Comparing the Marginal Excess Burden of Labor, Petrol, Cigarette, and Alcohol Taxes: An Application to the United Kingdom

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Abstract

This paper develops an analytical framework for comparing the marginal excess burden (MEB) of labor taxes and various commodity taxes, allowing for externalities and interactions between the taxes, and applies the analysis to the United Kingdom. Due to parameter uncertainty and model simplifications the results should be viewed with caution, nonetheless there are some useful insights.

For example, even though taxes on petrol and cigarettes confer externality benefits, and these goods are relatively weak leisure substitutes, the MEB of these taxes may substantially exceed that of the labor income tax, except under "high" scenarios for externality benefits. In contrast the MEB for alcohol taxes may be smaller than that of the labor tax, though it is still positive even if the tax is *below* marginal external costs. Finally, the distinction between whether additional revenue is spent on public goods or transfers is less significant for commodity taxes than for labor taxes.

Key Words: welfare cost, labor tax, cigarette tax, alcohol tax, petrol tax, externalities.

JEL Classification Numbers: H21, H23, Q28

Contents

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1. Introduction

Protests over high fuel taxes in European countries in the summer of 2000 heightened interest in the appropriate role of petrol taxes in the overall tax system. High fuel taxes have been defended on the grounds that they discourage driving, and thereby reduce traffic congestion, and pollution from petrol combustion. In addition, petrol taxes provide a valuable source of revenues to finance government spending on schools, hospitals, defense, and so on, thereby reducing the need to raise revenues from other sources, such as the personal income tax.

Clearly, taxes on petrol, and other "sin" taxes, such as taxes on cigarette and alcohol consumption, produce economic benefits by reducing various external costs. But they also cause economics costs, for example by inducing people to consume less of the taxed commodity and more of other commodities than they otherwise would. Other taxes also produce economic costs, for example labor taxes reduce the returns to work effort and reduce labor supply below levels that would maximize economic efficiency. The marginal excess burden (MEB) of a tax refers to the welfare loss (or gain), net of any external benefits, caused by the increase in the tax necessary to raise an extra dollar of revenue for the government.[1]

Knowing the MEB of different taxes is important because it critically determines the economic case for tax reforms, that is, the effects of cutting one tax at the expense of raising another tax, holding total tax revenues constant. To the extent that wide differences exist between, say, the MEB of labor and petrol taxes, there is scope for tax reform to significantly enhance economic welfare. The MEB of the tax

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[1] Sometimes the MEB is called the "marginal welfare cost of taxation". A related concept is the "marginal cost of public funds", which is equal to one plus the MEB.

system also plays a role in determining the economically efficient size of government (e.g. Feldstein 1997). The economic costs of any public spending—defense, aid for the needy, health, education, etc.—include not only the monetary outlays but also the additional excess burden from the higher taxes necessary to finance the required amount of revenue. In principle, maximizing economic efficiency involves expanding programs to the point where the social benefit from an extra dollar of spending equals one plus the MEB.

This paper differs from previous literature on the MEB of taxes in several respects. First, previous studies have tended to estimate the MEB of one tax—the labor or possibly capital income tax.[2] In contrast, we develop an analytical framework for assessing the MEB of a broad range of taxes, including taxes on petrol, cigarettes, and alcohol, in addition to the labor tax. In fact there appears to be little empirical literature on the MEB of commodity-specific taxes. Thus, there is not much evidence on which to judge the relative MEB of sin taxes, as opposed to income taxes, to raise a given amount of government revenue.[3]

Second, the paper extends calculations of the MEB by integrating estimates from the literature on externality assessment. These include pollution, accidents and congestion from driving, the additional risks of injury from driving under the influence of alcohol, and the external costs of smoking. It is worth noting that previous studies of these externalities (e.g., Manning et al., 1991, Viscusi, 1995) usually have not considered how they interact with the tax system. Thus, the paper indirectly contributes to the literature on externality assessment, as well as to the literature on the efficiency costs of taxes.

Third, a theme of the paper is that the MEB of commodity-specific taxes depends on how these taxes interact with tax distortions in the labor market. Ignoring these general equilibrium effects can give rise to biased MEB estimates, a point that has recently been demonstrated in a number of other policy contexts.[4] Of course it has long been recognized in the theoretical public finance literature that the general

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[2] See for example Ballard (1990), Ballard et al. (1985), Browning (1987) and (1994), Feldstein (1999), Judd (1987), Ng (2000), Snow and Warren (1996), and Stuart (1984).

[3] Ballard et al. (1985) look at excise taxes for the United States, although these were grouped into a single category for MEB calculation, and their model excludes external benefits.

[4] See for example Goulder et al. (1997) on environmental policies, Browning (1997) on monopoly pricing, and Parry and Oates (2000) for a review of the literature.

equilibrium welfare effects of taxes differ from the partial equilibrium welfare effects. The contribution of the recent literature is to begin spelling out the relative empirical magnitude of the spillover effects in the labor market under different parameter scenarios. This paper builds on this work by extending it to cover a wider range of taxes and interactions.

Fourth, our analysis is applied to the United Kingdom, whereas most previous studies focus on the United States. This has some intrinsic value—indeed we have not really come across any previous estimates of MEBs for the United Kingdom. Moreover, because the British Chancellor of the Exchequer adjusts taxes on labor, petrol, cigarettes and alcohol annually, some information about the MEB of these taxes would be particularly useful (tax adjustments in the United States are far less frequent).

We use an analytical model in order to make transparent the underlying parameters that determine the MEBs, and we illustrate the value of the MEB's over a broad range of parameter scenarios. *However*, more theoretical and empirical analysis beyond the scope of the paper needs to be done before recommendations for fiscal policy can be drawn with confidence. In particular, there is uncertainty and controversy surrounding some of the key parameter values, and most of the literature on externality assessment applies to the United States rather than the United Kingdom. Moreover, our model is simplified in a number of respects, for example it assumes competition in the labor and product markets and it abstracts from interactions with the capital market.[5] Nonetheless, our analysis does provide a unifying, albeit preliminary, framework for understanding to what extent the costs of alternative taxes may differ under different views about parameter values.

There are a number of noteworthy insights from the analysis. First, even though labor taxes are somewhat higher in the United Kingdom than in the United States, the MEB of labor taxation may not be much higher in the United Kingdom, at least for comparable labor supply elasticities.[6]

Second, even though taxes on petrol and cigarettes confer externality benefits, *and* these goods appear to be relatively weak substitutes for leisure, the MEB of these taxes may still exceed that of the

[5] Our paper is also in the Harberger-Browning tradition that focuses only on the efficiency impact of tax increases. More generally the distributional effects should also be taken into account, indeed the main reason for using income taxes instead of lump-sum taxes is that they can achieve distributional goals.

[6] Indeed the MEB of income taxes may be higher in the United States. This is because, unlike in the United Kingdom, there are very substantial tax deductions for housing and medical insurance that distort spending between tax-favored and non-tax-favored goods (e.g. Feldstein 1999).

labor income tax, and perhaps by a substantial amount. This is because the taxes on these goods are already very hefty, and therefore increasing the taxes produces large incremental welfare losses in the commodity markets, *unless* we assume externality benefits that seem high relative to the empirical literature on externality assessment.

Third, the MEB for alcohol taxes may be much smaller than that for other sin taxes; indeed it is smaller than the MEB of the labor tax in 62% of Monte Carlo simulations that we perform. The reason is that the commodity tax rate (as a percentage of price) is a lot lower than for the other commodities. However, the MEB is still positive, even in scenarios when the alcohol tax is *below* marginal external damages, due to the impact of the tax on raising product prices, reducing real wages, and compounding the labor market distortion.

Finally, we discuss how the form of additional public spending may affect the MEB. Previous studies show that the MEB for labor taxes is larger when revenues finance transfer spending rather than public goods, due to the negative income effect on labor supply in the former case (e.g., Wildasin 1984). We find that this distinction has less significance for the MEB of commodity taxes, mainly because the difference between the compensated and uncompensated commodity demand elasticities is relatively small.

