Does Britain or The United States Have the Right Gasoline Tax?

Ian W.H. Parry*

Resources for the Future

and

Kenneth A. Small

University of California, Irvine

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*Corresponding author: Resources for the Future, 1616 P Street NW, Washington, DC 20036. Email: parry@rff.org, phone: (202) 328-5151, web: www.rff.org/~parry.

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Abstract

This paper develops an analytical framework for assessing the optimal level of gasoline taxation taking into account pollution, congestion, and accident externalities, and interactions with the broader fiscal system. We provide calculations of the optimal level of gasoline taxation for both the US and the UK under a wide variety of assumptions about key parameter values. Under our central parameter values the optimal level of gasoline taxation is $0.97 for the US and $1.47 for the UK, *however* these optimal taxes can be considerably higher or lower under different parameter assumptions. The higher optimal tax for the UK is due to the higher miles per gallon used to convert congestion and accident costs per mile into costs per gallon of gasoline, and a higher value for (marginal) congestion costs. However, the importance of congestion and accident costs in the optimal fuel tax is substantially diminished because only a minor portion of the long run gasoline price demand elasticity is due to reduced driving. The optimal taxes are very close to corresponding values for marginal external costs, that is, on balance interactions with the tax system are offsetting.

1. Introduction

Recent demonstrations in Europe against high fuel prices heightened interest in the appropriate level of gasoline taxation. Excise taxes on fuel vary dramatically across different countries: Britain has the highest rate among industrial countries and the United States the lowest (see Figure 1). In Britain the excise tax on gasoline is about $2.80 per US gallon (50 pence per litre), or roughly three times the 2001 wholesale price. In the United States federal and state taxes amount to about 40 cents per gallon.[1]

The British government has defended high gasoline taxes on three main grounds. First, by penalizing gasoline consumption such taxes reduce both carbon emissions, which may affect the future global climate, and local air pollutants, which can be harmful to human health and visibility. Second, gasoline taxes raise the cost of driving and therefore indirectly reduce traffic congestion, and also traffic-related accidents such as deaths to pedestrians. Third, gasoline taxes provide a significant source of government revenue: in the UK, motor fuel revenue is nearly one-fourth as large as the entire revenue from personal income taxes (Chennells et al. 2000). Gasoline taxes have also been defended on other grounds, such as a user fee for the road network and to reduce dependency on supplies from the Middle East.

[1] Gasoline is also subject to sales taxation in the United States and value-added taxation in European countries. However these other taxes apply to (most) other goods, and therefore do not increase the price of gasoline relative to other goods.

There are a number of important externalities associated with driving, each potentially calling for a corrective Pigovian tax. However, the ideal tax for each would be on something other than gasoline. For pollution, a direct tax on emissions, unlike a tax on gasoline, would provide incentives to improve pollution abatement technologies in vehicles. For carbon dioxide, a tax on gasoline is closer to a direct Pigovian tax, but still not identical because different fuels contain different ratios of energy to carbon. As for congestion, gasoline taxes affect it through reducing total vehicle miles traveled (VMT), whereas peak-period congestion fees would also encourage people to consider avoiding peak hours and the most highly congested routes. An ideal tax to address accident externalities would charge according to miles driven rather than gasoline purchases, and would vary across people with different risks of causing accidents.[2]

Nonetheless, the ideal taxes to internalize these externalities have not been implemented for political or other reasons. Congestion taxes, especially, often raise objections on grounds of fairness because they can be very high for certain trips and some people will find it difficult to shift their behavior so as to lower their tax liability. Congestion and pollution taxes require great administrative sophistication because of the need to measure accurately the timing and location of travel and/or the real-world emissions of vehicles in use. Charging for accident externalities is administratively feasible through the insurance system, but runs counter to frequent attempts to reduce geographical differences in insurance rates. The fuel tax, by contrast, is administratively simple and well accepted in principle, even at very high tax rates in some nations. Therefore it is entirely appropriate to consider how externalities that are not directly priced should be taken into account in an assessment of gasoline taxes.

As for revenues, there is a well-developed public finance literature that permits a rigorous comparison of the efficiency of different tax instruments for raising needed revenues. Recently, this literature has been extended to compare externality taxes with labor-based taxes such as the income tax.[3] One of its key insights is that externality taxes have a similar distorting effect on labor supply as labor-based taxes, and that this usually reduces their efficiency compared to the standard partial-equilibrium analysis of Pigou (1920). It is now feasible to bring the insights of this literature to bear on a tax, such as the fuel tax, that is partially intended as an imperfect instrument for controlling externalities.

There is an empirical literature, mainly for the US, that attempts to quantify the external costs of transportation.[4] Typically these studies estimate total external costs or external costs per mile. However,

[2] For discussion of the efficiency of gasoline taxes versus ideal Pigouvian taxes at reducing externalities, see for example Walters (1961), U.K. Ministry of Transport (1964), De Borger and Proost (2000), and Parry (2001).

[3] See for example Bovenberg and van der Ploeg (1994), Bovenberg and Goulder (1996), Parry and Oates (2000).

[4] For example, Greene et al. (1997), Lee (1993), OTA (1994), Porter (1999).

there are a number of subtleties involved in using such estimates to obtain external costs per gallon of gasoline. For example, the impact of higher gasoline taxes on congestion and accidents is weaker to the extent that reduced gasoline demand results from people purchasing more fuel-efficient vehicles rather than reduced driving.

This paper presents and implements a formula for the optimal gasoline tax that accounts for both externalities and interactions with the tax system. This formula extends that of Bovenberg and Goulder (1996), who show how to adjust Pigouvian taxes to take into account interactions with pre-existing taxes on labor income. We furthermore consider the possibility that gasoline is a relatively weak substitute for leisure compared with other goods, and we incorporate feedback effects on labor supply from changes in congestion. We use our formula to estimate optimal gasoline taxes in the US and UK. In this way we illustrate why, and to what extent, the optimal tax may differ across countries, and under what circumstances, if any, the low US rates or the high UK rates can be justified.

In addition, we calculate the marginal excess burden of (existing) gasoline taxes and the welfare gains from both full and partial adjustment toward the optimal gasoline tax, in each country. We compute welfare effects both when revenues are used to replace other taxes and when they are used to increase public spending.

Some caveats are in order. First, estimates of the externality costs of transportation are subject to a lot of uncertainty and controversy, and therefore we cannot pin down the optimal gasoline tax with confidence. However, the implications of alternative parameter scenarios can easily be inferred from our analysis. Moreover, we can still put some plausible bounds on the optimal tax, and by using Monte Carlo simulations we can assess the likelihood that the tax might be above or below any particular level. A second caveat is that our analysis abstracts from some other arguments that have been used in defense of gasoline taxes, including road damage externalities and national security considerations, which could lead us to understate the optimal tax somewhat. However, we believe our analysis does capture the most important externalities, and, as noted later, the gasoline tax is an especially clumsy policy tool for addressing road damage or national security.

We summarize some of the results as follows. First, under our benchmark parameter assumptions the optimal gasoline tax in the US is \$0.97/gal and in the UK is \$1.47/gal, although much higher and much lower values are obtained under alternative parameter scenarios. The higher optimal tax for the UK mainly reflects the higher miles per gallon used to convert congestion and accident costs per mile into costs per gallon of gasoline, and a higher assumed value for marginal congestion costs.

