On the Costs of Policies to Reduce Greenhouse Gases from Passenger Vehicles

Ian W.H. Parry*
Resources for the Future

January 13, 2006

Paper prepared for a special issue of the *Journal of Urban Economics* in honor of Ken Small.

*Resources for the Future, 1616 P Street NW, Washington DC, 20036. Phone (202) 328-5151; email parry@rff.org; web www.rff.org/parry.cfm.

On the Costs of Policies to Reduce Greenhouse Gases from Passenger Vehicles

Abstract

Energy models suggest that the costs of reducing carbon emissions from the transportation sector are high relative to those for other sectors such as electricity generation. However this paper shows that taxes to reduce passenger vehicle emissions produce large net benefits, rather than costs, when account is taken of (a) their impact on reducing non-carbon externalities from passenger vehicle use and (b) interactions with the broader fiscal system. Both of these considerations also strengthen the case for using a tax-based approach to reduce emissions over fuel economy regulation, while fiscal considerations strengthen the case for taxes over (non-auctioned) emissions permits.

1. Introduction

Although the Energy Policy Act signed by President Bush in 2005 does not impose binding limits on emissions of carbon and other greenhouse gases, US policymakers continue to face growing domestic and international pressure to control emissions, in light of solidifying consensus among scientists that global warming is occurring, various state level initiatives to control carbon emissions, and the birth of carbon emissions trading in the European Union.[1] Understanding the economic costs of alternative proposals to control US emissions is critical both for balancing economic and environmental objectives, and for judging how to achieve environmental objectives at lowest cost.

The costs to the United States of reducing carbon emissions through a broad-based carbon tax, or equivalent cap-and-trade system, have been estimated from a variety of energy models. Cost estimates differ widely across the studies due to different assumptions about, for example, projected fuel prices, the ease of substituting carbon intensive fuels for other inputs, transitory costs to shifting capital between industries, and whether models incorporate interactions with the broader fiscal system.[2]

However one robust finding is that the costs of proportionate emission reductions from transportation fuels—or from petroleum uses more broadly, as many models do not decompose different uses of petroleum—are relatively large. Consequently, under a broad carbon tax proportionate emissions

[1] On the scientific consensus see the joint statement of various national academies at http://nationalacademies.org/onpi/06072005.pdf. Notable state level initiatives include the Regional Greenhouse Gas Initiative, an agreement among nine Northeastern and Mid-Atlantic states to limit carbon dioxide emissions from power plants through a cap-and-trade policy (see www.rggi.org), and AB 1493, a bill that would impose standards on carbon dioxide emissions per mile driven on new passenger vehicles sold in California (see www.arb.ca.gov/cc/cc.htm). Under the European Trading System, launched in January 2005, member states cap carbon emissions from a limited number of sectors, and then allow affected facilities to trade permits with any other facility within the European Union (see Kruger and Pizer 2004).

[2] For discussions of many of the different models see *The Energy Journal* 1999, special issue on *The Costs of the Kyoto Protocol*, and for discussions attempting to reconcile differences in the model results see Fischer and Morgenstern (2003), Ghersi and Toman (1999), and Repetto and Austin (1997).

reductions from transportation are far smaller than for other sectors, particularly electricity generation; for example, under various carbon tax simulations for 2010 and 2020 EIA (1998), Table 2, projected that proportionate emission reductions in transportation would be only 15–25% of those in electricity generation.

One reason for this finding is that the possibilities for substituting conventional motor fuels with low-carbon, or carbon free fuels, are currently limited in transportation, while coal, the most carbon insensitive fuel in electricity generation, can be replaced with natural gas and renewables. Another is simply that, due to very different carbon intensities, a carbon tax has a far more dramatic impact on coal prices than transportation fuel prices. A $50 per ton carbon tax amounts to 140% of the 2004 delivered nationwide price of coal to electric utilities but only 6% of the 2004 retail gasoline price.[3]

However, a drawback of the studies focusing on economy-wide carbon policies is that they pay little or no attention to sources of pre-existing distortion in the economy that may be affected by the policy change. As has long been recognized in public finance (e.g., Lipsey and Lancaster 1956-57, Harberger 1974) the magnitude, and even the sign, of the social welfare change induced by a new policy can be critically affected when second-best considerations are taken into account.

One potentially important source of pre-existing distortion is the range of non-carbon externalities associated with automobile use that fall in response to higher fuel prices, including local pollution emissions, energy security costs, highway congestion and accidents. The current gasoline tax appears to be well below the combined per gallon costs from these other externalities for passenger vehicles (e.g., Parry and Small 2005); this implies that higher gasoline taxes, or equivalently a tax on the carbon content of gasoline will, over some range, have a *negative* efficiency cost after these ancillary benefits are netted out.

In addition, economy-wide factor markets are badly distorted at the margin by the tax system. According to optimal commodity or Ramsey tax theory, up to a point (and leaving aside externalities), there is an efficiency gain from swapping product taxes for labor income taxes for products that are relative leisure complements (e.g., Corlett and Hague 1953-54, Sandmo 1976, Christiansen 1984). Recent empirical evidence suggests that gasoline (or driving) is in fact a relative leisure complement (West and Williams 2004, 2005), implying a further reduction in the marginal social costs of taxing gasoline emissions, at least if marginal revenues finance reductions in labor taxes.[4]

---

[3] A gallon of gasoline and a ton of coal contain 0.0024 and (approximately) 0.75 tons of carbon respectively (from http://bioenergy.ornl.gov/papers/misc/energy_conv.html). Fuel prices are taken from www.eia.doe.gov.

[4] Little attention has been paid to this issue in the context of carbon taxes, as energy models that do integrate the tax system (e.g., Goulder 1995) typically impose the restriction that all goods are equal substitutes for leisure (Jorgenson and Wilcoxen 1993 is an exception).

This paper discusses to what extent both non-carbon externalities and broader fiscal interactions lower the total and marginal social costs of reducing greenhouse gases from passenger vehicles under a variety of direct and indirect policies, including emissions taxes, (tradable) emissions permits, fuel economy standards, and mileage taxes.

In fact the welfare effects of each of these four policies have recently been studied, either on their own or in combination with one other policy, in a different strand of literature that does account for either passenger vehicle externalities, or fiscal interactions, or in some cases, both together.[5] The value added from this paper lies mainly in pulling the pieces together in a single unifying framework that compares policies for the same carbon emissions reduction, and that provides simple formulas or rules of thumb for approximately adjusting cost estimates. For transparency we consider a static, closed economy, using a diagrammatic approach to obtain formulas for welfare effects. Although our analysis lacks the sophistication of computational models with sectoral detail and, in some cases, dynamics we believe it provides a reasonable guide for roughly gauging how the costs of controlling passenger vehicle emissions are affected by other externalities and fiscal interactions.[6]

We estimate (long run) marginal and total cost curves for reducing (current) passenger vehicle emissions by up to 25% under alternative policies. With no pre-existing externality or tax distortions marginal cost curves for all policies have zero intercepts, but those for fuel economy standards and mileage taxes have relatively steep slopes, as they do not optimally exploit emissions reductions from deterring vehicle use or long run improvements in average vehicle fuel economy, respectively. For this case, total annualized costs of reducing emissions by 10% are computed at \$2.5, \$4.2 and \$6.4 billion under emissions taxes/permits, fuel economy standards, and mileage taxes, respectively.

Accounting for non-carbon externalities, net of the existing gasoline tax, causes a downward shift in the marginal cost curve under emissions taxes/permits because, for each gallon of reduced fuel, there is a combined externality benefit from reduced congestion, accidents, local emissions, and oil dependence that exceeds the cost of compounding the gasoline tax distortion. The curve now has an intercept of

---

[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; 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. And for a comparison of economy-wide carbon emissions taxes and permits in the presence of fiscal interactions see Goulder et al. (1997) and Goulder et al. (1999). Many of the results discussed below could be anticipated from these earlier studies.

[6] A further advantage of our simplified approach is that calibration to econometric evidence on behavioral responses to policies is straightforward. This is not always the case for more sophisticated computational models. For example, to maintain tractability the Goulder (1995) and Babiker et al. (2001) models impose structural restrictions that imply a petroleum demand elasticity of around unity in magnitude, which is larger than recent econometric evidence would suggest (e.g., Atkins and Jazayeri 2004, Greene and Ahmad 2005).

–$181 per ton of carbon and reducing emissions by 10% produces an annual net benefit of $3.5 billion. However, the downward shift is much greater for the marginal cost curve under the mileage tax; it has an intercept of –$677 per ton, and produces a net benefit of $16.4 billion for a 10% emissions reduction. The critical difference is that the mileage tax has a much bigger effect on reducing externalities that vary in proportion to miles driven, namely congestion, accidents and local emissions (regulated on a grams per mile basis); the combined magnitude of these externalities is very large relative to the remaining externality, energy security, which varies in proportion to fuel use. On the other hand, the marginal cost curve for the fuel economy standard is shifted up; it has an intercept of $117 per ton and a cost of $8.2 billion for a 10% emissions reduction. Costs increase for this policy as energy security benefits on their own are outweighed by the costs of compounding the fuel tax.

