divides into bus and car users. In other words, the bus users (N_b) are those with a wage rate smaller than w^*, and the car users (N_c) are those with a wage rate greater than w^*. With the introduction of a use and/or an ownership taxes, the corresponding value of w^* will change, yielding a new threshold wage rate with a new combination of (N_b, N_c).

This allows us to summarise the conditions under which $V^B = V^C$ for different tax structures in the following equations:

Use tax:

$$V^B(w_U^* T_b^w, P_g, P_T^b) = V^C(w_U^* T_C^w - F, P_g, (1+\tau_U)P_T^C) \tag{20}$$

Ownership tax:

$$V^B(w_f^* T_b^w,\ P_g\ , P_T^b\ )\ =\ V^C\,(w_f^* T_C^w - (1+\tau_f)F,\ \ P_g\ ,\ P_T^C\ ) \tag{21}$$

Joint Use and ownership tax:

$$V^B(w_j^* T_b^w,\ P_g\ , P_T^b\ )\ \ =\ V^C\,(w_j^* T_C^w\ -\ (1+\tau_f)F,\ P_g\ , (1+\tau_U)P_T^C\ ) \tag{22}$$

In computing an equilibrium for use tax, we assume that the revenue from the use tax (*R*) is returned to all commuters in lump sum fashion so that every commuter's income is augmented by (*R/N*) independently of their choice of mode. w_U^*, is then computed by equating indirect utility under the bus and car regimes.

The indirect utility functions given this government intervention (and Cobb Douglas utility functions) are as follows:

$$V^B\ =\ \ln(wT_b^w\ +\ R/N)\ \ -\alpha\ln(P_s)\ -(1-\alpha)\ln(P_T^b) \tag{23}$$

$$V^C\ =\ \ln(wT_c^w\ -\ F\ +R/N)\ \ -\alpha\ln(P_s)\ -(1-\alpha)\ln((1+\tau_U)P_T^c) \tag{24}$$

Equating (23) and (24) yields w_U^* which is given by:

$$w_U^*\ \ = [(k_P\,\text{-}1)\ R/N\ \text{-}\ \ k_P\,F]\ /\ [\,T_b^w\ \text{-}\ k_p T_c^w\ \ ] \tag{25}$$

where $k_p = \ P_T^b\ /[(1+\tau_U)P_T^c]$ and w_U^* is the threshold wage that divides the population into bus (N_b) and car users (N_c) under a use tax at rate of τ_U. The computed values of N_b and N_c, together with other model parameters, yield average damage as given in equation (10), which then determines the price of trips by bus and car.

The parametric specifications we use in our simulations reflecting this structure are taken to be representative of Singapore and are set out in Table 1.

[Place Table 1 here]

Next, we will explain how the parameter values are specified in the simulation model which is representative of the Singapore's experience. The α parameter for the Cobb-Douglas utility function in equation (1) is set at 0.8. This is a proxy for proportion of expenditure households spent on all other goods besides transport. Data from the *Singapore Statistical Highlights* (1998, p.57) indicates that the expenditure share of transport and communications to be around 20 %.

Fixed cost F is set at S\$8,000. The average price in Singapore of a medium size car is around S\$100,000, which includes a scrap value of around S\$20,000, so that the fixed cost of car ownership is around S\$80,000. Since cars are usually de-registered when they are 10 years old, the fixed cost of car ownership per year is taken to be S\$8,000.

To calibrate γ_b and γ_c in the damage function in equations (7) and (8), we pre-specify λ_b = 1.05 and λ_c = 1.15. Both λ_b and λ_c are greater than 1, reflecting that marginal damage is greater than zero and that the marginal damage from car is assumed to be higher than the marginal damage from bus.

