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Abstract

In this paper we study the welfare effects of a budgetary neutral increase in taxes on car commuters in a model that takes into account the presence of employer-paid parking at the workplace. Results include the following. First, we find that the presence of employer-paid parking substantially increases the welfare effect of such a tax reform, independent of the use of the revenues. The intuition is that congestion taxes not only correct congestion externalities, they also reduce the inefficiency caused by employer-paid parking. Second, different congestion effects of alternative recycling instruments and the presence of employer-paid parking jointly imply that recycling the tax revenues via higher public transport subsidies may yield much more favourable welfare effects than previously believed. It can easily outperform recycling the tax revenues via lower labour taxes. Third, cashing out parking costs to public transport users is found to generate substantial positive welfare effects. The theoretical predictions are illustrated using a numerical model calibrated on Belgian data.

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1. Introduction

It is now widely accepted by transport economists and policy-makers that several major inefficiencies are associated with the pricing of passenger transport markets. First, there is overwhelming evidence that peak road use is currently priced below marginal social cost in many European cities (see, e.g., De Borger and Proost (2001)). Economists have, therefore, advocated the use of some form of congestion charge, ranging from cordon prices to full electronic road pricing (see, among others, Small (1992), Verhoef, Nijkamp and Rietveld (1995), Arnott, de Palma and Lindsey (1993)). Moreover, as most congestion occurs during the journey-to-work, several models have incorporated the labour market effects of congestion and congestion taxes into the analysis (see, e.g., Parry and Bento (2001), Van Dender (2003), De Borger and Van Dender (2003)). Second, another large inefficiency in transport pricing is due to the fact that many car drivers do not pay for the resource cost of parking (for recent studies see, e.g., Shoup (2005), Calthrop, Proost and Van Dender (2000) and Calthrop (2001)). This inefficiency is also most pronounced for commuting trips. In the US, Shoup and Breinholt (1997) found that up to 95% of car commuters are offered free parking at the workplace, despite the fact that the true resource cost of parking is substantial. The average employer-paid parking subsidy in the US has been reported to be 50 percent greater than the total cost of gasoline for the average commute [Shoup (1993)].

Since the two transport inefficiencies mentioned above are closely related, it seems a useful exercise to study policies to reduce congestion within a framework that not only captures labour market interactions but also takes account of the presence of un-priced parking costs. In this paper, we study the implications of the existence of employer-paid parking for the welfare effects of introducing higher congestion taxes. The model we use is highly stylized. We consider a setting in which all peak transport demand is for commuting purposes. Commuters can either go to work by car, or they can use public transport. It is assumed that they do not pay the full resource cost of parking at the workplace because of (full or partial) employer-paid parking. Public transport use is also potentially subsidized. It is assumed for simplicity that public transport users neither contribute to, nor suffer from, congestion. Finally, all commuters are subject to a tax on labour income.
Within this framework, we study the welfare effects of a budgetary-neutral increase in congestion taxes, where the government has several options to recycle the extra tax revenues to consumers. We specifically compare reducing labour taxes with using the revenues to raise public transport subsidies. We are interested in (i) the impact of employer-paid parking on the welfare effects of the reforms studied, and (ii) the implications of free parking for the relative efficiency of different recycling instruments. The theoretical analysis is illustrated with several numerical exercises based on Belgian data.

The results of this paper are highly intuitive; they are easily summarized as follows. A first finding is that the existence of employer-paid parking raises the welfare gain of a budgetary-neutral increase in congestion taxes, independent of the policy instrument used to recycle the tax revenues. The reason is that congestion taxes not only correct congestion externalities, they also reduce the inefficiency caused by employer-paid parking. A second finding concerns the relative welfare effects of different recycling instruments. It is shown that, compared to earlier results reported in the literature, recycling higher congestion tax revenues to subsidize public transportation may have more favourable welfare implications than to recycle revenues via reductions in labour taxes. The reason is that labour tax reductions and public transport subsidies have very different effects on congestion and on the demand for parking. A third finding of this paper is that a policy of cashing out parking costs has substantial beneficial welfare effects; specifically, our simulation results produce orders of magnitude that are in line with those of Shoup’s (1997) case studies.

The current paper nicely fits into the recent literature. First, several papers have incorporated the link with the labour market in an analysis of a revenue neutral congestion tax reform (see, e.g., Parry and Bento (2001), Van Dender (2003), De Borger and Van Dender (2003)). These papers have convincingly shown that the feedback effects of congestion on transport demand and labour supply imply that transport tax increases have more favourable labour market outcomes than previously believed. Moreover, it has been suggested that using congestion toll revenues to provide more public transport subsidies is less efficient than recycling revenues by cutting labour taxes. This standard result (see, e.g., Parry and Bento (2001)) is, however, derived in a model that does not consider employer-paid parking; moreover, it is based on the implicit assumption that the effect of the tax reform on congestion is independent
of the revenue recycling policy. By relaxing this assumption and incorporating employer-paid parking, the current paper extends and qualifies earlier findings.

Second, a moderately large literature exists on the economics of parking. Many papers have pointed extensively at the perverse congestion effects induced by employer-paid parking (e.g., Wilson and Shoup (1990), Shoup and Breinholt (1997), and Shoup (2005)). Furthermore, Calthrop et al. (2000) studied the interaction between parking fees and cordon tolls in urban areas, and found them to be policy substitutes: for higher parking fees, the optimal cordon charge falls, and vice versa. The authors correctly argue that parking and congestion policies should be studied simultaneously. Unlike these studies, however, the current paper explicitly investigates the role of employer-paid parking for the desirability of congestion tax reform and for the relative efficiency of recycling instruments.

Structure of this paper is as follows. In Section 2, we introduce commuting transport demand and employer-paid parking into a simple model of a competitive labour market. In Section 3 we derive the main analytical results. A numerical illustration is described in Section 4. Conclusions and limitations of the model are given in Section 5.

2. Model Structure

In this section, we introduce the simplest possible framework to study transport tax reform in the presence of congestion, employer-paid parking and public transport subsidies. The model is designed to capture commuting transport in the morning or evening peak; it therefore ignores non-commuting transport as well as freight transport.