Accounting for interactions with labor tax distortions introduces two additional efficiency effects under revenue-neutral emissions taxes, or auctioned emissions permits (e.g., Goulder 1995). First is the revenue-recycling effect, or efficiency gain from using new revenues to reduce distortionary labor taxes; second is the tax-interaction effect, or the efficiency effect from the change in labor supply in response to the increase in price of gasoline relative to the price of leisure. The net impact from these two effects is to further shift down the marginal cost under the emissions tax; it now has an intercept of –$400 per ton, and the cost of reducing emissions by 10% is –$10.5 billion. However under the mileage tax the net gain from fiscal interactions is larger still as a much higher tax is needed to reduce emissions by a given amount; the cost of a 10% emissions reduction for this policy is –$35.1 billion! On the other hand, freely allocated emissions permits and fuel economy standards fail to produce a net gain from fiscal interactions, as they do not (directly) raise revenues for the government.

Summing up, reducing carbon emissions from passenger vehicles may result in large net benefits, rather than large costs, when non-carbon externalities and broader fiscal interactions are taken into account. However this does not apply to policies that fail to increase per mile driving costs (i.e. fuel economy standards) and the result is much weaker for policies that do not generate large revenue recycling benefits (i.e. freely allocated permits). Clearly there are much better policy instruments than emissions taxes and even uniform mileage taxes for addressing non-carbon externalities, such as road-specific, peak-period pricing to reduce traffic congestion. However, at least until these ideal policies have become widespread, there appears to be an overwhelming economic case for introducing (revenue-neutral) taxes to reduce greenhouse gas emissions from passenger vehicles, despite continuing controversy over the benefits from slowing atmospheric greenhouse gas accumulations.

The rest of the paper is organized as follows. Sections 2 and 3 discuss, respectively, how non-carbon externalities and fiscal considerations alter the costs of policies to control automobile emissions. A final section concludes and discusses various caveats to the analysis.

2. Non-Carbon Externalities and the Costs of Reducing Automobile Emissions

2.1. Diagrammatic Analysis of Higher Gasoline Taxes

A basic result from public finance theory is that the welfare effects of a product tax (or equivalent quantity restriction) can be inferred from changes in consumer benefits and producer costs in the directly affected market(s), if there are no pre-existing sources of distortion in other markets of the economy (e.g., Harberger 1974, Ch 2, 3). This partial equilibrium approach provides a valid approximation, regardless of induced demand and supply shifts elsewhere in the economy, so long as the assumed behavioral responses to the tax in the affected product market(s) are calibrated appropriately.

Consider Figure 1, which depicts the demand and supply curves for gasoline, G; these are defined as long run curves that allow households to adjust vehicle holdings, and vehicle manufacturers to incorporate fuel saving technologies, in response to fuel price changes. The supply curve for gasoline is assumed perfectly elastic and is defined inclusive of a pre-existing gasoline tax of t_G per gallon.[7] The height of the demand curve reflects the private benefit to motorists from the additional mileage enabled by consuming one more gallon of gasoline (net of travel time, vehicle maintenance costs, etc.). Assuming competition, the equilibrium (retail) price and quantity are p_G^0 and G^0 respectively, where 0 denotes an initial value prior to an emissions control policy.

Suppose a gallon of gasoline contains z tons of carbon and that a tax of t_C is now levied on carbon content; this is equivalent to a tax of $t_C z$ per gallon of gasoline. With full pass-through into retail prices, the new price and quantity are $p_G = t_C z + p_G^0$ and G in Figure 1. The efficiency cost of the new tax can be decomposed into two components, ignoring any externality benefits, and assuming, as we do throughout the paper, constant price coefficients (i.e. linear demand) over the relevant range. First *abc*, the familiar Harberger triangle reflecting the loss of gross benefits to consumers (area acG^0G), less savings in production costs gross of the fuel tax (area bcG^0G). Second, rectangle *bcgf*, the cost of compounding the pre-existing fuel tax distortion; this equals the quantity reduction times the prior tax wedge, or the prior distortion between marginal consumer benefit and marginal fuel supply cost (excluding the tax).

[7] In practice, the supply curve has a slight upward slope due to US monopsony power in the world oil market; this is accounted for below in our discussion of oil dependency costs. Besides the tax, the height of the supply curve reflects cost of crude oil purchase, fuel refining, and fuel transportation. We do not discuss diesel, as this currently accounts for a miniscule amount of passenger vehicle fuel consumed in the United States.

But now suppose gasoline use involves the following non-carbon external cost per gallon defined by:

(2.1) $E_G + E_M \beta$

E_G denotes an external cost that varies in proportion to gasoline use, namely energy security.[8] E_M denotes costs (expressed in cents per gallon) of externalities that vary with miles driven but not fuel economy, including traffic congestion and accidents, as well as local pollution from tailpipe emissions, which is regulated on a grams per mile basis.[9] β, which is assumed constant, denotes the fraction of a price-induced reduction in fuel use that is due to reduced driving; $1-\beta$ is the remaining fraction due to long run improvements in fuel economy (households buying smaller vehicles, manufacturers installing fuel saving technologies). The smaller is β the smaller the mileage-related externality benefits per gallon of reduced fuel use (Parry and Small 2005).[10]

The new carbon tax produces externality benefits shown by rectangle *decb* in Figure 1, equal to the reduction in gasoline times $E_G + E_M \beta$. At the margin the carbon tax is now welfare improving overall (leaving aside benefits of reduced greenhouse gases) if $E_G + E_M \beta > t_G + t_C z$, or if the distance *db* exceeds *af* in Figure 1.

2.2. Welfare Cost Formulas

It is straightforward to derive the following formula for the total welfare cost of reducing emissions through taxing gasoline (see Appendix):

(2.2) $$TC^{TAX} = -\left\{ \frac{E_G + \beta E_M - t_G}{z} \right\} \Delta Z - \frac{1}{2} \frac{p_G^0 Z^0}{z \eta_{GG}} \left(\frac{\Delta Z}{Z^0} \right)^2$$

[8] Local emissions released upstream (e.g., during crude oil transport, refining into gasoline, and transportation to gasoline stations) is also proportional to total gasoline use; however, due to tight regulation, the resulting external costs are relatively small, only 2 cents per gallon according to NRC (2002).

[9] See Fischer et al. (2005), Ch. 4 for evidence that tailpipe emissions vary with mileage rather than fuel use. This is explained by the long durability of state-of-the-art pollution abatement equipment over the vehicle life and that emissions standards are the same for all new cars, regardless of fuel economy; emissions standards for light trucks are currently being brought into line with those for cars.

[10] Per mile costs are converted to per gallon costs by multiplying by fuel economy or miles per gallon. To keep things simple we assume that E_M is constant; in practice it rises as higher fuel prices raise fuel economy, but this effect is modest for the range of carbon taxes we consider.

where $Z = zG$ is emissions from gasoline and $\Delta Z = Z^0 - Z$ is the emissions reduction. $\eta_{GG} = (dG / dp_G) p_G^0 / G^0$ is the own-price elasticity of demand for gasoline evaluated in the initial equilibrium. Differentiating (2.2) with respect to ΔZ gives the marginal welfare cost function:

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

Assuming $E_G + \beta E_M > t_G$ this curve has a negative intercept equal to the difference between the marginal external cost of fuel use and the pre-existing gasoline tax, where each is divided by *z* to express it per ton of carbon rather than per gallon of gasoline. The slope of the marginal cost curve is steeper (a) the more inelastic the demand for gasoline (the smaller is $-\eta_{GG}$), as this implies it is more costly for motorists to conserve fuel by driving less or buying fuel-efficient vehicles (b) the smaller is *z*, as this implies a larger reduction in gasoline is required to reduce emissions by a ton and (c) the larger is p_G^0 as this reflects the initial value to consumers per extra gallon of fuel. The marginal welfare cost can alternatively be expressed as a function of the carbon tax rather than the emissions reduction (see Appendix):

$$(2.4) \qquad MC^{TAX} = -\left\{ \frac{E_G + \beta E_M - t_G}{z} \right\} + t_C$$

Thus the marginal social cost of abatement equals the carbon tax only in the case when $E_G + \beta E_M = t_G$ and the gasoline tax exactly internalizes the non-carbon externalities.

The above welfare analysis is also applicable to the equivalent cap-and-trade system of carbon permits imposed on gasoline refiners that yields an equilibrium permit price equal to the carbon tax t_C, though this policy equivalence breaks down when account is taken of fiscal interactions (see below).[11]

Henceforth we only discuss formulas for marginal welfare costs; given that all these are linear functions it is straightforward to infer total welfare costs (estimates for both are provided in simulations below).