From estimates of transit time by bus and by car, together with data on the proportion of car user of 42% (Singapore General Household Survey 1995), we obtain the calibrated values of γ_b and γ_c as 0.68 and 1.63 respectively. The Singapore Bus Services (SBS) is one of the two major bus operators in Singapore and on its homepage, point-to-point average commuting time by buses are given. For comparability of data to the average time travelled by car, we use data on the travelling time by bus from the major bus interchanges at the more densely populated satellite towns to the busiest station during the weekday peak hours (i.e. the Raffles Place

Station). We then add on the wait time and walking time to the time travelled on bus to obtain the total transit time by bus. The average transit time (including wait time) for bus commuter is about 65 minutes per trip.

To calibrate the marginal damage, we assume a degree of equivalence between the number of commuters using the bus and cars, since most car commuters are solo drivers and damage incurred by one bus commuter is not the same as by one car driver. In estimating θ, we use the concept of passenger car unit (PCU), which measures the road space used by a moving vehicle. In our calibration of θ, we set the PCU of cars at 1, and that of bus at 2. These estimates, together with the assumption that the average bus loading during peak hour is 40, allow us to set the equivalence between bus and car commuters at 20.

To compute the total costs of trips for the different modal choice, we need to convert the average damage denominated in time in equation (10) into value terms. To do so, we need the median income for the car and bus commuters. For a compact city like Singapore it is not surprising that occupation is closely related to the mode of transport used. Those with better paid jobs tend to use car while those in lower paid categories use the public transport. Data from the General Household Survey 1995 show that the majority of the administrative and managerial worker (64%) and professional and technical workers (30%) use cars as the major mode of travel. Only 11% of the clerical, sales and services workers and 7% of the production and related workers drive to work. The median income per month for the bus user is S$1,400 and for the car user is S$3,750.

The value of time in average damages reflects the different market values of time for the different income earners. This is similar to Small (1983) who related the price of trips to the value of time, which is proportional to the marginal after-tax wage rate. These estimates on the value of time are used to calculate average damage before the imposition of any tax in Equations (7) and (8). This average damage estimate, together with the labour endowment of

208 hours per month and allows us to compute the labour supply for workers in the two regimes. The resulting income and prices of car and bus trips and price of goods then allows us to solve for the optimum consumption of goods and trips and hence utility maximising behaviour.

The gamma distribution over wage rates we use, $\Gamma(x) = w^{\zeta-1} e^{-w}$ is defined over a wage range from 0.5 to 20 with $\zeta = 6.5$ representing the per capita monthly income of approximately S$6,500.

4. SIMULATION RESULTS AND POLICY IMPLICATIONS

We measure changes in welfare across regimes as taxes change from ownership to use by aggregating the Hicksian Equivalent Variations (EVs) or Compensating Variations (CVs) over individuals. In trying to identify the impacts of different tax interventions, we confine our analysis to one instrument at a time. We increase gradually the tax rate for the particular regime and find the optimum tax rate that maximises the total EV or CV relative to the model base case. In any counterfactual equilibrium, tax revenues are returned to all commuters in a lump sum manner. We measure welfare not in a strict Pareto sense, but in terms of the *potential Pareto improvement* in social welfare. In other words, the issue is whether gainers from a tax intervention could hypothetically compensate the losers from the same intervention.

[Place Tables 2 and 3 here]

Tables 2 and 3 display model solutions in the presence of optimum use and ownership taxes. These results show that intervention, either through use or ownership taxes, raises utility for both car and bus users and that significant change in the use of cars and buses result. In the non-intervention benchmark equilibrium there are 42% car users; this drops to 13% and 15% respectively when use and ownership taxes were introduced.

Table 3 reports the Hicksian EVs as a percentage of GDP under the optimum ownership and use taxes. At the optimum use tax, car users who remain on the road are made better off since lower traffic congestion increases labour productivity. A smaller transit time means more units of labour are supplied to market activity. This group gains 10.02 % of real income. On the other hand, bus users, who also suffer from a loss in work time due to the congestion externality, are made only slightly better off with a tax on car use. However, use taxes result in welfare losses for car users who are taxed off the road and have switched to bus use. The loss amounts to 3.64 % of their initial income. [4]

In the new equilibrium with an ownership tax, car users are better off since on average the value of timesaving on the road exceeds the tax paid by car users. Bus users gain from the transit time saved from less road congestion and from the income effects generated from the lump sum revenue redistribution. In this case, fewer car users are taxed off the road, but they are also made worse off when they switch between transport modes.

