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Fuel taxes and tolls in cost-benefit analysis

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Abstract

When a project either generates or suppresses traffic, fuel taxes and tolls should be considered in the cost-benefit analysis. In this paper we present a simple partial equilibrium model showing that under linear demand, if factor costs are the unit of account and transfer payments are netted out at the outset, then the usual rule of the half works correctly for the incorporation of tolls in the calculus of social costs and benefits, but the incorporation of fuel taxes and other indirect taxes may require a corrective term.

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1. Introduction

When a fixed-trip matrix is used in the traffic forecast of a road infrastructure project[1], both tolls and fuel taxes may be treated as social transfers, and therefore ignored in a cost-benefit analysis presented as a calculus of social costs and benefits[2]. However, it is now widely recognized that the traffic generated or suppressed by an infrastructure may have a significant impact on the results of the investment appraisal (Williams and Moore, 1990; Mackie, 1996), and variable trip matrixes are being more widely used in the analyses. In such cases, the fuel taxes and tolls paid by the generated traffic do not cancel out as economic transfers, and must therefore be explicitly considered.

Recent European Union (EU) documents and EU sponsored projects emphasize the use of factor costs as the unit of account in cost-benefit analysis (Bickel *et al.*, 2006, EC, 2008). Several analyses of road infrastructure projects and high speed rail have been produced, based on the factor costs recommended by the Heatco project, and presented as a calculus of social costs and benefits, that is, netting out transfer payments at the outset. That is the case of the recent cost-benefit analyses of Portuguese road infrastructures (available in Portuguese at www.novasestradas.pt) and high-speed rail project infrastructures (available in Portuguese at www.rave.pt). We will present a simple model addressing the incorporation of indirect taxes and tolls in such a framework.

2. The model

Sugden (1998) analyses the treatment of indirect taxation in cost-benefit analysis of transport projects, focusing on the COBA method (see, e.g., DfT, 2001). This method assumes a fixed-trip matrix, and does not incorporate environmental impacts. Since we are following the Heatco and EU recommendations, our analysis is different.

We consider a road infrastructure project (building a new road, or improving an existing one), and we assume there is no saving (as in the model for the indirect tax correction factor presented by Sugden, 1998). We use the subscript 0 for the "Do-minimum" scenario and 1 for the "Do-something" scenario and we define t as the economy-wide rate of indirect tax on final consumption.

We will consider a non-work trip (the analysis of a work trip would be very similar). Let us assume for now that the trip will be made whether or not the project is undertaken – that is, the trip is included in the base traffic. We define:

P_i: traded resources used in the trip that are paid by the user and perceived as costs of the trip (e.g, fuel)[3], measured at factor prices, $i = 0,1$.

U_i: traded resources used in the trip that are paid by the user but not perceived as costs of the trip (possibly tyres, vehicle depreciation), measured at factor prices, $i = 0,1$.

[1] This is the case of the COBA method, used by the Department for Transport of the United Kingdom (DfT, 2001).

[2] For the difference between a calculus of social costs and benefits and a calculus of willingness-to-pay see, e.g., Sugden (1999).

[3] Some authors (e.g, Litman, 2009) refer to the costs of traded resources as market costs, and to the costs of non-traded resources as non-market costs. Since we are using the concept of market prices to denote the prices including indirect taxes, the use of such terminology might be confusing.

N_i: non-traded resources used in the trip (e.g, time), measured at factor prices, i=0,1.
TP_i: tolls and indirect taxes over perceived costs paid by the user, $i = 0,1$.
TU_i: indirect taxes over unperceived costs paid by the user, $i = 0,1$.
E_i: external cost of the trip (e.g, environmental cost), measured at factor prices, $i = 0,1$.

Since we explicitly consider external costs (including environmental costs, in line with Bickel *et al.*, 2006 and EC, 2008), we will not disregard any special taxes as being used to offset such external costs.