The rest of the paper is organized as follows. The next section describes the model assumptions. Sections 3 to 6 derive and implement formulas for the MEB for the various taxes. Section 7 provides some Monte Carlo analysis to gauge the likelihood that the MEB of one tax exceeds that of another. Section 8 concludes and discusses limitations to the analysis.

2. Model Assumptions

Consider a static, representative agent model where agents have the following utility function:

$$(2.1) \quad U = u(X_A, X_S, X_P, X_C, \bar{L} - X_L) + v(G^{PUB}) - \phi(Z)$$

X_A denotes consumption of alcohol, X_S is consumption of cigarettes, X_P is consumption of petrol, and X_C is aggregate consumption of all other market goods. $\bar{L} - X_L$ is leisure, or non-market time, where X_L is labor supply and $\bar{L}$ is the time endowment. $u(.)$, utility from market goods and leisure, is a quasi-concave function. G^{PUB} denotes the amount of public goods provided by the government (defense, police, etc.), and Z is an index of negative externalities. $v(.)$ is utility from public goods and $\phi(.)$ is disutility from externalities. The separability assumptions in (2.1) imply that changes in external effects and public goods do not have feedback effects on labor supply or the choice among consumption goods.[7]

The production of consumption goods is determined as follows:

(2.2) $Q_i = L_i \; i = A, S, P, C$

where Q_i is output and L_i is labor input. Thus the marginal product of labor is constant for all industries, and we choose units of output to imply marginal products of unity.[8] We assume that all firms in industries are competitive, hence payments to labor exhaust the value of output.

Goods market equilibrium requires that

(2.3) $Q_i = X_i \; i = A, S, P, C$

and labor market equilibrium requires

(2.4) $L_A + L_S + L_C + L_P + L_H = X_L$

Equations (2.3) and (2.4) simply equate demand and supply in each market. We normalize labor units to imply the gross wage rate is unity. Thus, given (2.2), the producer prices of goods are also unity.

We represent the tax system by the following parameters. t_L is a proportional tax on labor income (the implications of non-proportional taxes are discussed in Section 3). t_P, t_A, and t_S are per unit taxes on the consumption of petrol, alcohol, and cigarettes. Government tax revenues are used to finance spending on the public good, and transfer spending, G^T. Transfer spending represents government spending that is a perfect substitute for disposable income. Roughly speaking, this represents pensions and welfare benefits

[7] More generally, if public goods are substitutes (complements) for leisure then increasing their level will have a positive (negative) feedback effect on labor supply that would reduce (increase) our estimated MEBs (Atkinson and Stern, 1974).

[8] Our results would not be affected by introducing intermediate goods, so long as there were constant returns to scale and labor was the only primary input. We regard the assumption of constant returns (that is, flat supply curves) as reasonable in the long run, except perhaps for petrol. Here, supply curves could be upward sloping if there are rents to resource inputs (oil). In this case, some of the burden of the petrol tax might be absorbed by the rents (Perroni and Whalley, 1998).

but also public spending that is a close substitute for private spending, such as medical care and education.[9]

Budget balance requires that government spending equals total tax revenues, or

(2.5) $$G^{PUB} + G^{T} = t_L X_L + t_A X_A + t_S X_S + t_P X_P$$

The agent budget constraint amounts to

(2.6) $$(1+t_A)X_A + (1+t_S)X_S + (1+t_P)X_P + X_C = (1-t_L)X_L + G^T$$

This equation equates spending on consumption goods with net income from labor earnings and the government transfer payment.

To varying degrees some taxation of petrol, cigarettes, and alcohol could be justified on externality grounds (see below); that is,

(2.7) $$Z = Z(X_A, X_S, X_P);$$

where the partial derivatives Z_A, Z_S, and $Z_P > 0$.

From (2.1) and (2.6) the agent optimization problem can be expressed

(2.8) $$V(t_A, t_S, t_P, t_L, G^T, G^{PUB}, Z) = \text{Max } u(X_A, X_S, X_P, X_C, \overline{L} - X_L) + v(G^{PUB}) - \phi(Z)$$

$$+ \lambda\{(1-t_L)X_L + G^T - \{(1+t_A)X_A + (1+t_S)X_S + (1+t_P)X_p + X_C\}\}$$

where $V(.)$ is the indirect utility function and the Lagrange multiplier λ is the marginal utility of income. From differentiating we obtain

(2.8) $$\frac{\partial V}{\partial t_i} = -\lambda X_i \quad i = A, S, P, L$$

$$\frac{\partial V}{\partial G^T} = \lambda \quad \frac{\partial V}{\partial G^{PUB}} = v', \frac{\partial V}{\partial Z} = -\phi'$$

[9] If, for example, the government spends on public education, then households do not have to purchase private education, and hence they have more money to spend on other goods. In contrast, if the government provides more defense (a public good), households cannot reduce their own spending on defense to spend more on other goods.

Agents choose consumption goods and leisure to solve (2.8) taking government parameters and externalities as given. This yields the uncompensated demand and labor supply functions[10]

(2.10) $X_i = X_i(t_A, t_S, t_P, t_L, G^T)$ $i = A, S, P, C, L$.

3. General Formula for the MEB

In this section we derive a general formula for the MEB of a tax t_j where $j = L, A, S, P$, for cases when additional government revenue is spent on the public good and on the transfer payment.

(i) MEB Formula: Revenue Spent on Public Goods. We define the MEB for tax t_j for an extra pound spent on the public good by

$$MEB_j^{PUB} = \frac{-(d(V-v)/dt_j)/\lambda}{dG^{PUB}/dt_j} - 1$$

The numerator in the fraction term is the reduction in consumer surplus from an incremental increase in t_j. This equals the reduction in utility, excluding any utility benefits from extra public good provision. The denominator is the balanced budget increase in public goods from an incremental increase in t_j. Thus, the fraction term is the reduction in consumer surplus from financing an extra pound of spending, which is known as the marginal cost of public funds. To obtain the MEB we subtract one, that is, the extra revenue raised by the government.

From (2.8) when all other taxes and G^T are fixed

(3.2) $$\frac{d(V-v)}{dt_j} = \frac{\partial V}{\partial t_j} + \frac{\partial V}{\partial Z}\frac{dZ}{dt_j}$$

Differentiating the government budget constraint (2.5) with respect to G^{PUB} and t_j, using (2.10), gives

(3.3) $$\frac{dG^{PUB}}{dt_j} = X_j + t_L\frac{\partial X_L}{\partial t_j} + t_A\frac{\partial X_A}{\partial t_j} + t_S\frac{\partial X_S}{\partial t_j} + t_P\frac{\partial X^P}{\partial t_j}$$

Using (3.1) – (3.3) we can obtain

[10] Due to separability in the utility function the level of public goods and externalities does not appear in these functions.

$$(3.4) \quad MEB_j^T = \frac{-\left\{ t_L \dfrac{\partial X_L}{\partial t_j} + (t_A - M_A)\dfrac{\partial X_A}{\partial t_j} + (t_S - M_S)\dfrac{\partial X_S}{\partial t_j} + (t_P - M_P)\dfrac{\partial X_P}{\partial t_j} \right\}}{\dfrac{dG^{PUB}}{dt_j}}$$

where $M_A = \phi' Z_A / \lambda$ is marginal external damage in the alcohol market, and similarly for M_S and M_P. The numerator in (3.4) shows that the welfare loss from a marginal increase in t_j is the induced reduction in the quantity of labor supply, and consumption of alcohol, cigarettes, and petrol, where each quantity reduction is multiplied by the wedge between the marginal social benefit and marginal social cost in that particular market. In the labor market, the labor tax drives a wedge between the value marginal product of labor (equal to the gross wage) and the marginal opportunity cost of foregone leisure time (equal to the net wage). In commodity markets the wedge between marginal social benefit and marginal social cost is the tax net of marginal external damages. Clearly, if the quantity in a particular market increases, or if marginal external damage exceeds the commodity tax rate, then the corresponding term in the numerator of (3.5) is a welfare gain.

