Transport tax reforms, two-part tariffs, and revenue recycling

- A theoretical result

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Abstract

We explore the interaction between taxes on ownership and on use of cars when households face a discrete choice of purchasing a car or not. We use a simple labor-leisure model with a logit formulation for the discrete choice of car-ownership to examine how a tax reform, which shifts taxes from ownership to use of cars, affects welfare. Car transport is burdened with negative externalities which lead to feedback effects on both the internal, and the external, margin. We show that the welfare effect depends on choices on both the internal margin and the external margin, and that effects on the external margin might affect the congestion externality in car transport significantly. Furthermore, the effect of such a tax reform depends on the initial tax level on car transport.

1. Introduction

The importance of intervention in the transport sector has become obvious in recent years with externalities, and especially congestion externalities, increasing rapidly in almost every major city. The dilemma facing the transport authorities is that transport, while causing negative externalities is an essential part of society. This dilemma is pointed out in Parry & Bento (2001), where it is shown, that the implementation of marginal cost pricing to reduce externalities, can cause negative welfare effects if the extra costs of transport discourage labor supply.

This paper examines a tax reform in the transport sector. A fixed purchase (or ownership) tax on cars is substituted with a variable tax on the use of cars. This type of tax reform has, to our knowledge, not yet been analyzed consistently, since the ownership decision has been left out of the previous analysis.

We build upon several results from the economic literature. The explicit inclusion of time in economic models was first undertaken by Becker (1965), DeSerpa (1971), and others. They include time as a source of utility for households, either directly in the utility functions (DeSerpa), or indirectly through a household production function (Becker). This approach has since been used in numerous papers, among other: De Borger & Van Dender (2003) who analyze the effect of a tax reform on the value of time.

For the modeling of car ownership, we draw upon the results from Small & Rosen (1981). They present a framework for modeling welfare effects when discrete consumer choices have to be taken into account. De Borger (2000) demonstrates that the Small & Rosen approach can be implemented in a tax model, and he uses their framework to derive the optimal two-part tariff in a model of discrete choice which he also extends to a situation with externalities (De Borger 2001).

We show that the welfare effect of a tax reform depends on a combination of several factors, most of which are identified in some of the papers mentioned above. The new finding is that changes on the external margin (e.g., changes in car-ownership) could be large and should probably be modeled explicit if correct estimates of the welfare effects are to be obtained.

The paper has the following structure. Section 2 presents the modeling framework in which household decisions on the internal margin (how much to consume contingent on car-ownership) is analyzed. The choice on the external margin (the car-ownership decision) is also described in detail. The production sector and the government optimization problem are also presented. Section 3 derives an expression for the welfare effect of a tax reform shifting from fixed to variable taxation of ‘cars’. The final section concludes.

2. The model

We construct a model in which households decide on the consumption of goods and leisure, how much to work, and to commute by either private transport ('car') or public transport ('bus'). Our model deviates from the standard tax model in that we do not assume households to be identical. Instead, we assume all socioeconomic characteristics of the households to be identical but we add a random term that accounts for unobservable heterogeneity between households.

The production sector is fully competitive and operates under constant returns to scale. All producer prices are thus constant and equal to the marginal cost of production. The government tax goods, transport, and labor in order to generate revenue for some unspecified tasks (e.g., national defense or the health care system). We assume that congestion externalities are present in 'car transport'.

2.1 The households

Households consume two goods, 'pure leisure', L, and an aggregate consumption commodity, Z. Households supply labor, L^w, to the production sector and commute to work by either public transportation (’bus’) or private transportation (’car’). Households derive utility from consumption of the aggregate good, leisure and transportation. Thus the utility function can be written as

$$U(L,Z)+u(Z^b,Z^c) \tag{1}$$

where Z^b is a trip by bus and Z^c is a trip car defined in detail below. The reparability assumption separates the transport mode choice decision from the decision on how much to work. It also allows the possibility for households to prefer one mode over the other and thus that public and private transport are imperfect substitutes.