2.1 The household

We aggregate consumer decisions by assuming that all labour supply and transport demand decisions are the result of the optimising behaviour of a representative consumer. Household preferences are defined over the consumption of a clean general consumption good \( q_0 \), commuting by car \( q_1 \).

---

1 Several papers (for an overview, see Arnott, Rave and Schöb (2005)) look at other aspects of parking than the one we study in this paper. For example, Arnott, de Palma and Lindsey (1991) and Anderson and de Palma (2004) study the spatial pattern of parking over time, and how it is affected by various parking policies.
commuting by public transport $q_2$ and leisure $l$. We assume, following Parry and Bento (2001) and Van Dender (2003), that there is strict complementarity between labour supply $L$ and commuting, so that $L = q_1 + q_2$. In other words, each day of work requires one (round)trip. Optimisation by the representative household is then formulated as follows:

$$\text{max } u(q_0, q_1, q_2, l)$$

s.t.

$$q_0 + (\tau + c)q_1 + (r - s)q_2 = G + (w - t)L$$ \hspace{1cm} \text{(2)}$$

$$L = \frac{l}{(1+q_1)q_1 + (1+\phi)q_2 + l}$$ \hspace{1cm} \text{(3)}$$

where $u(.)$ is quasi-concave and continuous, and the multipliers associated with the constraints are given between brackets.

The first constraint is the budget restriction. The price of the clean consumption good is normalized at one. The unit price of car commuting consists of a pure resource cost (normalized at 0 since it does not matter for the analysis of this paper), a potential contribution $c$ for parking at the workplace, and a congestion tax $\tau$ imposed by the government. The resource cost of public transportation is denoted by $r$, so that the household pays a unit fare of $r - s$, where $s$ is the subsidy for public transport use. The government further provides a lump-sum transfer of $G$ to households, and it levies a labour tax $t$. Hence, the net daily wage is $w - t$, where $w$ is the pre-tax wage. The second restriction allocates the households’ total time endowment, denoted $L$, to leisure, labour and commuting. Note that $a$ is the time needed to make one car commuting trip; it is an increasing and convex function of $q_1$, see below. We assume public transport commuting to be un-congested; its travel time $\phi$ is constant.

From the optimization problem we derive Marshallian demand functions:

$$q_0 = q_0(w-t, \tau + c, r - s, a, G, \phi); \quad q_1 = q_1(w-t, \tau + c, r - s, a, G, \phi);$$

$$q_2 = q_2(w-t, \tau + c, r - s, a, G, \phi); \quad l = l(w-t, \tau + c, r - s, a, G, \phi)$$

Substituting demands into the utility function yields indirect utility:

$$V(w-t, \tau + c, r - s, a, G, \phi)$$

It has the following properties:
\[
\frac{\partial V}{\partial \tau} = -\lambda q_1; \quad \frac{\partial V}{\partial t} = -\lambda L; \quad \frac{\partial V}{\partial s} = \lambda q_3; \quad \frac{\partial V}{\partial G} = \lambda; \quad \frac{\partial V}{\partial a} = -\gamma q_1; \quad [2]
\]

2.2 The firm

Production on a competitive market is, without loss of generality, aggregated in one economy-wide firm. Labour is the only input; the production function is \( f(L) \) where, as indicated above, \( L = q_1 + q_2 \). All car commuters are assumed to park at work. Labour productivity is assumed to be independent of the travel mode used for commuting, but due to the long-run resource cost of parking for the firm they do imply different employment costs, see below. Wages for both types of employees are the same, however; i.e., there is no cashing out of parking costs\(^2\). Normalizing the market price of the final good at one, the profit of the firm can be written as:

\[
\pi = f(q_1 + q_2) - w(q_1 + q_2) - (p - c)q_i
\]

where \( p \) is the long-run resource cost of parking to the firm, and \( c \) is the (possibly zero) contribution of the car commuter for parking at work. Note that \( p \) should be interpreted as the true long-run opportunity cost of providing parking to car commuters. This is what the firm ‘saves’ in the long-run for workers that prefer not to commute by car.

Given equal wages and equal marginal productivities, but different total employment costs, for car commuters and people coming to work by public transport one easily shows, setting up the firm’s profit maximization problem, that there are two possibilities. If the firm only hires public transport users, then the wage reflects the marginal product of labour. If the firm hires both types of commuters, the first-order condition for the firm implies equality of the marginal product and the wage plus the non-wage unit labour cost of car commuters:

\[
f' - w - (p - c) = 0 \quad [3]
\]

Marginal productivity equals the unit labour cost of the ‘high-cost’ type of worker. We assume, consistent with empirical observations, that the firm indeed hires both types so that [3] holds.

\(^2\) As documented in the empirical literature (see, e.g., Shoup (1993, 1997)), employees commuting by public transport (or any other transport mode that leads to lower or zero parking costs) are in general not cashed out for the parking space they do not use.
3. Transport tax reform, employer-paid parking and revenue recycling

In this section, we discuss the welfare impact of a revenue-neutral marginal increase in the tax on car commuting. We first derive the general expression in the case of labour tax recycling and consider the implications of employer-paid parking. Next we look in more detail at different recycling instruments and the role of parking in determining their relative welfare effects. We focus on the main intuition throughout; technical details are delegated to appendices.

3.1. Tax reform and employer-paid parking

The social welfare function we use consists of representative household utility, normalized by marginal utility of income to express utility in monetary terms, and profits of the firm:

$$Z = \frac{1}{\lambda} V(w+\tau+c, r-s, a, G, \phi)+ f(q_1 + q_2) - w(q_1 + q_2) - (p-c)q_1.$$  \[4\]

Without affecting the nature of the results, we will in what follows assume that preferences are quasi-linear in the general consumption good, so that the marginal utility of household income is constant and normalized at one.