Second, because in the long term less than one-half of the tax-induced reduction in gasoline is due to reduced driving, it is appropriate to weight congestion and accident costs per mile by less than one-half when converting to costs per gallon of gasoline, and this substantially reduces their influence on the optimal gasoline tax. Furthermore, even though the current gasoline tax in the UK may exceed the optimal level in our analysis, this does not necessarily imply that the private costs of driving (including gasoline taxes) exceed the social costs of driving.

Third, the optimal gasoline tax when considered as part of the broader fiscal system does not differ greatly from the marginal external cost of gasoline for either country. That is, the inefficiency due to the narrow base of the fuel tax (relative to the income tax), the relatively weak substitution between gasoline and leisure, and the feedback effects of congestion on labor supply, are roughly offsetting factors.

The rest of the paper is organized as follows. Section 2 describes our analytical model and derives a formula for the optimal gasoline tax. Section 3 discusses parameter values. Section 4 presents calculations of the optimal gasoline tax for the United States and United Kingdom. Section 5 <not done yet> discusses the marginal excess burden of existing gasoline taxes, the welfare gains from partial and full adjustment to the optimal gasoline tax, and the welfare effects of gasoline taxes when revenues finance more spending rather than substituting for other taxes. Section 6 concludes and discusses some limitations to the analysis.

2. Analytical Framework

A. Model Assumptions

Consider a static, closed economy model with a large number of agents. The representative agent has the following utility function:

(2.1) $$U = u(\psi(C, M, T, G), N) - \varphi(P) - \delta(\rho A)$$

C is the quantity of an aggregate consumption good, M is vehicle miles traveled (VMT), T is time spent driving, G is government spending, N is leisure or non-market time, P is the quantity of (local and global) pollution, A is severity-adjusted traffic accidents and ρ is the portion of accident costs that is external (all variables are expressed in per capita terms). P, A and G are exogenous to individual agents. We include T in the utility function to allow for the opportunity cost of travel time to differ from the opportunity cost of work time (see below). $u(.)$ and $\psi(.)$ are quasi-concave functions; $\varphi(.)$ and $\delta(.)$ are weakly convex functions representing the disutility from pollution and from the risk of traffic accidents per vehicle mile.[5]

[5] The separability of pollution and accidents in (2.1) rules out the possibility that they could have feedback effects on labor supply, though we do capture feedback effects from congestion. Williams (2000) finds that the impacts on labor supply from pollution-induced health effects have ambiguous, and probably small, effects on the optimal pollution tax. The weak separability of leisure in (2.1) implies that consumption and VMT would increase in the same proportion following an income-compensated increase in the wage. This seems a reasonable approximation to us, given that a large portion of travel is people commuting to work. Relaxing this assumption would have the same

VMT is "produced" according to the following homogeneous function:

$$(2.2) \qquad M = M(F, H)$$

where F is gasoline consumption and H is expenditure on fuel efficiency (e.g. computer-controlled combustion, lighter alloys in engine or structural metal parts, or improved drive train). This function allows for a non-proportional relation between gasoline and VMT: in response to higher gasoline taxes people will buy more fuel-efficient cars (represented by an increase in H) in addition to driving less; hence the proportionate reduction in VMT is less than the proportionate reduction in gasoline. Our model does not incorporate truck driving because our focus is only on the gasoline tax.

Driving time is determined as follows:

$$(2.3) \qquad \pi = \pi(\overline{M}); \qquad T = \pi(\overline{M})M$$

π is the (average) time it takes to drive a mile, the inverse of the travel speed, and $\overline{M}$ is aggregate miles driven per capita. $\pi'(\overline{M}) > 0$, implying that an increase in VMT leads to more congested roads and, on average, this increases the time it takes to drive a given distance. Agents take $\pi(\overline{M})$ as fixed, that is they do not take account of their impact on adding to congestion and raising the average travel time for other drivers.

Pollution is determined by:

$$(2.4) \qquad P = P(\overline{F})$$

where $P'(.) > 0$ and $\overline{F}$ is aggregate fuel consumption per capita. Agents ignore the costs of pollution from their own driving since these costs are born by other agents. Because we do not model emissions fees, there is nothing to cause people to change the emissions characterization of their vehicles; therefore the assumption that pollution depends only on fuel consumption is an adequate approximation.[6]

The term $\delta(\rho A)$ in (2.1) represents the (expected) per capita disutility from the *external* cost of traffic accidents. Some accident costs are internalized; for example people should consider the risk of injury or death to themselves when deciding how much to drive, and these costs are implicitly included in H in the production function for M. But other costs, for example pedestrian and cyclist fatalities, are external and are counted in $\delta(.)$. The number of severity-adjusted accidents is determined by:

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effect as using a different value for the expenditure elasticity of VMT in the optimal tax formula derived below, and we consider a wide range of values for this parameter in our simulations.

[6] The damage from local air pollution, and from traffic congestion, varies considerably, both across regions and across time. However, since we are analyzing gasoline taxes imposed at the national level, rather than region- or time-specific charges, we can still use an aggregated model where pollution and congestion damages represent an average of damages across space and time, though there are some caveats to this noted in Section 3.

(2.5) $A(\overline{M}) = a(\overline{M})\overline{M}$

where a is the accident rate per mile and A is exogenous to agents. The sign of $a'(.)$ is ambiguous: the accident rate increases with congestion, but accidents can be less severe if heavier traffic causes people to drive slower (which will reduce a).

On the production side, we assume that firms are competitive and produce all market goods with labor (and possibly intermediate goods) with constant returns to scale. Therefore supply prices and the gross wages paid to labor are fixed. We normalize producer prices and the gross wage to unity.

The government has an exogenous revenue requirement G, financed by a tax of t_F on gasoline consumption and a tax of t_L on labor income. Therefore the net wage is $1-t_L$ and the consumer price of gasoline is $1+t_F$. As in the United Kingdom, gasoline tax revenues finance general public spending, but in Section 5 we consider the case in the United States where these revenues are earmarked for spending on transportation infrastructure. The government does not directly tax or regulate any of the three externalities, except as implicitly incorporated in the functions $\delta(.)$, $\pi(.)$, $P(.)$, $A(.)$, and $M(.)$.[7] Therefore the gasoline tax can increase efficiency directly by mitigating the pollution externality, and indirectly by reducing VMT and hence congestion and traffic accidents.

The agent's budget constraint is:

(2.6) $I = (1-t_L)L = C + (1+t_F)F + H$

where L is labor supply and I is disposable income, equal to spending on consumption, gasoline, and the other costs of driving. Agents are also subject to the time constraint:

(2.7) $L + N + T = \overline{L}$

where $\overline{L}$ is the agent's time endowment. This equation says that the sum of labor time, leisure time and driving time exhausts the time endowment.

Finally, the government budget constraint is:

(2.8) $t_L L + t_F F = G$

That is, revenues from the labor and gasoline taxes equal government spending.

B. A Formula for the Optimal Gasoline Tax

(i) Household Optimization. Using (2.1)-(2.3), (2.6) and (2.7), the household utility maximization problem can be expressed:

[7] For example, mandatory bumper requirements reduce $\delta(.)$ but increase input of H in producing M.