From (3.3) and (3.4) we can obtain the following empirically useful formula for *j* = *S*, *A*, *P*:

$$(3.5) \quad MEB_j^{PUB} = \frac{-\left\{ \dfrac{t_L}{1+t_j}\dfrac{X_L}{X_j}\eta_{Lj}^u + \dfrac{(t_S - M_S)}{1+t_j}\dfrac{X_S}{X_j}\eta_{Sj}^u + \dfrac{(t_A - M_A)}{1+t_j}\dfrac{X_A}{X_j}\eta_{Aj}^u + \dfrac{(t_P - M_P)}{1+t_j}\dfrac{X_P}{X_j}\eta_{Pj}^u \right\}}{1 + \dfrac{t_L}{1+t_j}\dfrac{X_L}{X_j}\eta_{Lj}^u + \dfrac{t_S}{1+t_j}\dfrac{X_S}{X_j}\eta_{Sj}^u + \dfrac{t_A}{1+t_j}\dfrac{X_A}{X_j}\eta_{Aj}^u + \dfrac{t_P}{1+t_j}\dfrac{X_P}{X_j}\eta_{Pj}^u}$$

where $\eta_{ij}^u = (\partial X_i / \partial t_j)(1+t_j)/X_i$ is the uncompensated elasticity for X_i (*i* = *S*, *A*, *P*) with respect to the price of X_j. For the case of $t_j = t_L$ we can define an analogous formula, except that the price of labor is $1 - t_L$ rather than $1 + t_j$.

(ii) MEB Formula: Revenue Returned Lump Sum. We define the MEB for tax t_j for an extra pound spent on the lump sum transfer by

$$(3.6) \quad MEB_j^T = \frac{-(dV/dt_j)/\lambda}{dG^T/dt_j}$$

From (2.8) when all other taxes and G^{PUB} are fixed,

$$(3.7) \quad \frac{dV}{dt_j} = \frac{\partial V}{\partial t_j} + \frac{\partial V}{\partial G^T}\frac{dG^T}{dt_j} + \frac{\partial V}{\partial Z}\frac{dZ}{dt_j}$$

The numerator in expression (3.6) is the general equilibrium welfare loss, expressed in pounds, from an incremental increase in tax t_j. From (3.7) this depends on the (partial equilibrium) utility loss from the tax increase, and the utility gain from the increased transfer spending and from any induced change in externalities. The denominator in (3.6) is the change in transfer payments. Thus, the MEB is the welfare loss per dollar of extra transfer spending.

Totally differentiating the government budget constraint (2.5) with respect to G^T and t_j, and using (2.10), the balanced budget increase in transfer spending can be expressed:

$$(3.8) \quad \frac{dG^T}{dt_j} = X_j + t_L \frac{dX_L}{dt_j} + t_A \frac{dX_A}{dt_j} + t_S \frac{dX_S}{dt_j} + t_P \frac{dX_P}{dt_j}$$

Using (3.6) – (3.8), (2.7) and (2.10) we can obtain, after some manipulation

$$(3.9) \quad MEB_j^T = \frac{-\left\{ t_L \frac{dX_L}{dt_j} + (t_A - M_A)\frac{dX_A}{dt_j} + (t_S - M_S)\frac{dX_S}{dt_j} + (t_P - M_P)\frac{dX_P}{dt_j} \right\}}{\frac{dG^T}{dt_j}}$$

This expression is analogous to the formula in (3.4), except that the coefficients are partially compensated because the income effect from the tax increase is partly offset by the increase in transfer payment.[11] From (3.8) and (3.9) we can obtain:

$$(3.10) \quad MEB_j^T = \frac{-\left\{ \frac{t_L}{1+t_j}\frac{X_L}{X_j}\eta_{Lj} + \frac{(t_S - M_S)}{1+t_j}\frac{X_S}{X_j}\eta_{Sj} + \frac{(t_A - M_A)}{1+t_j}\frac{X_A}{X_j}\eta_{Aj} + \frac{(t_P - M_P)}{1+t_j}\frac{X_P}{X_j}\eta_{Pj} \right\}}{1 + \frac{t_L}{1+t_j}\frac{X_L}{X_j}\eta_{Lj} + \frac{t_S}{1+t_j}\frac{X_S}{X_j}\eta_{Sj} + \frac{t_A}{1+t_j}\frac{X_A}{X_j}\eta_{Aj} + \frac{t_P}{1+t_j}\frac{X_P}{X_j}\eta_{Pj}}$$

where $\eta_{ij} = (dX_i / dt_j)(1+t_j)/X_i$ (η_{ij} differs from η_{ij}^u due to the income effect from increasing G^T). Again, for the case of $t_j = t_L$, we can define an analogous formula, with the price of labor equal to $1 - t_L$.

[11] The compensation is not exact becuase, from (3.8), $dG^T / dt_j \neq X_j$.

In the next four sections we estimate the MEBs of the four different taxes based on the formulas in (3.5) and (3.10). To keep the discussion focussed on the most important effects, however, we use approximate formulas that ignore relatively unimportant terms. For example, when we look at the petrol tax we ignore spillover effects in the cigarette market, because the degree of substitution between these goods is minimal. When we look at the labor tax we ignore spillover effects in commodity markets, because commodity markets are tiny in size relative to the labor market (however we do incorporate labor market effects when looking at commodity taxes).[12]

4. MEB of the Labor Tax

(i) Approximate Formulas. Based on (3.5) we use the following approximation for the MEB of the labor tax for revenue spent on a public good:

$$(4.1) \quad MEB_L^{PUB} \approx \frac{\frac{t_L}{1-t_L}\varepsilon_{LL}^u}{1-\frac{t_L}{1-t_L}\varepsilon_{LL}^u}$$

where $\varepsilon_{LL}^u = (\partial X_L / \partial(1-t_L))(1-t_L)/X_L = -\eta_{LL}^u$ is the uncompensated labor supply elasticity. Here we have ignored the impact of the labor tax in the commodity markets, the justification being that these markets are very small relative to the labor market.[13] A point to note about (4.1) is that the elasticities are uncompensated. As discussed elsewhere (e.g. Wildasin, 1984, Ballard and Fullerton, 1992), public goods are not a substitute for disposable income, therefore the increase in public spending has no income effect on labor supply.[14]

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[12] As discussed below, there is considerable uncertainty over the MEBs due to uncertainty about the major parameters, and this uncertainty is likely to swamp the additional uncertainty due to the terms that we neglect.

[13] X_A / X_L, X_S / X_L and X_P / X_L are approximately .03, .01 and .02 respectively (author's calculations using OECD (1996), pp. 558-9; EIA (2000), pp. 55, 102; the tax rates discussed below in Table 1 and assuming X_L is equivalent to GDP). Thus, the terms in η_{SL}^u, η_{AL}^u, and η_{PL}^u in (3.5) are likely to be trivially small.

[14] The formula in (4.1) is similar to that in other papers where the tax system consists of a single tax on labor income (e.g., Browning 1987, Mayshar 1991, Parry 1999a). In principle ε_{LL}^u could be negative, implying a negative MEB. However, the evidence suggests that, for the economy as a whole, this elasticity is probably positive (see below).

