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Author(s): Ian W. H. Parry and Kenneth A. Small

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

By IAN W. H. PARRY AND KENNETH A. SMALL*

Changing fuel prices and new energy policy initiatives have heightened interest in the appropriate level of gasoline taxation. These taxes vary dramatically across countries: Britain's tax of 50 pence per liter in 2000 (about \$2.80 per U.S. gallon) is the highest among industrial countries, while the United States, where federal and state taxes averaged about 40 cents/gal, has the lowest rate (International Energy Agency, 2000).

The British government has defended high gasoline taxes on three main grounds. First, by penalizing gasoline consumption, such taxes reduce emissions of carbon dioxide and local air pollutants. Second, they raise the cost of driving and therefore reduce traffic congestion and traffic-related accidents. Third, motor fuel taxes in the United Kingdom provide significant government revenue—nearly one-fourth as large as that from personal income taxes (Lucy Chenels et al., 2000)—and do so efficiently since fuel has a relatively low price elasticity.

A counterargument to the externality rationale is that, except for carbon dioxide, it would be better that a tax be placed on something other than fuel: local emissions, peak-period congestion, or miles driven, preferably with a rate that varies across people with different risks of causing accidents. Nonetheless, ideal externality taxes have not been widely implemented: they raise objections on equity grounds, they require administrative sophistication, and there is often stiff political opposition to introducing new

taxes. The fuel tax, by contrast, is administratively simple and well established in principle, even at very high rates in many nations. Therefore it is entirely appropriate to consider how externalities that are not directly priced should be taken into account in an assessment of fuel taxes.

As for revenues, a well-developed public-finance literature rigorously compares the efficiency of different tax instruments for raising revenues. Recently, this literature has been extended to compare externality taxes with labor-based taxes such as the income tax (e.g., A. Lans Bovenberg and Lawrence H. Goulder, 1996; Parry and Wallace E. Oates, 2000). 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.

A number of previous studies attempt to quantify the external costs of transportation; typically costs are estimated on a per-mile basis, and they sometimes are converted to a per-gallon equivalent by multiplying by average vehicle fuel efficiency or miles per gallon.¹ As our formulation makes clear, however, it is crucial to account for the endogeneity of fuel economy: to the extent that people respond to higher fuel taxes by purchasing more fuel-efficient vehicles rather than driving them less, the contribution of distance-based externalities to the optimal fuel tax is substantially diminished.

In this paper we derive the second-best optimal gasoline tax, disaggregating it into components that reflect external costs of congestion, accidents, and air pollution (local and global), as well as a "Ramsey tax" component that reflects the appropriate balance between excise

* Parry: Resources for the Future, 1616 P Street, NW, Washington, DC 20036 (e-mail: parry@rff.org); Small: Department of Economics, University of California, Irvine, CA 92697 (e-mail: ksmall@uci.edu). We are grateful to Klaus Conrad, Amihai Glazer, Howard Gruenspecht, Larry Goulder, Charles Lave, Don Pickrell, Richard Porter, Paul Portney, Stef Proost, Mike Toman, Kurt Van Dender, Sarah West, and David Wildasin for helpful comments and suggestions, and to Helen Wei for research assistance. Kenneth Small thanks the University of California Energy Institute for financial support.

¹ For example, John Peirson et al. (1995), Inge Mayeres et al. (1996), European Conference of Ministers of Transport (ECMT) (1998, ch. 3), Richard C. Porter (1999), Werner Rothengatter (2000), and various papers in David L. Greene et al. (1997).

taxes and labor taxes in financing the government's budget. Based on a detailed assessment of evidence on underlying parameter values, we apply the formula to the United States and United Kingdom, thereby illustrating why, and to what extent, the optimal tax may differ across countries, and under what circumstances, if any, current rates might be justified.

We summarize the results as follows. First, under our benchmark parameters the optimal gasoline tax in the United States is \$1.01/gal (more than twice the current rate) and in the United Kingdom is \$1.34/gal (slightly less than half the current rate). The higher optimal tax for the United Kingdom mainly reflects a higher assumed value for marginal congestion costs. Significantly different values are obtained under reasonable alternative parameter scenarios, but a Monte Carlo analysis suggests that it is unlikely for either the optimal U.S. tax to be as low as its current value, or the optimal U.K. tax to be as high as its current value.

Second, the congestion externality is the largest component of the optimal fuel tax. The Ramsey component is the next most important, followed closely by accidents and local air pollution. Global warming plays a relatively minor role—ironically, since it is the only component for which the fuel tax is (approximately) the right instrument.

Third, the optimal gasoline tax is greatly reduced by the fact that less than half of the tax-induced reduction in gasoline use is due to reduced driving, the rest coming from changes in average fleet fuel efficiency. If we had incorrectly assumed that vehicle miles change in proportion to changes in fuel consumption, we would have computed the optimal gasoline tax in both nations to be much higher, well over \$3.00/gal in the case of the United Kingdom.

Fourth, when considered as part of the broader fiscal system, the optimal gasoline tax is only moderately higher than the marginal external cost of gasoline. The Ramsey component is only about 25 cents/gallon, and this is offset in part by the higher excess burden of a narrow-based tax relative to a labor tax.