We assume that H households exist and that H is large. Households have the same earning capacity and thus the same wage rate, w. Furthermore, households have the same endowment of time, $\overline{L}$, and non-labor income y. A trip to work can be done by bus or by car and each trip takes up a certain amount of time which we will denote L^b and L^c. A trip is defined as traveling both to and from work. This means that households either go back and forth by car or by bus. Following Parry & Bento (2001) we assume that the number of working hours in one day is fixed and equal to one. This means that the supply of labor hours given by L^w is equal to the total number of commuting trips to work

$$L^w = Z^b + Z^c \tag{2}$$

We let Z be total travel by car and that this increase the time requirement for car transport and we thus have that

$$L' = \frac{\partial L^c(\bar{Z})}{\partial \bar{Z}} > 0 \tag{3}$$

Furthermore, we assume that households ignore their own influence on $\bar{Z}$ and, accordingly there is an externality problem in private transport. The bus service is not affected by congestion. Even though this is not completely realistic it can be defended by several arguments. Cities could have priority lanes for busses signs at crossings that give priority to public transport, or the bus time schedules may simply be set to be so slow that the congestion is part of the planned travel time.

Letting P, P^b, and P^c represent consumer prices on goods, public transport, and private transport, t_w be the tax on labor, $\bar{P}$ be the fixed cost of purchasing a car, y non-labor income and normalizing the wage rate w to one allow us to write the constraints which the households face as

$$PZ + P^b Z^b + P^c Z^c + \bar{P} = (1 - t_w)L^w + y \tag{4}$$

$$L + L^b Z^b + L^c Z^c + L^w = \bar{L} \tag{5}$$

We will label (4) the budget constraint and label (5) the time resource constraint. They are interdependent through L^w, Z^b and Z^c. As in De Jong (1990) we have that if $Z^c = 0$ then P=0 and thus that households not using a car will also not buy a car. Apart from the fixed cost P this part of the model is identical to the one used in Parry & Bento (2001).

2.1.1The household's choice at the internal margin

We now examine how a household behaves dependent on its choice of car ownership status. Since households owning a car and households not owning a car can choose between different consumption bundles ('non-owners' can not choose to travel by car) and face different budget constraints ('owners' have to pay a fixed fee $\bar{P}$) we analyze the two types of households separately.

The choice for car owners

Using the budget constraints given in (4) and (5) and assuming that the households ignore their own influence on the level of $\overline{Z}$ we can specify the utility maximization problem for car owners as

$$\begin{aligned} &\max_{L^1, Z^1, Z^{b1}, Z^{c1}} \{U(L^1, Z^1) + u(Z^{b1}, Z^{c1})\} \\ &\text{s.t. } PZ^1 + P^b Z^{b1} + P^c Z^{c1} + \overline{P} = (1 - t_w) L^{w1} + y \qquad (\lambda^{M1}) \\ &L^1 + L^b Z^{b1} + L^c Z^{c1} + L^{w1} = \overline{L} \qquad (\lambda^{T1}) \end{aligned} \tag{6}$$

where λ^{M1} is the marginal utility of income, λ^{T1} is the marginal utility of time as a resource and labor supply will be given by $L^{w1} = Z^{b1} + Z^{c1}$. With (6) being a standard maximization problem we can solve the system given by the first order conditions to obtain the following demand functions

$$L^1(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) \tag{7}$$

$$Z^1(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) \tag{8}$$

$$Z^{b1}(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) \tag{9}$$

$$Z^{c1}(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) \tag{10}$$

and the indirect utility function

$$\begin{aligned} &V^1(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) = \max_{L^1, Z^1, Z^{b1}, Z^{c1}} \{U(L^1, Z^1) + u(Z^{b1}, Z^{c1}) \\ &-\lambda^{M1}(PZ^1 + P^b Z^{b1} + P^c Z^{c1} + \overline{P} - (1 - t_w) L^{w1} + y) \\ &-\lambda^{T1}(L^1 + L^b Z^{b1} + L^c Z^{c1} + L^{w1} - \overline{L})\} \end{aligned} \tag{11}$$

which is now given as a function of variables exogenous to the household.