(2.9)

$$V(t_F, t_L, P, A, \pi, G) = \underset{C,M,N,F,Z}{Max} \quad u(\psi(C, M, \pi M, G), N) - \varphi(P) - \delta(\rho A) \ + \mu\{M(F,H) - M\}$$
$$+ \lambda\{(1-t_L)(\overline{L} - N - \pi M) - C - (1+t_F)F - H\}$$

where λ and μ are Lagrange multipliers and $V(.)$ is the indirect utility function. The first order conditions can be expressed, after using Euler's theorem ($M = M_F F + M_Z Z$):

$$\text{(2.10)} \quad \frac{u_C}{\lambda} = 1; \qquad \frac{u_N}{\lambda} = 1 - t_L; \quad \frac{u_M}{\lambda} = p_M;$$

$$p_M = (1+t_F)\alpha_{FM} + \alpha_{HM} + q\pi; \quad \alpha_{FM} = F/M; \quad \alpha_{HM} = H/M; \quad q = 1 - t_L - u_T/\lambda$$

Households equate the marginal benefit of driving (in dollars), u_M/λ, with p_M, the "full" price of driving. p_M includes the fuel per mile (α_{FM}) and other market inputs per mile (α_{HM}), multiplied by their respective prices. It also includes the time cost per mile multiplied by q, the opportunity cost of travel time. q is less (greater) than the net of tax wage (or opportunity cost of leisure) if the marginal utility of travel time (u_T) is positive (negative). Using these conditions, (2.7), and the homogeneity property of $M(.)$, we can obtain:[8]

$$\text{(2.11)} \quad C = C(p_M, t_L); \qquad M = M(p_M, t_L); \qquad L = L(p_M, t_L); \qquad p_M = p_M(t_F, \pi);$$

$$F = F(t_F, \pi, t_L) = \alpha_{FM}(t_F)M(p_M, t_L); \qquad H = H(t_F, \pi, t_L) = \alpha_{HM}(t_F)M(p_M, t_L)$$

Partially differentiating (2.9) we can obtain:

$$\text{(2.12)} \quad \frac{\partial V}{\partial t_F} = -\lambda F; \quad \frac{\partial V}{\partial t_L} = -\lambda L; \quad \frac{\partial V}{\partial P} = -\varphi'(P); \quad \frac{\partial V}{\partial A} = -\delta'(A); \quad \frac{\partial V}{\partial \pi} = -\lambda q M$$

(ii) Welfare Effect of the Gasoline Tax. Totally differentiating the government budget constraint (2.8), holding G constant, and using (2.11), we can obtain:

$$\text{(2.13)} \quad \frac{dt_L}{dt_F} = -\frac{F + t_F \dfrac{dF}{dt_F} + t_L \dfrac{dL}{dt_F}}{L}$$

This is the balanced budget reduction in the labor tax from an incremental increase in the gasoline tax.

The welfare effect of an incremental increase in the gasoline tax is found by differentiating the household's indirect utility function with respect to t_F, taking into account how changes in gasoline and

[8] The functions in (2.11) are independent of A and P because of the separability assumptions in (2.1), and we exclude G as an argument because G is fixed in this section.

VMT affect external costs, and the balanced budget change in t_L. Using (2.3)-(2.5), (2.9), and (2.11)-(2.13), this gives:

$$(2.14) \quad \frac{1}{\lambda}\frac{dV}{dt_F} = \left(E^P - t_F\right)\left(-\frac{dF}{dt_F}\right) + \left(E^C + E^A\right)\left(-\frac{dM}{dt_F}\right) + t_L \frac{dL}{dt_F}$$

where

$$(2.15) \quad E^P = \varphi' P' / \lambda\,; \qquad E^C = q\pi' M\,; \qquad E^A = \delta' \rho A' / \lambda\,.$$

Equation (2.14) decomposes the marginal welfare change (in dollars) into three effects. First, the welfare change in the gasoline market. This equals the reduction in gasoline consumption times the difference between the marginal pollution damage from gasoline, denoted E^P, and the gasoline tax. Second, the welfare gain from the reduction in VMT. This equals the reduction in VMT times the sum of the (marginal) external cost of congestion per mile (E^C) and the (marginal) external cost of accidents per mile (E^A) (all external costs are in per capita terms). E^C equals the opportunity cost of travel time, times the increase in travel time per mile due to an incremental increase in VMT (π'), times VMT. E^A equals the marginal disutility from the effect of increasing VMT on the external costs of severity-adjusted accidents. The third term in (2.14) is the welfare effect in the labor market from increasing the gasoline tax. It equals the change in labor supply times the wedge between the gross and net wage, that is the wedge between the value marginal product of labor and the marginal opportunity cost of forgone leisure time.

(iii) Optimal Gasoline Tax. Setting (2.14) to zero yields, after some manipulation, the following formula for the optimal gasoline tax (see Appendix A):

$$(2.16) \quad t_F = \overbrace{\frac{E^P + \beta(E^C + E^A)}{MEB_L}}^{\textit{externality correcting}} + \overbrace{\frac{(1-\eta_{MI})\varepsilon^c_{LL}}{\eta_{FF}} \frac{t_L(1+t_F)}{1-t_L}}^{\textit{Ramsey tax}} + \overbrace{\beta E^C \left\{\varepsilon_{LL} - (1-\eta_{MI})\varepsilon^c_{LL}\right\}\frac{t_L}{1-t_L}}^{\textit{Congestion feedback}}$$

where

$$(2.17) \quad \beta = \frac{dM/dt_F}{dF/dt_F}\,; \qquad MEB_L = \frac{t_L \frac{\partial L}{\partial t_L}}{L - t_L \frac{\partial L}{\partial t_L}} = \frac{\frac{t_L}{1-t_L}\varepsilon_{LL}}{1 - \frac{t_L}{1-t_L}\varepsilon_{LL}}$$

η_{MI} is the expenditure elasticity of demand for VMT, η_{FF} is the gasoline demand elasticity (defined more precisely in Appendix A), and ε_{LL} is a labor supply elasticity, where *c* denotes a compensated elasticity. All elasticities are expressed as positive numbers.

Equation (2.16) decomposes the optimal gasoline tax into three components. First, an externality-correcting component. The numerator in the first expression is the marginal external cost of gasoline. It equals the marginal pollution damage per gallon of gasoline, plus the marginal congestion and accident cost per mile, multiplied by β, the reduction in VMT per unit reduction in gasoline. We can obtain (see Appendix A):

$$(2.18) \quad \beta = \frac{M}{F}\frac{\eta_{FF}^{\overline{H}}}{\eta_{FF}}$$

where $\eta_{FF}^{\overline{H}}$ is the price elasticity of demand for gasoline with fuel efficiency held constant. The key point here is that, because $\eta_{FF}^{\overline{H}} < \eta_{FF}$, $\beta < M/F$, and *multiplying estimates of the marginal external costs of congestion and accidents per mile by miles per gallon would overestimate the marginal external costs of gasoline*. In other words, to the extent that a tax-induced reduction in gasoline causes households to purchase more fuel-efficient vehicles (increase *H*) rather than reduce VMT, the congestion and accident-related benefits from gasoline taxes are diminished. This is important because empirical studies suggest that at least half of the long run price responsiveness of gasoline is due to changes in fuel efficiency (see below).