Finally, we simulate a vehicle miles traveled (VMT) tax, which more directly addresses the distance-related externalities. The potential welfare gains from this policy are considerably larger than those from optimizing gasoline-tax rates—

nearly four times as large in the case of the United States. Indeed, optimized VMT taxes are quite high, equivalent to around \$2.50/gal for the United States and \$3/gal for the United Kingdom, leading therefore in both cases to a higher tax burden on motorists than currently exists.²

Our analysis abstracts from many potentially relevant considerations. One of the most prominent is dependence on oil imports. Adjustment costs during oil price disruptions may not be fully taken into account by energy suppliers or consumers. However, a careful assessment for the United States by Paul N. Leiby et al. (1997) puts the overall external costs from oil dependency at the equivalent of only a few cents per gallon of gasoline. In the United States, monopsony power in the world oil market could justify fuel taxes as part of strategic trade policy; but we expect that U.S. gasoline taxes have much less effect on world oil prices than does U.S. foreign policy. Nonetheless, there remains room for legitimate debate about the role of energy restraint in overall world politics, which is beyond our scope.

We also ignore distributional concerns. However, at least when measures of lifetime income (as opposed to annual income) are used, gasoline taxes appear to be less regressive than is commonly thought (e.g., James M. Poterba, 1991). Furthermore, there is scope for using other policies to offset any adverse distribu-

² A VMT tax has been advocated as a replacement for Oregon's fuel tax by the Road User Fee Task Force (2003), established by the Oregon Legislative Assembly. In the United Kingdom, a more far-reaching plan, endorsed by the government in June 2005, would introduce a nationwide system of variable VMT tax rates (Alistair Darling, 2005; U.K. Department for Transport, 2004).

³ Other considerations we do not address include the industrial organization of the oil industry, tax favoritism for the industry, and consumer myopia. We expect the first two considerations to affect primarily the distribution of economic rents rather than marginal resource costs. Consumer myopia may create a case for regulation rather than pricing if fuel economy is the primary goal (Greene, 1998), but is not particularly relevant to distance-related externalities. There are of course other external costs from motor vehicles, including road damage, noise, water pollution, vehicle and tire disposal, and policing needs. Estimates of these costs are small relative to those from congestion, accidents, and pollution—see, e.g., Mark A. Delucchi (1997), U.S. Department of Transportation (1997, pp. III-12-23, and 2000, section entitled "Other Highway-Related Costs" and Table 10).

tional effects of fuel prices, as arguably is done in Western Europe.³

The paper is organized as follows. Section I describes our analytical model and the optimal gasoline tax formula. Section II discusses parameter values. Section III presents the quantitative results. Section IV discusses model limitations and concludes.

I. Analytical Framework

A. Model Assumptions

Consider a static, closed economy model where the representative agent has utility function:

$$(1) \quad U = u(\psi(C, M, T, G), N) - \varphi(P) - \delta(A).$$

All variables are expressed in per capita terms. C is the quantity of a numeraire consumption good, M is vehicle-miles of travel, T is time spent driving, G is government spending, N is leisure, P is the quantity of (local and global) pollution, and A is severity-adjusted traffic accidents. The functions $u(\cdot)$ and $\psi(\cdot)$ are quasi-concave, whereas $\varphi(\cdot)$ and $\delta(\cdot)$ are weakly convex functions representing disutility from pollution and from (external) accident risk.⁴

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

$$(2) \quad M = M(F, H)$$

where F is fuel consumption and H is a monetary measure of other driving costs that depend on vehicle price and attributes. This function allows for a nonproportional relation between gasoline consumption and VMT. In response to higher gasoline taxes, people will drive less (reduce M) but they will also pay for improved vehicle fuel economy (a substitution from F to

H), through paying for computer-controlled combustion or improved drive train, sacrificing comfort or payload to drive smaller vehicles, etc.

Driving time is determined as follows:

$$(3) \quad T = \pi M = \pi(\bar{M})M$$

where π is the inverse of the average travel speed and \bar{M} is aggregate miles driven per capita. An increase in aggregate VMT leads to more congested roads, so $\pi' > 0$. Agents take π as fixed—they do not take account of their own impact on congestion.

We distinguish two types of pollutants: carbon dioxide (denoted P_F), which is proportional to fuel use, and local air pollutants (denoted P_M), which are proportional to miles driven. The latter type includes nitrogen oxides, hydrocarbons, and carbon monoxide, for which regulations force emissions per mile to be uniform across new passenger vehicles through the installation of abatement equipment. Units for P_F and P_M are chosen so we can combine them as:

$$(4) \quad P = P_F(\bar{F}) + P_M(\bar{M})$$

where $P'_F, P'_M > 0$ and \bar{F} is aggregate fuel consumption per capita. Agents ignore the costs of pollution from their own driving since these costs are borne by other agents.

The term $\delta(A)$ in (1) represents the expected disutility from the *external* cost of traffic accidents. Some accident costs are internal (e.g., own-driver injury risk) and are implicitly included in H . But others, such as pedestrian injuries, travel delays, and a portion of property damages, are not considered by individuals when deciding how much to drive, though they vary with the aggregate amount of driving:

$$(5) \quad A = A(\bar{M}) = a(\bar{M})\bar{M}$$

where $a(\bar{M})$ is the average external cost per mile. The sign of a' is ambiguous: heavier traffic causes more frequent but less severe accidents, as people drive closer together but more slowly.⁵

⁴ The separability of pollution and accidents in (1) rules out the possibility that they could have feedback effects on labor supply. Robertson C. Williams (2002) 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 is not as strong as it might appear, as discussed below in connection with the Ramsey component of the optimal tax.

⁵ We ignore any indirect effects on accident externalities via tax-induced changes in vehicle size. Current evidence

On the production side, we assume that firms are competitive and produce all market goods using labor with constant marginal products.⁶ Producer prices and the gross wage rate are fixed; all these prices are normalized to unity, aside from the producer price of gasoline, which we denote q_F .