The choice for non-car owners

Using the budget constraints given in (4) and (5) and assuming that the households ignore their own influence on the level of $\overline{Z}$ we can specify the utility maximization problem for car owners as

$$\begin{aligned} &\max_{L^0, Z^0, Z^{b0}} \{U(L^0, Z^0) + u(Z^{b0}, 0)\} \\ &\text{s.t. } PZ^0 + P^b Z^{b0} = (1 - t_w) L^{w0} + y \qquad (\lambda^{M0}) \\ &L^0 + L^b Z^{b0} + L^{w0} = \overline{L} \qquad (\lambda^{T0}) \end{aligned} \tag{12}$$

where λ^{M0} is the marginal utility of income, λ^{T0} is the marginal utility of time as a resource and labor supply will be given by $L^{w0} = Z^{b0} + Z^{c0}$. With (12) being a standard maximization problem we can solve the system given by the first order conditions to obtain the following demand functions

$$L^0(P, P^b, t_w, L^b, y, \overline{L}) \tag{13}$$

$$Z^0(P, P^b, t_w, L^b, y, \overline{L}) \tag{14}$$

$$Z^{b0}(P, P^b, t_w, L^b, y, \overline{L}) \tag{15}$$

and the indirect utility function

$$\begin{aligned} &V^0(P, P^b, t_w, L^b, y, \overline{L}) = \max_{L^0, Z^0, Z^{b0}} \{U(L^0, Z^0) + u(Z^{b0}, 0) \\ &-\lambda^{M0}(PZ^0 + P^b Z^{b0} - (1 - t_w)L^{w0} + y) \\ &-\lambda^{T0}(L^0 + L^b Z^{b0} + L^{w0} - \overline{L})\} \end{aligned} \tag{16}$$

which is now given as a function of variables exogenous to the household.

2.1.2 The household's choice at the external margin

Facing the price structure ($P, P^b, P^c, \overline{P}$), wage tax t_w, having non-labor income y, facing time requirements L^b and L^c together with externality level $\overline{Z}$ the household choose between the utility level V^0 and V^1. Since households are utility maximizing they choose $i \in \{0,1\}$ such that $V^i = \max\{V^0, V^1\}$. Using the random utility approach the households behave as if the indirect utility function is composed of an observable deterministic part, V^i together with stochastic error term ε^i. We write this as $V^i + \varepsilon^i$. The error term capture the unobservable characteristics which made the household choice seem random to the government. For simplicity and to ensure a closed form solutions we assume that these error terms are independently and identically distributed following a double exponentially distribution with the scale parameter normalized to 1. This gives us a logit model for discrete choice

We know (Ben-Akiva & Lerman (1985) that the probability of choosing not to buy a car, π^0, and the probability of choosing to buy a car, π^1, are given by

$$\pi^0(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) = \frac{e^{V^0}}{e^{V^0} + e^{V^1}} \tag{17}$$

$$\pi^1(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) = \frac{e^{V^1}}{e^{V^0} + e^{V^1}} \tag{18}$$

It is worth noting that the probabilities shown in (17) and (18) depend on all the parameters in the model. This means that even though households not owning a car do not affect the total level of congestion by changing behavior on the internal margin they still affect the level of congestion by changing behavior on the external margin. The expected maximum utility W for a representative household is given by

$$W = \ln(e^{V^0} + e^{V^1}) \tag{19}$$

which is also known as the log-sum. The demand for goods and commodities for a representative (or average) household as well as the supply of labor can now be written as

$$\tilde{Z} = \pi^0 Z^0 + \pi^1 Z^1 \tag{20}$$

$$\tilde{Z}^b = \pi^0 Z^{b0} + \pi^1 Z^{b1} \tag{21}$$

$$\tilde{Z}^c = \pi^1 Z^{c1} \tag{22}$$

$$\tilde{L}^w = \pi^0 L^{w0} + \pi^1 L^{w1} \tag{23}$$

which is a weighted average of the demand for the two types of households in the economy.

