DISCUSSION PAPER

December 2006 ■ RFF DP 06-14 REV

Are the Costs of Reducing Greenhouse Gases from Passenger Vehicles Negative?

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RESOURCES
FOR THE FUTURE

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Abstract

Energy models suggest that the costs of reducing carbon emissions from transportation are high relative to those for other sectors. This paper discusses why taxes (or equivalent permit systems) to reduce passenger vehicle emissions produce large net benefits, rather than costs, when account is taken of (a) their impact on reducing other highway externalities besides carbon and (b) interactions with the broader fiscal system. Both of these considerations also strengthen the case for a tax-based approach over fuel economy regulation, while fiscal considerations strengthen the case for taxes over grandfathered emissions permits. The paper also comments on the practical relevance of automobile fuel taxes, or their policy equivalents, to broader legislation intended to mitigate climate change.

Key Words: carbon policies, passenger vehicles, externalities, welfare costs

JEL Classification Numbers: Q54, R48, H23

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1. Introduction

U.S. policymakers face growing domestic and international pressure to control greenhouse gas emissions in light of solidifying scientific consensus that global warming is occurring, various state-level initiatives to control emissions, and the birth of carbon trading in Europe. Understanding the costs of alternative emissions control proposals is critical both for balancing economic and environmental objectives, and for achieving environmental objectives at lowest cost.

The costs to the United States of a nationwide carbon tax or cap-and-trade system have been estimated from various energy models. Although estimates differ widely, one robust finding is that the marginal costs of a given percentage reduction in emissions from transportation fuels (or petroleum more broadly) are much larger than the corresponding marginal costs in the power sector.[1] One reason for this is that possibilities for substituting alternative fuels for conventional motor fuels are currently limited; another is that, because of different carbon intensities, a carbon tax has a relatively larger effect on the cost of energy from coal-fired generation than from transportation fuels.[2]

Those studies pay little attention to preexisting distortions in the economy; however, as long recognized in public finance (e.g., Lipsey and Lancaster 1956–57; Harberger 1974) the magnitude and even the sign of the welfare impact of a new policy can be critically affected when second-best considerations are taken into account. One preexisting distortion is noncarbon externalities from automobiles that fall with higher fuel prices, including local pollution, energy security, congestion, and accidents; a new tax on the carbon content of gasoline, or a cap-and-trade policy imposed on refined gasoline, may involve *negative* efficiency costs if the preexisting gasoline tax is below combined per

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[*] Resources for the Future, 1616 P Street N.W., Washington, D.C. 20036. Phone (202) 328-5151; email parry@rff.org; web www.rff.org/parry.cfm. This paper was prepared for a special issue of the *Journal of Urban Economics* to honor the distinguished career of one of the world's leading transportation economists, Ken Small. I am grateful to Joe Aldy, David Brownstone, Jan Brueckner, Richard Newell, and two reviewers for very helpful comments on an earlier draft. And I am especially fortunate to have worked with, and learned from, one of my favorite economists, Ken Small, on other projects; he has done so much to improve the field of transportation economics and is an outstanding colleague.

[1] For discussions of different energy models, see *The Energy Journal 1999*, special issue, *The Costs of the Kyoto Protocol*, Conrad (2002), Fischer and Morgenstern (2003), Ghersi and Toman (1999), and Repetto and Austin (1997).

[2] A further possibility is that low-cost, fuel-saving technologies may have already been adopted in transportation because of higher energy taxes relative to other sectors.

gallon costs from these externalities. Moreover, new policies interact with distortions created by the broader fiscal system: if revenues from carbon taxes (or permits if they are auctioned) are used to reduce labor income taxes, labor supply can increase overall, leading to a further efficiency gain, if gasoline is a relative complement for leisure (Sandmo 1976; Christiansen 1984).

Objections have been raised to that line of argument. One is that noncarbon externalities are better addressed through other instruments, so why include them in an evaluation of carbon policy? If other externalities were perfectly internalized (e.g., through peak-period pricing on every road link in urban areas), welfare gains would be a lot larger than from indirectly mitigating them via carbon policy, and they would become irrelevant to the welfare effects of carbon policy. However, until these ideal policies have been fully implemented—which might be quite a while—carbon policies still improve welfare by mitigating other externalities, and this must be accounted for in an unbiased welfare assessment of near-term carbon policies.

As for labor tax distortions, it might be argued that these are a necessary cost to pay for needed public expenditure, so why are they relevant for carbon policy? But again, the unavoidable point is that if labor supply is at all responsive to carbon policy, there will be a welfare change in the labor market that needs to be included in the overall welfare evaluation of the carbon policy; whether that efficiency effect is large or small is mainly an empirical issue.

Skeptics of higher automobile fuel taxes raise two concerns about the practical value of studying them: first, that auto companies and other interest groups will likely stave off any attempt to increase taxes, and second, that even if they do not, the government may not use the extra revenues wisely. Do revenue-neutral fuel taxes, or the auctioned permit equivalent, have any relevance to current political debate?

Despite pledges by both candidates in the 2004 presidential election not to raise fuel taxes, it seems increasingly likely that legislation will move forward to implement a broad carbon cap-and-trade system, which will raise gasoline prices in the same way that a carbon tax would.[3] Moreover, it is now widely appreciated that if those permits were grandfathered to emissions sources, they would confer enormous profits on energy industries (and their relatively well-off stockholders) at the expense of energy consumers (e.g., Bovenberg et al. 2005). Some recent bills therefore propose grandfathering only a small amount of permits to affected industries to prevent their profits from declining; these proposals are almost equivalent to (modestly) raising gasoline taxes (in conjunction with taxes on other fossil fuels), with revenues retained by the government.

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[3] This applies to the upstream programs proposed in bills H.R. 6 and H.R. 5049, sponsored by Senator Jeff Bingaham and Representative Tom Udall, respectively.

The second concern may have some historical validity. Becker and Mulligan (2003) find that revenue windfalls have financed extra public spending more often than tax cuts in the past; if these decisions are driven more by political rather than by benevolent, welfare-maximizing motives, worries about revenues from new fuel taxes, or equivalent policies, are well founded.[4]

However, what matters are the details on permit allocation in the specific legislation before Congress. Admittedly, of the nongrandfathered permits, typically only a few are left aside for auctioning, with the revenues usually accruing to the Treasury; other permits are used to compensate low-income energy consumers, help displaced workers, or fund climate technology programs. Nonetheless, there is an elephant in the room, one that may ultimately tip the scales in favor of a lot more auctioning—the looming retirement of the baby-boom generation, which will likely force future governments to find new revenue sources to counteract growing pressure on the Medicaid and Social Security systems (Rangel 2005). To the extent that permit revenues help plug the deficit, they are effectively lowering tax burdens on future generations.

Meanwhile, as climate bills move forward in Congress, the academic community is becoming increasingly vocal in its advocacy of gasoline and carbon taxes that might be implemented either alongside or in place of the quantity-based approaches in current legislation (see Nordhaus 2006 and contributing members of the “Pigou Club” at Gregory Mankiw’s blog). With this backdrop, understanding the welfare effects of revenue-neutral automobile fuel taxes (or their equivalents), and how they compare with other policies that might be used to control vehicle emissions, is of more than academic interest.

Several recent studies relying on simple models, rather than disaggregated energy or computable general equilibrium models, have explored, in isolation, the welfare effects of certain automobile policies, accounting for highway externalities or fiscal interactions or sometimes both.[5] This paper does not add any major methodological innovations to the literature. Rather, its two purposes are first, to synthesize previous results by comparing, on a consistent basis, the welfare costs or benefits of a broad range of alterative policies to reduce passenger vehicle emissions; and second, to derive simple and intuitive rules

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[4] This seems to be less of a problem in European countries, where a variety of environmental tax shifts have recently been implemented; in fact, political parties in the United Kingdom are now frantically outbidding each other with promises of using green tax revenues to lower the personal tax burden. In contrast, however, the European Trading System in the European Union is essentially a grandfathered scheme; in the first phase of the program, member states could auction no more than 5 percent of their permit allocation.