2.3. Fuel Economy Standard

Another way to reduce automobile emissions would be through raising fuel economy standards on new passenger vehicles. Existing Corporate Average Fuel Economy (CAFE) regulations require

[11] Other factors may cause this efficiency equivalency to break down, such as uncertainty over abatement costs and differential incentives for induced innovation (e.g., Newell and Pizer 2003, Jaffe et al. 2003), but these issues are beyond our scope.

manufacturers to meet a sales-weighted average of 27.5 miles per gallon for their car fleets and 22.2 miles per gallon (by model year 2007) for their light-truck fleets (i.e., sport utility vehicles, minivans and pickups). Manufacturers might meet an increase in fuel economy standards in a variety of ways, including adoption of fuel saving technologies, reducing vehicle weight, and increasing their sales share of relatively fuel-efficient vehicles (e.g., Kleit 2004).

To examine this policy in a simple way (and sweeping over the divergence in car and light truck standards), let the demand for gasoline be $G = gM$, where g is average gasoline consumption per mile of the vehicle fleet (the inverse of fuel economy) and M is miles driven.[12] Consider Figure 2, which shows the marginal private benefit and cost of reducing fuel per mile by $\Delta g = g^0 - g$. The (annual) marginal benefit is simply $p_G^0 M^0$, the savings in fuel costs over mileage from a unit reduction in fuel per mile. The marginal cost is the (annualized) increase in vehicle costs as manufacturers incorporate new fuel-saving technologies. We make the simplifying assumption that mileage is unresponsive to higher fuel economy standards; although empirical studies on the rebound effect find that mileage increases in response to higher fuel economy, the most recent evidence suggests that this effect is modest.[13]

The marginal benefit and cost curve have the same intercept given our assumption that consumers correctly value fuel savings (see Section 5); therefore fuel economy is at the efficient level in the absence of regulation and externalities. The slope of the marginal cost curve is given by $-(M^0)^2/\{(1-\beta)dG/dp_G\}$.[14] Suppose the government imposes a maximum allowable limit on g below the free market level, equivalent to a minimum fuel economy standard (again we consider long run comparative statics with full turnover of the vehicle fleet). The cost of the resulting reduction in fuel per mile $\Delta g = g^0 - g$ is triangle *hij* in Figure 2; this triangle is the area under the marginal cost curve, less the area under the marginal benefit curve, and itself has area (one-half times base times height) $-(\Delta g M^0)^2/(2(1-\beta)dG/dp_G)$. Since there is no change in mileage, each unit reduction in gasoline

---

[12] We assume existing standards are non-binding which seems reasonable given the recent escalation in gasoline prices and that the car standard has not been changed since 1990 (this assumption is consistent with evidence in Small and VanDender 2005).

[13] Small and van Dender (2005) find the rebound effect—the portion of the fuel savings from better fuel economy that is offset by increased vehicle use—is currently around 10%, and will fall in the future as growth in real wages diminishes the importance of fuel costs relative to the time costs of driving. Moreover, their analysis does not incorporate the effect of fuel economy regulation on increasing vehicle prices; this will offset some of the increased mileage through reducing the overall size of the vehicle stock.

[14] To see this consider an incremental increase in the gasoline price. This shifts up the marginal benefit in Figure 2 by M^0 and by definition the induced reduction in fuel per mile is $d\Delta g/dp_G = -(1-\beta)(dG/dp_G)/M^0$. Dividing the former by the latter gives the slope of the marginal cost.

produces an externality benefit, net of the pre-existing fuel tax, of $E_G - t_G$. Combining these costs, substituting the reduction in emissions $\Delta Z = z_C \Delta g M^0$, and differentiating, we obtain the marginal cost for reducing emissions under the fuel economy standard (see Appendix):

$$\text{(2.5)} \qquad MC^{FE} = -\left\{\frac{E_G - t_G}{z_G}\right\} - \frac{1}{(z_G / p_G^0)(1-\beta)\eta_{GG}} \frac{\Delta Z}{Z^0}$$

Note that $(1-\beta)\eta_{GG}$ is equivalent to the gasoline demand elasticity with fuel economy variable but mileage held fixed at its initial level.

Comparing (2.3) and (2.5) there are two reasons why the marginal welfare cost of the fuel economy standard exceeds that under the fuel tax (for a given emissions reduction). First, the intercept of the marginal cost curve is greater because higher fuel economy standards do not reduce mileage-related external costs E_M. Second, the slope of the marginal cost curve is steeper because fuel economy standards exploit fewer substitution possibilities for reducing gasoline use; this is reflected in the gasoline demand elasticity being multiplied by fraction $1-\beta$.

2.4. Mileage Tax

Finally, we also consider a simple tax t_M on vehicle miles driven, which targets driving-related externalities more directly than taxing gasoline.[15] In this case the marginal welfare cost can be expressed (see Appendix):

$$\text{(2.6)} \qquad MC^{MILAGE} = -\left\{\frac{E_G + E_M - t_G}{z}\right\} - \frac{1}{(z_G / p_G^0)\beta\eta_{GG}} \frac{\Delta Z}{Z^0}$$

Here $\beta\eta_{GG}$ is equivalent to the gasoline demand elasticity with mileage variable but fuel economy held fixed. Comparing (2.6) and (2.3) there are two differences. The intercept for the mileage tax is lower because mileage-related external costs E_M are not multiplied by the fraction β; this is because all, rather than just a portion, of the reduction in emissions is due to reduced driving. On the other hand the slope of the marginal cost curve is steeper; again, the mileage tax exploits fewer substitution possibilities than the fuel tax, as it does not affect fuel economy, hence the gasoline demand elasticity is multiplied by β.

For a given emissions reduction we can show (see Appendix):

$$\text{(2.7)} \qquad t_M M^0 / G^0 = t_C z / \beta$$

---

[15] Even better would be a tax per mile that varied with the level of traffic congestion across region and time of day, and with driver accident risk. By focusing on a simple mileage tax, our discussion understates the potential efficiency gain from a more finely tuned mileage based tax.

where $t_M M^0 / G^0$ is the mileage tax, expressed on a per gallon basis, at initial fuel economy. The mileage tax equivalent exceeds the gasoline tax equivalent of the carbon tax because it does not improve fuel economy; therefore a higher mileage tax equivalent is needed to reduce emissions by the same amount as under the carbon tax.

2.5. Parameter Values

Baseline data on fuel consumption and prices are taken from EIA (2005) for 2004. And, unless otherwise noted, external costs, tax rates, and elasticities are taken from the review in Parry and Small (2005).

We assume initial emissions from gasoline Z^0 are 336 million tons, based on initial gasoline demand of 140 billion gallons, and z= 0.0024 tons of carbon per gallon (see above). We assume an initial retail gasoline price p_G^0 = \$2.00 per gallon, and a combined federal and state gasoline tax t_G = \$0.40 per gallon. The (long run) gasoline demand elasticity η_{GG} is taken to be –0.55, which represents a compromise between older econometric studies (which generally found more elastic responses) and more recent studies. And we assume, from Parry and Small (2005), that β = 0.4 (40% of the gasoline demand elasticity reflects reduced driving and 60% fuel economy improvement).

We assume external costs of 3.5, 3.0 and 2.0 cents per mile for traffic congestion, accidents, and local pollution which, in aggregate, convert to E_M = \$1.79 per gallon of gasoline, given assumed on-road fuel economy of 21 miles per gallon.[16] The congestion estimate represents the marginal congestion cost averaged across peak and off-peak driving periods, and across urban and rural areas of the United States, making allowance for the relatively weak sensitivity of peak urban driving (which is dominated by commuting) to fuel prices. The accident estimate captures various costs such as property damage, medical costs, and pedestrian injuries but excludes own-driver injury risk, which is viewed as internal. It also excludes injury risks to other drivers; all else the same, an extra vehicle on the road will raise the likelihood that other vehicles will crash, however the severity adjusted accident risk may not increase (and may even fall) if other drivers compensate by driving slower or more carefully. Local pollution affects are primarily mortality risks to vulnerable populations though damages per mile are falling over time as new-vehicle emissions per mile standards are made ever more stringent.

---

[16] Fuel economy is from www.epa.gov/otaq/fetrends.htm. Certified (i.e. dynamometer-tested) fuel economy (for the purposes of complying with fuel economy regulations) overstates average on-road fuel economy, which varies with traffic conditions, temperature, trip length, frequency of cold starts, driving style, etc., by an estimated 15% (NRC 2002).

Finally, following NRC (2002) we adopt a value of 12 cents per gallon for the marginal external cost of oil dependence. This reflects combined estimates of (a) the optimal tax to account for US monopsony power in the world oil market and (b) the risk of macroeconomic disruption costs during oil price shocks that may not be internalized by the private sector (e.g., the costs of temporarily idled labor or capital). This estimate should be viewed with caution as it is difficult to account for the risk of future price disruptions due, for example, to political developments in the Middle East, and to quantify the costs to US foreign and national security interests from oil revenues accruing to non-democratic nations nations, terrorist groups, etc.