Because of the larger base, it is not surprising that optimum ownership tax is reached at a lower rate (39.8%) than for the use tax (95.7%). However, results in Table 2 show that internalization of the congestion externality with use tax yields a higher total welfare gain (6.37% of total income) as compared to the corresponding total welfare gain under ownership tax (only 1.8%). This underlines how the ownership tax cannot fully restore Pareto optimality. The reason is that the ownership tax does not directly impact the price of trips, which in turn is the source of the congestion externality.

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[4] The welfare cost in this simulation comes from distortions from modal switching.. Wilson (1988) examines the effects of peak hour zone pricing (under the Area License Scheme) on scheduling changes and choices of transportation. In his model, the implementation of zone pricing during the peak hour decreases the utility of bus riders because of increased travel time, while car commuters benefited from the scheme. There is an

Table 2 also reports results on the revenue productivity of use and ownership taxes. We compute the "excess burden" or the "dead-weight loss" per dollar of tax revenue raised beginning from the optimal tax equilibrium. Simulations are run which increase the optimum ownership and use tax (i.e. $\tau_U^* = 95.7\%$ and $\tau_f^* = 39.8\%$), marginally by 0.01%. We then compute the MWC by taking the ratio of the change in the Hicksian EV resulting from the marginal increase in tax rate to the change in revenue from the marginally higher tax rate.

$$MWC = \Delta EV / \Delta R \tag{26}$$

In terms of revenue productivity, ownership taxes are strongly preferred to use taxes. For every dollar raised through the ownership tax, an excess burden of 1.46 cents is generated, as compared to the marginal excess burden of 3.17 cents for every dollar raised through use taxes. This is because an ownership tax is, in part, a lump sum tax borne from the surplus accruing to households who continue to use cars even with the tax. In contrast, the use tax changes the price of trips and is fully distortionary at the margin. As an externality correcting tax, the ownership tax falls far short of the use tax. However, as a revenue-raising device around the initial equilibrium, it is superior because it is largely non-distorting.

Finally, we have also used the model to study the effects of using combined ownership and use tax instruments to internalise the same congestion externality.[5] We fixed the proportion of car users at 10% and compute the equilibrium when we adopt the optimum use tax and solve for the ownership tax that yields only 10% car users. This equilibrium is then compared with the model solution when the optimum ownership tax is in place.

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overall fall in welfare for the society as a whole. The estimation by McCarthy and Tay (1993) also suggests that there is negative welfare effect from peak hour zone pricing.

[5] The second best rule is to expand the capacity of a road until the marginal capital cost is equal to the marginal external congestion cost (see Hau (1992), p. 29). But we assume fixed traffic infrastructure in our model.

[Place table 4 here]

Our results in Table 4 show that if we have the welfare-maximizing use tax in place, at τ_U^* = 95.8 %, in order to meet the target of 10% car commuters, it is necessary to impose an ownership tax of 5.6%. On the other hand, if the optimum welfare maximising ownership tax τ_f^* = 39.8% is used; a 9.7 % tax on car use will achieve the target of 10% car users.

While both fiscal instruments can be used to achieve the target level of car use, the two equilibria yield different welfare implications. In terms of maximising welfare, it is better to set the optimum ownership tax first and then introducing a second fiscal instrument. Since the society's welfare is already maximised at τ_U^* = 95.8 % and τ_f^* = 39.8%, the use of another instrument will not enhance welfare. Society as a whole will be made worse off and, as expected, the group that is made worse off are the car users.