[5] See Parry and Small (2005) on gasoline and mileage taxes, and West and Williams (2004) on gasoline taxes, with prior externalities and fiscal interactions; Austin and Dinan (2005), Kleit (2004), and Parry et al. (2004) on fuel economy standards with prior externalities; and West and Williams (2005) on fuel economy standards with fiscal interactions.

of thumb (which are not explicit in other studies) for approximately adjusting welfare estimates from large-scale energy models to account for interactions with pre-existing distortions.

Briefly, reducing carbon emissions from passenger vehicles may result in very large net benefits (excluding the climate benefits), rather than large costs, when noncarbon externalities and broader fiscal interactions are taken into account. This applies to revenue-neutral emissions or fuel taxes, and even more so to mileage taxes, which have a more direct impact on reducing the two largest external costs—traffic congestion and accidents. However, this result is unlikely for grandfathered carbon emissions permits, or, equivalently, a gasoline voucher system (Feldstein 2006), which do not directly raise revenues for the government and therefore forgo the opportunity for efficiency gains from using extra revenue to reduce labor taxes. As for fuel economy standards, second-best considerations increase rather than reduce overall costs, as they slightly increase (rather than reduce) per mile driving costs and raise no revenues; thus, they perform badly relative to other policies in our analysis.

Clearly, there are important dimensions to instrument choice that are beyond our scope. For example, uncertainty over abatement costs and household equity effects also seems to favor carbon taxes over grandfathered permits (e.g., Pizer 2002; Dinan and Rogers 2002). Moreover, to the extent there are spillover benefits within the auto sector or to other countries, such as China, from new technologies induced by emissions control policies, welfare gains are larger than estimated here. And fuel economy regulations may address a market failure due to consumer undervaluation of fuel economy, in which case we overstate efficiency costs for this policy (e.g., Greene 1998); however, whether there is a quantitatively important market failure remains an open empirical issue.

Nonetheless, leaving aside those issues *and the benefits from reducing carbon emissions* (Nordhaus and Boyer 2000, Tol 2005) there is a solid efficiency case for higher taxes on automobile fuel or use to reduce emissions, or their permit equivalents, so long as revenues do not end up financing pork-barrel spending. Given that existing climate bills would only moderately affect fuel prices (e.g., even a $50 carbon price translates into only 12 cents per gallon of gasoline), supplementary measures (preferably taxes) targeted at the transportation sector may be appropriate.

The rest of the paper is organized as follows. In Sections 2 and 3 we use a graphical approach to explain how noncarbon externalities and fiscal considerations, respectively, alter the costs of policies to control automobile emissions; we also derive formulas for welfare effects and implement them based on a best assessment of parameter evidence. A concluding section elaborates on distributional effects, additional complications in the balance between commodity and income taxes, broader fiscal distortions, R&D issues, and second-best issues in other carbon-emitting sectors.

2. The Role of Noncarbon Externalities

2.1. Carbon Tax

According to general equilibrium public finance, the welfare effects of a product tax can be calculated from changes in consumer benefits and producer costs in the market affected by the tax, assuming (for now) there are no other distortions in the economy (Harberger 1974, ch. 2, 3). Figure 1 depicts the market for gasoline, *G*, where the height of the demand curve reflects private benefits to motorists from mileage per extra gallon, net of travel time, insurance, vehicle purchase and maintenance costs, etc., and the supply curve is perfectly elastic and defined inclusive of a preexisting gasoline tax of t_G.[6] These are long-run curves; that is, we are comparing annual steady-state gasoline use with different fuel prices, after full turnover of the vehicle fleet. We assume, for simplicity, that all price coefficients are constant over the relevant range; this should not introduce any substantial error, given that we consider relatively modest quantity changes.

Suppose a carbon tax of t_C per ton is levied, which raises the gasoline price from p_G^0 to $p_G = t_C z + p_G^0$, where *z* is carbon content per gallon. The efficiency cost of this tax (ignoring externality benefits) consists of the usual Harberger triangle, *abc* in Figure 1, plus rectangle *bcgf*, equal to the quantity reduction ΔG times the distortion between marginal consumer benefit and the (pretax) marginal fuel supply cost.

Now suppose gasoline use involves a noncarbon external cost per gallon defined by

$$E_G + E_M \beta \qquad (2.1)$$

E_G denotes an external cost that varies in proportion to gasoline use, namely the cost of oil dependence (see below). E_M denotes costs (in cents per gallon) of externalities that vary with miles driven but not fuel economy, including traffic congestion, accidents, and local pollution from tailpipe emissions, which are regulated on a grams per mile basis.[7] β, which is assumed constant, is the fraction of a price-induced

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[6] Besides the tax, the height of the supply curve reflects the costs of crude oil purchase (currently around \$1.40 per gallon) and fuel refining (around \$0.30–\$0.50 per gallon). State and local sales taxes amount to around \$0.18 per gallon; however, since these taxes apply to most other consumption goods, they do not affect the price of gasoline relative to other goods.

In practice, the supply curve may have a slight upward slope because the United States has limited monopsony power in the world oil market; this is accounted for in our estimate of energy security costs below. Constraints in refinery capacity may also create some modest market power, though we are not aware of solid evidence on this. Finally, we do not discuss diesel because (unlike in Europe) this accounts for a small amount of passenger vehicle fuel.

[7] Emissions standards are the same for all new cars, and therefore (assuming standards are binding and control technologies are durable) an improvement in new vehicle fuel economy will have no effect on local emissions; standards for light trucks are currently being harmonized with those for cars. We ignore local damage from upstream emissions leakageas, according to NRC (2002), this is only 2 cents per gallon.

reduction in fuel use due to reduced driving, as opposed to long-run improvements in average vehicle fuel economy; the smaller is β, the smaller the mileage-related externality benefits per gallon reduction of fuel (Parry and Small 2005). The carbon tax produces externality benefits of rectangle *decb* in Figure 1; at the margin the carbon tax is now welfare improving (leaving aside climate benefits) up to where $t_G + t_C z = E_G + E_M \beta$.

The marginal welfare cost of the carbon tax can be expressed as follows (see Appendix):

$$(2.2) \qquad MC^{TAX} = -\left\{\frac{E_G + \beta E_M - t_G}{z}\right\} - \frac{p_G^0}{z\eta_{GG}}\frac{\Delta Z}{Z^0}$$

where $Z = zG$ is emissions, and $\eta_{GG} = (dG/dp_G)p_G^0/G^0$ is the price elasticity of gasoline demand (evaluated at $t_C = 0$). MC^{TAX} has a negative intercept equal to the difference between the marginal external cost of fuel use and the preexisting gasoline tax, expressed per ton of carbon. The slope of MC^{TAX} is steeper (a) the more inelastic the demand for gasoline, as this implies it is increasingly costly for motorists to conserve on fuel, and (b) the smaller is z, as this implies a larger reduction in gasoline is required to reduce emissions by a ton. In our model so far, marginal costs under a cap-and-trade permit system would be identical to those for the carbon tax for a given emissions reduction.

2.2. Mileage Tax

Now consider a simple tax per vehicle mile, which reduces mileage but has no effect on fuel economy; this policy is equivalent to a tax on gasoline, with gasoline demand conditional on a given fuel economy.[8] If, with fuel economy variable, a fuel tax of $t_C z$ reduces gasoline demand by ΔG, then a fuel tax equivalent of $t_C z/\beta$ is needed to reduce gasoline consumption by the same amount when fuel economy is fixed. Therefore, the slope of the gasoline demand curve conditional on fuel economy is $1/\beta$ times the slope of the unconditional demand curve; consequently, the Harberger triangle under the mileage tax is *ibc* in Figure 2 rather than *abc*.

The marginal welfare cost for the mileage tax is

Evidence suggests that light-duty trucks pose greater fatality risks to other road users than cars, and therefore a shift in the vehicle fleet toward cars may reduce external accident costs (White 2004). However, we ignore this complication, given that most of the increase in fuel economy in response to higher gasoline taxes likely comes from incorporation of fuel-saving technologies in new vehicles rather than changes in fleet composition (Kleit 2004).