For revenues spent on the transfer payment, and ignoring impacts in commodity markets, we can obtain from (2.10) and (3.9)

$$(4.2) \quad MEB_L^T \approx \frac{-t_L \dfrac{\partial X_L}{\partial t_L}}{\dfrac{dG^T}{dt_L}} - t_L \frac{\partial X_L}{\partial G^T}$$

From (2.10) and (3.8)

$$(4.3) \quad \frac{dG^T}{dt_L} \approx \frac{X_L + t_L \dfrac{\partial X_L}{\partial t_L}}{1 - t_L \dfrac{\partial X_L}{\partial G^T}}$$

From (4.2) and (4.3), and noting that $\partial X_L / \partial t_L = \partial X_L^c / \partial t_L - (\partial X_L / \partial G^T) X_L$ from the Slutsky equation (*c* denotes compensated), we obtain:

$$(4.4) \quad MEB_L^T \approx \frac{\dfrac{t_L}{1-t_L} \varepsilon_{LL}^c}{1 - \dfrac{t_L}{1-t_L} \varepsilon_{LL}^u}$$

where ε_{LL}^c is the compensated labor supply elasticity.

In this case an increase in the transfer payment raises disposable income and reduces labor supply because leisure is a normal good—this works to aggravate the overall reduction in labor supply caused by the (uncompensated) increase in labor tax. In other words because $\varepsilon_{LL}^c > \varepsilon_{LL}^u$, then $MEB_L^T > MEB_L^{PUB}$. But agents are only partially compensated for the tax increase, hence MEB_L^T depends on both compensated and uncompensated elasticities. This is because the reduction in worker surplus from an incremental increase in the labor tax is X_L, but the additional labor tax revenue raised and returned lump sum is (approximately) $X_L + t_L dX_L / dt_L < X_L$.[15] The issue of how additional revenues are spent is important when assessing the MEB of labor tax increases, because a relatively wide divergence exists

[15] In Browning's (1987) MEB formula, all elasticities are compensated. This is because he assumes the dollar of revenue is spent in such a way as to keep agents at the same level of utility, rather than being returned lump sum.

between the compensated and uncompensated labor supply elasticity (this is not the case for commodity demand elasticities).

(ii) Parameter values. Table 1 summarizes all the parameter assumptions used throughout the paper. We emphasize that there is considerable uncertainty and controversy surrounding some of these parameters, and our parameter scenarios are only meant to be illustrative. We use the labels "central value" and "plausible range" to simplify the discussion—they should not be taken too literally.

In our highly aggregated model, the labor supply elasticities represent the combined responsiveness of the participation rate, and average hours worked per employee, to changes in net wages averaged across all members (male and female) of the labor force. A plethora of studies have been done for the United States and plausible values might be is 0.2 for the (economy-wide) uncompensated labor supply elasticity and 0.35 for the compensated elasticity.[16] A few studies have been done for the United Kingdom, and these yield broadly similar values.[17] Due to the range of different estimates in the literature, we also consider values of 0.05 and 0.35 for the uncompensated elasticity and 0.2 to 0.5 for the compensated elasticity About two-thirds of the responsiveness is due to the participation decision and one-third is due to the hours worked decision.

For our purposes, the distortion in the labor market represents the wedge the tax system drives between what employers pay for labor and the amount of goods that employees can purchase with labor earnings. Thus, labor tax wedge reflects the combined effect of income taxes, national insurance contributions, and value added taxes. Our estimation of the labor tax rate follows Mendoza et al. (1994) and is described in Appendix A. We assume a central value of 39%, and a range of 36 to 42% (for 1990). The contribution of various taxes (in the central case) is as follows: personal income taxes, 13%; national insurance contributions (i.e., payroll taxes), 12%; and general sales taxes (excluding taxes on petrol, alcohol, and cigarettes), 14%.

(iii) Results. As reported in Table 2, under our central parameter values the MEB for transfer spending is 0.26 (second row, column (b)). But there is a wide range of possible outcomes: under our low values for the tax rate and labor supply elasticities, the MEB falls to 0.12, whereas under our high values

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[16] These figures are obtained from a simple average of opinion among labor economists reported in Fuchs et al. (1998), Table 2, attaching weights of 0.6 and 0.4 for the male and female elasticities respectively. See Killingsworth (1983) and Blundell and MaCurdy (1999) for further discussion.

[17] See for example Blundell et al. (1988), Arellano and Meghir (1992) and Blundell (1997).

for these parameters, it is 0.48, which is more than four times as large. Uncertainty over the MEB is driven more by uncertainty over labor supply elasticities than tax rates: varying the tax rate across its assumed range increases/decreases our central estimate by about one-sixth (column (b)), whereas varying the labor supply elasticities increases/decreases it by around one-half (second row).

When revenues finance public goods, the MEB is significantly smaller, since the relevant labor supply elasticities are uncompensated rather than being a mixture of uncompensated and compensated effects. The MEB is 0.15 under our central parameter values, about 58% of that for transfer spending. Again, there is a wide range of possible outcomes from 0.03 to 0.34. The results in Table 2 are broadly consistent with calculations for the United States (e.g. Browning 1987, Ballard 1990) even though the US labor tax is somewhat lower than for the United Kingdom.

5. Petrol Tax

(i) Approximate Formulas. For the MEB of the petrol tax with revenues spent on the public good we start with the following approximation, based on (3.5):

$$(5.1) \quad MEB_P^{PUB} \approx \frac{-\left\{ \dfrac{t_L}{1+t_P}\dfrac{X_L}{X_P}\eta_{LP}^u + \dfrac{(t_P - M_P)}{1+t_P}\eta_{PP}^u \right\}}{1 + \dfrac{t_L}{1+t_P}\dfrac{X_L}{X_P}\eta_{LP}^u + \dfrac{t_P}{1+t_P}\eta_{PP}^u}$$

Here we have ignored the cross-price effects in the alcohol and cigarette markets, because these markets are not closely related to the petrol market (i.e., we would expect $\eta_{SP}^u, \eta_{AP}^u \approx 0$). Neither is the labor market. But because it is so large relative to the petrol market (X_L / X_P is very large), it takes only a small change in labor supply to generate a welfare effect that is significant *relative* to that in the petrol market.

To obtain a value for η_{LP}^u we make the assumption that consumption goods and leisure are weakly separable in the utility function.[18] In this case $\eta_{LP}^u (X_L /(1+t_P) X_P) = -\eta_P^I \varepsilon_{LL}^u /(1-t_L)$, where

[18] This implies that travel and other consumption would increase in the same proportion following an income-compensated increase in labor supply. This seems a reasonable approximation, given that a large portion of travel is people commuting to work. However, relaxing this assumption would have the same effect as using a different value for the expenditure elasticity for gasoline in the MEB formula below, and we consider a range of values for this parameter in our simulations.

η_P^I is the income elasticity of demand for petrol and *I* is income (see Appendix B). Substituting into (5.1) gives:

$$MEB_P^{PUB} \approx \frac{\frac{t_L}{1-t_L}\eta_P^I\varepsilon_{LL}^u - \frac{(t_P - M_P)}{1+t_P}\eta_{PP}^u}{1-\frac{t_L}{1-t_L}\eta_P^I\varepsilon_{LL}^u + \frac{t_P}{1+t_P}\eta_{PP}^u}$$

Suppose that we ignored the labor market effects in (5.2) (assume $t_L = 0$). Then the MEB is positive if the petrol tax exceeds marginal external damages ($t_P > M_P$) and negative if it is less than marginal external damages (note that $\eta_{PP}^u < 0$). But labor market effects arise because an increase in the price of consumption goods reduces the real household wage, thereby reducing the return to work effort and labor supply. The reduction in labor supply compounds the welfare cost of pre-existing taxes on labor. This effect, often termed the "tax-interaction effect", has recently been analyzed in many other policy contexts (e.g., Goulder et al. 1997, Parry and Oates 2000, Browning 1997). On average the income elasticity for consumption goods must be unity. In this case ($\eta_P^I = 1$), comparing (5.2) and (4.1), the MEB of the petrol tax is necessarily larger than that of the labor tax if the petrol tax exceeds marginal external damages. This accords with intuition: the petrol tax has a narrower base than the labor tax and therefore causes more distortion (if $t_P > M_P$) because there are more substitution possibilities for avoiding a narrower tax.