5. CONCLUSION

We have constructed a general equilibrium model that includes congestion externalities to compare the merits of ownership versus use taxes in a numerical simulation exercise using Singaporean data for the mid 1990's. We suggest that this can be applied to traffic control policy design elsewhere in Asia. In the model we use, usage taxes can fully internalize congestion externalities while an ownership tax cannot. This is because ownership taxes do not directly change the price of trips, which at the margin are the source of the externality. However, in terms of revenue productivity, ownership taxes are substantially more efficient as they result in smaller marginal excess burden than use taxes.[6] Ownership taxes are heavily borne by people who continue to drive cars and thus are borne out of their surplus from their regime choice.

Our traffic congestion model captures elements of traffic flow externalities stressed by Vickrey (1969), and as congestion in cities usually occurs in localized bottlenecks on stretches of expressways to the Central Business District, bridges, interchanges or narrow streets our model may be thought realistic. There are, however, several missing elements. The model does not capture land price changes, shifts in wages and does not model any household or business location choice. We have also not included a work-leisure choice or leisure-modal choice, although in practice there is a trade-off between time spent on transit and time spent at work. While the model captures modal choice, it neither incorporates trade-offs between peak and off peak travel times nor trip scheduling as modelled by Wilson (1988). The model also abstracts from city planning in traffic policy, which in Singapore has always been seen as important, with the design of a number of satellite mini towns with shops, businesses, and service centres dispersed from the core area as part of the land use policy. These challenging extensions are all left for future work.

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[6] The Hicksian EVs are calculated by returning all revenue to all commuters in a lump sum manner. We can interpret this as revenue from motor vehicles are not earmarked but go to the production of a public good which will benefit all individuals equally. Welfare measures may be sensitive to the redistributive schemes used in the calculations, for example if the revenue is returned as subsidies to the bus users.

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Table 1
Parameters specification used in simulation model representative of Singapore (US$1 = S$1.74)

- Utility function: $\alpha = 0.8$
- Fixed cost F = \$8,000
- Median income of car user: S\$3,750
- Median income of bus user: S\$1500
- Damage function: $\gamma_b = 0.68$, $\lambda_b = 1.05$, $\gamma_{c\,c} = 1.53$, $\lambda_c = 1.15$
- Equivalence between N_b and N_c: $N_b = \theta N_c$, $\theta = 20$
- Gamma distribution: $\Gamma(x) = w^{\zeta-1} e^{-w}$, $0.5 < w < 20$, $\zeta = 6.5$

Table 2
Results from internalizing congestion externalities using ownership and use taxes

	Non-intervention market solution	*Intervention with an optimum use tax*	*Intervention with an optimum Ownership tax*
Critical Wage (w*)	6.7	9.4	9.2
Optimum tax rate (%)	n.a.	95.7	39.8
Proportion of car users (%)	42	13	15
Change in car users from the non-intervention equilibrium (%)		69.2	65.8

Table 3
Welfare impacts of implementing optimum use and ownership taxes

	Optimum Use tax τ_U^*	*Optimum Ownership Tax* τ_f^*
Optimum tax rate (%)	95.7	39.8
Hicksian EV as percent of total real income:		
• All commuters	6.37	1.80
• Bus users	-0.01	0.40
• Car users	10.02	1.50
• Car users who switch to bus under the new equilibrium	-3.64	-0.11
Marginal excess burden of raising an extra dollar of tax revenue	3.17 cents	1.46 cents

Note: The same parameters specifications as in Table 1 are used in the computation of the counterfactual equilibria.

Table 4

Welfare implications of using mixed fiscal instruments that limit car users to be 10% of commuters

	Use tax together with $\tau_f^* = 39.8\%$	*Ownership tax together with* $\tau_U^* = 95.7\%$
Tax rate to cap car users to 10%	9.7	5.6
Optimal wage (w*)	9.9	9.9
Hicksian EV as percent of GDP:		
• All commuters	-51.1	-8.85
• Bus users	-0.003	-0.06
• Car users	-54.2	-9.21
• Car users who switch to bus under the new equilibrium	3.12	0.301