[8] A uniform mileage tax might cause a change in vehicle fleet composition that lowers average fuel economy as it increases vehicle operating costs per mile by a larger proportion for gas sippers than for gas guzzlers; this effect is ignored in our analysis.

$$(2.3) \qquad MC^{MILE} = -\left\{\frac{E_G + E_M - t_G}{z}\right\} - \frac{1}{(z/p_G^0)\beta\eta_{GG}}\frac{\Delta Z}{Z^0}$$

The intercept of MC^{MILE} is lower than that for MC^{TAX} because mileage-related external costs E_M are not multiplied by fraction β; in this case all, rather than just a portion, of the reduction in emissions is from reduced driving. On the other hand, MC^{MILE} has a steeper slope equal to $1/\beta$ times the slope under the fuel or carbon tax, as this policy exploits only one of the two margins for reducing fuel use.

2.3. Fuel Economy Standard

Another way to reduce auto emissions is through higher fuel economy standards on new passenger vehicles.[9] To examine the long-run cost of this policy in a simplified way, assume, for the moment, that the policy reduces fuel economy with no effect on mileage or the vehicle stock; again, we consider the welfare cost of the fuel tax that would have the equivalent effect as the fuel economy standard. With mileage fixed and fuel economy variable, a fuel tax of $t_C z/(1-\beta)$ is needed to reduce gasoline demand by ΔG in Figure 2; thus, the demand curve conditional on mileage has a slope equal to $1/(1-\beta)$ times that of the unconditional demand curve, and the Harberger triangle for the fuel tax equivalent is *hbc*.

Now suppose that a portion r of fuel savings from improved fuel economy is offset as people drive more in response to lower per mile fuel costs; r is actually fairly small, in part because higher vehicle costs reduce the demand for vehicles, which counteracts the effect of greater miles driven per vehicle. Accounting for this “rebound effect,” a fuel tax equivalent of $t_C z/\{(1-\beta)(1-r)\}$ is now required to reduce gasoline demand by ΔG. The marginal cost of reducing emissions is given by

$$(2.4) \qquad MC^{FE} = -\left\{\frac{E_G - t_G - rE_M}{z}\right\} - \frac{p_G^0}{z(1-\beta)(1-r)\eta_{GG}}\frac{\Delta Z}{Z^0}$$

The intercept of MC^{FE} exceeds that for MC^{TAX} because higher fuel economy standards (slightly) increase rather than reduce mileage-related external costs. MC^{FE} also has a steeper slope than MC^{TAX} because it exploits fuel savings only from higher fuel economy and increases rather than reduces mileage.[10]

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[9] Existing corporate average fuel economy (CAFE) standards require manufacturers to meet sales-weighted averages of 27.5 and 22.5 miles per gallon for their car and light-truck fleets, respectively. We assume existing standards are nonbinding, which seems reasonable given that fuel prices have recently escalated and the car standard has not been altered since 1990 (see Small and van Dender 2005 for more discussion). As already noted, we ignore the contentious issue of whether consumers undervalue fuel economy (cf. Greene 1998 and Austin and Dinan 2005).

[10] Our long-run analysis neglects a short-term disadvantage of fuel economy regulations in that they apply only to new vehicles and therefore take several years or more to have much impact on total gasoline consumption; in contrast, fuel taxes encourage owners of both new and old vehicles to economize on use and prompt earlier retirement of old, fuel-inefficient vehicles.

2.4. Parameter Values

The purpose of the empirical applications in this and the next section is to provide a rough indication of how prior distortions change the welfare impacts of different carbon policies under our best assessment of parameter values. Given that our formulas are very easy to compute under alternative parameter assumptions, we do not provide sensitivity analysis; nevertheless, it should be borne in mind that parameters are uncertain. For example, as regards congestion, there is dispersion in empirical estimates of the value of travel time, and assumptions about the delay to others caused by one extra driver are sensitive to peak-period travel flows and bottlenecks at interchanges. And accident costs are sensitive to assumptions about the value of life and whether one extra driver increases injury risks and other costs to existing motorists if those drivers take more care in heavier traffic volumes.

Baseline price and quantities are taken from EIA (2005) for 2004, and unless otherwise noted, all other parameters are based on the review in Parry and Small (2005). Initial carbon emissions Z^0 = 336 million tons, equal to gasoline demand of 140 billion gallons, times tons of carbon per gallon of gasoline, z = 0.0024 (NRC 2002). We assume an initial retail gasoline price p_G^0 = \$2.00 per gallon, a combined federal and state gasoline tax t_G = \$0.40 per gallon, and a (long-run) gasoline demand elasticity η_{GG} = –0.55, and β = 0.4 (i.e., 40 percent of the gasoline demand elasticity reflects reduced driving and 60 percent fuel economy improvement). For the rebound effect, we assume r = 0.05, based on Small and van Dender (2005).[11]

We adopt values of 3.5, 3.0 and 2.0 cents per mile for traffic congestion, accidents, and local pollution, or E_M = \$1.79 per gallon, given on-road fuel economy of 21 miles per gallon.[12] Following NRC (2002), we assume E_G = 12 cents per gallon for the marginal external cost of oil dependence, reflecting the risk of macroeconomic disruption costs from oil price shocks that may not be internalized by the private sector and the appropriate tax to account for U.S. market power in the world oil market.[13] Note that mileage-related external costs are 15 times fuel-related external costs; consequently, policies that

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[11] The rebound effect is smaller than the magnitude of the elasticity of mileage with respect to fuel prices; in both cases vehicle demand falls, thereby playing a counteracting role in the former case and a reinforcing role in the latter.

[12] For simplicity we assume E_M is constant. Although mileage externalities are fixed in cents per mile, they increase when expressed in cents per gallon as fuel economy rises; however, this effect is modest for the range of carbon taxes we consider.

[13] This estimate omits any harm to U.S. foreign and national security interests from oil revenues' accruing to nondemocratic nations, terrorist groups, etc., and the military burden of protecting oil flows from the Persian Gulf; in this regard our results may be conservative.

achieve a given emissions reduction through reduced driving alone will have a much larger externality benefit than policies that achieve the same emissions reduction partly, or entirely, through improved fuel economy.

2.5. Welfare Costs

Figure 3 shows estimates of marginal and total abatement costs under the three policies for emissions reductions up to 25 percent, using the above formulas and parameters. We note results for a 10 percent emissions reduction, which would require a carbon tax of $152 per ton (equivalent to a gasoline tax increase of 36 cents per gallon), a mileage tax equivalent (at current fuel economy) to 90 cents per gallon, or (approximately) a 10 percent increase in regulated fuel economy.

Panel (a) shows marginal costs when we ignore prior external costs and fuel taxes, and hence all the curves have zero intercepts. Marginal costs under the carbon tax (or permits) rise linearly to $379 per ton at a 25 percent emissions reduction. Marginal costs for the mileage tax and fuel economy standard are 2.5 and 1.7 times as large, respectively, because they place the entire burden of emissions control on reduced mileage or improved fuel economy rather than striking the optimal balance between the two. Total annual welfare costs for a 10 percent emissions reduction, indicated in panel (c), are $2.5 billion, $6.4 billion, and $4.2 billion under the carbon tax, mileage tax, and fuel economy standard, respectively.[14]

However, marginal and total cost estimates, and policy rankings, change dramatically when we account for externalities and prior fuel taxes, as shown in panels (b) and (d). The marginal cost for the carbon tax shifts down, has an intercept of –$181 per ton, and is below the horizontal axis for emissions reductions up to 12 percent; reducing emissions by 10 percent now produces a welfare *gain* of $3.5 billion. Under the equivalent mileage tax, however, the welfare gain is even larger, $16.4 billion, because this policy reduces mileage-related external costs by a much greater amount for each ton abated. Conversely, marginal costs increase for the fuel economy standard as this policy (slightly) increases mileage-related external costs, and energy security benefits fall short of the costs of compounding the prior gasoline tax; reducing emissions by 10 percent under this policy costs $8.4 billion.