We are assuming that there is no saving, so we know that in order to make the trip the user will forfeit consumption of other resources with a value F_i calculated as:

$$F_i = \frac{P_i + U_i + TP_i + TU_i}{1+t}, i = 0,1 \qquad (1)$$

General consumption is taxed at the indirect tax rate t, so we must divide the monetary cost of the trip by a factor that reflects this tax, in order to measure forfeit consumption at factor prices. Since the user only perceives part of the costs as effective costs of the trip, the forfeit consumption that is perceived by the user will be:

$$FP_i = \frac{P_i + TP_i}{1+t}, i = 0,1 \qquad (2)$$

We define V as the "gross value" of the trip: the value obtained by the user by making the trip, gross of all the costs, and measured at factor prices. We assume that V is the same whether the project is undertaken or not. Since we are considering the case in which the trip is made whether or not the project is undertaken, the value derived from making the trip must be larger than the perceived cost. So, the net perceived user benefit from making the trip, denoted by B_i and measured at factor prices, will be non-negative in both scenarios:

$$B_i = V - (N_i + FP_i) \geq 0, i = 0,1 \qquad (3)$$

Notice that, since we consider a non-work trip, the true cost of tangible resources will be the value of the consumption forfeit by the user in order to obtain them. The net social impact of the trip, S_i, will be given by:

$$S_i = \left(B_i - \frac{U_i + TU_i}{1+t} \right) + (F_i - P_i - U_i) - E_i, i = 0,1 \qquad (4)$$

The first term of S_i is the true net user benefit (perceived net benefit minus unperceived costs), the second is the effect of the trip on the available resources and the third is the external cost. Plugging (1)-(3) into (4) we get:

$$S_i = V - N_i - P_i - U_i - E_i, i = 0,1 \qquad (5)$$

The changes in the social impact of the trip due to the project will be:

$$\Delta = S_1 - S_0 = (N_0 - N_1) + (P_0 - P_1) + (U_0 - U_1) + (E_0 - E_1) \tag{6}$$

As expected, indirect taxes (like fuel taxes) and tolls do not enter (6), since they cancel out as transfers. In fact, aside from presentational differences, this is a standard result.

Now let us assume that the trip is generated by the project – it will only be made if the project is undertaken (the analysis of a suppressed trip would be similar). Since the trip is made in the "Do-something" but not in the "Do-minimum" scenario, it must be the case that the perceived user benefit is non-negative in the former scenario and non-positive in the latter one:

$$B_0 \le 0 \le B_1 \Leftrightarrow N_1 + FP_1 \le V \le N_0 + FP_0 \tag{7}$$

If demand is linear on the perceived cost, V will be uniformly distributed on $[N_1 + FP_1, N_0 + FP_0]$. So, for a generated trip, the expected gross value will be:

$$E(V) = \frac{N_1 + FP_1 + N_0 + FP_0}{2} \tag{8}$$

By (3) and (8), the expected value of the net perceived user benefit in the "Do-something" scenario is:

$$E(B_1) = \frac{(N_0 + FP_0) - (N_1 + FP_1)}{2} \tag{9}$$

Plugging (9) into the expected value of (4), we get:

$$E(S_1) = \left(\frac{(N_0 + FP_0) - (N_1 + FP_1)}{2} - \frac{U_1 + TU_1}{1+t} \right) + (F_1 - P_1 - U_1) - E_1 \tag{10}$$

Using (1)-(2) in (10), and taking into account that the trip is made only in scenario 1 (meaning that $E(S_0) = 0$), we get the following social impact of the project:

$$\Delta = E(S_1) - E(S_0) = \frac{N_0 - N_1}{2} + \frac{P_0 - P_1}{2} - U_1 - E_1 + \frac{(TP_0 - P_0 \cdot t) + (TP_1 - P_1 \cdot t)}{2 \cdot (1+t)} \tag{11}$$

The first two terms of (11) show that the rule of the half should be used for appraising the impacts of the project on the perceived user costs before indirect taxes and tolls. The third and fourth terms show that unperceived and external costs should be subtracted from the social surplus. We note that the prescribed treatment of the unperceived costs of generated traffic is not clear in most cost-benefit guides – it is interesting to find out that unperceived costs affect not only the traffic forecast but also the subsequent appraisal, since they have a different impact from the perceived costs. So, it is very important to know which user costs should be assumed to be perceived in the traffic forecast, in order to produce an appraisal that is consistent with the forecast assumptions.

What interests us most is the fifth term of (11). This term represents the average excess of tolls and indirect taxes on perceived costs over the general indirect tax rate, for the "Do-something" and "Do-minimum" scenarios, discounted by a factor 1+*t*. Looking at (6), we notice that there was no corresponding term in the social surplus of the base traffic. The reason is that taxes and tolls are, in fact, economic transfers that enter expression (11) only because of what they allow us to infer about the value of the trip for the new users of the infrastructure. We will further examine the meaning of this term in the next section.