Now consider the welfare impact of a budgetary-neutral marginal increase in the car tax $\tau$, where the government budget is held constant by reducing the labour tax. The government budget constraint is written as:

$$tL + \eta_1 - s_2 = G$$  \[5\]

where, to facilitate comparison with earlier results in the literature, we assume $G$ to be exogenously given. In Appendix A we show that the welfare effect we are looking for can be written as:

$$\left. \frac{dZ}{d\tau} \right|_{G, \Delta} = (\tau - MEC) \left. \frac{dq_1}{d\tau} \right|_{G, \Delta} + t \left. \frac{dL}{d\tau} \right|_{G, \Delta} + (p-c-s) \left. \frac{dq_2}{d\tau} \right|_{G, \Delta}.$$  \[6\]

In this expression, MEC is the marginal external cost of road use, defined as $-\frac{\partial V}{\partial a'}$. The notation $\left. \frac{dZ}{d\tau} \right|_{G, \Delta}$ is used to indicate that we consider the welfare change holding the government budget constant and recycling the revenues through a reduction in the labour tax.

To interpret [6], note that the welfare change depends on the impact of the tax on the distortions on the market for car travel, the labour market and the
public transport market. The first two effects are well known from the literature (Parry and Bento (2001), Calthrop (2001), Calthrop et al. (2007)). The first one suggests that raising the congestion tax is welfare-improving to the extent that the current tax is below marginal external cost and the tax increase is successful in reducing commuting demand by car. The second term indicates that the reform is welfare-improving to the extent that it raises employment.

The third term captures the welfare effects via the public transport market. It is here that the role of employer-paid parking enters. In the absence of employer-paid parking \((p = c)\), this final term captures the standard welfare loss on the public transport market due to public transport subsidies. Note, however, that the presence of employer-paid parking \((p - c > 0)\) reduces this distortion. Commuters using public transport save on parking resource costs. This implies an extra benefit of the congestion tax increase. Within the setting of this model, therefore, the effect of employer-paid parking is to mitigate the welfare distortion on the market for the public (i.e., non-car) transport mode. If the parking subsidy exceeds the public transport subsidy then raising the congestion toll actually increases welfare on the market for the mode not requiring parking space.

Combining the implications on the three markets, (6) implies that a budgetary-neutral increase in the congestion tax raises welfare if the current tax is far below marginal external cost, if the employment effects are positive or small, and if the implicit subsidy to car users due to employer-paid parking is large relative to the subsidy to public transport. We return to the implications of the tax for the different markets in more detail below.

Finally, note that setting the right-hand side of expression [6] equal to zero, optimal welfare is obtained when the congestion tax equals marginal external cost, the labour tax is zero and the implicit subsidy to car users in the form of employer-paid parking equals the subsidy to public transportation. One possibility in this respect is to eliminate both employer-paid parking and public transport subsidies. Note, however, that equality of the two subsidies suffices to attain the welfare optimum; in that case the subsidy is lump-sum.

3.2 The relative efficiency of different recycling instruments

In the previous subsection it was assumed -- following, among many others -- Bovenberg and Goulder (1996) and Van Dender (2003) -- that recycling of the transport tax revenues was in the form of labour tax reductions. This seems plausible. The high marginal welfare cost of labour taxation suggests
favourable welfare effects of reducing labour taxes. In fact, under some simplifying assumptions Parry and Bento (2001, Appendix) formally show that recycling the revenues via lower labour taxes indeed produces better welfare results than recycling in a lump-sum fashion or in the form of higher subsidies to public transport. However, in deriving this result they assumed for simplicity that the effect of the tax increase on congestion was independent of the recycling instruments used. In this sub-section, we reconsider the issue by relaxing this assumption and taking into account the existence of employer-paid parking.

In the case of labour tax recycling, the welfare effect of a congestion tax increase was given by (6). When additional transport tax revenues are used instead to increase public transport subsidies, we show in Appendix A that the welfare change can be written analogously as follows:

\[ \frac{dZ}{d\tau} \bigg|_{G,\Delta s} = (\tau - MEC)\left. \frac{dq_1}{d\tau} \right|_{G,\Delta s} + \left. \frac{dL}{d\tau} \right|_{G,\Delta s} + (p - c - s)\left. \frac{dq_2}{d\tau} \right|_{G,\Delta s} \]  

[7]

where the notation \( \Delta s \) reflects recycling by raising subsidies. To compare (6) and (7) we consecutively discuss the sign and the relative magnitude of the terms capturing the distortions on the markets for car commuting, labour, and public transport.

The effects of different recycling instruments on commuting by car

Intuitively, there are good reasons to believe that the recycling instrument itself makes a lot of difference for the demand for commuting by car and, hence, for congestion. When congestion tax revenues are used to raise public transport subsidies, recycling strengthens the effect of higher congestion taxes, because cheaper public transport reduces commuting by car even further. However, when revenues are used to reduce the tax on labour employment is stimulated and, consequently, may well lead to more commuting by car. Hence, it seems plausible that congestion will go down more when public transport subsidies are used as the recycling instrument.

One easily shows that this intuition is correct\(^3\). To see this, first consider recycling through labour taxes. Totally differentiating the demand function for commuting by car, we have:

\(^3\) We have chosen the approach followed in this and the next subsection because it is the most intuitive to make our point. A less intuitive and mathematically more rigorous procedure is to simultaneously solve for the effects of the congestion tax on employment, on car commuting demand, and on the level of the recycling instrument that is used. This procedure yields, obviously, the same qualitative results. Details are available from the authors.
\[
\frac{dq_1}{d\tau} \bigg|_{G,M} = \frac{\partial q_1}{\partial \tau} + \frac{\partial q_1}{\partial t} \frac{dt}{d\tau} \bigg|_{G} + \frac{\partial q_1}{\partial a} a' \frac{dq_1}{d\tau} \bigg|_{G,M} \tag{8}
\]

The first term on the right hand side is the direct effect of the transport tax on car commuting demand, holding congestion and the labour tax constant. The second and third terms capture, respectively, the effect of the use of the revenues and the indirect demand impact of the tax change via higher congestion. It follows from (8) that:

\[
\frac{dq_1}{d\tau} \bigg|_{G,M} = \frac{\partial q_1}{\partial \tau} + \frac{\partial q_1}{\partial t} \frac{dt}{d\tau} \bigg|_{G} \frac{1}{1 - \frac{\partial q_1}{\partial a} a'} \tag{9}
\]

where the denominator corrects for the feedback effect of congestion on demand. Using a similar approach, we derive the equivalent expression in case recycling of tax revenues operates via public transport subsidies:

\[
\frac{dq_1}{d\tau} \bigg|_{G,M} = \frac{\partial q_1}{\partial \tau} + \frac{\partial q_1}{\partial s} \frac{ds}{d\tau} \bigg|_{G} \frac{1}{1 - \frac{\partial q_1}{\partial a} a'} \tag{10}
\]