2.2 The production sector and the public transport sector

We assume that all production sectors are fully competitive and operate under constant returns to scale. No profits thus exist and the producer prices p, p^b and p^c for commodities, public transport (a 'ticket') and private transport ('fuel') become constant and equal to the marginal cost of production. The government can tax both private and public transport. Letting t^b and t^b represent the tax on public and private transport we can write

$$P^b = p^b + t^b \tag{24}$$

$$P^c = p^c + t^c \tag{25}$$

We assume that the fixed fee $\overline{P}$ for the purchase of a 'car' is paid directly to the government. This assumption might seem a bit strange but it does not affect the analysis.

2.3 The government

The government has to raise revenue G for some unspecified purposes using the taxes defined in (24) and (25) together with the labor tax t_w and the fixed fee, $\overline{P}$. We write the social welfare function for a representative household as

$$W(P, P^b, P^c, \overline{P}, t_w, L^b, L^c(\overline{Z}), y, \overline{L}) = \ln(e^{V^0} + e^{V^1}) \tag{26}$$

which the government seeks to maximize. We define the governments' revenue function R as

$$R(\overline{P}, t_w, t^b, t^c) = \pi^1 \overline{P} + t_w \hat{L}^w + t^b Z^b + t^c Z^c \tag{27}$$

where the first term is the fixed fee collected from car users, the second term is the total labor tax and the last two terms represent taxes on bus and car respectively. The government's budget constraint is now given by

$$R(\overline{P}, t_w, t^b, t^c) = G \tag{28}$$

Taking a closer look at (26) we see that the effect of changes in parameters are a weighted sum of changes in the indirect utility functions for households owning a car and households not owning a car. Letting Θ represent some policy parameter that is changed, the change in maximum expected utility will be given by

$$\frac{\partial W}{\partial \Theta} = \pi^0 \frac{\partial V^0}{\partial \Theta} + \pi^1 \frac{\partial V^1}{\partial \Theta} \tag{29}$$

where we can interpret the probabilities as fractions of households not owning and owning a car. Since for households being at the border between having and not having a car we have $V^0 = V^1$ the change in probability at the margin does not change the overall welfare. A change in probabilities does therefore not enter the expression above directly.

3. Tax reform analysis

In this section we examine how the welfare changes when the government implements a tax reform reducing the purchase tax on cars to variable taxes on the use of cars.

3.1 Helpful derivations

We know that

$$\frac{\partial W}{\partial t^c} = -\pi^1 \lambda^{M1} Z^{c1} \tag{30}$$

$$\frac{\partial W}{\partial \overline{P}} = -\pi^1 \lambda^{M1} \tag{31}$$

$$\frac{\partial W}{\partial L^c} = -\pi^1 \lambda^{T1} Z^{c1} \tag{32}$$

Commenting on these effects affects we se that (30) and (32) resembles the results from Parry & Bento (2001) except for the probability weighting included here. Note that the effect of the fixed fee derived in (31) is identical to the effect of a lump-sum transfer in the Parry and Bento paper (again except for the probability weighting here). This is a consequence of $\overline{P}$ only having an income effect on the internal margin for car owners.

3.2 Feedback effects

It will be advantageous to know how the demand for private transport changes as a function of the fixed fee. Since we have externalities in the model we expect feedback effects to be present both on the internal margin and on the external margin in the demand for private transport. To simplify notation we will assume that $\overline{Z} = \tilde{Z}^c$ ignoring the number of households H in the derivations. This has no effect on the analysis since we can include the number of households H in the definition of L^c. Evaluating the change in demand when the fixed fee changes and the revenue is recycled through t^c we find that

$$\frac{\partial \tilde{Z}^c}{\partial \overline{P}} = \frac{\left(\frac{\partial \pi^1}{\partial \overline{P}} + \frac{\partial \pi^1}{\partial t^c}\frac{dt^c}{d\overline{P}}\right) Z^{c1} + \left(\frac{\partial Z^{c1}}{\partial \overline{P}} + \frac{\partial Z^{c1}}{\partial t^c}\frac{dt^c}{d\overline{P}}\right)\pi^1}{\left(1 - L'\left(\frac{\partial Z^{c1}}{\partial L^c}\pi^1 + \frac{\partial \pi^1}{\partial L^c} Z^{c1}\right)\right)} \tag{33}$$