Summing over fuel and mileage externalities, after weighting the latter by β, yields $E_G + \beta E_M$ = \$0.83 per gallon. However the critical point for our purposes is that E_M is 15 times E_F. Consequently, the non-carbon externality benefits from the mileage tax will be much greater than for the fuel tax as the former has more impact on mileage for a given emissions reduction.

2.6. Calculations of Welfare Costs

Figure 3 displays estimates of marginal and (annualized) total abatement costs under the three policies for carbon emissions reductions from gasoline up to 25%, using the above parameters and equations (2.4)–(2.6). Our discussion notes results for a 10% emissions reduction; this requires 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) of 90 cents per gallon, or an increase in regulated fuel economy of 10%.

Panel (a) shows marginal costs when we ignore prior external costs and fuel taxes, and hence all the curves have zero intercepts. The marginal cost for the carbon tax (or permits) rises linearly to \$379 per ton at a 25% emissions reduction; marginal costs for the mileage tax and fuel economy standard are 2.5 and 1.7 times as large, respectively, as they exploit fewer fuel conservation opportunities. Total (annual) welfare costs for a 10% emissions reduction, indicated in panel (c), are 2.5, 6.4 and 4.2 billion per annum, under the carbon tax, mileage tax, and fuel economy standard, respectively.[17]

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 and has an intercept of –\$181 per ton; the marginal cost is below the horizontal axis for emissions reductions up to 12%, and total welfare costs are negative for emissions reductions

[17] For comparison, using a computational model that distinguishes different manufacturers and ten vehicles types, Austin and Dinan (2005), Table 3, estimate that reducing long gasoline demand by 10% 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% through higher fuel economy would be \$1.4 billion.

below 24%. Thus, ignoring the net effect of externalities and prior fuel taxes leads to a huge overestimate of the welfare costs of abatement under a carbon tax—around \$6.0 billion for a 10% emissions reduction.

However the degree of overstatement is even more striking for the mileage tax, which reduces mileage-related external costs by a larger amount per ton of emissions reductions. Under this policy the intercept for the marginal cost is –\$677 per ton and marginal costs are negative for emissions reductions below 18%. Although the curve has a relatively steep slope, the marginal cost is still below that for the carbon tax for emission reductions below 22%; overall the policy produces a very large net gain, amounting to \$16.4 billion for a 10% emissions reduction. Conversely costs increase for the fuel economy standard; this policy does not generate any mileage-related externality benefits and energy security benefits fall short of the costs of compounding the prior gasoline tax. The marginal cost for this policy now has an intercept of +\$117 per ton, while the total cost of reducing emissions by 10% is \$8.2 billion.

3. Automobile Policies and Fiscal Interactions

We now extend the previous analysis to account for interactions with the broader fiscal system. For simplicity, we retain our static framework and represent the rest of the tax system by a single tax in the labor market t_L, meant to reflect the combined effect of federal and state income taxes, employer and employee payroll taxes, and sales taxes.[18] We assume this revenue is spent on a public good that, implicitly, is separable in the household utility function.[19]

Figure 4 depicts the economy-wide labor market. The demand for labor is perfectly elastic, which follows, through the non-substitution theorem, from the assumption of one primary factor (labor) and constant returns production; assuming competition, the height of the demand curve is equivalent to the value marginal product of labor. The labor supply curve (assumed linear over the relevant range) is upward sloping as higher net wages encourage overtime, the spouse of a working partner to join the labor force, older workers to delay retirement, existing workers to take a second job, etc. The height of this curve reflects the marginal opportunity cost of labor supply in terms of the forgone non-market time (e.g., in child rearing, leisure pursuits). The efficiency maximizing amount of labor supply would be L^*, where the marginal social benefit and cost of labor supply are equated; L^* would be forthcoming in an undistorted market. However, by creating a wedge of t_L between the gross wage, which is normalized to

[18] It is reasonable to exclude interactions with the capital market, which is also distorted by taxes, given that gasoline is primarily a consumption good (Bovenberg and Goulder 1997).

[19] This assumption implies that changes in government spending do not affect the marginal benefit from work effort relative to the marginal benefit from non-market time. This is a neutral assumption given the lack of empirical evidence on this issue and, at least for some important cases such as spending on defense and police, it seems reasonable.

unity, and net wage, labor taxes drive down labor supply to $L^0 < L^*$ in Figure 3; the resulting efficiency cost is shown by the shaded triangle.

It will be helpful to define the following:

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

where superscript u denotes an uncompensated price effect and $\varepsilon_{LL} = \{\partial L / \partial(1-t_L)\}(1-t_L)/L^0$ denotes the (economy-wide) labor supply elasticity. MWC^u is the marginal welfare cost or marginal excess burden of labor taxation; that is, the welfare cost of raising an extra dollar of labor tax revenue. The numerator in the first expression for MWC^u is the efficiency cost from an incremental increase in the labor tax, that is, the induced reduction in labor supply times the wedge between the marginal social benefit and cost of labor supply. The denominator is the marginal labor tax revenue $L + t_L \partial L / \partial t_L$. The second expression in (3.1) defines MWC^u in terms of t_L and ε_{LL}^u.[20]

3.1. Additional Welfare Effects from Carbon Taxes

We now need to add two welfare effects to the previous analysis of carbon taxes—the so-called "revenue-recycling" and "tax-interaction" effects. These effects are familiar from the literature on environmental tax shifts (e.g., Goulder 1995, Parry 1995, Bovenberg and Goulder 2002), though we will use a broader definition of revenue recycling. Specifically, we define the revenue-recycling effect as the efficiency gain from using extra revenue raised by the new tax to either reduce the pre-existing labor tax or increase public spending. It is given by:

$$(3.2)\qquad RR^{TAX} = \{t_C(Z^0 - \Delta Z) - t_G \Delta G\} MEG$$

where $\Delta G = G^0 - G$ is the reduction in gasoline demand. *MEG* is the marginal efficiency gain per dollar of new revenue; $MEG = MWC^u$ when revenues finance reductions in labor taxes, while if they finance increased public spending *MEG* is the value to households per dollar of spending minus one. The revenue-recycling effect in (3.1) is the product of *MEG* and the change in government revenue induced by

[20] We assume MWC^u is constant throughout the analysis, which is reasonable because proportionate changes in labor supply in response to carbon policies are small. As noted below, empirical evidence suggests the economy-wide uncompensated labor supply elasticity is positive. In some other studies (e.g., Browning 1987) the marginal welfare cost is defined as a function of compensated rather than uncompensated labor supply elasticities because those studies focus on the efficiency cost of financing lump sum transfer spending to households which compensates them for the tax increase.

the new tax; the latter is the carbon tax revenue, $t_C(Z^0 - \Delta Z)$, minus the loss of gasoline tax revenue from the induced fall in gasoline demand, $t_G \Delta G$.

The tax-interaction effect is the welfare change from the change in labor supply/substitution into leisure, as the carbon tax raises the price of gasoline relative to leisure. It can be expressed:

(3.3) $$TI^t = -(1 + MEG)t_L \frac{\partial L}{\partial p_G} t_C z$$

Thus if $\partial L / \partial p_G < 0$ the tax interaction effect equals the reduction in labor supply in response to the tax-induced increase in fuel price, $-(\partial L / \partial p_G) t_C z$, times the tax distortion in the labor market, plus the product of *MEG* and the loss of labor tax revenue, $-t_L(\partial L / \partial p_G) t_C z$. Applying the Slutsky equation, and the Slutsky symmetry property, to $\partial L / \partial p_G$ gives, after some manipulation (see Appendix):

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

where $\eta_{GL} = \{\partial G / \partial(1 - t_L)\}(1 - t_L)/G$ 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 the only source of household income is labor income, consumption is proportional to labor supply; therefore ε_{LL}^c is equivalent to the elasticity of consumption as a whole with respect to the net wage or price of leisure. Thus, gasoline is a relatively weak, average, or relatively strong substitute for leisure (compared to consumption in general) according to whether η_{GL}^c is less than, equal to, or greater than ε_{LL}^c, or θ_G is less than, equal to, or greater than unity.

Suppose the tax is revenue neutral ($MEG = MWC^u$), gasoline is an average leisure substitute (θ_G = 1), and that $t_G = 0$. Comparing (3.2) and (3.4) after making these substitutions, we can see that the tax-interaction effect exceeds the revenue-recycling effect for a non-marginal carbon tax, implying a net welfare loss from interactions with the tax system (e.g., Parry 1995, Goulder et al. 1997).[21] And the

[21] This is consistent with widely accepted theory on optimal commodity taxation. The intuition is that (ignoring externalities) raising revenue from narrow product taxes involves higher efficiency costs than raising revenue from broad labor taxes, due to greater substitution possibilities for avoiding the product tax (gasoline taxes can be avoided by substituting into other consumption goods as well as into leisure).