To compare (9) and (10), start by observing that:

\[
\frac{\partial q_1}{\partial \tau} = -\partial q_1 \quad \frac{\partial q_1}{\partial a} a' \quad \frac{\partial q_1}{\partial t} = -\partial q_1 \quad \frac{\partial q_1}{\partial s} \quad d\tau \quad d\tau \bigg|_{G,M} \quad \frac{1}{1 - \frac{\partial q_1}{\partial a} a'} \quad (11)
\]

To evaluate the difference, note first note that \(\frac{\partial q_1}{\partial s}\) is negative: higher subsidies to public transport reduce commuting by car. Although the sign of \(\frac{\partial q_1}{\partial t}\) is ambiguous in general, it is highly plausibly negative as well: given the strict complementarity of labour supply and total commuting demand, a higher labour tax is likely to reduce commuting demand. Second, observe that \(\frac{dt}{d\tau} \bigg|_{G}\) and \(\frac{ds}{d\tau} \bigg|_{G}\) are respectively negative and positive. As long as a higher congestion tax
brings in extra revenues and the economy is not situated on the wrong side of the Laffer curve, labour tax rates can be reduced. Similarly, higher congestion tax revenues imply more public transport subsidies, holding the government budget constant. Finally, the denominator of (11) is positive.

Summarizing the above discussion, we then have:

$$\left. \frac{dq_l}{d\tau} \right|_{G,\Delta} - \left. \frac{dq_l}{d\tau} \right|_{G,\Delta} > 0$$  \hspace{1cm} (12)

Since both individual terms in (12) are negative, interpretation is straightforward: a higher congestion tax used to subsidize public transport leads to a larger decrease in car traffic than would be the case when extra revenues are used to cut labour taxes.

**The effect of different recycling instruments on employment**

Next consider potential differences in the employment effects of the two recycling regimes. Totally differentiating the labour supply function shows that we have:

$$\left. \frac{dL}{d\tau} \right|_{G,\Delta} = \frac{\partial L}{\partial \tau} + \frac{\partial L}{\partial \tau} \frac{dt}{G} + \frac{\partial L}{\partial \tau} \frac{dq_l}{G,\Delta}$$  \hspace{1cm} (13a)

$$\left. \frac{dL}{d\tau} \right|_{G,\Delta} = \frac{\partial L}{\partial \tau} + \frac{\partial L}{\partial \tau} \frac{ds}{G} + \frac{\partial L}{\partial \tau} \frac{dq_l}{G,\Delta}$$  \hspace{1cm} (13b)

The first term on the right hand side of each equation is the direct effect, holding the recycling instrument and congestion levels constant. The second term captures the employment effect of recycling, the third term measures the indirect effect through tax-induced changes in congestion: the tax increase reduces congestion, which in turn raises employment.

Expressions (13a)-(13b) imply:

$$\left. \frac{dL}{d\tau} \right|_{G,\Delta} - \left. \frac{dL}{d\tau} \right|_{G,\Delta} = \left[ \frac{\partial L}{\partial \tau} \right]_{G,\Delta} - \left. \frac{\partial L}{\partial \tau} \right|_{G,\Delta} \frac{dt}{G} - \left. \frac{\partial L}{\partial \tau} \right|_{G,\Delta} \frac{ds}{G} + \frac{\partial L}{\partial \tau} \frac{dq_l}{G,\Delta} \left( \frac{dq_l}{G,\Delta} - \frac{dq_l}{G,\Delta} \right)$$  \hspace{1cm} (14)

This suggests that the recycling instrument matters for employment for two different reasons. First, lower labour taxes directly stimulate labour supply whereas higher public transport subsidies mainly affect mode choice, so that labour supply effects are likely to be much smaller. Indeed, Parry and Bento (2001, Appendix) show that the first term between the square brackets is positive: on this account, labour tax recycling has more favourable employment effects than raising public transport subsidies. However, there is a second effect
that has been ignored in earlier literature; it is captured by the final term on the right hand side of (14). To the extent that congestion itself affects labour supply, public transport subsidies have more favourable employment effects. This directly follows from (12).

As the two effects just described point in different directions, the relative employment implications of using different recycling instruments (i.e., the sign of (14)) are ambiguous in general. Consequently, it is instructive to consider a special case. In Appendix B we show, assuming that the wage elasticities of commuting demand by car and by public transport are equal, that:

\[
\begin{align*}
\frac{dL}{d\tau} & = \{M\} \left[ \frac{dq_l}{d\tau} \right] \\
\frac{dL}{d\tau} & = \{M\} \left[ \frac{dq_l}{d\tau} \right]
\end{align*}
\]

so that (14) simplifies to:

\[
\begin{align*}
\frac{dL}{d\tau} - \frac{dL}{d\tau} & = \{M\} \left[ \frac{dq_l}{d\tau} - \frac{dq_l}{d\tau} \right] \\
& = \{M\} \left[ \frac{dq_l}{d\tau} - \frac{dq_l}{d\tau} \right]
\end{align*}
\]

so that (14) simplifies to:

\[
\begin{align*}
\frac{dL}{d\tau} - \frac{dL}{d\tau} & = \{M\} \left[ \frac{dq_l}{d\tau} - \frac{dq_l}{d\tau} \right] \\
& = \{M\} \left[ \frac{dq_l}{d\tau} - \frac{dq_l}{d\tau} \right]
\end{align*}
\]

where

\[
M = \frac{1}{1 + \frac{(t-s)}{L} \frac{\partial L}{\partial t}} \frac{L}{\partial t} a,
\]

A sufficient condition for the denominator of (17) to be positive is that an incremental increase in the labour tax raises labour tax revenues. The sign of the numerator depends on tax and subsidy rates and on the importance of congestion for employment.