The externality-correcting component of the optimal gasoline tax in (2.16) is equal to the marginal external cost of gasoline, divided by one plus MEB_L, the marginal excess burden of labor taxation.[9] MEB_L equals the welfare cost in the labor market from an incremental increase in t_L divided by the marginal revenue and is positive because $\varepsilon_{LL} > 0$ (see below). Shifting taxes off labor and onto a consumption good, or in our case VMT, slightly reduces labor supply when that "good" is an average substitute for leisure. Trading off the efficiency loss in the labor market with the efficiency gain from correcting the externality implies that the optimal externality tax is less than marginal external cost.

However travel may not be an average leisure substitute, and the second expression in (2.16), the Ramsey tax component, adjusts for this. This component is positive, zero, or negative, if the expenditure elasticity for VMT is less than one, one, or greater than one. Travel is a relatively strong (weak) substitute for leisure if the expenditure elasticity for VMT is greater (less) than one, when leisure is weakly separable in utility (Deaton 1981). Thus, leaving aside the other two expressions in (2.16), gasoline should be taxed (subsidized) relative to other goods if travel is a relatively weak (strong) substitute for leisure.[10]

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[9] A similar formula is derived in Bovenberg and van der Ploeg (1994) and Bovenberg and Goulder (1996).

[10] This is a familiar result from the theory of optimal commodity taxes (e.g. Sandmo 1976).

The third component of the optimal gasoline tax is due to the positive feedback effect of reduced congestion on labor supply (e.g. Parry and Bento 2000). Reduced congestion reduces the full price of travel (see (2.10)) relative to leisure hence it leads to a substitution effect between leisure and travel. From (2.16) and (2.17), when congestion accounts for all external costs and VMT is an average leisure substitute (E^P=E^A=0, η_{MI} =1), then the optimal gasoline tax equals the marginal congestion cost ($t_F = \beta E^C$). In other words, even though the gasoline tax raises revenues for the government, a necessary (though not sufficient) condition for the optimal tax to exceed that justified on externality grounds is that travel must be a relatively weak substitute for leisure (η_{MI}<1).

Finally, from the government budget constraint (2.8)

(2.19) $t_L = \alpha_G - t_F \alpha_F$

where $\alpha_G = G / L$ and $\alpha_F = F / L$ are the shares of government spending and gasoline production in national output.

The system of equations (2.16)-(2.19) can be solved numerically to yield the optimal gasoline tax, given values for the various parameters. A remaining issue is that the observed, or estimated values for these parameters apply to the existing equilibrium (with non-optimal gasoline taxes) whereas the above formulas depend on the values of these parameters at the social optimum. To infer the appropriate values we need to make some functional form assumptions. For the most part, we assume that share parameters and elasticities are constant, and we use observed data directly in the formulas. In the sensitivity analysis below we show that allowing for endogenous elasticities and share parameters has only a minor effect on the results.

3. Parameter Values

In this section we choose parameter values for simulations. Because we are more interested in obtaining plausible magnitudes than definitive results, we are free with approximations. For each parameter, we specify a central value, and a plausible range for sensitivity analysis, which can be thought of roughly as 90% confidence intervals. Table 1 summarizes the parameter assumptions.

Often there are US and UK studies of the same parameters, but they may not use the same assumptions. We would like any parameter differences across nations to reflect real differences in conditions. Therefore, where possible, we adjust studies for cross-national comparability. Because all these figures are approximate, we do not worry too much about precise exchange rates and price levels. Generally we are attempting to put things in US$ at year-2000 price levels; we do this by updating each nation's figures as appropriate, then applying the end-2000 exchange rates of UK£1 =US$1.40 and ECU1= US$0.90.

Fuel economy (miles/gal), $1/\alpha_{FM}$. Data for the late 1990s show average fuel economy at 20 miles/gal for US passenger cars and other 2-axle 4-tire vehicles (averaging 1998 and 1999 data). For the UK, the figure for petrol-powered 4-wheeled cars is 30 miles/gal (averaging 1997 and 1999 data).[11] We consider a range of 15-25 miles/gal for the US and 25-35 miles/gal for the UK.

Pollution damages (cents/gal), E^P. First consider local (i.e. troposhperic) air pollution. Quinet (1997) reviews the literature from Europe. McCubbin and Delucchi (1999) describe a comprehensive study for the United States, while Small and Kazimi (1995) consider the Los Angeles region. Delucchi (2000) reviews evidence on a wider variety of environmental costs from motor vehicles, but finds air pollution by far the most important. The US studies are in reasonable agreement. They suggest that costs of local pollution from motor vehicles are in the range of roughly 0.4 to 4.8 cents/mile for newer automobiles typical of the year-2000 fleet.[12] Using our central fuel economy assumption gives 8-96 cents/gal for the US, with a geometric mean of 27 cents/gal. The European studies reviewed by Quinet give similar results.[13]

Global warming costs are much more speculative, due to the long time period involved, great uncertainties in the atmospheric modeling, and our inability to forecast adaptive technologies that may be in place a half-century or more from now. Tol et al. (2000) review the estimates and conclude that: "it is questionable to assume that the marginal damage costs exceed $50 /tC (metric ton carbon)", where $50/tC is equivalent to 16 cents/gal.[14] ECMT (1998, p. 70) cite estimates ranging from $2-$10/tC. These values

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[11] See FHA (1999 table VM-1) and DOE (2000, table 2.4).

[12] The cost estimates are dominated by health costs, especially willingness to pay to reduce mortality risk. For US-wide estimates McCubbin and Delucchi (1999, Table 4, row 1) give a range 0.58–7.71 cents per vehicle-mile for light-duty vehicles in 1990; updating to 2000 prices gives 0.8–12.4 cents. For the mix of light-duty vehicles operating in the Los Angeles region in 1992, Small and Kazimi (1995) provide a central estimate of 3.3 cents per vehicle-mile, at 1992 prices; or 4 cents per mile in year 2000 (however pollution in Los Angeles is much worse than on average for the US). All these estimates are based on vehicles in use in the early 1990s. Small and Kazimi (Table 8) estimate costs from the California light-duty vehicle fleet projected for 2000 to be about half those from the 1992 fleet, so we multiply the above estimates by one-half.

[13] For the European estimates, we obtain a range of 11-83 cents/gal from Quinet's Table A.1, after deleting extreme high and low estimates, multiplying the results from the early 1990s by 1.4 to adjust for inflation, and using our central value for UK fuel efficiency. A study by ECMT (1998 Table 78) obtained a value of 36 cents per gallon for the UK.

[14] Quinet (1997) uses 7.6 barrels of gasoline per 1tC, and there are 42 gallons in a barrel.

are small in comparison to local pollution, though they do not account for the small risk of catastrophe that could be caused, for example, by a discontinuous shift in oceanic currents.

Putting the above figures together, adopt a central value of 35 cents/gal for pollution costs for both countries and a range of 5-85 cents/gal.

Marginal congestion cost (cents/mile), E^C. Congestion is a sharply nonlinear phenomenon, and highly variable across times and locations. Therefore the (marginal) congestion cost per mile for an entire nation depends crucially on the proportion of its traffic that occurs in high-density areas at peak-period.