More generally though, there are two reasons why, *in principle*, the MEB of the petrol tax could be less than that of the labor tax. First, marginal external damages might exceed the petrol tax. Second, petrol appears to be a necessity good ($0 < \eta_P^I < 1$), which implies that it is a relatively weak substitute for leisure in our analysis (because petrol is still a normal as opposed to an inferior good, it cannot be a *complement* for leisure in our analysis).[19]

Finally, if the incremental tax revenue financed spending on the transfer payment rather than the public good, the petrol demand and labor supply elasticity in the numerator in (5.2) would be compensated, as in the previous case.

[19] See Deaton (1981) for a detailed discussion of why, when leisure is weakly separable in the utility function, a good is a complement, weak leisure substitute, and strong leisure substitute, when it is an inferior good, a necessity good and a luxury good, respectively.

(ii) Parameter Values. We group leaded petrol, unleaded petrol, and diesel fuel into one composite commodity. Excise duties on these fuels are very substantial in the United Kingdom and amounted to about 70% of the retail price in 1999 (Chennells et al. 1999, Table 7). Normalizing the producer price to unity, this implies $t_P = 2.33$.[20]

Estimates of the long run (uncompensated) own price and income elasticities for petrol are broadly similar across countries (e.g., Dahl 1986). We adopt a range of 0.4 to 1.0 for (the magnitude of) each of these elasticities, with a central value of 0.7. About half of the price response is due to reduced vehicle miles traveled, and half is due to people switching to more fuel-efficient cars. [21] We use the same values for the compensated and uncompensated demand elasticity.[22]

Externalities associated with vehicle travel include pollution, noise, accidents, and congestion. ECMT (1998), Table 78, estimated that air pollution damages from auto emissions in the United Kingdom were 8.4 ECU per 1000 vehicle km in 1997, which amounts to about 6.5 pence per liter of petrol.[23] This estimate is subject to uncertainty and controversy, for example due to uncertainty over peoples' willingness to pay for reducing health risks. We assume a range of 3 to 10 pence per liter for this component. To incorporate potential future climate change damages from carbon emissions we assume low, medium, and high damage estimates of \$0, \$25 and \$50 dollars per ton of carbon, based on Nordhaus (1994), or £0, £16 and £31 per ton. Assuming one ton of carbon is produced by 335 gallons

[20] These fuels are also subject to value added tax (VAT). However, VAT is applied to goods in general, that is, it does not raise the price of fuels relative to other consumption goods. Hence, VAT is imputed as a labor tax in our analysis.

[21] Estimates of the elasticity of vehicle miles traveled with respect to money costs are roughly about half the size of the petrol demand elasticities in Table 1 (Small, 1992).

[22] From the Slutsky equation $\eta^u_{PP} = \eta^c_{PP} - \eta^I_P (X_P / I)$. Since X_P / I is very small and η^u_{PP} and η^I_P are broadly the same magnitude, then $\eta^u_{PP} \approx \eta^c_{PP}$.

[23] This assumes 1.50 ECU = £1 in 1997 and a fleet average of 11.6 km per liter (ECMT 1998, Table 73), or 32 miles per gallon (1 liter = 0.22 gallons). The damages are mainly caused by the mortality effects of particulates, volatile organic compounds, and other pollutants. This estimate is broadly consistent with those for the United States. For example, Small and Kazimi (1995) obtain a central estimate for pollution damages of about 3 cents per mile for the (relatively polluted) Los Angeles region. Assuming U.S. cars average 20 miles per gallon, and that £1 = \$1.60, this amounts to 8.3 pence per liter.

(=1531 liters) of petrol (Manne and Richels 1992), these scenarios imply (relatively modest) damages of 0, 1, and 2 pence per liter.

We divide estimates of the external costs of noise, accidents, and congestion per mile by 2, because petrol taxes reduce these externalities only through their impact on reducing vehicle miles traveled, but not by their effect on reducing petrol per mile driven (see above). Estimates of noise damage per vehicle kilometer for the United Kingdom amount to about half the central estimates from air pollution damage (see ECMT 1998, Tables 59 and 78), implying a cost of 1.6 pence per liter.

ECMT (1998) estimated that accident costs from auto travel were 35 ECU per 1000 vehicle km in 1997 for the United Kingdom (see Table 46), or 27.5 pence per liter.[24] We assume low and high damage costs of 14 pence per liter and 42 pence per liter. In addition we assume that the fraction of accident costs that are external is 10%, 30%, and 50% in our low, medium and high damage scenarios (i.e. either 90%, 70% or 50% of costs are private).[25] Putting these figures together, and dividing by 2, gives damage scenarios of 0.7, 4.1 and 10.5 pence per liter.

Newbery (1990), Table 2, estimated that the marginal congestion cost was 3.4 pence per km (averaged across driving in urban and rural areas and peak and off-peak periods in the United Kingdom). This figure converts to about 20 pence per liter, and we assume low and high values of 10 and 30 pence per liter. Thus, congestion is the most important component of external costs (this is a familiar result for a broad range of developed countries; see EC, 1995).

In sum, adding up all the components gives a marginal external damage for petrol of 33 pence per liter in our central case, with a range of 15 to 54 pence per liter. The petrol tax is about 50 pence per liter

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[24] Again the huge bulk of these costs is due to mortality effects, and are sensitive to alternative assumptions about the value of a statistical life. For the U.S. estimated accident costs tend to be somewhat higher. For example Small and Gómez-Ibáñez (1999), pp. 1965 suggest a best estimate of 18 cents per mile, or 50 pence per liter. This larger figure is mainly due to a higher assumed value for a statistical life (since average incomes and hence willingness to pay to avoid risks are higher in the U.S.).

[25] See e.g., Small and Gómez-Ibáñez (1999) for a discussion of which accident costs are internal and external. Note that an individual should take into account the risk of injury/death to herself when deciding how much to drive, and that insurance policies may go up when a financial claim is made. On the other hand, a driver does not pay the full value of a statistical life when she kills another driver or pedestrian.

(Chennells et al. 1999, Table 7); therefore dividing by 50 and multiplying by t_P = 2.33 gives marginal external damages of approximately 0.6, 1.5 and 2.4, relative to the producer price (Table 1).[26]

(iii) Results. Table 3 shows the implications of these parameter assumptions for the MEB of the petrol tax. Each cell entry shows outcomes under our low, medium, and high external damage scenarios (reading from left to right within a cell). The table is divided into three parts. The first row shows the MEB for transfer spending when we ignore the cross-price effects on labor supply ($\eta_{LP} = 0$). Here we see that the MEB varies between −0.07 and 1.7. In other words, the tax exceeds marginal external damages in most cases, implying an MEB that could be quite large. The MEB in the first row is very sensitive to the own price demand elasticity: changing this elasticity from −.4 to −1.0 increases the MEB from 0.14 to 0.83 under our central value for external damages (comparing columns (a) and (c)). The MEB is also very sensitive to alternative scenarios for marginal external damages. It is −0.03 for the high-damage scenario and 0.71 for the low-damage scenario, under our central demand elasticity (column (b)).

The second set of rows shows the MEB (for transfer spending) when we incorporate the effect on labor supply. Here there are two key points. First, in general, allowing for labor supply effects substantially raises the MEB of the petrol tax. For example, in our central case the MEB increases from 0.34 to 0.79—which is an increase of 130% (compare middle entry in first and third rows, column (b)). Even in the case when the substitution between petrol and leisure is weakest (column (a)) labor supply effects raise the MEB of the petrol tax by 40% to 180%, under our medium values for labor market parameters. In short, ignoring labor supply effects would produce a substantial underestimate of the overall MEB for the petrol tax.