3. The Role of Fiscal Interactions

We now integrate the above analysis into a general equilibrium model containing a preexisting tax of t_L on labor income, reflecting federal and state income taxes, employer and employee payroll taxes,

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[14] For comparison, using a computational model that distinguishes different manufacturers and 10 vehicles types, Austin and Dinan (2005, Table 3) estimate that reducing long-term gasoline demand by 10 percent through higher fuel economy standards would cost $3.6 billion per annum. Kleit (2004, Table 5) estimates that the long-run cost of reducing gasoline demand by around 3 percent through higher fuel economy would be $1.4 billion.

and broad sales taxes (Section 4 discusses interactions with the capital market). Figure 4 shows the economy-wide labor market where the demand for labor is perfectly elastic, assuming competition, constant returns, and that labor is the only primary factor; the height of this curve is the gross wage paid by firms or value marginal product of labor, normalized to unity. Though inelastic, the labor supply curve is still upward sloping as higher net wages encourage overtime, labor force participation, delayed retirement, etc.; the height of this curve reflects the marginal opportunity cost of forgone nonmarket time (e.g., child rearing, leisure pursuits). By creating a distortion between the gross and net wage, the labor tax depresses labor supply below the efficiency-maximizing level L^* to L^0; the resulting deadweight loss is the shaded triangle.

We define

$$(3.1) \qquad MEC_{t_L} = \frac{-t_L \dfrac{\partial L}{\partial t_L}}{\dfrac{\partial (t_L L)}{\partial t_L}} = \frac{\dfrac{t_L}{1-t_L}\varepsilon_{LL}^u}{1-\dfrac{t_L}{1-t_L}\varepsilon_{LL}^u}$$

where $\varepsilon_{LL} = \{\partial L / \partial(1-t_L)\}(1-t_L)/L^0$ is the labor supply elasticity and u denotes an uncompensated effect. MEC_{t_L} is the efficiency cost of an incremental increase in the labor tax, $-t_L \partial L / \partial t_L$, expressed per dollar of extra labor tax revenue.

3.1. Additional Welfare Effects from Carbon Taxes

In this general equilibrium setting there are two additional welfare effects of corrective taxes (e.g., Goulder et al. 1999). First, the “revenue-recycling effect” is given by

$$(3.2) \qquad RR^{TAX} = \{t_C Z - t_G \Delta G\} MEC_{t_L}$$

This expression is the carbon tax revenue, $t_C Z$, net of the reduction in gasoline tax revenue, $t_G \Delta G$, and multiplied by the efficiency gain from recycling a dollar of extra tax revenue in labor tax reductions. In the derivations below we assume t_L always adjusts to maintain government budget balance; in the Appendix we also derive welfare formulas for the case when government spending adjusts instead.

The second welfare change, the “tax-interaction effect,” is

$$(3.3) \qquad TI^{TAX} = -(1+MEC_{t_L}) t_L \frac{\Delta L}{\Delta p_G}$$

that is, the change in labor supply, or substitution into leisure, from the increase in the price of gasoline relative to the price of leisure, $\Delta L / \Delta p_G$, times the labor tax wedge, times $1+MEC_{t_L}$ to account for the change in labor tax revenue, which is offset by adjusting t_L. Some manipulation gives (see Appendix)

(3.4) $$TI^{t} = \left\{1 + (\theta_G - 1)\frac{\varepsilon_{LL}^{c}}{\varepsilon_{LL}^{u}}\right\} t_C \left(Z^0 - \frac{\Delta Z}{2}\right) MEC_{t_L}, \qquad \theta_G = \frac{\eta_{GL}^{c}}{\varepsilon_{LL}^{c}}$$

where $\eta_{GL} = \{\partial G / \partial(1 - t_L)\}(1 - t_L)/G^0$ denotes the elasticity of demand for gasoline with respect to the net wage or price of leisure, and superscript *c* denotes a compensated elasticity. In our model, where aggregate consumption is proportional to labor supply, the compensated labor supply elasticity ε_{LL}^{c} is equivalent to the elasticity of the average consumption good with respect to the price of leisure.

If gasoline is an average substitute for leisure, then $\theta_G = 1$; comparing (3.2) and (3.4), the tax-interaction effect exceeds the revenue-recycling effect, implying a net welfare loss from interactions with the tax system. If, however, as we argue below, gasoline is a relative complement for leisure, then $\theta_G < 1$, and the tax-interaction effect can be dominated by the revenue-recycling effect.[15] Differentiating the revenue-recycling and tax-interaction effects with respect to ΔZ, and combining with (2.2), the overall marginal cost of reducing emissions under the carbon tax is (see Appendix)

(3.5) $$MC^{TAX} + \frac{t_G}{z} MEC_{t_L} + \frac{\left((1 - \theta_G)\frac{\varepsilon_{LL}^{c}}{\varepsilon_{LL}^{u}}\left(1 - \frac{\Delta Z}{Z_0}\right) - \frac{\Delta Z}{Z_0}\right) MEC_{t_L}}{(z / p_G^0)\eta_{GG}}$$

3.2. Carbon Permits

Now suppose automobile emissions are reduced by a cap-and-trade permit system imposed on gasoline suppliers, where a permit is required for each ton of carbon in the fuel. If τ_C is the equilibrium permit price, the gasoline price is $p_G = \tau_C z + p_G^0$, since fuel suppliers must pay $\tau_C z$ for permits to sell an extra gallon, or forgo sales revenue of that amount by using their own permit allocation. Therefore, permits have exactly the same impact on fuel prices, and the same tax-interaction effect, as a carbon tax of t_C, when $\tau_C = t_C$; moreover, if all permits are auctioned, the revenue-recycling effect is also the same.

However, if permits are grandfathered, the government forgoes direct revenues of $\tau_C(Z^0 - \Delta Z)$; instead, this represents a rent transfer that will be reflected in higher equity values for grandfathered firms. We assume this supernormal profit income is taxed at a rate of t_π, reflecting combined corporate and property taxes at the firm level and dividend and capital gains taxes at the personal level.

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[15] These results are consistent with widely accepted theory in public finance (e.g., Sandmo 1975). Kaplow (2005) suggests that interactions between externality taxes and labor taxes wash out with heterogeneous agents for "distribution neutral" tax shifts. However, this result hinges on two conditions, neither of which applies in our case; that the polluting good is an average leisure substitute, and that any external costs reduce the marginal value of work relative to that of leisure.

Nonetheless, welfare costs are larger under this policy than under the tax as the revenue-recycling effect is smaller. A more subtle point is that the tax-interaction effect is also larger as households (which own firms) are partly compensated for the gasoline price increase via capital gains and dividend income; this compensation reduces labor supply, since leisure is a normal good.

Analogous to (3.5), the marginal welfare effect for this policy is (see Appendix)

$$(3.6) \qquad MC^{TAX} + \frac{t_G}{z} MEC_{t_L} + \frac{\left((t_\pi - \theta_G)\dfrac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\left(1-\dfrac{\Delta Z}{Z_0}\right) - t_\pi \dfrac{\Delta Z}{Z_0} \right) MEC_{t_L}}{(z / p_G^0)\eta_{GG}}$$

3.3. Mileage Tax

The marginal welfare effect of the mileage tax is (see Appendix)

$$(3.7) \qquad MC^{MILE} + \frac{t_G}{z} MEC_{t_L} + \frac{\left((1 - \theta_G)\dfrac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\left(1-\dfrac{\Delta Z}{Z_0}\right) - \dfrac{\Delta Z}{Z_0} \right) MEC_{t_L}}{(z / p_G^0)\beta\eta_{GG}}$$

Comparing (3.5) and (3.7), the net welfare effect of the tax-interaction and revenue-recycling effects is magnified to the extent that $\beta < 1$. This is because the mileage tax (when expressed on a per gallon basis) must be larger than the fuel tax for a given emissions reduction.[16]

3.4. Fuel Economy Standard

No revenues are raised under the fuel economy standard. In fact, the revenue-recycling effect, $-t_G \Delta G \cdot MEC_{t_L}$, is negative (though small) as revenues from the erosion of the fuel tax are made up through higher labor taxes. The tax-interaction effect is $-(1+MEG)t_L \Delta L / \Delta p_M$ where p_M is driving costs expressed on a per mile basis, consisting of both vehicle ownership and operating costs. The increase in driving costs Δp_M for a given reduction in fuel use per mile Δg is triangle *hij* in Figure 2 (the increase in vehicle costs less fuel savings) divided by mileage. Here the price effect is second order rather than first order; that is, unlike under emissions taxes and permits, there is no increase in driving costs from the pass-through of tax payments or permit rents; this implies the tax-interaction effect will be weaker (see also Goulder et al. 1999). The marginal welfare cost for this policy can be expressed (see Appendix) as follows:

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[16] We assume that the compensated elasticity of mileage with respect to the price of leisure equals that for gasoline with respect to the price of leisure; this is reasonable because mileage and gasoline should change in roughly the same proportion following changes in the price of leisure.