Government expenditures are financed by taxes at rates t_F on gasoline consumption and t_L on labor income.⁷ The government budget constraint is:

$$(6) \quad t_L L + t_F F = G$$

where L is labor supply. We take government spending as exogenous so that higher gasoline tax revenues finance labor tax reductions.⁸ The government does not directly tax or regulate any of the three externalities, except as implicitly incorporated in the functions $\delta(\cdot)$, $M(\cdot)$, $\pi(\cdot)$, $P_F(\cdot)$, $P_M(\cdot)$, and $a(\cdot)$.⁹

seems to suggest partially offsetting effects from changes in aggregate fleet composition: a shift from the largest passenger vehicles to moderate-sized vehicles decreases the average severity of accidents, while a shift from moderate to small vehicles increases it. See National Research Council (NRC), 2002, p. 72, and also Ted Miller et al. (1998) and Parry (2004).

⁶ We ignore use of gasoline in production. Only 3.2 percent of the gasoline used for highway travel in the United States is used for medium or heavy trucks (Stacy C. Davis, 2001, Table 2.4), and the majority of light trucks are used as passenger vehicles, so this omission is unlikely to be important.

⁷ We ignore taxes on capital; Bovenberg and Goulder (1997) find that capital market interactions do not greatly alter the welfare costs of gasoline taxes, as gasoline is primarily a consumption good. We also ignore additional deadweight losses due to various income tax deductions and exemptions, and so may understate the attractiveness of using fuel taxes to substitute for income taxes. A rationale for assuming a proportional labor tax is that most response of labor supply to wages arises from changes in labor-force participation.

⁸ If, instead, gasoline-tax revenues were used to finance additional public spending such as on highways, the optimal gasoline tax would be higher (lower) than that calculated here, if the social value of additional spending were greater (less) than the social value of using extra revenue to cut distortionary income taxes. However, if gasoline taxes were ever raised to our computed optimum of a dollar per gallon for the United States, revenues raised would easily exceed highway requirements. Thus the marginal revenue would go to the general government budget (as it already does in the United Kingdom) rather than being earmarked.

⁹ For example, requirements for reformulated gasoline and sturdier bumpers reduce pollution and accident costs,

The agent's budget constraint is:

$$(7) \quad C + (q_F + t_F)F + H = I = (1 - t_L)L$$

where I is disposable income, $1 - t_L$ is the net wage rate, and $q_F + t_F$ is the consumer price of gasoline. Agents are also subject to a time constraint on labor, leisure, and driving:

$$(8) \quad L + N + T = \bar{L}$$

where \bar{L} is the agent's time endowment.

B. Optimal Gasoline Tax Formula

We maximize household utility with respect to the gasoline tax while accounting for changes in the labor tax (to maintain government budget balance), for induced changes in fuel use, VMT, and labor supply, and for utility effects from changes in external costs. The full derivation is in Parry and Small (2004). The result is:

$$(9a) \quad t_F^* = \underbrace{\frac{\text{Adjusted Pigovian tax}}{1 + MEB_L}}_{\text{Ramsey tax}} + \underbrace{\frac{(1 - \eta_{MI})\epsilon_{LL}^c \cdot t_L(q_F + t_F)}{\eta_{FF} \cdot (1 - t_L)}}_{\text{Congestion feedback}} + \underbrace{\frac{\beta M}{F} E^c\{\epsilon_{LL} - (1 - \eta_{MI})\epsilon_{LL}^c\}}_{\text{Congestion feedback}} \frac{t_L}{1 - t_L}$$

but also increase the financial cost of driving and therefore affect $M(\cdot)$ as well as $P_F(\cdot)$, $P_M(\cdot)$, and $a(\cdot)$. We assume that fuel-efficiency standards in the United States would not be binding at the optimal tax rates estimated in this paper, which are well above current rates. An additional reason for this assumption is that even with regulated new-car technology, people may alter fuel efficiency through their choices of vehicle mix, driving habits, and maintenance practice.

where

$$(9b) \quad MEC_F \equiv E^{P_F} + (E^C + E^A + E^{P_M})\beta M/F$$

$$(9c) \quad \beta \equiv \frac{\eta_{MF}}{\eta_{FF}}$$

$$(9d) \quad MEB_L \equiv \frac{-t_L \frac{\partial L}{\partial t_L}}{L + t_L \frac{\partial L}{\partial t_L}} = \frac{\frac{t_L}{1 - t_L} \varepsilon_{LL}}{1 - \frac{t_L}{1 - t_L} \varepsilon_{LL}}$$

$$(9e) \quad E^{P_F} = \varphi' P'_F / \lambda; \quad E^{P_M} = \varphi' P'_M / \lambda;$$

$$E^C = v\pi' M; \quad E^A = \delta' A' / \lambda;$$

$$v \equiv 1 - t_L - u_T / \lambda.$$

In these formulas, η_{MI} is the elasticity of demand for VMT with respect to disposable income, η_{FF} is the own-price elasticity of demand for gasoline, η_{MF} is the elasticity of VMT with respect to the consumer gasoline price, and ε_{LL} and ε_{LL}^C are the uncompensated and compensated labor supply elasticities. All elasticities are expressed as positive numbers (analytical definitions for them are provided in Parry and Small, 2004). λ is the marginal utility of income and v is the value of travel time.¹⁰

In interpreting (9), let us start with MEC_F , the marginal external cost of fuel use. It equals the marginal damage from carbon emissions (E^{P_F}), plus the marginal congestion, accident, and distance-related pollution costs (E^C , E^A , and E^{P_M} , respectively); the latter are expressed per mile and multiplied by miles per gallon M/F and by β , which is the fraction of the gasoline demand elasticity due to reduced VMT. If fuel efficiency were fixed, VMT would change in proportion to fuel use, so that $\eta_{MF} = \eta_{FF}$ and $\beta = 1$. Empirical studies suggest, however, that probably less than half of the long-run price responsiveness of gasoline consumption is due to changes in VMT, i.e., $\beta < 0.5$. This substan-

tially diminishes the mileage-related externality benefits per gallon of reduced fuel consumption.