Second, *for given labor market parameters the MEB of the petrol tax almost always exceeds that for the labor tax*, *and by a potentially large amount*. For example, under our medium values for the labor tax and labor supply elasticities, the MEB of the labor tax is 0.26 (third row, Table 3). But the MEB for the petrol tax is larger than this in eight out of nine cases, and could be as high as 4.3 (middle row of second section, Table 3). The reason is that there is generally a large gap between the petrol tax and marginal external damages. Therefore, increasing the petrol tax produces a relatively large welfare loss in

[26] Some level of fuel taxation could also be justified on the grounds that it is a user fee to cover the costs of providing and maintaining the road system. However, this is really an argument for higher diesel taxes rather than petrol taxes, because road damage is primarily caused by lorries rather than cars (Newbery, 1988).

the petrol market in most of our scenarios, and this loss more than compensates for the relatively weak degree of substitution between petrol and leisure.

The bottom three rows of Table 3 show the MEB when revenues are spent on a public good. The estimated MEBs are smaller than when transfers finance transfer payments, but the difference is generally more modest than in the case of the labor tax (Table 2). This is because the MEB also depends on commodity demand elasticities as well as labor supply elasticities, and the difference between compensated and uncompensated effects is relatively smaller in the former case.

Finally, this table again shows a very wide range of possible outcomes for the MEB under alternative parameter assumptions, underscoring the need for the Monte Carlo analysis in Section 7.

6. Cigarette and Alcohol Taxes

(i) Approximate Formulas. For the MEB of the cigarette tax with revenues spent on the public good, we use the following approximation from (3.5):

$$(6.1)\qquad MEB_S^{PUB} \approx \frac{\dfrac{t_L}{1+t_S}\eta_P^I\varepsilon_{LL}^u - \dfrac{(t_S - M_S)}{1+t_S}\eta_{SS}^u - \dfrac{(t_A - M_A)}{1+t_S}\dfrac{X_A}{X_S}\eta_{AS}^u}{1-\dfrac{t_L}{1+t_S}\eta_P^I\varepsilon_{LL}^u + \dfrac{t_S}{1+t_S}\eta_{SS}^u + \dfrac{t_A}{1+t_S}\dfrac{X_A}{X_S}\eta_{AS}^u}$$

Here we include interactions with the alcohol and labor markets, but not the petrol market (because we would expect $\eta_{PS}^u \approx 0$). In addition we have made the analogous assumption to before: $\eta_{LS}^u(X_L / X_S) = -\eta_S^I\varepsilon_{LL}^u$, where η_S^I is the income elasticity for cigarettes.

If alcohol and cigarettes are complements ($\eta_{AS}^u < 0$), an increase in the cigarette tax will reduce alcohol demand, producing a welfare loss (gain) if the alcohol tax is greater (less) than the marginal external damages from alcohol consumption. This demand shift also reduces revenue from alcohol taxes. Converse results apply for the case of substitutes ($\eta_{AS}^u > 0$). Again, elasticities in the numerator in (6.1) would be compensated if the incremental revenue were spent on the transfer payment. The MEB formulas for the alcohol tax are exactly symmetrical to those for the cigarette tax.

(ii) Parameter Values. Tobacco duties are very high in the United Kingdom and amount to about 65% of the retail price of a pack of cigarettes (Chennells et al. 1999, Table 7). For simplicity we lump

beer, wine, and spirits into one composite commodity; alcohol taxes amount to about 27% of the retail price of this composite.[27] Normalizing producer prices to unity gives $t_s = 1.86$ and $t_A = 0.37$. The ratio of alcohol to cigarette production, X_A/X_S, is taken to be 3 (see Section 4(i)).

A large number of studies have estimated the (uncompensated) own price elasticity, and income elasticity, for cigarettes for different countries (for surveys see e.g., Viscusi 1992, Ch. 5, Chaloupka and Warner 1999). We adopt low, medium, and high values of 0.3, 0.6 and 0.9 for the income elasticity and the magnitude of η_{SS}^{u} and η_{SS}^{c}. One noteworthy point is that long-run elasticities, which are more relevant for our analysis, are significantly larger than short-run elasticities, due to the complementarity between current and future demand for addictive goods.[28] The elasticities for alcoholic beverages are a little higher (e.g., Decker and Schwartz 2000), and we use low, medium, and high values of 0.4, 0.7 and 1.0 for the own price demand and income elasticities.

A priori, it is not clear whether cigarettes and alcohol are complements or substitutes. On the one hand, people are more likely to consume more of both goods when they go out to restaurants or bars (which suggests complementarity); on the other hand, having a beer at home to relax can be a substitute for having a cigarette. Indeed the evidence is mixed. Jones (1989) and Decker and Schwartz (2000) estimate the elasticity of demand for cigarettes with respect to alcohol is about −0.14 (complements), while Goel and Morey (1995) estimate this elasticity is +0.10 (substitutes). We illustrate cases of both complements and substitutes when the cross-price elasticity for alcohol with respect to price of cigarettes is either + or − one quarter of the own price elasticity for cigarettes, and similarly for alcohol.

A comprehensive study by Viscusi (1995) suggests that marginal external damages from cigarettes may not be that large—typically well below 40 cents (27 pence) per pack—for a variety of reasons.[29] But there is much dispute about these estimates (Chaloupka and Warner 1999); for example,

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[27] Duties on beer, wine, and spirits are 14%, 35% and 46% respectively (Chennells et al. 1999, Table 7). Assuming beer counts for half of alcohol consumption, and wine and spirits a quarter each, gives a weighted average tax rate of 27%.

[28] For example, Becker et al. (1994) estimate a short-run elasticity of 0.4 and a long run elasticity of 0.75.

[29] First, some evidence suggests that people may actually *over*-estimate rather than *under*-estimate the long-run health risks to them from smoking. Second, smokers may *not* impose a net cost on the public finances. If anything, the short-term medical costs of treating smoking-related illnesses seem to be outweighed by the effect of reduced life expectancy on reducing pension and medical expenses in old age. Third, the average tar content, and hence

they ignore the possibility that people underestimate the risk of becoming addicted and being unable to quit smoking even though they would like to (in 1996 two thirds of smokers wanted to give up (DOH, 2000)). We assume low, medium, and high damage scenarios of 15, 30, and 45 pence per pack (i.e. a range of 23–75 cents per pack), which amount to about 30%, 60%, and 90% of the producer price.[30]

A comprehensive study by Manning et al. (1991) estimates that the external costs of alcohol consumption are 48 cents per ounce of ethanol-equivalent (pp. 102), that is, 8.8 ounces of wine or 26.4 ounces of beer. This amounts to about 35% of the producer price of alcohol, which is very close to the U.K. tax rate.[31] The bulk of these costs reflect external costs of alcohol-related traffic accidents. We adopt a range of 20% to 50% for the external costs.[32]

(iii) Results. Table 4 shows the range of outcomes for the MEB of the cigarette tax (with revenues spent on the transfer payment). In each cell, we show the range of outcomes as we vary the marginal external damages from cigarettes between the low and high values (given other parameter values).

In row (a) we (incorrectly) ignore interactions with the alcohol and labor market. Here we see that the MEB varies from 0.13 to 1.2. Clearly, the MEB is very sensitive to alternative assumptions about the demand elasticity for cigarettes; it is about six times as high when the demand elasticity is −0.9 rather than −0.3. The MEB is less sensitive to different assumptions about marginal external damages, because, even in the high damage scenario, external costs amount to barely more than half of the cigarette tax.

In rows (b) and (c) we allow for interactions with the alcohol market assuming our central value for marginal external damages from alcohol. In general these interactions do not greatly affect the MEB for cigarettes even though the alcohol market is three times the size of the cigarette market. This reflects

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potential health risks, of cigarettes has fallen over the past few decades. Fourth, the exposure of passive smokers has been reduced as regulations have restricted smoking in the work place and other public places.

[30] Marginal external damages are probably somewhat larger in the United Kingdom. In particular, regulations limiting exposure of passive smokers are less evolved than in the United States.