The numerator capture the effect of the change in fixed fee had there been no externalities present in the model since there is a direct response to the increase in P and a response from the revenue recycling given by $\frac{\partial Z^{c1}}{\partial t^c}\frac{dt^c}{d\overline{P}}$. With externalities present in the model a feedback effect is present which is captured by the denominator. By assumption L′>0 and since we expect private transport to be a normal good the increase in L^c will cause the generalized price to increase. We therefore have that $\frac{\partial Z^{c1}}{\partial L^c} < 0$ and $\frac{\partial \pi^1}{\partial L^c} < 0$ thus making the denominator exceeds 1. Since we normally also expect that $L'' = \frac{\partial L'}{\partial \overline{Z}}$ to be larger than zero the feedback effect becomes larger when the congestion externality increase. Furthermore we see that the size of the feedback effect is determined by both the change on the internal margin and the change on the external margin.

3.3 Shifting from fixed to variable tax on cars

We now examine the effect of changing the fixed tax $\overline{P}$ on the purchase of cars and financing this by making changes in the variable tax t^c on the use of cars. The welfare effect is given by

$$\frac{dW}{d\overline{P}} = \frac{\partial W}{\partial \overline{P}} + \frac{\partial W}{\partial t^c}\frac{dt^c}{d\overline{P}} + \frac{\partial W}{\partial L^c} L' \frac{dZ^c}{d\overline{P}} \tag{34}$$

The first term on the right hand side is the direct effect on welfare from the change. The second term captures the revenue recycling effect that works through t^c. The last term capture the welfare effect of the changes in the level of congestion. We now differentiate the government budget constraint (28) with regards to $\overline{P}$ using $\frac{dG}{d\overline{P}} = 0$ to get

$$\frac{dt^c}{d\overline{P}} = -\frac{\frac{d\pi^1}{d\overline{P}}\overline{P} + \pi^1 + t^c \frac{d\tilde{Z}^c}{d\overline{P}} + t_w \frac{d\hat{L}^w}{d\overline{P}}}{\tilde{Z}^c} \tag{35}$$

Substituting this together with (30), (31) and (32) into (34) and doing some simple manipulation gives

$$\frac{dW}{d\overline{P}} = \lambda^{M1}\left(\frac{d\pi^1}{d\overline{P}}\overline{P} + \left[t_w \frac{d\hat{L}^w}{d\overline{P}} + \left\{-\frac{\frac{\partial Z^c}{\partial \overline{P}} + \frac{\partial Z^c}{\partial t^c}\frac{dt^c}{d\overline{P}}}{1-L'\frac{\partial Z^c}{\partial L^c}}\right\}\left\{\frac{\lambda^{T1}}{\lambda^{M1}} Z^c L' - t^c\right\}\right]\right) \tag{36}$$

Taking a closer look at this expression we see that several effects affect the outcome of the proposed tax reform. The expression in square brackets is comprised of two terms. The first term, $t_w \frac{d\hat{L}^w}{d\overline{P}}$, captures the labor market effect since changes in labor supply will change the tax revenue collected. The second term in the square brackets is a bit more complex. The first part captures changes in the demand for private transport including both tax interaction effects and feedback effects. The second part of this term describes the difference between the marginal external cost of transport, $\frac{\lambda^{T1}}{\lambda^{M1}} Z^c L'$, and the tax on transport t^c. The sign of this term depends on the level at which t^c is set. If it is above the marginal cost the term is negative and if it is set below marginal cost it is positive. In the special case where the tax on transport is equal to the marginal external costs we see that this term cancels out. The term in square brackets is structurally identical to formula 10 in Parry & Bento (2001). The remaining term, $\frac{d\pi^1}{d\overline{P}}\overline{P}$, captures revenue effects coming from changes in the number of car owners.

4. Concluding remarks

This paper shows that decisions on the external margin, e.g., of car ownership, are an important element in welfare evaluation of tax reforms. Omission of decisions on the external margin could therefore be critical. Using a simple model for household decisions, taxation, and discrete choice, we show how the feedback effect as well as the welfare effect depends on the ownership decision and on the interaction with the labor supply decision. The next step is to implement the results in a numerical model in order to examine the size of the effects. This is left for future research.

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