The optimal gasoline tax in (9a) differs from MEC_F due to three effects arising from interactions with the tax system. The first is that MEC_F is divided by $1 + MEB_L$, where MEB_L is the marginal excess burden of labor taxation.¹¹ This adjustment reflects the fact that gasoline taxes have a narrow base relative to labor taxes, and in this respect are less efficient at raising revenues; it has recently been discussed in the context of environmental externalities (e.g., Bovenberg and Goulder, 1996).

The second effect is the Ramsey tax component. It follows from Angus Deaton (1981) that when leisure is weakly separable in utility, as it is in (1) above, travel is a relatively weak substitute for leisure, provided the expenditure elasticity for VMT, η_{MF} , is less than one (which appears to be the case empirically). Thus, the Ramsey component is a force for taxing gasoline at a higher rate than other consumption—the more so the more price-inelastic is its demand.¹²

The third component of (9a) is the positive feedback effect of reduced congestion on labor supply (cf., Parry and Antonio M. Bento, 2001). Reduced congestion leads to a reallocation of the household's time endowment away from travel toward labor supply and leisure; this is welfare improving to the extent labor supply increases because labor is taxed. This raises the

¹¹ MEB_L equals the welfare cost in the labor market from an incremental increase in t_L , divided by the marginal tax revenue. That welfare cost is the tax wedge between the gross wage (or value marginal product of labor) and net wage (or marginal opportunity cost of foregone leisure), times the induced reduction in labor supply.

¹² This is a familiar result from the theory of optimal commodity taxes (Agnar Sandmo, 1976). Relaxing the weak separability assumption would have the same effect as using a lower (higher) value for η_{MF} , if an income-compensated increase in the wage rate resulted in a higher (lower) ratio of travel to labor supply. Thus we can assess the implications of this assumption via sensitivity analysis on η_{MF} . The Ramsey tax component combines two effects that have been termed the revenue-recycling and tax-interaction effects (e.g., Goulder et al., 1997). The former is the efficiency gain from using gasoline tax revenues to cut the labor tax; the latter is the efficiency loss from the reduction in labor supply, as higher fuel prices erode the real value of household wages. The tax-interaction effect exceeds the revenue-recycling effect, implying a positive Ramsey tax, when the taxed commodity is a relatively weak leisure substitute, as it is in our numerical calculations.

¹⁰ As we see from (9e), travel time involves both an opportunity cost, via (8), and a utility cost. Thus it need not equal the net wage rate. In practice, we use direct empirical measurements of v and so do not depend on the specific definition in (9e).

optimal fuel tax, but only slightly, according to our empirical results in Section IV.

Fuel economy, M/F , is chosen by the consumer and of course depends on the gasoline tax. We approximate this dependence by a constant-elasticity formula:

$$(10) \quad \frac{M}{F} = \frac{M^0}{F^0} \left(\frac{q_F + t_F}{q_F + t_F^0} \right)^{-(\eta_{MF} - \eta_{FF})}$$

where superscript 0 denotes an initial value. We assume all elasticities are constant; the system of equations (6), (9), and (10) can then be solved numerically for t_F and other variables, given values for the various parameters.¹³

Welfare benefits of an incremental tax change can be calculated by computing the total derivative of (1) with respect to t_F and dividing by the marginal utility of income λ . We show in Parry and Small (2004) that the resulting per capita welfare benefits of an incremental tax change, expressed as a proportion of initial pre-tax fuel costs, are:

$$(11) \quad \frac{dW}{dt_F} = (1 + MEB_L) \left\{ \frac{\eta_{FF}}{q_F(q_F + t_F^0)} \frac{F}{F^0} \right\} (t_F^* - t_F)$$

where F^0 is initial per capita fuel consumption. Starting with a current tax rate, we can numerically integrate (11) over t_F to obtain the welfare gain from moving to any other tax rate.

Finally, our equations can also simulate a VMT tax, i.e., a tax on travel distance denominated in cents per vehicle-mile, by modifying them so that travel changes exactly in proportion to fuel use. As shown in Parry and Small

(2004), this modification is accomplished by setting $\beta = 1$ (so that $\eta_{FF} = \eta_{MF}$), setting η_{MF} at the same value as used in the fuel-tax calculations, and holding fuel efficiency constant.¹⁴ The VMT tax has a greater impact on reducing externalities than the fuel tax, per dollar of revenue raised, as most externalities are mileage-related. In addition, the own-price elasticity is smaller for VMT than for fuel use because of fewer substitution possibilities, so the revenue-raising function of the VMT tax is more efficient. These effects result in higher values for the Adjusted Pigovian and Ramsey tax components in (9a), as is easily seen by setting $\beta = 1$ and decreasing the value of η_{FF} ; this more than compensates for the smaller congestion feedback effect caused by the smaller value of M/F under the VMT tax.

II. Parameter Values

Our parameter values are based on comprehensive reviews of the relevant literatures, as detailed in Parry and Small (2004). Here we summarize only the main points.¹⁵ For most

¹⁴ In our numerical calculations we assume that both the fuel tax and any fuel efficiency standards are replaced by the VMT tax, so that fuel efficiency is set at the value given by (10) with $t_F = 0$. Under these assumptions, the VMT tax rates that we consider in Section III result in the same or less aggregate fuel consumption as that in the initial situation, making it plausible that fuel efficiency standards might be scrapped as part of a deal to institute a VMT tax.