(3.8) $$MC^{FE} + \frac{t_G}{z} MEC_{t_L} - \frac{\left(\frac{\Delta Z}{Z^0}\right)\left(1+(\theta_G - 1)\frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\right) MEC_{t_L}}{(z/p^0_G)(1-\beta)\eta_{GG}}$$

3.5. Parameters

Following Parry and Small (2005), we assume values of 0.2 and 0.35 for the uncompensated and compensated labor supply elasticities, ε^u_{LL} and ε^c_{LL}, respectively, and following Goulder et al. (1999), we adopt a value of 0.4 for both labor and profit taxes, t_L and t_π; our assumptions imply MEC_{t_L} = 0.15.[17] We consider cases when revenue changes are neutralized by adjusting either the labor tax or public spending (see the formulas in the Appendix). In the latter case, for illustration we assume the efficiency gain from public spending is zero (i.e., the social value per dollar of spending is a dollar); more generally, the net welfare gain from fiscal interactions is less/greater than in the revenue-neutral case if the marginal efficiency gain from public spending is less/greater than MEC_{t_L}.[18]

The (compensated) elasticity of gasoline with respect to the price of leisure can be decomposed as follows (see Appendix):

(3.9) $$\eta^c_{GL} = \eta_{GI}\varepsilon^c_{LL} + \eta^{c,I}_{GL}$$

where η_{GI} is the expenditure elasticity for gasoline and $\eta^{c,I}_{GL}$ is the gasoline-leisure cross-price elasticity for given disposable income. The first component on the right in (3.9) reflects the allocation of extra income to gasoline following increased work effort in response to a compensated increase in the household wage; the second component reflects possible changes in the marginal utility from passenger travel relative to the marginal utility of other consumption goods, as leisure falls. To the extent that gasoline or driving is a necessity good, or $\eta^{c,I}_{GL}$ < 0, gasoline will be a relative complement for leisure.

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[17] These labor supply elasticities are broadly consistent with those in the empirical labor literature (Blundell and MaCurdy 1999, Fuchs et al. 1998) and represent an average over males and females, hours worked, and participation elasticities; they are also representative of assumptions in tax simulation models and in revenue forecasting by the Congressional Research Service. The uncompensated elasticity is positive, despite the zero or slightly negative hours worked elasticity for males, because the female participation elasticity is significantly positive. We believe our chosen labor supply elasticities are conservative; evidence from other sources—for example, international comparisons of tax rates and hours worked—suggest much larger responses (Prescott 2006).

[18] If government spending were set optimally, the value to households per extra dollar of spending would equal $1+MEC_{t_L}$. In this case it does not matter whether additional revenue (at the margin) is spent or used to reduce taxes.

Estimates of income elasticities (which approximate expenditure elasticities) for mileage and gasoline are positive but below unity; Parry and Small (2005) assume a mileage expenditure elasticity of 0.6. A priori, the sign of $\eta_{GL}^{c,I}$ is not clear; commuting trips will increase as people work more, but leisure trips will decline. West and Williams (2005) directly obtain the gasoline-leisure cross-price elasticity from econometrically estimating an "almost ideal demand system" with household data. Their results suggest $\eta_{GL}^{c,I} < 0$, and averaging across results for households of different sizes implies that θ_G is approximately 0.2. More empirical studies are clearly required to pin down the gasoline-leisure cross-price elasticity with more confidence; we err on the side of caution and adopt the higher value, $\theta_G = 0.6$.

3.6. Welfare Costs

Figure 5 shows marginal and total welfare costs under alternative revenue uses for different policies; comparing with Figure 3(b) and (d) indicates the impact of fiscal interactions.

Under the revenue-neutral carbon tax, the net gain from the revenue-recycling and tax-interaction effects further reduces the intercept of the marginal welfare cost curve from –\$181 to –\$318 per ton; for the 10 percent emissions reduction there is an overall welfare gain of \$7.8 billion, of which fiscal interactions contribute \$4.3 billion. In contrast, fiscal interactions increase the overall costs of emissions permits (relative to the cost of the emissions tax in Figure 3); at a 10 percent emissions reduction there is now a (very small) net cost of \$0.2 billion, compared with a net gain of \$3.5 billion when fiscal interactions are ignored.

Again, welfare gains are greatest under the mileage tax, amounting to a striking \$28.3 billion for a 10 percent emissions reduction! The contribution of fiscal interactions is \$11.9 billion; this is larger than for the carbon tax because a higher tax equivalent is required to reduce emissions by the same amount under the mileage tax. Costs for the fuel economy standard are slightly larger with fiscal interactions as there is no revenue-recycling effect to counteract the (small) tax-interaction effect.

Finally, when revenues finance public spending that has a social value per dollar equal to a dollar, fiscal interactions now raise policy costs in all cases as there is a revenue-recycling effect to counteract the costly tax-interaction effect. Nonetheless, the qualitative ranking of policy costs remains the same, and the total costs of the tax policies are still negative over a significant range of emissions reductions.

4. Further Issues

Although there appears to be a solid case on pure efficiency grounds for higher (revenue-neutral) taxes on automobile fuel or use (or their permit equivalents), there are some additional issues that merit consideration.

One is household equity; gasoline taxes are generally regressive, though less so when a measure of lifetime rather than annual income is used (Poterba 1989). However, a full distributional analysis also needs to account for automatic indexing of income tax thresholds and benefits in response to an increase in the consumer price level, externality benefits (e.g., from reduced congestion and accidents) that accrue disproportionately to motorists, and government recycling of extra revenues.[19]

If, even after allowing for these counteracting factors, poor households still suffer disproportionately, should this hold up action to combat global warming? My own view is no, because distributional issues are probably better addressed through adjustments to the broader tax and benefit system rather than attempting to incorporate (contentious) equity weights into the welfare assessment of automobile policies.[20] An objection to this view is that even if low-income households as a group are roughly compensated though broader policy adjustments, those low-income households that use automobiles more intensively than others still suffer. This is really a philosophical issue of whether household preferences should be taken into account in the design of policies aimed at ensuring an acceptable living standard for low-income people. Another objection is that in practice governments may not make the broader adjustments needed to fully compensate low-income families; however, as noted earlier, equity concerns have played some role in the allocation of nongrandfathered permits in existing climate bills (though to date the concern has been with higher electricity prices rather than higher gasoline prices).

Another issue beyond our scope is the relation of our analysis to theoretical literature in public finance that pays closer attention to the role of commodity taxes in optimal tax systems. A widely cited paper by Atkinson and Stiglitz (1976) showed that the revenue-raising case for commodity taxes disappears if (a) leisure is weakly separable from all consumption goods in utility, (b) households have identical preferences, and (c) the government chooses the set of marginal income tax rates so as to minimize the equity-weighted deadweight costs of the tax system. Although these conditions sound restrictive, the basic point is that there might be scope for adjusting the existing income tax system so as to offset, in part, the revenue-raising case for higher automobile taxation.

On the other hand, by omitting distortions in the capital market and ignoring various tax exemptions and deductions, our analysis may significantly understate the welfare gains from revenue-neutral gasoline and mileage taxes. Bovenberg and Goulder (1997) find that higher gasoline prices have

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[19] Automatic indexing may not fully compensate low-income households if (a) their gasoline budget share is greater than that for the average household (the average share is used in updating the Consumer Price Index) and (b) their taxable income over and above deductions and exemptions, plus benefits, is well below their disposable income.