[31] In 1991, the average price of a liter of wine (33.8 oz.) was about $5 and the average price of a six-pack (72 oz.) of beer was about $4.50 for.

[32] Of course the external costs of alcohol and cigarettes may be different in the United Kingdom than in the United States, for example if people have different willingness to pay for reduced health risks, but we are not aware of much externality assessment literature for the United Kingdom.

the substantially smaller wedge between tax and marginal external damage in the alcohol market compared with the cigarette market.

In rows (d)–(f) we allow for labor market effects (and no cross-price effects in the alcohol market). Labor market effects substantially increase the MEB for cigarettes—by around 50%–90% with our medium values for labor market parameters (comparing rows (a) and (e) in Table 4).[33] Again, the labor market effect is sufficient to raise the MEB for cigarettes above the MEB for labor taxes in nearly all cases: the entries in row (e) range from 0.22 to 2.3, while the MEB for the labor tax in our central case is 0.26 for transfer spending.[34] In short, the demand elasticity for cigarettes has to be very low and marginal external damages, very high for the MEB of the cigarette tax to be less than that for the labor tax.

Table 5 shows the MEB for the alcohol tax (for transfer spending). Ignoring cross-price effects, in row (a) we see that the MEB is much lower than the corresponding case for the cigarette tax and is negative in some of the cases. This reflects the fact that the alcohol tax is much lower relative to marginal external damages and is less than marginal external damages in some scenarios. Allowing for interactions with the cigarette market does not make much difference (comparing rows (b) and (c) to (a)). Although the price wedge in the cigarette market is relatively large, this market is small in size relative to the alcohol market, which greatly reduces the relative importance of the spillover effect.

However, the impact of the alcohol tax on reducing labor supply substantially increases the MEB (rows (d)–(f)). Even under our low values for labor market parameters, the MEB is positive even when the alcohol tax is below marginal external damages. In our central case (row (e), column (f)), the MEB for the alcohol tax is roughly the same size as that for the labor tax (0.26).

7. Comparing the MEBs with Monte Carlo Simulations

We now turn to Monte Carlo simulations to try and narrow some of the uncertainty over the MEBs, and to compare the likelihood of one MEB exceeding another. We specify explicit distribution

[33] Goulder and Williams (1999) also find that the costs of cigarette taxes are significantly larger, due to their effect on compounding labor tax distortions. In their analysis cigarettes are an average (rather than weak) leisure substitute, and they abstract from externality benefits.

[34] All the entries in row (d) exceed 0.12 (the MEB for the labor tax with low tax rates and elasticities). In row (f) the MEB varies from 0.29 to 4.4, while the MEB for the labor tax with high tax rates and high elasticities is 0.34.

functions for the uncertain parameters in Table 1; for the most part we assume these distributions are triangular.[35] The midpoint of these distributions equals the central values in Table 1, and we assume an 80% probability that the parameter value lies within the ranges specified in Table 1.[36] We allow each parameter to vary independently from its distribution 10,000 times, and we obtain the resulting probability density functions for each of the MEBs.

Table 6 shows the 80% confidence intervals for each of the MEBs (for transfer spending). Here we see that the MEB for the labor income tax lies between 0.18 and 0.34 in 80% of the simulations. The 80% confidence interval for the MEB of the petrol tax is 0.35 to 1.8; for the cigarette tax, 0.36 to 1.5; and for the alcohol tax, 0.11 to 0.39.

In Table 7 we indicate the qualitative ranking of the taxes. This table shows the probability that the MEB of each commodity tax exceeds that of the labor tax by more than 0%, 50%, 100% and 200%.[37] Here, we see that the MEB of the petrol tax almost always exceeds that of the labor tax; indeed it is more than twice as large as the MEB of the labor tax with 75% probability and more than three times as large with 51% probability. Similar results apply for the cigarette tax. In contrast, the MEB of the alcohol tax is actually *smaller* than that of the labor tax in 62% of the simulations.

Finally, in Table 8 we compare MEBs when additional government spending is on a public good rather than transfers. As discussed above, the MEB is significantly lower for the labor tax but less so for the commodity taxes. In this case the probability that the MEB of the petrol tax is more than double that of the labor tax rises to 80%, and for the cigarette tax the probability rises to 91%. For the alcohol tax, however, the MEB is still *less* than that for the labor tax in the majority of the simulations.

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[35] We used the ANALYTICA software to do the Monte Carlo simulations (the programs are available upon request). We experimented with uniform distributions for the parameters. This had a modest impact on widening the confidence intervals for the MEBs. However, it had very little effect on the likelihood of one MEB exceeding another.

[36] Thus, for example, the minimum and maximum values for the uncompensated labor supply elasticity are 0.0125 and 0.5375 (= 0.2 ± (0.35–0.2)/0.8).

[37] That is, we calculate the proportion of times in our Monte Carlo simulations that $(MEB_i^T - MEB_L^T)/MEB_L^T$ exceeds 0, 1, and 2 ($i = P,S,A$).

8. Conclusion

This paper discusses some of the important parameters that determine the marginal excess burden (MEB) of labor taxes and various sin taxes, using a unifying framework that accounts for externalities and linkages between the different taxes. Using illustrative parameters for the United Kingdom, we showed that the MEB of petrol and cigarette taxes might substantially exceed that of the labor income tax—even though these goods are relatively weak substitutes for leisure—unless we assume "high" scenarios for externality benefits. In contrast the MEB for alcohol taxes may be smaller than that of the labor tax, though it is still positive even if the tax is below marginal external costs. The distinction between whether additional revenue is spent on public goods or transfers appears to be less significant for commodity taxes than for labor taxes.

The results should be viewed with caution given the uncertainty over various parameters, though it would be straightforward to revise the MEB calculations in the light of future empirical evidence. Moreover, the model is only meant to be a building block to a much more sophisticated evaluation of fiscal policy. There are a number of ways the analysis might be extended to incorporate factors that may significantly affect the empirical magnitude of the MEBs. For example we have assumed competitive labor and product markets. It might be useful in future work to consider the implications of wage bargaining and imperfect competition. We have also used a static analysis in which labor is the only primary input. Another extension might be to incorporate capital accumulation and interactions with the (tax-distorted) capital market.

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Table 1. Summary of Parameter Values Assumed in Calculations

Parameter	Central value	Plausible range
Labor tax rate, t_L	.39	.36 to .42
Uncomp. labor supply elasticity, ε_{LL}^{u}	.2	.05 to .35
Comp. labor supply elasticity, ε_{LL}^{c}	.35	.2 to .5
Petrol tax (relative to producer price), t_P	2.33	2.33
[a]Petrol demand and income elasts., η_{PP}^{u}, η_{PP}^{c}, η_{P}^{I}	.7	.4 to 1.0
MED from petrol (rel. to prod. price), $\phi' Z_P / \lambda$	1.5	.6 to 2.4
air pollution (pence per liter)	6.5	3 to 10
carbon (pence per liter)	1.0	0 to 2.0
noise (pence per liter)	1.6	1.6
accidents (pence per liter)	4.1	.7 to 10.5
congestion (pence per liter)	20	10 to 30
Cigarette tax (relative to producer price), t_S	1.86	1.86
Alcohol tax (relative to producer price), t_A	.37	.37
[a]Cig. demand and income elasts., η_{SS}^{u}, η_{SS}^{c}, η_{S}^{I}	.6	.3 to.9
[a]Alc. demand and expend. elasts., η_{AA}^{u}, η_{AA}^{c}, η_{A}^{I}	.7	.4 to 1.0
Cross-price elast. of cigs. wrt alc., η_{SA}^{u}, η_{SA}^{c}	0	−.25 to .25
Cross-price elast. of alc. wrt cigs., η_{AS}^{u}, η_{AS}^{c}	0	−.23 to .23
Production ratio of alc. to cigs., X_A/X_S	3	3
MED from cig. (rel. to prod. price), $\phi' Z_S / \lambda$	.6	.3 to 1.0
MED from alcohol. (rel. to prod. price), $\phi' Z_A / \lambda$	.35	.2 to .5

[a] Demand elasticities are expressed as positive numbers.