Close inspection of (16) shows that the relative employment effects of recycling via public transport subsidies are always larger in absolute value. If the feedback effects of congestion on labour supply are substantial (or for modest values of \(\tau\) and \(s\), \(\{M\}\) is negative, and the labour supply effects of higher congestion taxes are actually positive. It then follows from (16) that it is also better for employment to recycle congestion tax revenues via higher public transport subsidies. However, if congestion does not strongly affect employment, employment effects of congestion taxes are negative, and they are more negative when recycling is in the form of higher public transport subsidies than with labour tax recycling.
The effect of different recycling instruments on public transport demand

One expects that public transportation demand will increase more when subsidies to public transport are raised than when labour taxes are lowered. To formally prove this, let us assume for simplicity that the wage elasticities of car and public transport commuting are equal. Then it suffices to combine (15) with the definition \( L = q_1 + q_2 \) to find:

\[
\frac{dq_2}{d\tau} \bigg|_{G,\Delta} - \frac{dq_1}{d\tau} \bigg|_{G,\Delta} = \{N\} \left[ \frac{dq_1}{d\tau} \bigg|_{G,\Delta} - \frac{dq_1}{d\tau} \bigg|_{G,\Delta} \right] < 0
\]

where

\[
N = - \frac{1 + \frac{(t + \tau) \partial L}{L} \frac{\partial a}{\partial t} - \frac{\partial L}{\partial a}}{1 + \frac{(t - s) \partial L}{L} \frac{\partial a}{\partial t}} < 0
\]

Here \( N < 0 \) because (assuming the economy is not on the wrong side of the Laffer curve) both numerator and denominator are positive. Expression (18) is then negative due to (12). It implies larger positive effects on public transport demand with subsidy recycling than with labour tax recycling. This confirms our intuition.

3.3 Tax reform, employer-paid parking and recycling policies: summary

In summary, the analysis of this theoretical section yields two important lessons. First, the existence of employer-paid parking implies that the benefits of congestion tax reform are larger than previously believed (see 3.1). Congestion taxes not only correct congestion externalities, they also reduce the inefficiency caused by employer-paid parking by stimulating employees to commute by public transport.

Second, the analysis of section 3.2 does not allow unambiguous conclusions with respect to the relative performance of different recycling instruments, but it does suggest that the relative welfare effects of recycling through higher public transport subsidies can be much more favourable than suggested in earlier literature. To see this, reconsider the overall relative welfare effects of different recycling policies, as given by [6] and [7]. A first factor is that we showed that subsidizing public transport has larger effects on congestion than labour tax recycling. Assuming that the current congestion tax is below marginal external cost \( (\tau - MEC < 0) \), this implies a larger welfare benefit on the car commuter market and, if congestion has sufficiently strong effects on labour
supply, we also have larger positive employment effects. A second factor that may improve the relative performance of public transport subsidies as a recycling instrument is the presence of large employer-paid parking costs. Although public transport subsidies generate a welfare loss on the public transport market, employer-paid parking costs imply that recycling via public transport subsidies generates extra benefits, because it saves on parking costs. If employer-paid parking costs are large, stimulating public transport demand may for this reason imply a welfare gain rather than a welfare loss, see the final terms of (6)-(7). This gain is larger for recycling via subsidies.

### 4. Numerical illustration

We develop a simple numerical model to evaluate the welfare implications of the introduction of a small budgetary-neutral road congestion toll; recycling is either in the form of a labour tax cut or higher public transport subsidies. The parameter values are chosen such that the model roughly reflects realistic orders of magnitude for the Belgian context.

### 4.1 Model structure and calibration

We largely follow the theoretical framework given before, but impose somewhat more structure on the problem to facilitate the calibration. The representative consumer’s preferences are modelled using a simple nested CES utility tree. The structure of preferences is given in Figure 1.

Preferences are assumed separable in two aggregate subutility functions. The first one is denoted A (non-work related utility) and captures leisure and an aggregate consumption good, the second one (B) refers to work-related components and consists of commuting by car and public transport, respectively. Note that the sum of the two types of commuting demand gives labour supply by the assumption of perfect complementarity.

Turning to details, we specify utility as:

\[
U = \left( \alpha_1 A^{\sigma_u - 1} + \alpha_2 B^{\sigma_u - 1} \right)^{\frac{1}{\sigma_u - 1}}
\]
where the subutilities $A$ and $B$ are defined as:

$$
A = \left( \alpha_1 l^{\sigma_A} + \alpha_4 q_A^{\sigma_A - 1} \right)^{\sigma_A - 1}
$$

$$
B = \left( \alpha_5 q_1^{\sigma_B} + \alpha_6 q_2^{\sigma_B - 1} \right)^{\sigma_B - 1}
$$

The $\sigma$'s reflect the relevant substitution elasticities, and the $\alpha$'s are share parameters.

Calibration of the model is based on a combination of observable information and a number of assumptions on behavioural parameters. As for the labour market, the labour force participation rate is taken to be 36% (as in Van Dender (2001)). The length of the working day is fixed at 8 hours per day. The representative individual is therefore assumed to supply 2.88 hours of labour per day (i.e. $8 \times 0.36$). The gross wage is 16.25€/hour; the initial labour tax amounts to 40%. As in Van Dender (2001), we assume a one-way commuting trip to be 20 km on average. In line with the Belgian Mobility Survey (Pollet, 2000), in the reference situation two thirds of all commuting are car trips, and one third are public transport trips.

The cost structure of car transportation was taken from recent key data from the Belgian Automobile Association (VAB). They report that a medium sized car that drives 16,000 km/year implies an average cost of 0.363 €/km which includes amortization, insurance, vehicle tax, fuel costs, etc. Less than 20% of the observed average car cost (0.062€/km) is spent on fuel taxes. In the numerical illustration, taxes on fuel are considered as the initial tax on car commuters.