¹⁵ Additional parameters not detailed in the text include the following. Data for the late 1990s show average on-road fuel efficiency (M_0/F_0) at about 20 and 30 miles/gal for passenger vehicles in the United States and United Kingdom, respectively. Based on the large empirical literature on labor supply elasticities (e.g., Richard W. Blundell and Thomas MaCurdy, 1999), we assume $\epsilon_{LL} = 0.2$ and $\epsilon_{LL}^c = 0.35$ for both countries. Estimates of the expenditure elasticity for VMT (η_{MV}) are typically between about 0.35 and 0.8, based on Don Pickrell and Paul Schimek (1997); expecting it to be a little higher in the United Kingdom (there is more room there for vehicle ownership to grow and more opportunity for mode shifts to and from public transport), we set its central value at 0.6 for the United States and 0.8 for the United Kingdom, with plus or minus half this value as the range. We assume that the ratio of total government spending to GDP is 0.35 for the United States and 0.45 for the United Kingdom, based on adding the average labor and consumption tax rates given by Enrique G. Mendoza et al. (1994). For the producer price of gasoline (q_F), we use 94 cents/gal and \$1.01/gal for the United States and United Kingdom, respectively.

¹³ The other variables determined as part of the solution include F , M , t_L , L , and G . Two additional relationships are required, which we choose as follows. First, F depends on fuel price ($q_F + t_F$) with constant elasticity $-\eta_{FF}$. Second, from (6), $t_L = G/L - t_F F/L$, with F determined solely by the tax rate. To simplify calculations, we hold L constant in this calculation, and we also hold M constant at its initial value in (9e) so that the congestion externality is constant. Because labor supply and vehicle-miles traveled are not very sensitive to the policies considered, these simplifications do not significantly affect our calculation of optimal fuel-tax rates.

parameters we specify a central value and also a plausible range; the latter is intended as roughly a 90-percent confidence interval. Where possible, we adjust U.S. and U.K. studies for cross-national comparability and update to U.S. dollars at year-2000 price levels.¹⁶

A. Pollution Damages, E^{P_M} and E^{P_F}

U.S. studies suggest that local pollution costs—which are dominated by health costs—are roughly 0.4–5.4 cents/mile for automobiles typical of the year-2000 fleet, with a central value of 1.9 cents/mile (USDOT, 2000). European studies give similar if slightly smaller results. We use the same values for both countries, namely a central value of 2 cents/mile with range 0.4–10. Global warming costs are much more speculative; nevertheless a large number of studies overwhelmingly support the upper limit of \$50/tC (metric ton carbon) suggested by Richard S. J. Tol et al. (2000, p. 199).¹⁷ A few authors argue for much higher values by assuming a zero rate of time preference. We take the central value to be \$25/tC (6 cents/gal) with range \$0.7–100 (0.2–24 cents/gal).

B. External Congestion Cost, E^C

Only a few studies estimate marginal external congestion costs averaged across time and place. One is by David M. Newbery (1990), who estimates them for the United Kingdom at the equivalent of roughly 10–12 U.S. cents/mile (after being updated by us to 2000). For the United States, studies suggest middle values of 2.5 to 5 cents/mile, with a considerable range of uncertainty.¹⁸ Probably some of the cross-

country difference reflects different assumptions, but some is caused by higher population density and urbanization in the United Kingdom. These estimates should be adjusted downward for our purposes because driving on congested roads (which is dominated by work trips) is less sensitive to changes in fuel prices than driving on uncongested roads, and it is the former that mainly affects the value of E^C . We therefore adopt central values somewhat below those implied by the studies just cited, and somewhat closer together: namely 3.5 and 7 cents/mile for the United States and United Kingdom, respectively. We consider ranges of 1.5–9 cents/mile for the United States and 3–15 cents/mile for the United Kingdom.

C. External Accident Cost, E^A

Several researchers have found average costs of motor vehicle accidents to be quite large, comparable to time costs (Newbery, 1988; Small, 1992). However, highway injuries have declined significantly since the studies of the 1980s due to improved vehicle safety. And most of these costs are not external: drivers presumably take into account the uninsured portions of risks to themselves and probably to other family members, while traffic laws and graduated insurance rates create penalties that drivers may perceive as costs incurred on an expected basis. Furthermore, as already noted, it is not clear that a' in equation (5), relating severity-adjusted accident rates to total travel, is positive—i.e., it is not clear that marginal external accident costs are any larger than average external accident costs.¹⁹ Taking these considerations into account, evidence from three recent reviews suggests to us a value for marginal external accident costs in 2000 of 3 and 2.4 cents/mile as the central estimates for the United States and United Kingdom, respectively.²⁰ In each case,

¹⁶ We update the studies to 2000 prices in their own currencies, then apply the end-2000 exchange rates of U.K.£1 = U.S.\$1.40 and €1 = U.S.\$0.90.

¹⁷ David Pearce (2003) finds the most plausible estimates to be in the range \$6.5–40.5/tC after adjusting both for equity weighting and time-varying discount rates. ECMT (1998, p. 70) cites estimates ranging from \$2–\$10/tC. William D. Nordhaus and Joseph Boyer (2000, p. 175) find an upper limit of \$15 per ton.

¹⁸ See, especially, Delucchi (1997) and USDOT (1997). By way of comparison, Mayeres (2000, Table 5) obtains marginal congestion costs for Belgium equivalent to around 12 cents/mile.

¹⁹ See, for example, Lasse Fridstrøm and Siv Ingebrigtsen (1991), Newbery (1990), and Small and Jose A. Gomez-Ibanez (1999).