There are a number of studies of congestion costs for individual cities, but few that attempt an average over a nation. One good one is Newbery (1990), who estimates the marginal external cost of congestion for 11 road classes in the UK in 1990. These vary from 0.05pence/km on “other rural roads” to 36.4pence/km for central urban areas during peak periods (his table 2). The average, weighted by vehicle-kilometers of travel, is 3.4pence/km, or around 10-12 cents/mile after updating to 2000.[15] For Belgium, Mayeres (2000 Table 5) and Mayeres and Proost (2001a) obtain marginal congestion costs equivalent to around 13-15 cents per mile.

For the US, Delucchi (1997) estimates 1990 external congestion costs from private vehicles at 0.67 to 3.26 cents per passenger-mile, which we update to about 1.2-9.4 cents/vehicle-mile at 2000 prices with a geometric mean of 3.4 cents/mile. However, this estimate is for the average cost of congestion rather than the marginal, and we would expect the latter to be more than twice the former if the marginal congestion function is convex rather than linear. Still, we might expect marginal congestion costs to be higher in the UK than the US, because the UK has a much higher overall population density than the US (for example, one-sixth of the population lives in London where street congestion is notoriously bad).[16]

These averaged marginal cost estimates would be appropriate for our purposes if the elasticity of VMT on congested and uncongested roads with respect to gasoline prices were the same. However traffic volumes on highly congested roads are much less sensitive to prices than traffic volumes at off-peak periods or on rural roads, and a correspondingly lower weight should be attached to the (very high)

[15] Scaling up Newbery’s estimate by wage inflation (about 64% in UK manufacturing between 2000 and 1990, ILO 2000, table 5A, p. 894) gives about 12.5 cents/mile. Wardman (2001) suggests that the opportunity cost of travel time increases by wage growth to the power 0.5, which instead would yield 9.6 cents per mile. We do not adjust for increased congestion levels, because some or all of that is offset by people moving to less-congested regions (Gordon and Richardson, 1994).

[16] Mohring (1999) estimates that the average peak-period marginal external cost for roads in the Minneapolis area, counting all roads included in the regional transportation model, is 18 cents/mile in 1990 while Newbery’s estimate for urban peak-period travel is 51 cents/mile for 1990, suggesting that congestion is more severe in urban centers in the UK. Moreover, the proportion of all 1990 US automobile travel that took place in urban areas was 59.5% (FHA 1990, Table VM-2) whereas Newbery’s table suggests that about two-thirds of UK travel was urban.

marginal congestion costs on peak-urban roads.[17] We adopt central values of 5 cents/mile and 8 cents/mile for the marginal congestion cost averaged across the US and UK respectively, and we consider ranges of values up to 10 cents/mile for the US and 17 cent/mile for the UK.

Marginal accident cost (cents/mile), E^A. From (2.5) and (2.15), $E^A = \rho(a + a'\overline{M})$, where we have normalized $\delta' / \lambda = 1$, so that a is the accident cost per mile. It is well established that a is quite large, perhaps about 15-20 cents per vehicle-mile in the US and the UK (Small and Gomez-Ibanez 2000, Small, 1992, pp. 78-84), however, it is uncertain what portion of these is external (ρ). Around 90% or more of these estimated costs are due to fatalities and injuries, and drivers should at least take into account the risks to themselves.[18] Added to this is the fact that traffic laws provide for penalties, which drivers may perceive as costs that they incur on an expected basis. Moreover, as noted above the sign of a' is unclear: some studies have suggested that more traffic *decreases* the severity-adjusted accident rate ($a' < 0$) because accidents are less deadly with slower traffic (Fridstrom and Ingebrigtsen, 1991).[19]

One estimate that takes these considerations into account (though he does not consider the possibility that $a' < 0$) is that by Newbery (1988), who estimates 1985 UK accident externalities from automobiles at 2.0 to 4.9 p/km. Updating gives 4.8-12.1 cents per mile, with a geometric mean of 7.6 cents/mile.[20] Mayeres and Proost (2001a) and Mayeres (2000) use estimates of 3 or 4 cents per mile for Belgium, from updating an earlier study. In the absence of a good reason to believe the US and the UK are very different, we adopt a central value of 5 cents/mile, with a range of 2-10 cents/mile, for both nations.

[17] The main reason is that on highly congested roads, a given reduction in traffic significantly lowers the time cost of using the road, and the road tends to fill up again with new drivers. Mayeres and Proost (2001b), table 4 report that peak car trips are only one third as sensitive to price as trips on uncongested roads, and reducing the relative weight attached to peak-period costs accordingly would reduce their overall marginal congestion cost estimate by 36%.

[18] However, deaths to pedestrians and cyclists are probably not internalized, and these amount to about 3 cents per mile in the US (Porter 1999 pp. 194).

[19] See Delucchi (1998) and Small and Gomez-Ibanez (1999) for more discussion of these issues.

[20] Newbery uses a "value of life" of close to US$4 million, which is also the magnitude suggested by several reviews of US evidence and used in recent studies (Small and Gomez-Ibanez, 1999). Unlike value of time, we do not inflate Newbery's value because while the value of statistical life may be higher than in 1985, the risk of accidents is lower due to safety improvements in roadways and vehicles.

Gasoline demand elasticity. Goodwin (1992, table 1) reviews a number of time series and cross-section estimates of gasoline price demand elasticities, and based on the mean and standard deviation of the studies we use a value of -0.8, and a range of plus or minus 0.3.[21]

A number of studies have attempted to separate out the VMT and fuel-efficiency components of the long run gasoline demand elasticity. These studies suggest that the VMT component is anything from below 10% up to 50%.[22] Based on this information, we chose a central value for $\eta_{FF}^{\bar{H}} / \eta_{FF}$ of 0.3, and a range of 0.1 to 0.5.

Expenditure elasticity of demand for VMT, η_{MI}. It has been more common to estimate the income elasticity of demand for gasoline rather than for VMT, and the former appears to be about one in the long run (Dahl and Sterner 1991). However there have been some attempts to directly estimate the VMT expenditure elasticity: these are typically between about 0.35 and 0.8, although a few estimates exceed unity.[23] We might expect the expenditure elasticity to be a little higher in the UK because there is more room for vehicle ownership to grow, and more room for mode shifts away from public transport. We set the central value for income elasticity at 0.6 for the US and 0.8 for the UK. For a range, we choose plus or minus half the central value.

Labor market and other parameters. The remaining parameters are much less important for the optimal gasoline tax than the parameters just described. There is a large literature on labor supply elasticities for the US (see e.g. Blundell and MacCurdy 1999 for a review of both US and UK studies, and also Fuchs et al. 1998). Based on this literature for both countries we adopt a central value of the uncompensated labor supply elasticity of 0.2, and a range of 0.1 to 0.3, and for the compensated elasticity a central value of

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[21] We decompose η_{FF} in (2.16) into the (uncompensated) price elasticity of demand, and the feedback effect on gasoline when the extra revenue is returned in a labor tax cut (see Appendix A). The latter component is determined within the model, but it is of minor importance.