Shoup (1997) reports employer-paid parking costs up to $165 per month in the US. Calthrop et al. (2001) estimate the cost of parking per trip to Brussels approximately equal to the vehicle-operating and capital costs of a trip (for our model, this would imply a parking cost of 14.52€ per day). Unfortunately, no proxy for the average parking cost of Belgium is available. In our numerical example we use a value of 7.5€ per day. A sensitivity analysis over a wide range of values reveals that the qualitative conclusions of this paper remain valid (although, of course, the magnitude of the welfare effects varies for different values of parking costs). In the reference equilibrium, commuters are assumed not to contribute in parking costs at all ($\xi$ is thus set to zero).
The public transport fare is set to 2,07€ per round-trip, which is consistent with an average fare of 5,6 eurocents per kilometre for Belgian public railroads\(^4\). In our illustration, we assume furthermore that public transportation is heavily subsidized: Belgian data show that 43,4% of the costs of a passenger rail trip is covered by the government\(^5\). In the numerical example the round-trip cost thus equals 3,66€, from which 2,07€ is paid by the commuter, and 1,59€ is subsidized by the government.

To capture congestion, we calculate an aggregate speed-flow relationship for both the urban and the non-urban roads. Kirwan et al. (1995) show that the exponential type of aggregate congestion function is the most plausible. The parameters of both congestion functions for the transport situation in Belgium are estimated from three observation points. Mayeres et al. (1996) consider an average speed in rush hours of 38,2 km/hr in the Brussels-Capital Region. An increase in traffic flow with 20 percent leads to an average speed of 23,7 km/hr. Finally, there is the free-flow situation with a traffic flow approaching zero and an average speed of 50 km/hr. Combination of the three speeds yields the urban exponential congestion function. In a similar way, the non-urban congestion function is estimated from data presented in De Borger and Proost (2001). Both are depicted in Fig. 2. In the numerical model, the urban and non-urban congestion function are weighted with the observed share of passenger kilometres on urban roads and highways (35% of traffic is observed on urban roads and 65% is observed on highways\(^6\)). Note that that the daily travel time for a round trip by car in the reference situation is 62 minutes. The value of time, directly resulting from the calibration, is 7,5 €/hr (or 76,9% of the net wage), which is close to the value used by Van Dender (2001).

**Insert Figure 2 about here**

The parameters of the CES utility structure were chosen such that the partial uncompensated elasticity of labour supply is 0.2 (in line with estimates of Fuchs et al. (1998) and Parry and Bento (2001)). The uncompensated wage elasticities of public transport demand and road transport demand are assumed to be equal: both elasticities are set to 0.2 (sensitivity analysis in section 4.3 will

\(^4\) For 2005, Belgian Railroads report a total of 3,264,000.000 commuter passenger kilometers. Revenues (excl. government subsidies) amount to 168,687.000€ (source: NMBS Statistical Abstract 2005).
\(^6\) Mobility Portal of StatBel (a division of the Federal Public Service Economy).
demonstrate the robustness of the results with respect to different elasticity values). Finally, we set the uncompensated price elasticity of demand, for both car and public transportation trips, equal to -0.33. This is within the range of estimates reported in the recent literature (see Gunn and de Jongh (2001)).

4.2 Tax reform, parking costs, and recycling instruments: numerical results

We consider the effects of increasing the tax on car commuting by 1€ per commuting roundtrip of 40 km; the results are summarised in Table 1. The implications are reported for two recycling instruments: lower labour taxes (column 3 of table 1), and lower public transportation fares (column 4 of table 1).

First, we find that, for both recycling policies, the congestion tax reform produces positive welfare effects. The reason is that initial congestion taxes are substantially below marginal external cost, and the negative effects due to existing public transport subsidies, although substantial, are dominated by the positive effects of lower parking costs. For both recycling policies, we find less road traffic and more public transport demand.

Second, however, we note from table 1 that, consistent with the theoretical section, relative changes in transportation demand are much more pronounced when revenues are used to subsidize public transport than when net wages are increased by reducing the labour tax. To illustrate the implications, we see that average speed of car traffic increases by some 1.5 km/hr when labour taxes are lowered; an increase of almost 4.5 km/hr is observed when revenues are used to cut the fares of public transport. We further find that also the absolute change in labour supply is larger when revenues are recycled through lower public transport fares than when labour taxes are reduced.

Recycling via public transport subsidies yields stronger positive welfare effects than lower labour taxes do. Welfare is measured in euros per person per day. It appears from table 1 that a 1€ congestion tax increase results in a welfare increase of 8.9 cents when taxes are used to decrease labour taxes. It however results in a 25.5 cents welfare increase when higher public transport subsidies are granted. This is due to a larger effect on road traffic, resulting in lower parking costs, and less congestion; the latter effect further stimulates labour supply above the impact of the congestion tax itself.

Insert Table 1 about here
As mentioned earlier, reliable estimates for the average level of Belgian parking costs are difficult to obtain. In Figure 3 we therefore present the increase in welfare for a wide range of parking costs (we let \( p - c \) vary from 0€ to 24€ per day). Tax policies are identical as before: increase the congestion tax by 1€ per commuting roundtrip, and use the additional revenues to subsidize public transportation or to cut labour taxes. Some interesting conclusions follow. First, even in the absence of parking costs, the tax reform yields, for both recycling policies, positive welfare effects. The welfare gain does however increase strongly for larger parking costs. For the reference equilibrium parking cost (i.e. 7,5€/day) the positive welfare effect for both recycling policies is ca. 30% larger than when parking costs are assumed to be non-existent. In this sense, the total welfare gain is thus to a significant extent the consequence of the existence of parking costs.

**Insert Figure 3 about here**

Second, in line with the theoretical model, for larger parking costs, the absolute difference in welfare gain for different recycling instruments becomes larger: for a parking cost of 24€/day, the gain in welfare by subsidizing public transportation is ca. 38 cents compared to 13 cents when labour taxes are reduced.

Third, noting that a lower parking cost \( p \) on the horizontal axis in Figure 3 is equivalent to a higher parking cost contribution \( c \), it follows that when employees pay more for parking, the welfare effect of a congestion tax reform is reduced. If the representative household however partially pays for its demand for parking space, the incentive to increase congestion taxes will be less outspoken, because the tax does not have to correct the inefficiency caused by employer-paid parking.