²⁰ The reviews we rely upon are Delucchi (1997), USDOT (1997), and Newbery (1988) (the last corrected for a transcription error from an earlier working paper). The main reasons for a higher cost in the United States than the United Kingdom are that U.S. motorists apparently have a greater willingness to pay for reduction in injury and death,

TABLE 1—BENCHMARK CALCULATIONS OF THE OPTIMAL GASOLINE TAX RATE
(All figures in cents/gal at U.S. 2000 prices)

	United States	United Kingdom
Elements in equation (2.9)		
Fuel efficiency, M/F (miles/gal)	22.6	25.6
Marginal external cost, MEC_F	83	123
Pollution—fuel component, E^{PF}	6	6
Pollution—distance component, $E^{PM} \cdot \beta M/F$	18	20
Congestion component, $E^C \cdot \beta M/F$	32	72
Accident component, $E^A \cdot \beta M/F$	27	25
Adjustment to MEC_F for excess burden, $MEC_F \cdot [(1 + MEB_D)^{-1} - 1]$	-9	-19
Components of optimal gasoline tax rate		
Adjusted Pigovian tax	74	104
Pollution, fuel-related	5	5
Pollution, distance-related	16	17
Congestion	29	61
Accidents	24	21
Ramsey tax	26	23
Congestion feedback	1	7
Optimal gasoline tax rate (t_F^*)	101	134
Naive gasoline tax rate, ^a MEC_F	176	348

^a The naive rate is MEC_F computed from (9b) with $M/F = M^0/F^0$ and $\beta = 1$.

we divide the central estimate by 2.5 to get the low estimate, and multiply by 2.5 for the high estimate.

D. Gasoline Price Elasticities, η_{FF} and η_{MF}

The many time-series and cross-sectional studies of demand for gasoline generally find price elasticities between 0.5 and 1.1 in magnitude before 1990, but much lower values later, with a best estimate proposed by the U.S. Department of Energy (USDOE, 1996) of 0.38.²¹ We adopt a compromise value for η_{FF} that is somewhat closer to the recent estimates, namely 0.55, with a range 0.3 to 0.9.

Studies of the response of total vehicle travel

and the United States has a higher average fatality rate from motor vehicles.

²¹ Reviews of the earlier studies include Carol Dahl and Thomas Sterner (1991) and Phil B. Goodwin (1992). The lower values from more recent studies occur partly because those studies better control for corporate average fuel economy standards, correlation between vehicle age and fuel economy, and geographical correlation between fuel price and other variable costs of driving. In addition, the share of gasoline in the total costs of driving has come down.

to fuel prices typically get much lower long-run elasticities, mostly between 20 and 60 percent of η_{FF} .²² We choose a central value for β of 0.4, and a range of 0.2 to 0.6. This central value is close to the recommendations of Olof Johansson and Lee Schipper (1997) and USDOE (1996).

III. Empirical Results

A. Optimal Tax Rates

As shown in Table 1, under our central parameters the optimal gasoline tax is \$1.01/gal for the United States, more than twice the current rate, and \$1.34/gal for the United Kingdom, less than half the current rate. Thus, according to these estimates, the tax rate is justifiably higher in the United Kingdom than in the United States, but the current size of the difference is much too large. The difference between

²² Examples include Goodwin (1992, Table 2); James Luk and Stephen Hepburn (1993); USDOE (1996, pp. 5-83 to 5-87); Paul Schimek (1996); Johansson and Schipper (1997); and Greene et al. (1999, pp. 6-10).

TABLE 2—WELFARE EFFECTS OF GASOLINE TAX RATES USING BENCHMARK PARAMETERS
(Relative to current rate, expressed as percent of initial pretax fuel expenditures)

Fuel tax rate	United States		United Kingdom	
	Rate (cents/gal)	Welfare change (percent of pretax expenditure)	Rate (cents/gal)	Welfare change (percent of pretax expenditure)
0	0	-21.2	0	-51.2
$0.50t_F^*$	50	2.7	67	11.4
$0.75t_F^*$	76	6.4	100	20.3
Optimal rate (t_F^*)	101	7.4	134	22.7
$1.25t_F^*$	126	6.6	167	21.0
$1.50t_F^*$	151	4.7	201	16.5
Naive rate ^a (MEC_F^1)	176	1.9	348	-17.9

^a See note to Table 1 for definition.

the calculated optima in the two countries is due primarily to the higher assumed congestion costs for the United Kingdom. Of the three externalities included in MEC_F , congestion is easily the largest component in the United Kingdom but only slightly larger than accidents and air pollution in the United States. The global warming component is the smallest of the four externalities and would remain so even if we were to triple our central estimate of global warming costs.

On net, fiscal interactions raise the optimal tax above the marginal external cost, MEC_F , by 9 to 22 percent. For example, in the United States, $MEC_F = 83$ cents/gal. It gets adjusted downward by 9 cents/gal for excess burden (i.e., for the relatively narrow base of the gasoline tax compared to a labor tax), then upward by a Ramsey tax component of 26 cents/gal and by a congestion feedback effect of 1 cent/gal.

Finally, if we had naively assumed that VMT changes in proportion to fuel use ($\beta = 1$), and ignored fiscal interactions, estimated optimal taxes would have been dramatically higher, at \$1.76/gal for the United States and \$3.48/gal for the United Kingdom (see last row of Table 1). This underscores the crucial importance of properly modeling endogenous fuel economy.

B. Welfare Effects

Table 2 shows the welfare effects of the second-best optimum t_F^* and the “naive” value just described. Raising the U.S. tax from its current rate (40 cents/gal) to the optimal rate (\$1.01/gal) would yield a welfare gain equal to

7.4 percent of initial pre-tax fuel expenditures. Raising it to the naive rate (\$1.76/gal), by contrast, would overshoot the optimal rate so much as to yield very little net benefit. For the United Kingdom, reducing the current tax (\$2.80/gal) to the optimal (\$1.34/gal) would yield a welfare gain of 22.7 percent of pre-tax gasoline expenditures, while increasing the tax to the naive rate of \$3.43 would create a welfare loss of nearly 18 percent of pre-tax expenditures.