[22] The VMT-portion of the gasoline demand elasticity in Sweeney (1978) is 8%, in Tanner (1983) 38%, in Schipper and Johannson 48%, in Crandell 27% and in Pickrell and Schimek (1999) is 8-20%. A simple mean of these studies is 27%. Note that higher fuel efficiency reduces the cost of driving and has a "rebound effect" that diminishes the effect of higher gasoline prices on VMT. An indirect way to infer the effect of gasoline prices on VMT is to multiply estimates of the elasticity of VMT with respect to money costs of driving by the share of fuel in the money costs of driving. Based on studies discussed in Small (1992), this would yield a value of around -0.05 to -0.2 for $\eta_{FF}^{\bar{H}}$, or less than one quarter of the overall gasoline demand elasticity.

[23] Based on Pickrell and Schimek (1997), and Pickrell (personal communication).

0.35 and a range of 0.25 to 0.5.[24] For the labor taxes we use 0.36 for the US with a range of 0.32-0.4, and for the UK a tax of 0.4 with a range of 0.36-0.44.[25] Finally, we assume production shares (α_F) of 0.012 for the US and 0.009 for the UK <details>.

4. Optimal Tax Calculations

A. Benchmark Calculations

Table 2 illustrates the components of the optimal gasoline tax for both countries, under our assumed central parameters. Of course these results are sensitive to different parameter assumptions (see below) nonetheless they do at least give a feel for the size of the different components of the optimal tax discussed in Section 2. There are several noteworthy points.

First, under our central parameter values the optimal gasoline tax for the US is $0.97, about 2.5 times the current US tax rate, and $1.47 for the UK, about one-half of the current UK tax rate.

Second, the marginal external costs of gasoline are $1.52/gal for the UK and $0.95 for the US. This difference between the countries is due to the higher miles per gallon in the UK implying that given accident and congestion costs per mile translate into higher costs per gallon of gasoline, and because marginal congestion costs per mile are assumed higher for the UK. Congestion, accident and pollution cost each account for roughly a third of the marginal external costs for the US: while congestion costs are relatively more important for the UK.[26]

The marginal excess burden of labor taxation is about 0.15 for both countries (based on the uncompensated labor supply elasticity), implying that the externality-correcting component of the optimal gasoline tax is lower than the marginal external cost of gasoline by about 13%. The Ramsey-tax component of the optimal gasoline tax is of relatively minor importance, 9 cents/gal for each country, and similarly for the congestion feedback term, 3-6 cents/gal. On net the optimal gasoline tax, when considered as part of the broader tax system, is very close to the marginal external cost. In other words,

[24] Note that these elastcities reflect both participation and hours worked decisions, averaged across males and females.

[25] See e.g. Lucas (1990). Note that it is primarily the average rather than the marginal rate of tax that is relevant, since most of the labor supply response is due to changes in participation rather than hours worked.

[26] Accident costs, and particularly congestion costs, are comparably much larger in studies that assess external costs *per mile*. For example, in Mayeres and Proost (2001a, Table 4) congestion costs and accident costs are ten times and three times pollution costs, respectively. However, we have multiplied accident costs and congestion costs by 0.3, the VMT portion of the gasoline demand elasticity, to translate into costs per gallon. In addition, we used a lower marginal congestion cost to account for the weak sensitivity of peak-period driving versus rural and off-peak driving to gasoline prices.

the argument that gasoline taxes should be set above levels justified on externality grounds because they provide a source of revenues seems questionable (at least on efficiency grounds).

B. Sensitivity Analysis

The results in Table 2 should be treated with a great deal of caution because they are sensitive to different parameter assumptions. In figure 2 we vary each of six key parameter values at a time, holding all other parameters at their central values, to illustrate how they affect the optimal gasoline tax (the results are much less sensitive to other parameters such as labor supply elasticities). The upper and lower curves in each panel correspond to the UK and US respectively, and 'X' denotes the optimal tax in the benchmark case (in Table 2).

In the top left panel of Figure 2 pollution damages are varied between \$0.05 and \$0.85/gal. Here the optimal gasoline tax varies between \$0.71 and \$1.42/gal for the US and between \$1.21 and \$1.90/gal for the UK. In the middle upper panel marginal congestion costs per mile are varied between 2 and 17 cents/mile. The optimal gasoline tax rises to a maximum of \$2.17 for the UK if marginal congestion costs are 17 cents/mile, and for the US it falls to a low of \$0.77/gal if congestion costs are 2 cents/mile. For a given assumed marginal congestion cost for both countries, the gap between the two curves in this panel is \$0.21-\$0.63/gal, which mainly reflects the different assumption about miles per gallon for the two countries. The upper right panel in Figure 2 varies marginal accident costs per mile between 2 and 10 cents. Here the optimal gasoline tax varies between \$0.81 and \$1.24/gal for the US and between \$1.23 and \$1.86 for the UK.

The lower left panel varies the miles per gallon parameter between 15 and 35. Increasing this parameter raises the cost of congestion and accidents when converted from per mile to per gallon. For a given miles per gallon, the gap between the curves is around \$0.12-\$0.27, which isolates the effect of assuming higher marginal congestion costs for the UK. The lower middle panel in Figure 2 varies the VMT portion of the gasoline demand elasticity. The results are particularly sensitive to this parameter. For example, if this parameter were as low as 0.1 the optimal gasoline tax for the US falls to \$0.55/gal and for the UK to \$0.79, while if it is 0.5, the optimal gasoline tax rises to \$1.35/gal for the US and \$2.14 for the UK. The lower right panel varies the expenditure elasticity of VMT between 0.3 and 1.2. The lower the value of this parameter the weaker the degree of substitution between travel and leisure. This increases the Ramsey tax component of the optimal gasoline tax, but it also diminishes the congestion feedback effect (see (2.16)). On balance, the effects on the overall optimal gasoline tax are relatively modest.[27]

[27] The results are not very sensitive to labor taxes and labor supply elasticities. Varying these parameters across the ranges in Table 1 changes the optimal gasoline taxes by around plus or minus 5 cents/gal.

<sensitivity with respect to variable elasticities and share parameters—to be completed>

C. Monte Carlo Analysis

Clearly, a wide range of outcomes for the optimal gasoline taxes is possible under alternative parameter scenarios. We now use Monte Carlo simulations to assess how likely different outcomes might be, given our parameter ranges. For simplicity, we just focus on the marginal external cost of gasoline, since this is close to the optimal gasoline tax. For pollution, congestion and accident costs, we fit a gamma-distribution with 5% and 95% confidence levels equal to the minimum and maximum values for these parameters as specified in Table 1, and mean equal to the central values (these distributions are skewed to the left). For miles per gallon and the VMT portion of the gasoline demand elasticity, we simply assume a uniform distribution over the parameter ranges (the central values in table 1 are the midpoints of the ranges for these two parameters). In each simulation we allow each parameter to be drawn at random from its distribution, we calculate marginal external costs (according to equations (2.16) and (2.18)), and repeat this exercise 1000 times for both countries.

From this exercise, table 3 shows the probability that marginal external costs exceed given values. Here we see that for the US, the probability that the marginal external cost exceeds \$0.50 is 0.88, the probability it exceeds \$1.00/gal is 0.40, and the probability it exceeds \$1.50/gal is 0.10. For the UK, marginal external costs are above \$1.00 with probability 0.76, above \$1.50 with probability 0.44, and above \$2.00 with probability 0.22.