4.3 Some sensitivity results for different wage elasticities of demand

We test to what extent the welfare effects depend on the assumption of equal wage elasticities of car and public transport commuting demand. The wage elasticity of public transport demand (with a reference equilibrium value of 0,2) is varied between 0 and 0,4. As the interest of this exercise is in changing the sign and magnitude of \((\varepsilon_2 - \varepsilon_1)\), see the theoretical section, we keep the wage elasticity
of labour supply constant at its initial value of 0.2. Given the perfect complementarity assumption between labour supply and commuting, lower values of $\varepsilon_2$ imply higher values for $\varepsilon_1$, and vice versa.

Figure 4 illustrates the sensitivity of the total welfare effect for different values of $\varepsilon_2$, for the two recycling policies. Relative decreases/increases in the wage elasticities of transportation demand have no major impacts on the welfare effects of the various revenue recycling policies. For a relative wide variety of elasticities, the main results of this paper hold: i) both policies have a positive welfare impact, and ii) recycling via public transport subsidies yields more welfare gains than a labour tax cut does.

Insert Figure 4 about here

4.4 Cashing out parking costs: some simulation results

Finally, we briefly consider the implications of cashing out parking costs. The idea of firms cashing out parking costs to employees who do not use parking space has received quite some attention in the empirical literature, mainly in the work of Shoup (1993, 1997, 2005). It is argued that employer-paid parking is to a large extent responsible for the observed congestion peaks, because free parking is a serious motivation to commute by car. In this section we perform a simple simulation exercise to see the implications of a full cashing out of parking costs.

Results are summarized in Table 2. We find that cashing out evidently leads to a direct increase of the real full wage of public transport commuters. A complete cash out results in differentiated full wages for car and train users. Strong changes in the fraction of employees commuting by car (from 66.67% to 61.01%) and by public transport (from 33.33% to 38.99%) are observed. The change in the labour participation rate is less significant (from 36% to 36.22%).

Insert Table 2 about here

Although direct comparison is difficult, it is fair to say that the changes in transport demands resulting from our simple model are in line with the results reported by Shoup (1997). He evaluates the effects of cashing out employer-paid parking for eight case studies in California. Reductions in solo commuting range from 3 to 22 percentage points, which is in line with the reduction (of a complete
cash out) of 5.66 percentage points in our numerical model. Furthermore, Shoup (1997) calculated that public transport increased with 3 percentage points, which is lower than the increase of 5.6 percentage points in Table 2. Note, however, that in our simplified model the sole alternative for car commuting is public transportation. In the case studies considered by Shoup (1997), different other travel modes are possible (carpool, walk, bicycle, etc.). The increase in public transportation in our model is therefore expected to be somewhat biased upward.

5. Conclusion

In this paper we introduced employer-paid parking in a model of commuting road tolls and reconsidered the relative efficiency of different recycling instruments. Several interesting conclusions were derived. First, the existence of employer-paid parking raises the welfare effect of a budgetary-neutral increase in congestion taxes. Moreover, this result holds independent of the policy instrument used to recycle the congestion tax revenues. A second finding is related to the relative welfare effects of different recycling instruments. It is shown that in many realistic settings, and contrary to earlier results reported in the literature, it may actually be more efficient to recycle higher congestion tax revenues to subsidize public transportation than to recycle revenues via reductions in labour taxes. The reason is that labour tax reductions and public transport subsidies have very different effects on congestion and on the demand for parking (and hence on parking costs). Finally, a third finding of this paper is that, when we consider a parking cost cashing out policy, our simulation results are in line with those of Shoup’s (1997) case studies.

There are a number of obvious limitations to our analysis. First, we assume that labour supply and traffic demand are strict complements. Introduction of leisure transportation, or labour supply that does not involve commuting (e.g. telecommuting), might decrease the relative efficiency recycling via public transport subsidies compared to labour tax cuts. Second, although a large empirical literature confirms that the presence of employer-paid parking is responsible for a large part of peak-hour congestion, the underlying motives (e.g. fringe benefits) for employers to offer free parking is not studied in this paper.
**Bibliography**


Appendix A

The welfare change of a marginal increase in the congestion tax, when the revenues are used to reduce the labour tax, can (using (4)) be written as:

\[
\frac{dZ}{d\tau} \bigg|_{G,A} = \frac{\partial V}{\partial \tau} + \frac{\partial V}{\partial t} \frac{dt}{d\tau} \bigg|_{G,A} + \frac{\partial V}{\partial a} a \frac{dq_a}{d\tau} \bigg|_{G,A} + (p-c) \frac{dq_2}{d\tau} \bigg|_{G,A} \tag{A1}
\]

Note that, to arrive at the final term on the right hand side, we differentiated the firm’s profit with respect to the congestion tax and used the first-order condition for profit maximizing behaviour: \( f’(w) - (p - c) = 0 \). The notation \( \bigg|_{G,A} \) indicates that the budget is held constant by adapting the labour tax.

Differentiating the government budget constraint \([5]\) and noting that \( L = q_1 + q_2 \), we obtain the budgetary-neutral change in the labour tax associated with a transport tax increase as:

\[
\frac{dt}{d\tau} \bigg|_G = - \frac{q_1 + (\tau + s) \frac{dq_1}{d\tau} \bigg|_{G,A} + (t-s) \frac{dL}{d\tau} \bigg|_{G,A}}{L} \tag{A2}
\]

where

\[
\frac{dq_1}{d\tau} \bigg|_{G,A} = \frac{\partial q_1}{\partial \tau} + \frac{\partial q_1}{\partial t} \frac{dt}{d\tau} \bigg|_G + \frac{\partial q_1}{\partial a} a \frac{dq_a}{d\tau} \bigg|_{G,A}
\]

\[
\frac{dL}{d\tau} \bigg|_{G,A} = \frac{\partial L}{\partial \tau} + \frac{\partial L}{\partial t} \frac{dt}{d\tau} \bigg|_G + \frac{\partial L}{\partial a} a \frac{dq_a}{d\tau} \bigg|_{G,A}
\]