Table 2. MEB of Labor Taxes

	labor tax rate	Labor supply elasticity: low	medium	high
		(a)	(b)	(c)
MEB for Transfer Spending	.36	.12	.22	.35
	.39	.13	.26	.41
	.42	.15	.30	.48
MEB for Public Goods	.36	.03	.13	.25
	.39	.03	.15	.29
	.42	.04	.17	.34

Table 3. MEB of Petrol Taxes

		own price elasticity: −.4	−.7	−1.0
		(a)	(b)	(c)
1. MEB with no cross-price effects		−.01, .14, .29	−.03, .34, .71	−.07, .83, 1.7
2. MEB with effect on labor supply				
labor tax and	low	.05, .20, .36	.13, .52, .90	.34, 1.3, 2.3
labor supply	medium	.12, .28, .44	.34, .79, 1.2	1.2, 2.7, 4.3
elasticities	high	.22, .40, .57	.72, 1.3, 1.9	7.3, 13, 19
3. MEB for public good				
labor tax and	low	0, .16, .31	.01, .40, .78	.03, 1.0, 2.0
labor supply	medium	.06, .23, .39	.18, .63, 1.1	.61, 2.2, 3.8
elasticities	high	.15, .32, .50	.49, 1.1, 1.6	5.0, 11, 17

Table 4. MEB of Cigarette Taxes

		own price elasticity		
		−.3	−.6	−.9
		(a)	(b)	(c)
MEB with no cross-price effects	(a)	.13−.20	.33−.54	.73−1.2
MEB with cross-price effects on alc.[a]				
complements	(b)	.14−.22	.40−.65	1.2−1.9
substitutes	(c)	.11−.19	.28−.46	.53−.86
MEB with cross-price effects on labor				
low	(d)	.17−.25	.45−.67	1.0−1.5
medium	(e)	.22−.30	.63−.87	1.7−2.3
high	(f)	.29−.37	.91−1.2	3.4-−4.4

[a] Assumes central value for external costs of alcohol.

Table 5. MEB of Alcohol Taxes

		own price elasticity		
		−.4	−.7	−1.0
		(a)	(b)	(c)
MEB with no cross-price effects	(a)	−.04 to .06	−.08 to .11	−.13 to .17
MEB with cross-price effects on cigs.[a]				
complements	(b)	−.02 to .07	−.04 to .16	−.07 to .26
substitutes	(c)	−.06 to .03	−.11 to .06	−.18 to .10
MEB with cross-price effects on labor				
low	(d)	.01 to .11	.02 to .21	.03 to .34
medium	(e)	.06 to .17	.13 to .34	.21 to .58
high	(f)	.13 to .25	.30 to .54	.56 to 1.0

[a] Assumes central value for external costs of cigarettes.

Table 6. Confidence Intervals for MEBs

tax	Mean MEB	80% confidence interval
labor	.26	.18 − .34
petrol	.79	.35 − 1.8
cigarette	.75	.36 −1.5
alcohol	.24	.11 −.39

Table 7. Comparing Commodity Tax MEBs to the Labor Tax MEB

Tax	Probability that MEB of tax exceeds that of labor tax by more than			
	0%	50%	100%	200%
petrol	.97	.87	.75	.51
cigarettes	.98	.89	.76	.49
alcohol	.38	.10	.02	0

Table 8. MEB Comparison for Spending on Public Goods

Tax	Probability that MEB of tax exceeds that of labor tax by more than			
	0%	50%	100%	200%
petrol	.99	.95	.87	.70
cigarettes	1	.97	.91	.76
alcohol	.43	.18	.08	.02

Appendix A: Estimation of the Labor Tax

To estimate the average rate of labor tax we follow (approximately) the procedure in Mendoza *et al.* (1994) using OECD's (1997) *Revenue Statistics* (Table 60) and *National Accounts* (pp. 616) for 1990. One difficulty here is that income tax revenues are not decomposed into those from labor and capital income. It seems reasonable to assume, however, that labor and capital income are taxed at the same rate in the United Kingdom. Thus, we can calculate the average tax rate on all income as follows:

(B1) $$t_I = \frac{1100}{OSPUE + PEI + W}$$

where:

1100 is taxes on income, profit, and capital gains of individuals, £57,233 million.

OSPUE is the operating surplus of private unincorporated enterprises, £71,245 million.

PEI is agent property and entrepreneurial income, £72,760 million.

W is wages and salaries, £275,669 million.

This calculation gives $t_I = 0.14$.

The average rate of tax on labor income is given by:

(B2) $$t_L = \frac{t_I W + 2000 + 5000}{W + 2200}$$

where:

2000 is total national insurance contributions, £35,303 million.

5000 is taxes on goods and services, although we net out excises on tobacco, petrol, and alcohol,[38] £41,362 million.

2200 is employers' contribution to national insurance, £20,091 million.

The denominator in (B2) is gross wages paid by employers. Thus from this formula we obtain values of 13% for the income tax, 12% for national insurance contributions, and 14% for sales taxes.

Our calculation abstracts from two complications, which act in opposing directions. First, the marginal rate of tax typically exceeds the average rate because the income tax is progressive rather than proportional. However, given that non-income taxes account for two-thirds of the total taxes imputed to labor and that about two-thirds of the labor supply response is due to the participation decision (which

[38] These are in the 5121 series and amount to £19, 794 million.

depends on the average tax rate), this omission does not make much difference.[39] On the other hand, our estimate may overstate the actual tax burden to the extent that people anticipate a larger state pension in retirement the more national insurance contributions they pay, that is, the national insurance tax is not fully distortionary (Browning 1985, Feldstein and Samwick 1992). Our calculations allow the labor tax to vary between 36 and 42%.

Appendix B: Deriving Equation (5.2)

Using the definition of η^u_{LP}:

$$\text{(B1)} \quad \eta^u_{LP} \frac{X_L}{(1+t_P)X_P} = \frac{\partial X_L}{\partial t_P} \frac{1}{X_P}$$

As noted in Section 5(ii), we can use the approximation $\partial X_L / \partial t_P \approx \partial X^c_L / \partial t_P$ from the Slutsky equation, becuase X_P / X_L is very small. Using Slutsky symmetry

$$\text{(B2)} \quad \frac{\partial X^c_L}{\partial t_P} = \frac{\partial X^c_P}{\partial t_L}$$

When leisure is weakly separable from goods in the utility function we can write (e.g., Layard and Walters 1978, pp. 166)

$$\text{(B3)} \quad \frac{\partial X^c_P}{\partial t_L} = \frac{\partial X_P}{\partial I} \frac{\partial I}{\partial t_L}$$

where $I = L$ is gross labor income, which changes by $\partial X_L / \partial t_L$. Making these substitutions in (B1) we can obtain

$$\eta^u_{LP} \frac{X_L}{(1+t_P)X_P} = -\left(\frac{\partial X_L}{\partial (1-t_L)} \frac{1-t_L}{L} \right) \left(\frac{\partial X_P}{\partial I} \frac{I}{X_P} \right) \frac{L}{(1-t_L)I}$$

Substituting the definitions of the elasticities gives the expression in the text.

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[39] Mendoza et al. (1994), Table 7, find that estimates of marginal tax rates are about 9 points greater than average tax rates for the United Kingdom in 1983. Attaching a weight of 0.33 to the marginal rate (which affects hours worked) and 0.67 to the average rate (which affects participation), this would raise our overall labor tax wedge to 42%. Other MEB studies typically use an estimate of the marginal tax rate. Thus, these other studies implicitly attribute all of the labor supply response to changes in hours worked and none to the participation decision. In this respect, these studies overestimate the MEB.