5. The Marginal Excess Burden of Gasoline Taxes and the Welfare Gain from Tax Reform

to be completed

6. Conclusion

This paper develops an analytical framework for assessing the optimal level of gasoline taxation taking into account pollution, congestion and accident externalities, and interactions with the broader fiscal system. We provide calculations of the optimal level of gasoline taxation for both the US and the UK under a wide variety of assumptions about key parameter values. Under our central parameter values the optimal level of gasoline taxation is \$0.97 for the US and \$1.47 for the UK, *however* these optimal taxes can be considerably higher or lower under different parameter assumptions. The central estimate for the US is about 2.5 times the existing US gasoline tax, and for the UK is about one-half of the existing UK tax.

The higher optimal tax for the UK is due to the higher miles per gallon used to convert congestion and accident costs per mile into costs per gallon and a higher assumed value for (marginal) congestion costs. However the importance of congestion and accident costs in the optimal fuel tax is greatly diminished because only a minor portion of the gasoline price demand elasticity is due to reduced driving. The optimal taxes are very close to corresponding values for marginal external costs, implying that interactions with the tax system are of minor importance. That is, the inefficiency due to the narrow base of the fuel tax (relative to the income tax) roughly compensates for relatively weak substitution between vehicle miles traveled and leisure, and the feedback effects of congestion on labor supply.

Aside from the parameter uncertainty, there are a number of caveats related to the model specification. <discuss road user fee, national security, oil spills, etc. discussed in Porter. Flat supply curve for gasoline>

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Appendix A: Analytical Derivations for Section 2

For the analytical derivations we define the following terms:

$$\text{(A1)}\qquad I=(1-t_L)L\,;\quad \eta_{MI}=\frac{\partial M}{\partial I}\frac{I}{M}\,;\qquad \varepsilon_{LL}=-\frac{\partial L}{\partial t_L}\frac{1-t_L}{L}\,;\qquad \varepsilon_{LL}^{c}=-\frac{\partial L^{c}}{\partial t_L}\frac{1-t_L}{L}\,;$$

$$\eta_{LI}=\frac{\partial L}{\partial I}\frac{I}{L}\,;\quad \eta_{FF}=\frac{dF}{dt_F}\frac{1+t_F}{F}\,;\qquad \eta_{FF}^{\overline{M}}=\frac{\partial F^{\overline{M}}}{\partial t_F}\frac{1+t_F}{F}\,;\qquad \theta_{FI}=\frac{(1+t_F)F}{I}$$

Deriving (2.16). From (2.11):

$$\text{(B1)}\qquad \frac{dL}{dt_F}=\frac{\partial L}{\partial t_F}+\frac{\partial L}{\partial \pi}\frac{d\pi}{dt_F}+\frac{\partial L}{\partial t_L}\frac{dt_L}{dt_F}$$

Differentiating (2.8), and using (2.11), an alternative expression for the change in labor tax is:

(B2) $$\frac{dt_L}{dt_F} = -\frac{F + t_F \dfrac{dF}{dt_F} + t_L\left(\dfrac{\partial L}{\partial t_F} + \dfrac{\partial L}{\partial \pi}\dfrac{d\pi}{dt_F}\right)}{L + t_L \dfrac{\partial L}{\partial t_L}}$$

From (B1) and (B2):

(B3) $$t_L \frac{dL}{dt_F} = MEB_L \cdot t_F \frac{dF}{dt_F} + \frac{MEB_L}{\partial L / \partial t_L}\left\{\frac{\partial L}{\partial t_F} L - \frac{\partial L}{\partial t_L} F + L \frac{\partial L}{\partial \pi}\frac{d\pi}{dt_F}\right\}$$

where, using the definition of ε_{LL} from (A1),

(B4) $$MEB_L = \frac{-t_L \dfrac{\partial L}{\partial t_L}}{L + t_L \dfrac{\partial L}{\partial t_L}} = \frac{\dfrac{t_L}{1-t_L}\varepsilon_{LL}}{1 - \dfrac{t_L}{1-t_L}\varepsilon_{LL}}$$

Using (2.10) and (2.11):

(B5) $$\frac{\partial L}{\partial t_F} = \frac{\partial L}{\partial p_M}\alpha_{FM}\,; \qquad \frac{\partial L}{\partial \pi} = \frac{\partial L}{\partial p_M} q\,; \qquad \frac{d\pi}{dt_F} = \pi' \frac{dM}{dt_F}$$

From the Slutsky equations:

(B6) $$\frac{\partial L}{\partial p_M} = \frac{\partial L^c}{\partial p_M} - \frac{\partial L}{\partial I} M\,; \; \frac{\partial L}{\partial t_L} = \frac{\partial L^c}{\partial t_L} - \frac{\partial L}{\partial I} L$$

where c denotes a compensated coefficient. From the Slutsky symmetry property for goods in the utility function:

(B7) $$\frac{\partial L^c}{\partial p_M} = \frac{\partial M^c}{\partial t_L}$$

Because leisure is weakly separable in the utility function changes in the demand for consumption and VMT occur only through changes in disposable income following a change in the labor tax (e.g. Layard and Walters 1978, pp. 166). Therefore:

(B8) $$\frac{\partial M^c}{\partial t_L} = \frac{\partial M}{\partial I}(1-t_L)\frac{\partial L^c}{\partial t_L}$$

where $(1-t_L)\partial L^c / \partial t_L$ is the change in disposable income following a compensated increase in the labor tax. Using (B5)-(B8), and the definitions of I, η_{MI} and E^C from (A1) and (2.15):

(B9) $$\frac{\partial L}{\partial t_F} L - \frac{\partial L}{\partial t_L} F = F \frac{\partial L^c}{\partial t_L}(\eta_{MI} - 1)\,; \qquad L \frac{\partial L}{\partial \pi}\frac{d\pi}{dt_F} = \left\{\eta_{MI}\frac{\partial L^c}{\partial t_L} - \frac{\partial L}{\partial I} L\right\} E^C \frac{dM}{dt_F}$$

Substituting (B9) in (B3), using the definitions of ε_{LL}, ε_{LL}^{c} and η_{LI} in (B3), and using the Slutsky equation $\varepsilon_{LL} = \varepsilon_{LL}^{c} + \eta_{LI}$ gives:

(B10) $$t_L \frac{dL}{dt_F} = MEB_L \cdot t_F \frac{dF}{dt_F} - \frac{MEB_L}{\varepsilon_{LL}} \left\{ \varepsilon_{LL}^{c} F(\eta_{MI} - 1) + E^C \frac{dM}{dt_F} \left\{ \varepsilon_{LL} - (1 - \eta_{MI}) \varepsilon_{LL}^{c} \right\} \right\}$$

From (B4), (B10), equating (2.14) to zero, and suing the definition of η_{FF} in (A1), we can obtain (2.16).