Kaplow (2004) suggests that fiscal interactions become irrelevant to the setting of optimal environmental taxes when distributional effects are taken into account. However his argument applies only to goods that are average leisure substitutes which, we argue below, is not the case for gasoline. Moreover, as shown by Williams (2005), his result is not due to the incorporation of distributional effects but rather from the assumption that external costs always reduce the marginal value of work time relative to leisure time, and hence reducing externalities has a positive feedback effect on labor supply. This assumption is plausible only for a limited number of externalities, revenue-recycling effect is further diminished when $t_G > 0$ and we account for the erosion of pre-existing gasoline tax revenues in response to the new carbon tax. However, if gasoline is a relatively weak leisure substitute ($\theta_G < 1$), the tax-interaction effect is smaller, admitting the possibility of an overall efficiency gain from interactions with the tax system. In fact the tax-interaction effect is zero when $\theta_G = 1 - \varepsilon_{LL}^u / \varepsilon_{LL}^c > 0$. This condition is approximately satisfied for our parameter values below; here the pure substitution effect from gasoline into leisure in response to the higher gasoline price is offset by the income effect of the price increase that reduces leisure, a normal good. Finally, when new tax revenues finance extra public spending, the welfare gain from the revenue-recycling effect increases or decreases relative to the tax-interaction effect according to whether the efficiency gain from extra public spending is greater or less than that from cutting distortionary taxes (i.e. *MEG* is greater or less than MWC^u).

Subtracting (3.2) from (3.4), substituting for t_C, differentiating with respect to ΔZ, and adding to (2.3), the marginal welfare cost of the emissions tax can now be expressed (see Appendix):

$$(3.5) \qquad MC^{TAX} + \frac{t_G}{z} MEG + \frac{\left(1 - \frac{2\Delta Z}{Z^0}\right) MEG - \left(1 - \frac{\Delta Z}{Z^0}\right)\left(1 + (\theta_G - 1)\frac{\varepsilon_{LL}^c}{\varepsilon_{LL}^u}\right) MWC^u \left(\frac{1 + MEG}{1 + MWC^u}\right)}{(z / p_G^0)\eta_{GG}}$$

3.2. Carbon Permits

Now suppose that, instead of carbon taxes, automobile emissions are reduced through the imposition of a cap-and-trade permit system imposed on gasoline suppliers, where a permit is required for each ton of carbon contained in the fuel. Denoting the equilibrium permit price by τ_C, then the equilibrium price of gasoline will be $p_G = \tau_C z + p_G^0$, since fuel suppliers must either pay $\tau_C z$ for permits from other firms to sell an extra gallon of fuel, or else forgo sales revenues of the same amount by using up their own permit endowment. Thus, permits have the same effect on gasoline prices, consumption, and emissions as under a carbon tax of t_C, when $\tau_C = t_C$. Furthermore, if all the permits were auctioned off by the government at the equilibrium permit price it would raise the same revenue as under the equivalent carbon tax; in this case the welfare effects of the permit policy, including the revenue-recycling and tax-interaction effects, would be the same as for the equivalent carbon tax.

---

such as work-related traffic congestion. Parry and Small (2005) account for these feedback effects but they are empirically small in the case of fuel taxes, so we ignore them here.

However there is an important divergence between the policies when the permits are given out for free to firms, as they have been in prior trading programs (e.g., Goulder et al. 1997).[22] In this case the government forgoes direct revenues of $\tau_C(Z^0 - \Delta Z)$; instead this transfer accrues to firms that receive free permit allocations. Assuming, for the moment, that rent income is not taxed, the analogous term to the revenue-recycling effect in (3.1) is now a loss, given by:

(3.6) $$RR^{PERM} = -t_G \Delta G \cdot MEG$$

Again, since the policy increases the price of gasoline relative to leisure it leads to a welfare loss from the tax interaction effect given by (see Appendix):

(3.7) $$TI^{PERM} = \left\{ \theta_G \frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}} \right\} t_C \left(Z^0 - \frac{\Delta Z}{2} \right) MWC^u \left(\frac{1+MEG}{1+MWC^u} \right)$$

Comparing (3.4) and (3.7) the tax-interaction effect is larger in this case; note that $1-\varepsilon^c_{LL}/\varepsilon^u_{LL} < 0$ because the compensated labor supply elasticity exceeds the uncompensated elasticity due to leisure being a normal good. Under this policy households, who own firms, are partly compensated for the gasoline price increase via the capital gains and dividend income that ultimately accrues to them following the capitalization of permit rents $\tau_C(Z^0 - \Delta Z)$ in firm equity values. This compensation leads to a reduction in labor supply (since leisure is a normal good); in the simulations below the tax-interaction effect is a positive cost under emissions permits even though it is approximately zero under emissions taxes.[23]

Now suppose, more realistically, that profit income is taxed at a rate of t_π, reflecting the combined effect of corporate and property taxes at the firm level and dividend and capital gains taxes at the household level. In this case the welfare effects of the policy are given by a weighted average of those for the carbon tax and freely allocated permits with zero rent taxes where the weights are t_π and $1- t_\pi$ respectively. Analogous to (3.5) the marginal welfare effect for the permit policy is (see Appendix):

(3.8) $$MC^{TAX} + \frac{t_G}{z} MEG + \frac{t_\pi \left(1 - \frac{2\Delta Z}{Z^0}\right) MEG - \left(1 - \frac{\Delta Z}{Z^0}\right)\left(\theta_G \frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}} + t_\pi \left(1 - \frac{\varepsilon^c_{LL}}{\varepsilon^u_{LL}}\right)\right) MWC^u \left(\frac{1+MEG}{1+MWC^u}\right)}{(z/p^0_G)\eta_{GG}}$$

[22] Most or all permits were given out for free in programs to reduce the lead content of gasoline, ozone-depleting chemicals, and utility emissions of SO2 in the United States and in the carbon-trading program in the European Union.

[23] Households also receive compensation under the carbon tax, though this income effect is taken into account in our formula for the revenue-recycling effect.

3.3 Fuel Economy Standard

There is no revenue-recycling effect under the fuel economy standard. However, there is a tax-interaction effect given by

(3.9) $$TI^{FE} = -(1+MEG)t_L \frac{\partial L}{\partial p_M} \Delta p_M$$

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 total increase in vehicle costs less fuel savings) divided by mileage M^0. 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 that the tax-interaction effect will be weaker under the fuel economy regulation than under emissions taxes and permits (see also Goulder et al. 1999). For this case the marginal welfare cost can be expressed (see Appendix):

(3.10) $$MC^{FE} + \frac{t_G}{z} MEG - \frac{\left(\frac{\Delta Z}{Z^0}\right)\left(1+(\theta_M - 1)\frac{\varepsilon_{LL}^c}{\varepsilon_{LL}^u}\right) MWC^u \left(\frac{1+MEG}{1+MWC^u}\right)}{(z/p_G^0)(1-\beta)\eta_{GG}}, \qquad \theta_M = \frac{\eta_{ML}^c}{\varepsilon_{LL}^c}$$

where $\eta_{ML}^c = (\partial M / \partial(1-t_L))(1-t_L)/M^0$ is the (compensated) elasticity of mileage with respect to the price of leisure. We assume that θ_G = θ_M, that is, mileage and gasoline have the same degree of substitution with leisure; this is reasonable because mileage and gasoline should change in roughly the same proportion following changes in the price of leisure.

3.4 Mileage tax

Finally, the mileage tax generates a revenue-recycling effect analogous to that in (3.2) from extra revenues of $t_M(M^0 - \Delta M) - t_G \Delta G$ and a tax-interaction effect analogous to that in (3.9) with the per mile price increase of $\Delta p_M = t_M$. The marginal welfare effect of the mileage tax (see Appendix):

(3.11) $$MC^{MILEAGE} + \frac{t_G}{z} MEG$$
$$+ \frac{\left(1-\frac{2\Delta Z}{Z^0}\right) MEG - \left(1-\frac{\Delta Z}{Z^0}\right)\left(1+(\theta_M - 1)\frac{\varepsilon_{LL}^c}{\varepsilon_{LL}^u}\right) MWC^u \left(\frac{1+MEG}{1+MWC^u}\right)}{(z/p_G^0)\beta\eta_{GG}}$$

Comparing (3.4) and (3.11) 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 (see (2.7)).

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_{LL}^{u} and ε_{LL}^{c}, respectively, and following Goulder et al. (1999) we adopt a value of 0.40 for the labor tax t_L. From (3.2) these values imply MWC^u = 0.15.[24] Also from Goulder et al. (1999) we assume labor and rent income are taxed at the same rate ($t_\pi = 0.40$). We consider cases when policies are revenue neutral, $MEG = MWC^u$, and when $MEG = 0$, that is, changes in revenue are reflected in changes in government spending for which there are no efficiency benefits, or the social value per dollar of spending is a dollar. This latter assumption is for illustrative purposes; clearly the revenue-recycling effect could be larger with increased public spending if $MEG > MWC^u$.