3. Particular cases

According to (11), the net impact of indirect taxes and tolls on generated trips is given by:

$$\frac{\left(TP_0 - P_0 \cdot t\right) + \left(TP_1 - P_1 \cdot t\right)}{2 \cdot \left(1+t\right)} \qquad (12)$$

Under multiple indirect taxes and tolls (that is, some perceived costs being taxed at the general indirect tax rate, others at special rates, and possibly additional tolls), the value of (12) will be the sum of the impacts of the particular components. If there are *n* components of the perceived cost and, for component *j*, the resource cost is P_i^j and the indirect taxes and tolls are TP_i^j, then

$$\frac{\left(TP_0 - P_0 \cdot t\right) + \left(TP_1 - P_1 \cdot t\right)}{2 \cdot \left(1+t\right)} = \sum_{j=1}^{n} \frac{\left(TP_0^j - P_0^j \cdot t\right) + \left(TP_1^j - P_1^j \cdot t\right)}{2 \cdot \left(1+t\right)} \qquad (13)$$

It must be the case that:

$$P_i = \sum_{j=1}^{n} P_i^j$$
$$TP_i = \sum_{j=1}^{n} TP_i^j \qquad (14)$$

We will now consider, for some different types of resources and tolls, the value of the term:

$$\frac{\left(TP_0^j - P_0^j \cdot t\right) + \left(TP_1^j - P_1^j \cdot t\right)}{2 \cdot \left(1+t\right)} \qquad (15)$$

Let us consider a resource subject to the general tax rate *t*. For such a resource, $TP_i^j = P_i^j \cdot t$. This means that for such a resource the value of (15) will be zero, and that the indirect tax on that resource has no impact on the appraisal of the social surplus.

Consider now a resource subject to an indirect tax that is higher than the general tax rate (this is usually the case of fuel). This means that $TP_i^j > P_i^j \cdot t$, and that (15) will have a positive value. Let us look at this special tax as an additional tax *v* applied after the general tax, so that $TP_i^j = P_i^j \cdot (1+t) \cdot (1+v) - P_i^j$. Expression (15) becomes:

$$\frac{P_0^j \cdot v + P_1^j \cdot v}{2} \tag{16}$$

In line with several other authors (e.g, Litman, 2009), we conclude that under special taxes, only the level of tax above the general tax rate shall be considered in the analysis. But it is important to notice that it is not the value of the taxes above the general rate collected in the "Do-something" scenario that is added to the social surplus – instead, as shown by (16), it is the average between the value collected in the "Do-something" and the "Do-minimum" scenarios (if the trip was also made in the latter scenario). When we consider fuel taxes, the relevant impact is not the value of the fuel taxes of generated traffic collected in the "Do-something" scenario, but instead it is the average of this value and the value of fuel taxes the generated traffic would produce in the "Do-minimum" scenario, if it would be making the trips.

The case in which the resource is subject to an indirect tax *u* that is lower than the general tax can be considered by defining $v = (u-t)/(1+t) < 0$, and using (16). In such case, $v < 0$, the impact of the tax on the social surplus will be negative. In the case of an untaxed resource, we have $v = -t/(1+t)$.

Finally, let us consider tolls. In the case of a toll, there is no physical resource involved, so $P_i^j = 0$. So, expression (15) becomes:

$$\frac{TP_0^j + TP_1^j}{2 \cdot (1+t)} \tag{17}$$

The impact of tolls collected on generated traffic is thus the average between the before-tax value of the tolls collected in the "Do-something" scenario and the before-tax value of the tolls that would be collected if the generated traffic would be making the trips in the "Do-minimum" scenario. In the case of a new toll, only applied in the "Do-something" scenario, we conclude that the social surplus is equal to half of the before-tax tolls collected on the generated traffic.

4. Conclusions

Cost-benefit guides are often unclear as to the way to incorporate fuel taxes and tolls in the analysis (e.g, CE, 2008). We considered an analysis based on factor costs and presented as a calculus of social costs and benefits (as in several recent cost-benefit analyses), and resorted to a simple model to determine the correct way to incorporate indirect taxes and tolls in the analysis. From this model we concluded that:

- Unperceived user costs from generated traffic shall be subtracted from the social surplus.
- Only the level of indirect tax above or below the general rate must be considered, and only for the generated or suppressed traffic. The net social impact is the average between the abnormal amount of indirect tax that is collected in the "Do-something" scenario and the one that would be collected if the generated traffic would also be making the trips in the "Do-minimum" scenario.
- Tolls shall only be considered for the generated traffic, and their impact is calculated as the average between the before-tax value of the collected tolls in the "Do-something" scenario and the before-tax value of the tolls that would be collected if the generated traffic would also be making the trips in the "Do-minimum" scenario.

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