C. VMT Tax

Table 3 shows results for a VMT tax. In row A we replace the existing fuel tax with a VMT tax of equal revenue yield²³ and in row B we consider the optimized VMT tax. For both nations, the optimal VMT tax is very high, around 15 cents per vehicle-mile. It brings in much more revenue than the optimal fuel tax: 1.7 and 2.5 times as much in the United Kingdom and United States, respectively (not shown in the table). The welfare gains from imposing it are also considerable: for the United States, they are nearly four times those from raising the current fuel tax to its optimal level. For the United

²³ As shown in Parry and Small (2004), the equal-revenue rate is $t_F^0 F/M$, where t_F^0 is the initial fuel-tax rate and F/M is the value of fuel economy chosen with the fuel tax eliminated (17.7 miles/gal for the United States, 19.4 for the United Kingdom). At this rate, the VMT tax results in greater fuel intensity (gallons per VMT) but less travel (VMT) than in the initial fuel-tax regime, in just such a way that aggregate fuel consumption remains unchanged and so does aggregate revenue.

TABLE 3—VMT TAX: BENCHMARK PARAMETERS

VMT tax rate	United States			United Kingdom		
	VMT tax rate (cents/mile) ($t_F^v F/M$)	Equivalent fuel tax rate ^a (cents/gal) (t_F^e)	Welfare change ^b (percent of pretax fuel expenditure)	VMT tax rate (cents/mile) ($t_F^v F/M$)	Equivalent fuel tax rate (cents/gal) (t_F^e)	Welfare change ^b (percent of pretax fuel expenditure)
A. Equal-revenue ($t_F^0 F/M$)	2.25	40	1.0	14.5	280	27.4
B. Optimal ($t_F^{*v} F/M$)	14.0	248	28.4	15.5	300	27.5
Components of t_F^{*v} :						
Adjusted Pigov. tax		142			193	
Ramsey tax		104			94	
Congestion feedback		2			13	

^a The quantity t_F^v is a fuel-tax equivalent to the VMT tax, defined as the VMT tax rate times M/F . Its optimal value t_F^{*v} is obtained from equation (9a) with $\beta = 1$, with M/F held at its value when $t_F = 0$, and with η_{FF} set to the measured empirical value of η_{MF} .

^b Welfare effect of replacing the initial fuel tax by a VMT tax at the rate shown. It is obtained first by calculating the welfare change from reducing the fuel tax to zero, then adding the welfare change from increasing the VMT tax to the value under consideration.

Kingdom, the fact that an optimal VMT tax would raise the overall tax burden on motorists stands in sharp contrast to the optimized fuel tax.

Even a revenue-neutral shift of taxes from gasoline to VMT is a very attractive policy for the United Kingdom. The resulting tax rate of 14.5 cents/mile is only a little lower than the optimal VMT tax, and the welfare gains from imposing it while eliminating the current fuel tax are still larger than those from optimizing the gasoline tax.

Table 3 also shows a breakdown of the optimal VMT tax (converted to a per-gallon equivalent) into the three components listed in equation (9a). This breakdown reveals that the Ramsey component plays a relatively larger role here: it accounts for 42 percent of the optimal rate in the United States and 31 percent in the United Kingdom. This is because the VMT elasticity with respect to fuel cost is quite small, 0.22 in our base calculations, making VMT a more attractive target than fuel for a Ramsey tax.²⁴

D. Sensitivity Analysis

In Figure 1, we vary each of the six most important parameters across their specified

ranges one at a time, holding all other parameters at their central values (“X” denotes the benchmark optimal tax). In most cases, optimal taxes vary by around \$1.00/gal or less as we cover the range of each parameter. Results are more sensitive to congestion costs, due to their dominance in the optimal tax calculation. U.K. results are also especially sensitive to β , the fraction of the gasoline demand elasticity accounted for by changes in VMT; this is because β multiplies mileage-related externalities, which are larger for the United Kingdom. Still, in every case shown the optimal tax rate is greater than its initial value in the United States, and less than its initial value in the United Kingdom.

To give a sense of how likely different outcomes might be, we performed some simple Monte Carlo simulations, with parameters for external costs and the VMT portion of the gasoline demand elasticity drawn at random 1,000 times from selected distributions using our parameter ranges as 90-percent confidence intervals.²⁵ Table 4 shows the frequencies with which the optimal tax is less than a given value in these simulations. For the United States, the probability that the optimal tax is less than the

²⁴ For more details on these calculations and additional results, see Parry and Small (2004).

²⁵ To avoid solving simultaneous equations, we kept fiscal adjustments constant and equal to their values in the benchmark calculations; hence optimal taxes are approximate. See Parry and Small (2004) for details.