[20] That is, recycling of tax revenues might be tilted in favor of lower-income groups; the efficiency implications of this primarily depend on the labor force participation elasticity for this group relative to that for all households.

little impact in the capital market because passenger travel is essentially a consumption rather than investment good. To the extent revenue recycling lowers taxes on capital and the resulting efficiency gains exceed those from cutting labor taxes, however, the welfare gains from revenue-neutral automobile taxes are greater than estimated above. And this effect is reinforced to the extent that lowering income taxes also reduces the bias in favor of tax-preferred spending, such as owner-occupied housing and employer-provided medical insurance (Parry and Bento 2000).

Even though the case for taxation of auto fuel or use seems fairly robust to these broader considerations, the scope for reducing greenhouse gases given current automobile technologies is limited, as reflected in the modest size of the gasoline demand elasticity. Greater emissions reductions over the longer term depend on whether alternative technologies, such as plug-in hybrid or hydrogen fuel cell vehicles, become commercially viable. And the potential benefits from such technologies, if successfully developed, are large if they could be deployed in China and other industrializing countries before their transportation infrastructure becomes heavily dependent on conventional fuels. So it is not a matter of just implementing emissions mitigation policies for U.S. automobiles. These policies need to be supplemented with inducements for basic research into alternative automotive technologies; such technology-push policies have been the centerpiece of the Bush administration’s response to global warming, though whether the overall technology budget and its allocation among alternative research areas are the most efficient remains an open question.

Finally, although prior distortions are important to integrate into welfare assessments of controls on auto emissions, what about policies affecting other sectors, particularly electricity generation? Carbon policies would have the added benefit of reducing local air emissions from power plants; however, according to Burtraw et al. (2003), the externality benefits under a carbon tax amount to around $12 per ton of reduced carbon, which is small relative to noncarbon externality benefits from autos, estimated above at $181 per ton. On the other hand, although electricity is effectively an input into all consumption goods and is therefore probably best viewed as an average leisure substitute, there are other reasons why fiscal interactions are also significant for carbon policy in the power sector. In particular, base load or inframarginal production is often from carbon-intensive coal plants while marginal production is often from natural gas plants, which are cleaner. This means that a portion of abatement costs and carbon tax payments (or permit rents) comes at the expense of inframarginal rents rather than being fully passed forward into higher peak-period prices, implying a smaller tax-interaction effect. Parry (2005), for example, estimated that reducing power plant emissions by 10 percent under revenue-neutral permits produces a net benefit of $0.5 billion (excluding climate benefits) rather than a cost, as the revenue-recycling effect dominates the tax-interaction effect.

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Appendix

Deriving Equation (2.2)

In Figure 1, the welfare cost of the gasoline reduction induced by the new tax is rectangle *bcgf* less rectangle *decb* plus triangle *abc*. Thus the cost is

$$\text{(A1)} \qquad (t_G - (E_G + \beta E_M))\Delta G + \frac{1}{2}\Delta p_G \Delta G$$

Using $\eta_{GG} = (dG / dp_G)\, p_G^0 / G^0$

$$\text{(A2)} \qquad \Delta p_G = -\frac{dp_G}{dG}\Delta G = -p_G^0 \frac{\Delta G}{G^0 \eta_{GG}}$$

Substituting (A2) and $G = Z / z$ in (A1) gives

$$\text{(A3)}\qquad -\left\{\frac{E_G+\beta E_M-t_G}{z}\right\}\Delta Z-\frac{1}{2}\frac{p_G^0}{z\eta_{GG}Z^0}\Delta Z^2$$

Differentiating (A3) with respect to ΔZ gives (2.2).

Deriving (3.4)

From the Slutsky equation

$$\text{(A4)}\qquad \frac{\partial L}{\partial p_G}=\frac{\partial L^c}{\partial p_G}-\frac{\partial L}{\partial I}G$$

where $\partial L/\partial I$ denotes the income-coefficient on labor supply. We assume $\partial L^c/\partial p_G$ and $\partial L/\partial I$ are constant. $\partial L/\partial p_G$ varies because the first-order income effect from an incremental increase in the fuel price, *G*, falls with successive increases in the fuel price. Thus:

$$\text{(A5)}\qquad \frac{\Delta L}{\Delta p_G}=\left(\frac{\partial L^c}{\partial p_G}-\frac{\partial L}{\partial I}(G^0-\Delta G/2)\right)\Delta p_G$$

where $(G^0-\Delta G)/2$ is fuel consumption, averaged across that before and after the price increase. Applying Slutsky symmetry, factoring out $(G^0-\Delta G/2)/(1-t_L)$ and substituting $G=Z/z$ gives

$$\text{(A6)}\qquad \frac{\Delta L}{\Delta p_G}=-\left(\frac{\partial G^c}{\partial(1-t_L)}\frac{1-t_L}{(G^0-\Delta G/2)}+(1-t_L)\frac{\partial L}{\partial I}\right)\frac{(Z^0-\Delta Z/2)\Delta p_G}{z(1-t_L)}$$

From the Slutsky equation

$$\text{(A7)}\qquad \frac{\partial L}{\partial(1-t_L)}=\frac{\partial L^c}{\partial(1-t_L)}+\frac{\partial L}{\partial I}L$$

Using (A7) to substitute out for $\partial L/\partial I$ in (A6), approximating $G^0-\Delta G/2$ by G^0 since ΔG is relatively small, and using $\Delta p_G=zt_C$ gives

$$\text{(A8)}\qquad \frac{\Delta L}{\Delta p_G}=-\frac{1}{1-t_L}\left(\varepsilon_{LL}^u-\varepsilon_{LL}^c+\eta_{GL}^c\right)t_C\left(Z^0-\frac{\Delta Z}{2}\right)$$

where ε_{LL}^u, ε_{LL}^c and η_{GL}^c are defined in the text, and u and c denote uncompensated and compensated effects. Factoring out ε_{LL}^u gives

$$\text{(A9)}\qquad \frac{\Delta L}{\Delta p_G}=-\frac{\varepsilon_{LL}^u}{1-t_L}\left(1+(\theta_G-1)\frac{\varepsilon_{LL}^c}{\varepsilon_{LL}^u}\right)t_C\left(Z^0-\frac{\Delta Z}{2}\right)$$

where θ_G is defined in the text. Multiplying this expression by $-(1+MEC_{t_L})t_L$, and noting, from (3.1), that $MEC_{t_L}/(1+MEC_{t_L})=\varepsilon_{LL}^u t_L/(1-t_L)$ gives (3.4).

Deriving (3.5)

The increase in gasoline price is $t_C z=(dp_G/dG)\Delta G$ or, substituting η_{GG} and $G=Z/z$

$$\text{(A10)}\qquad t_C=\frac{\Delta Z}{Z^0}\frac{1}{\eta_{GG}z/p_G^0}$$

Subtracting (3.2) from (3.4), substituting (A10) and $\Delta G=\Delta Z/z$ gives

(A11) $$\frac{t_G \Delta Z}{z} MEC_{t_L} + \frac{\left\{(1-\theta_G)\frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\left(\Delta Z - \frac{\Delta Z^2}{2Z^0}\right) - \frac{\Delta Z^2}{2Z^0}\right\} MEC_{t_L}}{(z / p^0_G)\eta_{GG}}$$

Differentiating with respect to ΔZ and adding MC^{TAX}, we obtain (3.5).

Deriving (3.6)

The tax-interaction effect under emissions permits is different from that under the emissions tax because of the income effect on labor supply from the recycling of firm rents $\Delta p_G (G^0 - \Delta G)$ in profit income to households. Thus, analogous to (A5), the change in labor supply is

(A12) $$\frac{\Delta L}{\Delta p_G} = \left(\frac{\partial L^c}{\partial p_G} - \frac{\partial L}{\partial I}\frac{\Delta G}{2}\right)\Delta p_G$$

Since $\Delta G / 2$ is small relative to $G^0 - \Delta G / 2$ we approximate by assuming

(A13) $$\frac{\Delta L}{\Delta p_G} \approx \frac{\partial L^c}{\partial p_G}\Delta p_G$$

Following the derivation of (3.4) using (A13) instead of (A5), and a revenue-recycling effect of $\{t_\pi t_C Z - t_G \Delta G\} MEC_{t_L}$ in place of (3.2) yields (3.6).