Substitution of [2] and [A2] in expression [A1] then gives the welfare effect [6] reported in the main body of the paper. An analogous procedure shows that the welfare effect, when additional revenues are used to subsidize the use of public transportation, is:

\[
\frac{dZ}{d\tau} \bigg|_{G,A} = \frac{\partial V}{\partial \tau} + \frac{\partial V}{\partial s} \frac{ds}{d\tau} \bigg|_G + \frac{\partial V}{\partial a} a \frac{dq_a}{d\tau} \bigg|_{G,A} + (p-c) \frac{dq_2}{d\tau} \bigg|_{G,A} \tag{A3}
\]

where:

\[
\frac{ds}{d\tau} \bigg|_G = \frac{q_1 + (\tau + s) \frac{dq_1}{d\tau} \bigg|_{G,A} + (t-s) \frac{dL}{d\tau} \bigg|_{G,A}}{q_2} \tag{A4}
\]

and

Appendix B

In this appendix we consider in more detail the employment effects of the tax reform using different recycling instruments. For labour tax recycling, we start from:

\[
\frac{dL}{d\tau}\bigg|_{G,M} = \frac{\partial L}{\partial \tau} + \frac{\partial L}{\partial t} \frac{dt}{d\tau}_{G} + \frac{\partial L}{\partial a} \frac{dq_{1}}{d\tau}_{G,M}
\]

Using (A2) we can rewrite this as, after straightforward algebra:

\[
\frac{dL}{d\tau}\bigg|_{G,M} = \left[ \frac{\partial L}{\partial t} \frac{q_{1}}{L} - \frac{\partial L}{\partial t} \right] + \left\{ \left[ -\frac{(\tau + s) \partial L}{L} \frac{\partial L}{\partial a} + \frac{\partial L}{\partial a} \right] \frac{dq_{1}}{d\tau}_{G,M} \right\} + \left[ 1 + \frac{\partial L (t-s)}{\partial t} \right] \frac{dq_{1}}{d\tau}_{G,M}
\]

(A1)

A sufficient condition for the denominator of (B1) to be positive is that an incremental increase in the labour tax raises labour tax revenues (so we remain on the correct side of the Laffer curve).

Similarly, starting from

\[
\frac{dL}{d\tau}\bigg|_{G,M} = \frac{\partial L}{\partial \tau} + \frac{\partial L}{\partial s} \frac{ds}{d\tau}_{G} + \frac{\partial L}{\partial a} \frac{dq_{1}}{d\tau}_{G,M}
\]

the total labour supply effect when recycling is via increased public transport subsidies can be written, using (A4), as:

\[
\frac{dL}{d\tau}\bigg|_{G,M} = \left[ \frac{\partial L}{\partial s} + \frac{q_{1}}{q_{2}} \frac{\partial L}{\partial s} \right] + \left\{ \left[ \frac{(\tau + s) \partial L}{q_{2}} + \frac{\partial L}{\partial a} \right] \frac{dq_{1}}{d\tau}_{G,M} \right\} + \left[ 1 + \frac{\partial L (t-s)}{\partial s} \right] \frac{dq_{1}}{d\tau}_{G,M}
\]

(B2)
To simplify (B1)-(B2), note that under the quasi-linear preference structure assumed for the theoretical model, one easily shows symmetric price effects:

\[
\frac{\partial q_2}{\partial t} = -\frac{\partial L}{\partial s}, \quad \frac{\partial q_1}{\partial t} = \frac{\partial L}{\partial \tau}, \quad \frac{\partial q_2}{\partial t} = -\frac{\partial q_1}{\partial s}
\]

Using these relations and the definition \( L = q_1 + q_2 \), we have the following relations:

\[
\frac{\partial L}{\partial \tau} - \frac{q_1}{L} \frac{\partial L}{\partial t} = \frac{\partial q_1}{\partial t} - \frac{q_1}{L} \frac{\partial L}{\partial t} = \frac{1}{L} \left( q_2 \frac{\partial q_1}{\partial t} - q_1 \frac{\partial q_2}{\partial t} \right) = \frac{q_1 q_2}{L(w-t)} (\epsilon_2 - \epsilon_1)
\]

\[
\frac{\partial L}{\partial \tau} + \frac{q_1}{q_2} \frac{\partial L}{\partial s} = \frac{\partial q_1}{\partial t} - \frac{q_1}{q_2} \frac{\partial q_2}{\partial t} = \frac{q_1}{(w-t)} (\epsilon_2 - \epsilon_1)
\]

\[
\frac{1}{L} \frac{\partial L}{\partial t} = \frac{1}{q_1} \frac{\partial L}{\partial \tau} - \frac{1}{q_2} \frac{1}{(w-t)} (\epsilon_2 - \epsilon_1)
\]

Here

\[
\epsilon_2 = \frac{\partial q_2}{\partial (w-t)} q_2; \epsilon_1 = \frac{\partial q_1}{\partial (w-t)} q_1
\]

are the net wage elasticities of public transport demand and road transport demand.

Assuming equal elasticities, simple algebra then shows that we can rewrite [B1] and [B2] as:

\[
\left. \frac{dL}{d\tau} \right|_{G,M} = \left. \left\{ \frac{(\tau + s) \partial L}{L} \partial t + \partial L \partial a \right\} \frac{dq_1}{d\tau} \right|_{G,M}
\]

\[
\left. \frac{dL}{d\tau} \right|_{G,N} = \left. \left\{ \frac{(\tau + s) \partial L}{L} \partial t + \partial L \partial a \right\} \frac{dq_1}{d\tau} \right|_{G,N}
\]

These expressions are (15) in the main body of the paper.
Figure 1: The nested CES utility structure

![Diagram of the nested CES utility structure]

Figure 2: The aggregate congestion function: urban roads (left), non-urban roads (right).

![Graphs showing the aggregate congestion function for urban and non-urban roads]
Figure 3: Tax reform welfare effects for different costs of parking

Note: The upper level curve reflects subsidy recycling, the lower level curve labor tax recycling

Figure 4: Sensitivity of total welfare with respect to $\varepsilon_2$

Note: The upper level curve reflects subsidy recycling, the lower level curve labor tax recycling
### Table 1: Higher congestion taxes for two revenue recycling policies

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### Table 2: Simulation of cashing out parking costs

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