Parry and Small (2005) obtained a value of 0.6 for θ_M by assuming consumption and driving are weakly separable from leisure in the household utility function; in this case θ_M is simply the expenditure elasticity for driving, and is less than unity if driving is a necessity (rather than luxury). West and Williams (2005) provide the first econometric evidence on the gasoline/leisure cross price elasticity by using household survey data to estimate an Almost Ideal Demand System over gasoline, general consumption, and leisure; this system does not impose the weak separability assumption. Averaging across their results for one-and two-adult households in their Tables 4 and 5 yields a value for θ_G of approximately 0.2. We adopt a value of $\theta_G = \theta_M = 0.4$.[25]

3.6 Calculations of Welfare Costs

In Figure 5 panels (a) and (b) show marginal welfare costs when labor taxes and public spending respectively are varied to maintain government budget balance. Again, costs are shown for emissions reductions up to 25% and for the four policies using the above parameters and equations (3.5), (3.8),

[24] For a discussion of empirical studies and expert views on labor supply elasticities see Blundell and MaCurdy (1999) and Fuchs et al. (1998) respectively. The economy-wide uncompensated labor supply elasticity is positive, despite the zero or slightly negative hours worked elasticity for males, because the participation elasticity for secondary family workers is significantly positive.

[25] This is a plausible upper bound value. Around one-third of passenger trips are people commuting to work (calculated from US DOC 2003, Tables 1090 and 1093); these trips should increase in rough proportion to labor force participation rates. However the remaining two-thirds of non-commuting trips which are primarily leisure-related should, at best, be unaffected by a compensated increase in the net wage, and may well fall with reduced leisure time.

(3.10), and (3.11). Panels (c) and (d) show total welfare costs. Comparing panels (a) and (b) with Figure 3(b), and panels (c) and (d) with Figure 3(d) indicates the impact of fiscal interactions.

Beginning with the revenue-neutral case, for the carbon tax, the revenue-recycling effect dominates the tax-interaction effect, given that gasoline is a relatively weak substitute for leisure; in fact the tax-interaction effect is approximately zero. The net impact from these two effects is to reduce the intercept of the marginal welfare cost curve from \$181 to \$400 per ton. The policy produces a large overall welfare gain across the range of emissions reductions; for the 10% reduction the gain is \$10.5 billion, compared with a net gain of \$3.5 billion when fiscal interactions are ignored.

Despite the failure to directly raise revenue, fiscal interactions increase the overall costs of emissions permits (relative to the cost of the emissions tax in Figure 3) by only a modest amount. This is because the government still obtains 40% of the permit rents through rent taxation, and the efficiency gain from recycling these revenues offsets most of the tax-interaction effect, given the relatively weak substitution between gasoline and leisure.[26] Although there is an overall net gain of \$2.5 billion at a 10% emissions reduction under the permit policy, this is \$8.0 billion less than under the equivalent carbon tax.

Again, welfare gains are greatest under the mileage tax, amounting to a striking \$35.1 billion for a 10% emissions reduction. Just over half of this welfare gain is due to the net gain from fiscal interactions; 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 approximately unaffected by fiscal interactions; there is no revenue-recycling effect and, as under the emissions tax, the tax-interaction effect is approximately zero.

Finally when revenues finance public spending that has a social value per dollar equal to a dollar, fiscal interactions approximately wash out under all policies (compare Figure 5(b) and (d) with Figure 3 (b) and (d)). The revenue-recycling effect under the emissions and mileage tax disappears and, given our assumption about θ_G, the tax-interaction effect is approximately zero under these polices and the fuel economy standard. Emissions permits are moderately more costly than the emissions tax, due to the income effect of rents on labor supply.

4. Conclusion

This paper presents and estimates formulas to adjust the cost of alternative policies to reduce passenger vehicle greenhouse gas emissions to account for their impacts on non-carbon externalities and distortions elsewhere in the economy created by the tax system. We show that with these impacts carbon or fuel taxes, and particularly mileage taxes, produce large net benefits (rather than costs) without even

[26] As discussed above, the tax-interaction effect is positive rather than approximately zero under emissions permits due to the income effect on labor supply from permit rents.

counting climate benefits. This is less applicable for (non-auctioned) emissions permits as they do not directly raise revenues that can substitute for other distortionary taxes. Fuel economy standards do not raise revenues either; moreover, unlike other policies, they fail to reduce the most important non-carbon externalities, as they do not have a first order effect on raising driving costs.

There are a number of caveats to the discussion. One is that we may significantly understate the gains from emissions or mileage taxes by ignoring the effect of the tax system on distorting the household consumption bundle through tax preferences for spending on home ownership, medical insurance, etc. Recent literature has shown that the efficiency costs of income taxes, and hence the gains from using new revenue sources to cut income taxes, are greater when these additional distortions are taken into account (see Parry and Bento 2000 and the discussion of public finance studies therein). On the other hand, as we illustrate in sensitivity analysis, the net benefits from carbon or mileage taxes are reduced if revenues finance low-valued public spending rather than tax reductions.

Another caveat is that we may overstate the costs of fuel economy standards by ignoring the possibility that they address a market failure due to consumer undervaluation of fuel economy. However, due to a lack of solid empirical evidence on the issue, whether there is in fact a market failure is much disputed (cf. Greene 1998 and Austin and Dinan 2005). Finally, issues of political feasibility are beyond our scope. A carbon tax required to reduce gasoline emissions by 10% would increase fuel prices by about 35 cents per gallon, while the required mileage tax would be equivalent to increasing fuel prices by 90 cents. These are large increases given that the federal tax was last increased in 1993, and by only 4 cents, despite a major effort by the Clinton Administration.

References

F.J. Atkins, S.M.T. Jazayeri, A Literature Review of Demand Studies in World Oil Markets, Discussion paper 2004-07, Department of Economics, University of Calgary, Calgary, Alberta, Canada, 2004.

D. Austin, T. Dinan, Clearing the Air: The Costs and Consequences of Higher CADE Standards and Increased Gasoline Taxes, Journal of Environmental Economics and Management 50 (2005), 562-582.

M.H. Babiker, J.M. Reilly, M. Mayer, R.S. Eckhaus, I. Sue Wing, R.C. Hyman, The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Revisions, Sensitivites, and Comparisons of Results, MIT Joint Program on the Science and Policy of Global Change, MIT, Cambridge, MA, 2001.

R. Blundell, T. MaCurdy, Labor Supply: A Review of Alternative Approaches, in O. Ashenfelter and D. Card, eds., Handbook of Labor Economics, Elsevier, New York, 1999.

A.L. Bovenberg, L.H. Goulder, Costs of Environmentally Motivated Taxes in the Presence of Other Taxes: General Equilibrium Analyses, National Tax Journal 50 (1997), 59-88.

A.L. Bovenberg, L.H. Goulder,. Environmental Taxation, in A. Auerbach and M. Feldstein, eds., Handbook of Public Economics (second edition), New York, North-Holland, 2002.

E.K. Browning, On the Marginal Welfare Cost of Taxation, American Economic Review 77 (1987), 11-23.

V. Christiansen, Which Commodity Taxes Should Supplement the Income Tax?, Journal of Public Economics 24 (1984), 195-220.

W.J. Corlette, D.C. Hague, Complementarity and the Excess Burden of Taxation, Review of Economic Studies 21 (1953-54), 21-30.

EIA, Impacts of the Kyoto Protocol on US Energy Markets and Economic Activity, US Energy Information Administration, Washington, DC, 1998.

EIA, Emissions of Greenhouse Gases in the United States 2003, Energy Information Administration, US Department of Energy, Washington DC, 2005.

C. Fischer, R. Morgenstern, Carbon Abatement Costs: Why the Wide range of Estimates?, Discussion paper 03-42, Resources for the Future, Washington, DC, 2003.

C. Fischer, W. Harrington, I.W.H. Parry, Economic Impacts of Tightening the Corporate Average Fuel Economy Standards, report prepared for the US Environmental Protection Agency, 2005.

V.R. Fuchs, A.B. Krueger, J.M. Poterba, Economists' Views about Parameters, Values and Policies: Survey Results in Labor and Public Economics, Journal of Economic Literature 36 (1998), 1387-1425.

F. Ghersi and M.A. Toman, Modeling Challenges in Analyzing Greenhouse Gas Trading, in Understanding the Design and Performance of Emissions Trading Systems for Greenhouse gas Emissions: Proceedings of an Experts' Workshop to Identify Research Needs and Priorities, Washington DC, Resources for the Future, 1999.

L.H. Goulder, Environmental Taxation and the 'Double Dividend': A Reader's Guide, International Tax and Public Finance 2 (1995b), 157-83.

L.H. Goulder, I.W.H. Parry, D. Burtraw, Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions, RAND Journal of Economics 28 (1997), 708-31.