Deriving (3.7)

This is obtained by following the same steps as in the derivation of (3.5) using t_C / β in place of t_C, as a higher fuel tax equivalent is need to reduce emissions by a given amount when fuel economy is held fixed.

Deriving (3.8)

As discussed in the text, the fuel tax equivalent under this policy is $t_C / \{(1-\beta)(1-r)\}$. And following Goulder et al.'s (1999) analysis of performance standards, we can write the tax-interaction effect as

(A14) $$TI^t = \left\{1 + (\theta_G - 1)\frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\right\}\frac{t_C}{(1-\beta)(1-r)}\left(\frac{\Delta Z}{2}\right) MEC_{t_L}$$

This differs from (3.4) because of the higher fuel tax equivalent and also because the loss of household surplus from the policy is simply the Harberger triangle in the fuel market, since there is no first-order income effect from a fuel price increase. Following the derivation of (3.5), using (A14) in place of (A4), and replacing the revenue-recycling effect by $-t_G \Delta G \cdot MEC_{t_L}$ gives (3.8).

Deriving (3.9)

We can separate the compensated coefficient of gasoline with respect to the price of leisure into a component with disposable income fixed and another component reflecting the effect of higher labor income as follows:

$$\frac{\partial G^{c}}{\partial(1-t_{L})}=\frac{\partial G^{c,I}}{\partial(1-t_{L})}+\frac{\partial G}{\partial I}(1-t_{L})\frac{\partial L^{c}}{\partial(1-t_{L})}$$

Multiplying by $(1-t_{L})/G$ and using $I=(1-t_{L})L$ gives (3.9), where $\eta_{GI}=(\partial G/\partial I)I/G$ is the expenditure elasticity for gasoline (equivalent to the income elasticity with labor supply fixed).

Figures

Figure 1. Welfare Effects of the Gasoline Tax

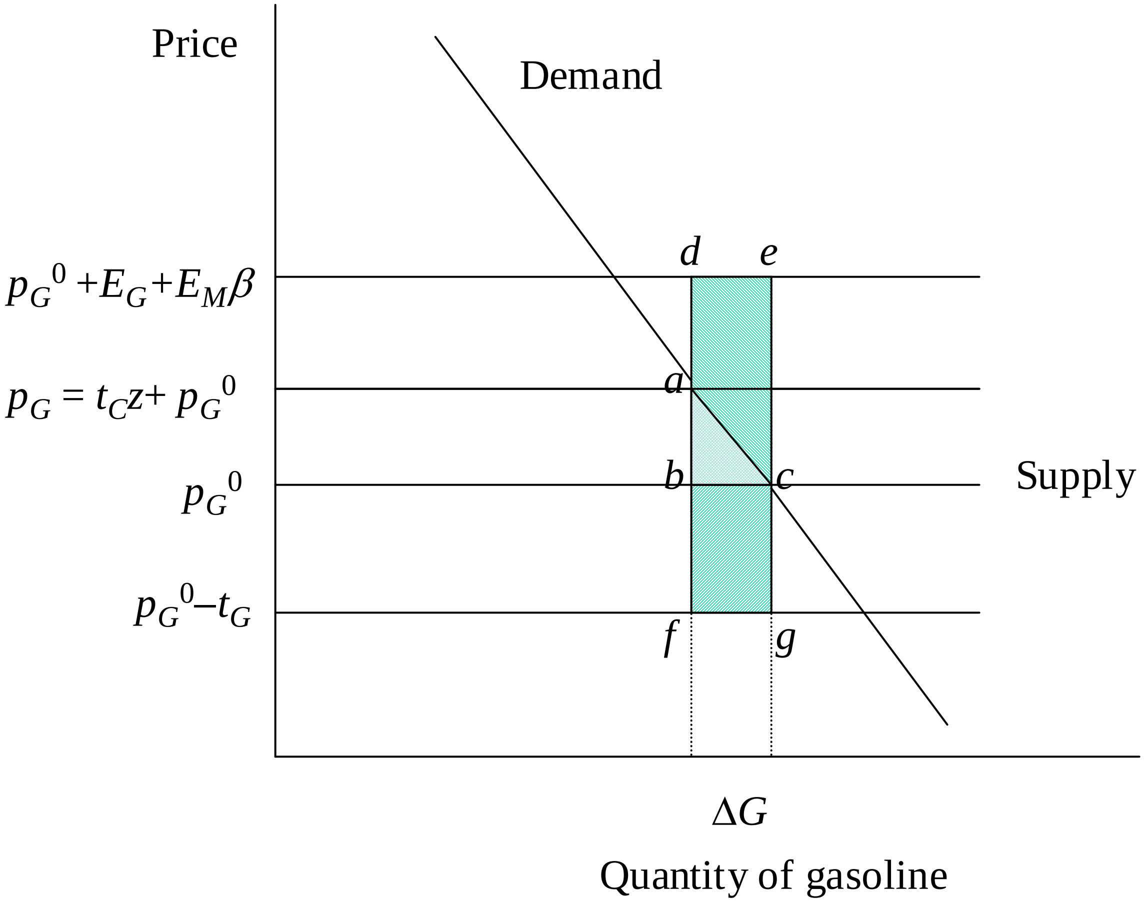

Figure 2. Welfare Cost of Fuel-Economy Standard and Mileage Tax

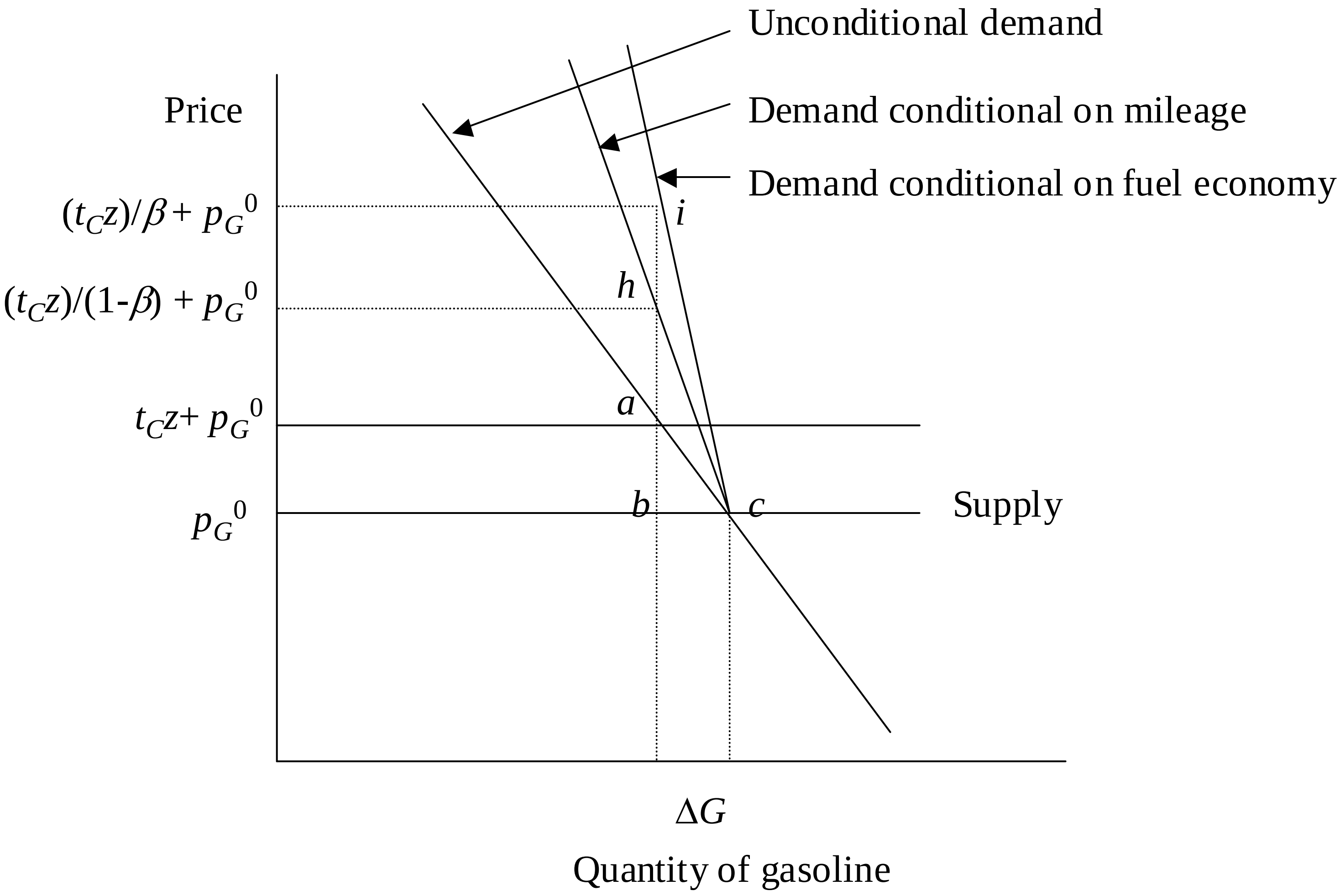

Figure 3. Marginal and Total Costs of Reducing Emissions with Preexisting Externalities
(for 2004)