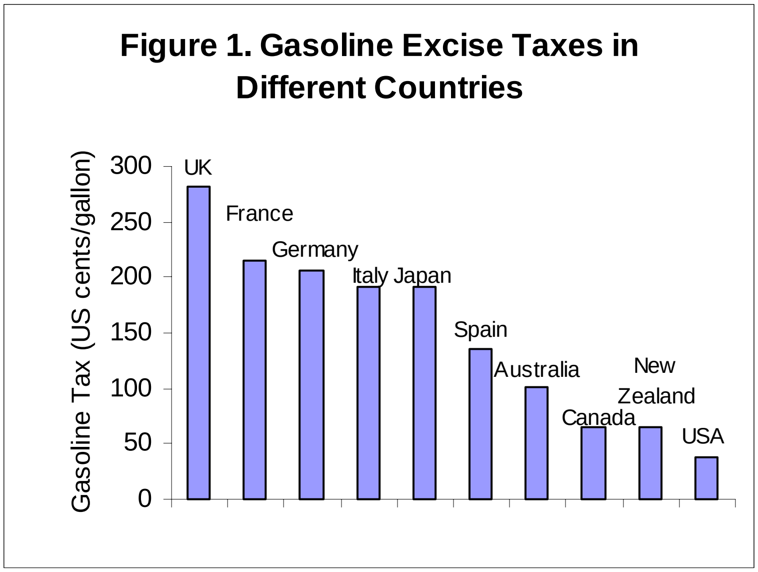
Deriving (2.18). From (2.11):

(C1) $$\frac{dF}{dt_F} = \frac{dF^{\overline{M}}}{dt_F} + \alpha_{FM} \frac{dM}{dt_F}$$

where $dF^{\overline{M}} / dt_F = \alpha'_{FM} M$. Rearranging in terms of dM / dt_F, we can obtain:

(C2) $$\frac{dM / dt_F}{dF / dt_F} = \frac{1}{\alpha_{FM}} \left\{ 1 - \frac{dF^{\overline{M}} / dt_F}{dF / dt_F} \right\}$$

Using (C2) the definitions of η_{FF} and $\eta_{FF}^{\overline{M}}$ from (A1), and the definition of α_{FM} gives (2.18).



Source: International Energy Association, Energy Prices and Taxes, First Quarter 2000.

Figure 2. Sensitivity of Optimal Gasoline Tax to Parameter Variation

(— US ······ UK)

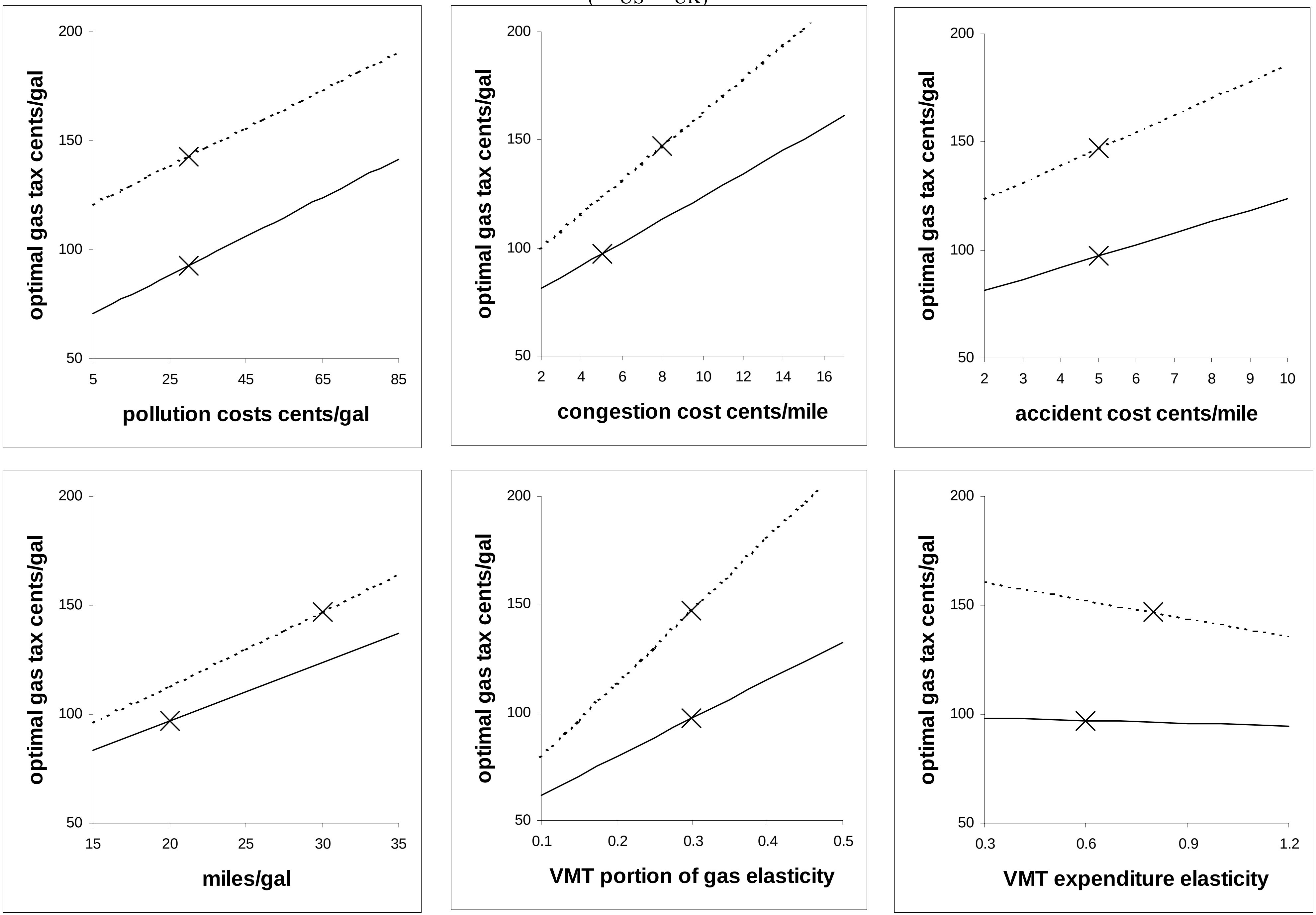


Table 1. Parameter Assumptions

Parameter	US		UK	
	Central value	range	Central value	range
miles per gallon	20	15-25	30	25-35
Pollution damages cents/gal	35	5-85	35	5-85
Congestion costs cents/mile	5	2-10	8	2-17
Accident costs cents/mile	5	2-10	5	2-10
Price elasticity of demand for gasoline	-0.8	-0.5 to -1.1	-0.8	-0.5 to -1.1
VMT portion of gas demand elasticity	0.3	0.1-0.5	0.3	0.1-0.5
VMT expenditure elasticity	0.6	0.3-0.9	0.8	0.4-1.2
Uncomp. Labor supply elasticity	0.2	0.1-0.3	0.2	0.1-0.3
Compensated labor supply elasticity	0.35	0.25-0.5	0.35	0.25-0.5
Labor tax	0.36	0.32-0.4	0.4	0.36-0.44
Gasoline production shares	0.012	-	0.009	-
Producer price of gasoline $/gal	0.94	-	1.01	-
Gasoline tax $/gal	0.38	-	2.82	-

Table 2. Benchmark Calculations of the Optimal Gasoline Tax
(All figures in cents/gal)

	US	UK
Pollution cost	35	35
Congestion cost	30	72
Accident cost	30	45
Marginal external cost	95	152
Externality-correcting tax	84	132
Ramsey tax	9	9
Congestion feedback	3	6
Optimal gasoline tax	97	147

Table 3. Monte Carlo Results for Marginal External Costs

	Probability that marginal external cost of gasoline is greater than					
	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00
US	.88	.40	.10	.01	0	0
UK	0.97	.76	.44	.22	0.09	.03