L.H. Goulder, I.W.H. Parry, R.C. Williams, D. Burtraw, The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting, Journal of Public Economics 72 (1999), 329-360.

D.L. Greene, Why CAFE Worked, Energy Policy 26 (1998): 595-613.

D.L. Greene, S. Ahmad, Costs of US Oil Dependence: 2005 Update, Oak Ridge National Laboratory, Oak Ridge, TN, 2005.

A.C. Harberger, Taxation and Welfare, University of Chicago Press, Chicago, 1974.

A.B. Jaffe, R.G. Newell, R.N. Stavins, Technological Change and the Environment, in K. Mäler, J. Vincent, eds., Handbook of Environmental Economics, North-Holland/Elsevier Science, 461-516, 2003.

D.W. Jorgenson, P.J. Wilcoxen, Reducing US Carbon Emissions: An Econometric General Equilibrium Assessment, Resource and Energy Economics 15 (1993), 7-26.

L. Kaplow, On the (Ir)Relevance of Distribution and Labor Supply Distortion to Government Policy, Journal of Economic Perspectives Fall (2004), 159-176.

A.N. Kleit, Impacts of Long-Range Increases in the Corporate Average Fuel Economy (CAFE) Standard, Economic Inquiry 42 (2004), 279-294.

J.A. Kruger and W.A. Pizer, The EU Emissions Trading Directive: Opportunities and Potential Pitfalls, Discussion paper # 04-24, Resources for the Future, Washington, DC, 2004.

R.G. Lipsey, K. Lancaster, The General Thoery of Second Best, Review of Economic Studies 25 (1956-57), 11-32.

R.G. Newell, and W.A. Pizer, Regulating Stock Externalities Under Uncertainty, Journal of Environmental Economics and Management 45 (2003), 416-432.

NRC, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Research Council, Washington, DC, National Academy Press, 2002.

I.W.H. Parry, Pollution Taxes and Revenue Recycling, Journal of Environmental Economics and Management 29 (1995), S64-S77.

I.W.H. Parry, A.M. Bento, Tax Deductions, Environmental Policy, and the "Double Dividend" Hypothesis, Journal of Environmental Economics and Management 39 (2000), 67-96.

I.W.H. Parry, K.A. Small, Does Britain or The United States Have the Right Gasoline Tax?, American Economic Review 95 (2005), 1276-1289.

R. Repetto, D. Austin, The Costs of Climate Protection: A Guide for the Perplexed, Washington, DC, World Resources Institute, 1997.

A. Sandmo, Optimal Taxation: An Introduction to the Literature, Journal of Public Economics 6 (1976), 37-54.

K.A. Small, K. Van Dender, The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using US State Data 1966-2001, working paper, Department of Economics, University of California, Irvine, 2005.

US DOC, Statistical Abstract of the United States 2003, US Department of Commerce, Census Bureau, Washington, DC, 2003.

S. West, R.C. Williams, Empirical Estimates for Environmental Policy Making in a Second-Best Setting, Discussion paper, Macalester College, 2004.

S. West, R.C. Williams, The Cost of Reducing gasoline Consumption, American Economic Review Papers and Proceedings 95 (2005): 294-299.

R.C. Williams, Optimal Commodity Taxes, Public Good Provision, and Pollution Taxes: Reconciling Results from Representative-Agent and Multiple-Agent Models, Working paper, University of Texas at Austin, 2005.

Appendix <to be completed>

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

(A1) $$-(E_G + \beta E_M - t_G)(G^0 - G) + \frac{1}{2}\Delta p_G (G^0 - G)$$

Using the definition of the gasoline demand elasticity

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

Substituting (A2) in (A1) gives:

(A3) $$-(E_G + \beta E_M - t_G)(G^0 - G) - \frac{1}{2}\left\{\frac{G^0 - G}{G^0}\right\}^2 \frac{p_G^0 G^0}{\eta_{GG}}$$

Substituting $G = Z / z_G$ in (A3) gives (2.2).

Deriving (2.4)

This is easily obtained by substituting $\Delta Z = -z(dG / dp_G)(t_C z)$ into the second term in (2.3), and using the definition of η_{GG}.