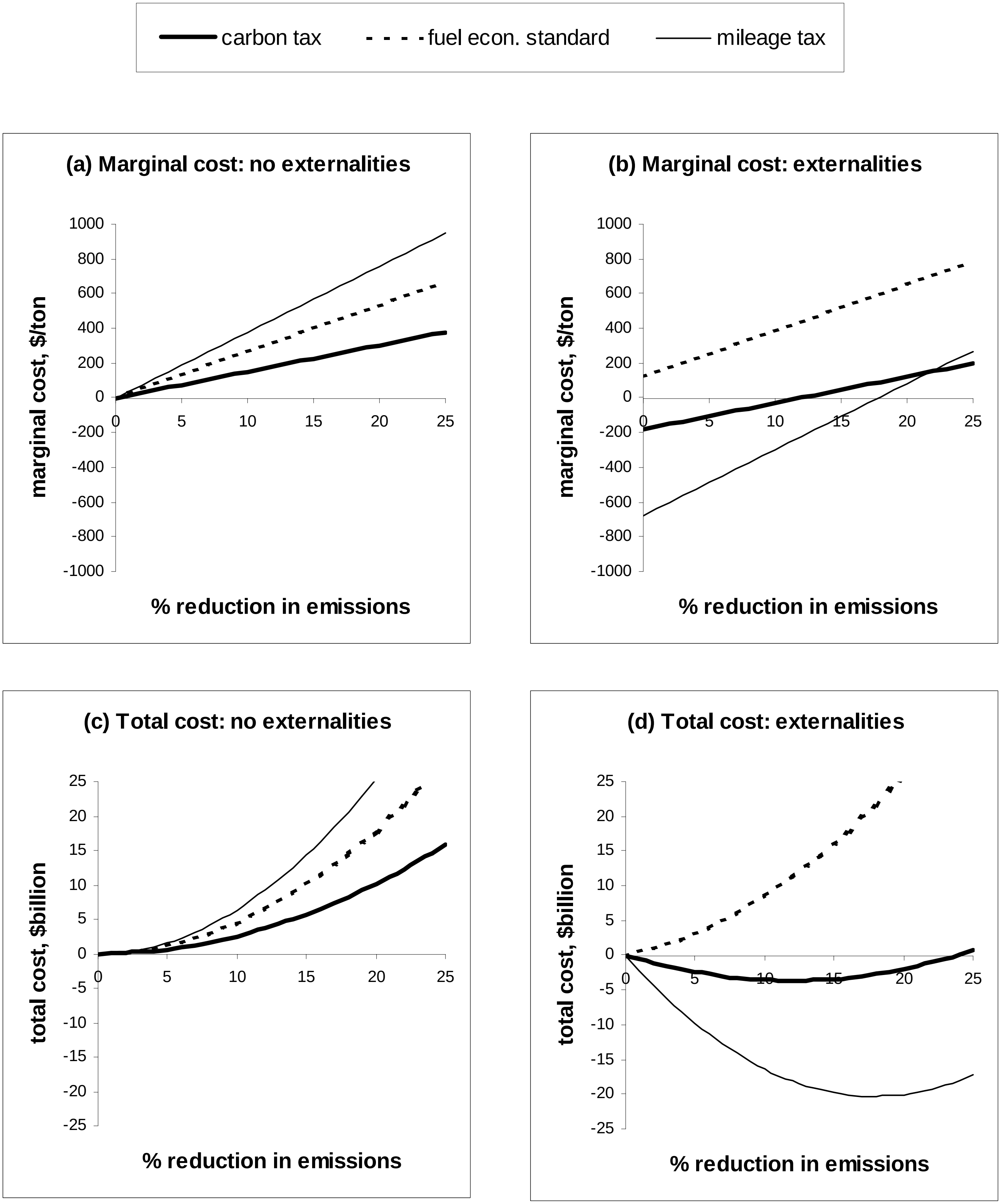

Figure 4. Welfare Effect of the Labor Tax

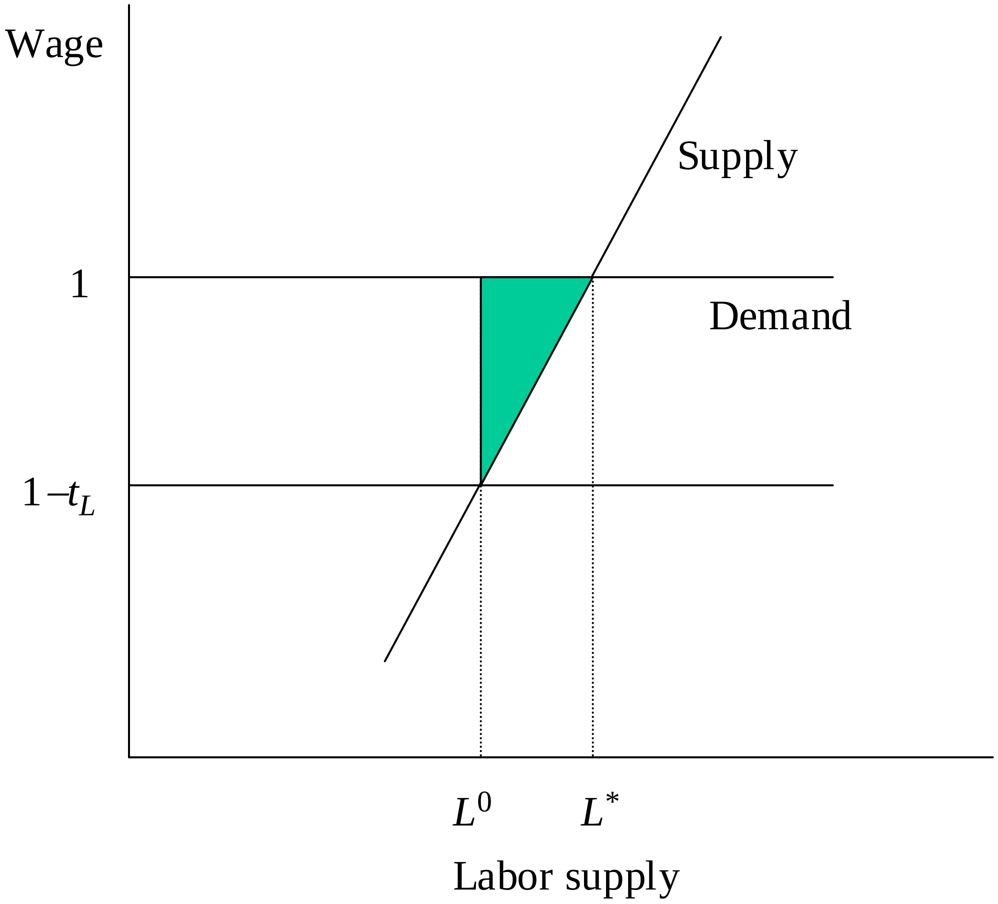

Figure 5. Costs of Reducing Gasoline Emissions with Fiscal Interactions and Externalities
(for 2004)