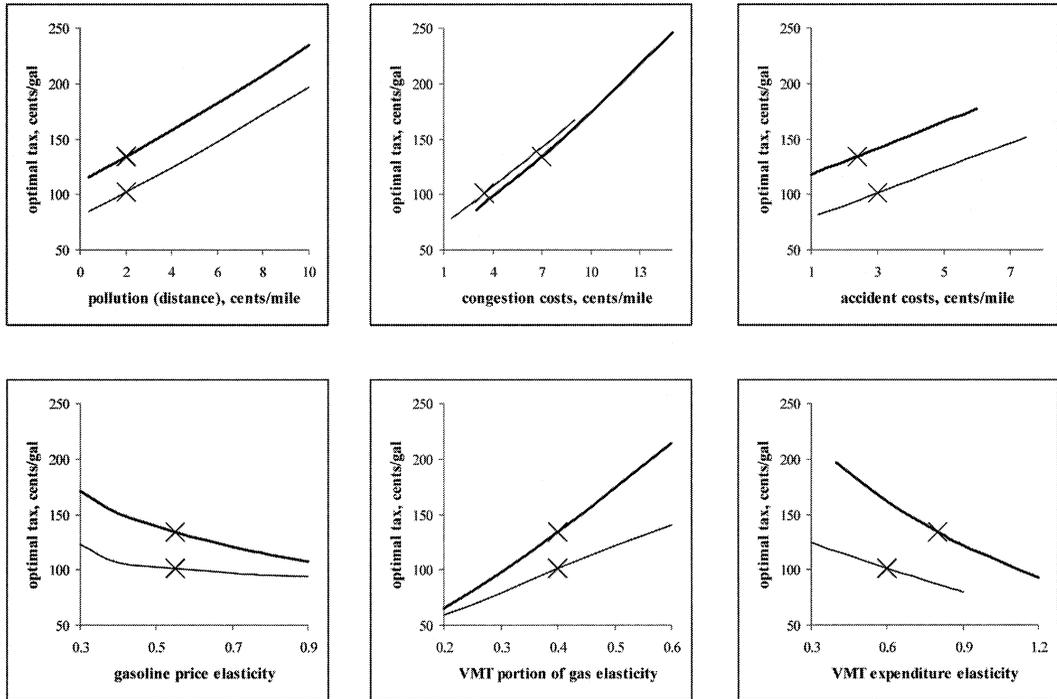


FIGURE 1. SENSITIVITY OF OPTIMAL GASOLINE TAX TO PARAMETER VARIATION
(— US — UK)

TABLE 4—MONTE CARLO RESULTS FOR APPROXIMATE OPTIMAL GASOLINE TAX

United States		United Kingdom	
Amount in U.S. cents/gallon (X)	Probability that $t_F^* < X$	Amount in U.S. cents/gallon (X)	Probability that $t_F^* < X$
25	0	50	0
40	0.01	100	0.30
75	0.29	150	0.68
100	0.58	200	0.90
150	0.89	280	0.98

current tax of 40 cents/gal is only 0.01; while for the United Kingdom, the optimal tax is below the current tax of \$2.80/gal with probability 0.98.

IV. Conclusion

Our best assessment is that the optimal gasoline tax for the United States is more than double its current rate, while that for the United Kingdom is about half its current rate. The most important

externality is traffic congestion; but the fuel tax turns out to be a rather poor means of controlling distance-related externalities like congestion because it is too indirect, causing greater shifts in fuel economy than in amount of travel. A direct tax on amount of travel (vehicle-miles) performs far better in both nations, especially in the United Kingdom, where a switch from fuel to vehicle travel as the tax base, even with no change in overall tax burden on travel, has greater benefits than any possible change in the fuel-tax rate.

It seems unlikely that current fuel taxes in either nation, or their difference, could be explained as optimal by using a broader notion of social welfare that took account of distributional weights.²⁶

²⁶ Ehtisham Ahmad and Nicholas Stern (1984) show how to estimate a set of distributional weights that might justify observed commodity tax systems, calling the procedure the “inverse optimum problem.” In their Indian application, they found that no such set of positive weights existed, indicating unexploited opportunities for improving social welfare, which they took as evidence of political rather than distributional explanations for some features of the tax system.

Leaving aside externalities, a heavy reliance on fuel taxes might be appropriate if gasoline is consumed disproportionately by high-income groups and they are given low distributional weights. However, studies find that budget shares for gasoline are either constant or mildly declining with income across U.S. households, especially with measures of lifetime income (Poterba, 1991; Howard Chernick and Andrew Reschovsky, 1997). Probably the gasoline tax is somewhat more progressive in the United Kingdom, where auto ownership is less widely distributed, but not to the extent of justifying such a high tax rate.

High fuel taxes might also be justified if those benefiting from externality mitigation have a higher welfare weight than those bearing the burden of the tax. However, it is essentially the same group—motorists—who both pay the fuel tax and suffer from the most important externalities, namely congestion and accidents. Furthermore, the cost of both of these externalities probably rises with income due to higher willingness to pay for time and safety.

Most likely, the explanations for the current rates lie in political factors. There are several possibilities. First, the more politically decentralized and ethnically diverse United States has maintained both a lower overall tax burden and a system of “checks and balances” on central government, including rules dedicating most highway-related tax revenues to highway expenditures. Thus, there is less pressure in the United States to find administratively convenient revenue sources such as the fuel tax, and it is difficult to justify a tax rate above that required to fund the highway system. Second, low population density and less available public transit in the United States mean that motor vehicle use is widespread; fuel taxes are therefore very visible to a broad spectrum of citizens. Third, the United States has many sources of petroleum, the exploitation of which involves politically important business interests. These interests, along with construction and automobile manufacture, form the core of the famous “highway lobby,” which has historically supported policies favoring motor vehicle transportation and opposing strong measures to achieve fuel economy. The United Kingdom has neither the same breadth in its oil industry nor a comparably strong automobile manufacturing industry. The strength of these political factors is

supported by the evidence of Henrik Hammar et al. (2004) that high gasoline consumption Granger-causes low gasoline price, rather than vice versa, based on data from 22 OECD nations over the period 1978–2000.

Paradoxically, the prospects are remote in either nation for substantial movement toward an optimal fuel tax. In the United States, the Clinton Administration achieved an increase in the federal gasoline tax rate of only 4 cents/gal in 1993, despite a major effort. In the United Kingdom, the Conservative Party’s 2001 election pledge to cut gasoline taxes by 6 pence/liter (32 cents/gal) failed to resonate with an electorate concerned about funding public services. Thus, political as well as economic arguments may favor attempts to move from a fuel-based tax toward a mileage-based tax, rather than trying to optimize the fuel tax.

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