Figure 1. Welfare Effects of the Gasoline Tax

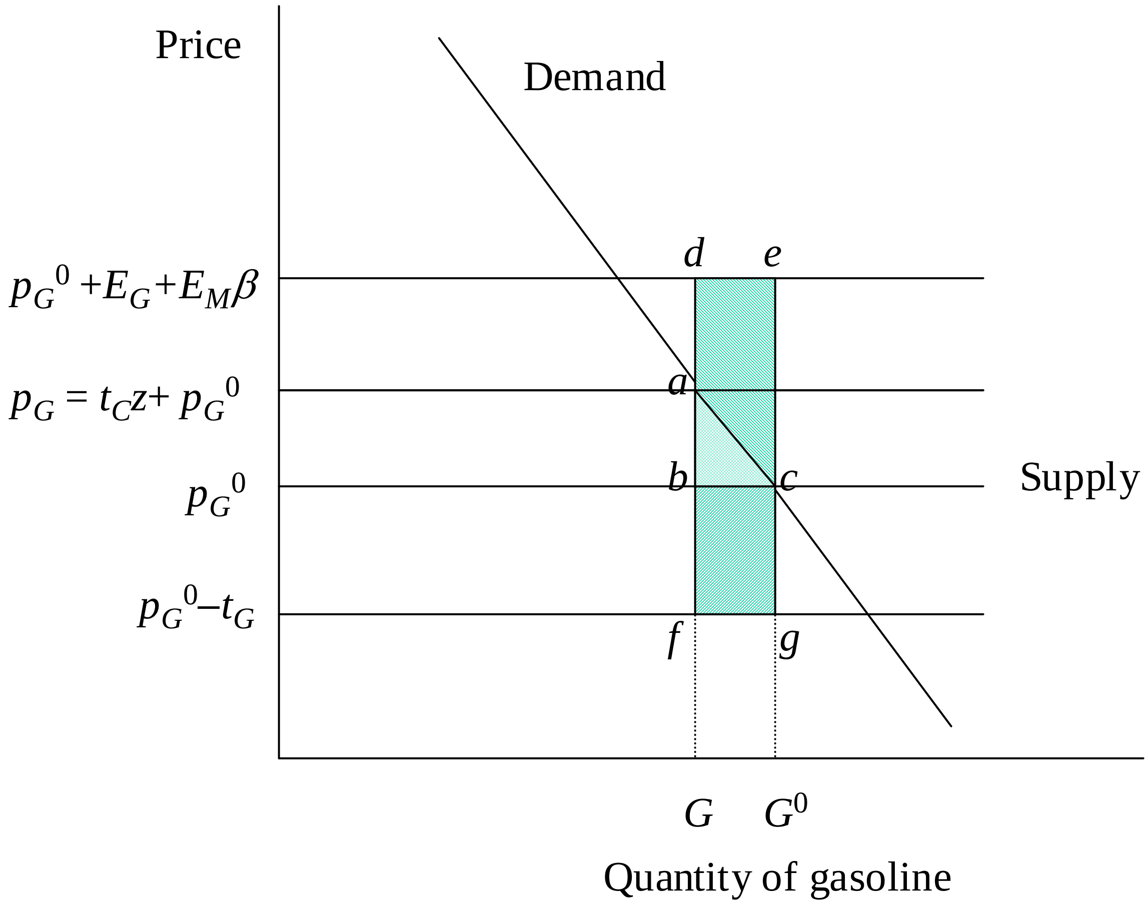

Figure 2. Cost of Higher Fuel Economy Standards

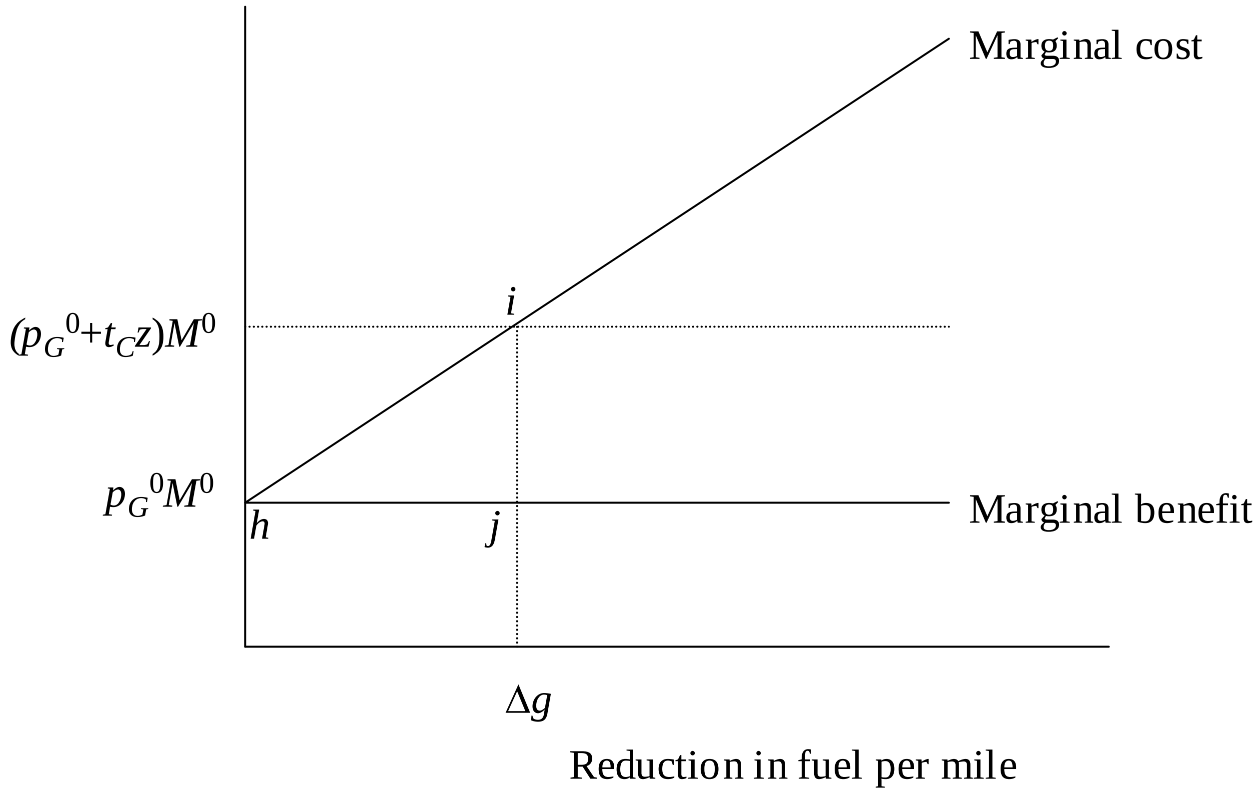

Figure 3. Marginal and Total Costs of Reducing Emissions with Pre-Existing Externalities
(for 2004)

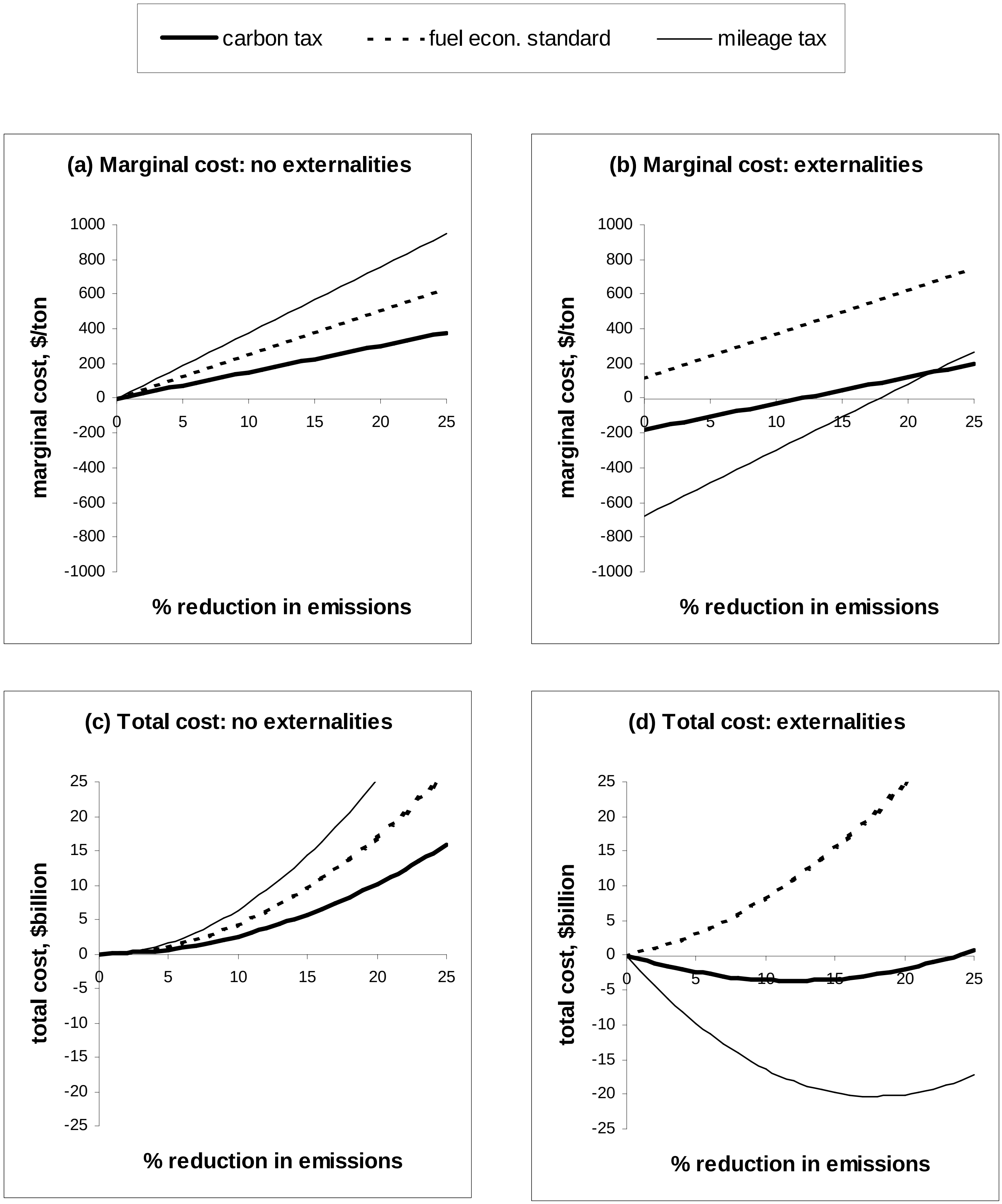

Figure 4. Welfare Effects of the Labor Tax

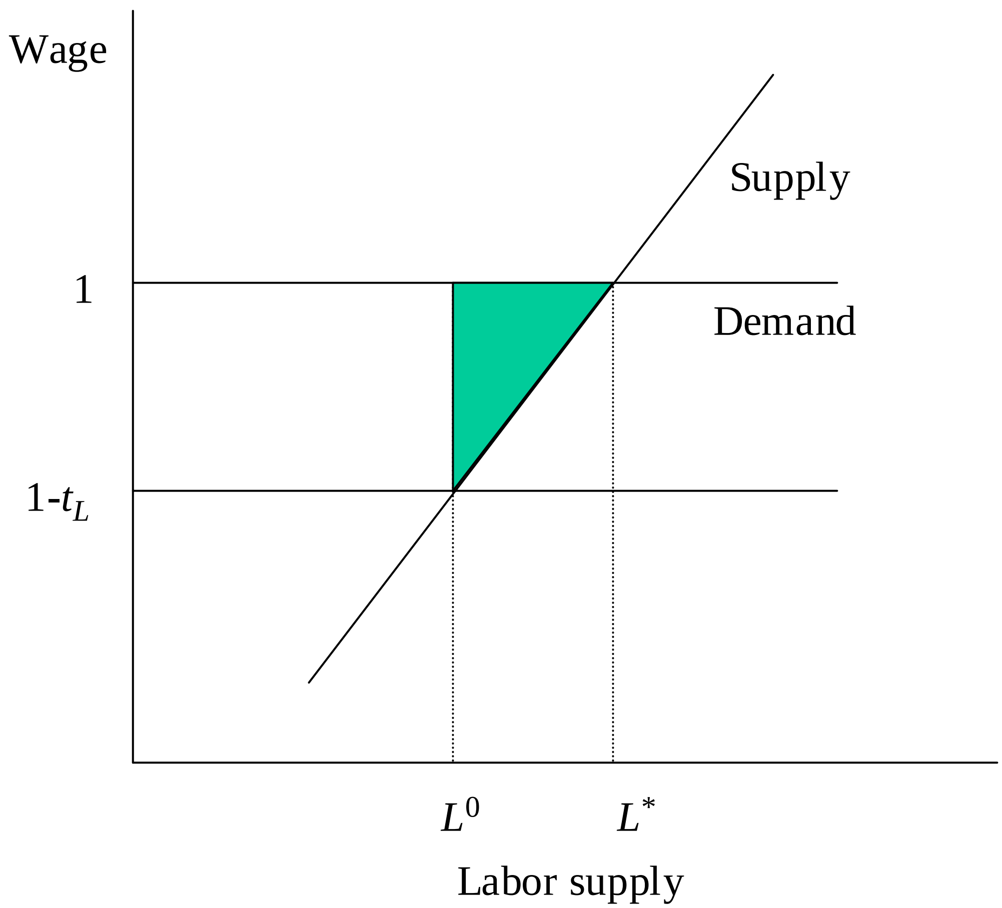

Figure 5. Costs of Reducing Gasoline Emissions with Fiscal Interactions and Externalities
(for 2004)