DISCUSSION PAPER

Fiscal and Externality Rationales for Alcohol Taxes

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RESOURCES
FOR THE FUTURE

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Abstract

This paper develops and implements an analytical framework for estimating the optimal levels and welfare effects of alcohol taxes and drunk-driver penalties, accounting for externalities and how policies interact with the broader fiscal system. We find that the fiscal component of the optimal alcohol tax exceeds the externality-correcting component under many parameter scenarios and assumptions about revenue recycling; overall, the optimal tax is anything from three to more than ten times the current tax. For more incremental reforms, however, welfare gains from stiffer drunk-driver fines and non-pecuniary penalties are larger, even though they involve implementation costs, possible first-order deadweight losses, and fiscal considerations play a minor role. In contrast to current practice, fiscal considerations warrant relatively heavier taxation of beer and relatively lighter taxation of spirits.

Key Words: alcohol tax, drunk-driver penalty, fiscal effects, external costs, welfare effects

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1. Introduction

Although alcohol excise taxes raise $12 billion in revenue for federal and state governments, tax rates are at historically low levels; alcohol taxes currently are 12 percent of pre-tax prices compared with 50 percent in 1970 (Kenkel 1996). Federal tax rates were last increased in 1984 and 1991 as part of deficit-reduction packages; given looming budgetary pressures as the baby-boom generation begins to retire, it is an opportune time to reassess the role of alcohol taxes as a revenue-raising measure.

Previous literature on efficient alcohol taxes (Manning et al. 1989, 1991; Phelps 1988; Pogue and Sgontz 1989; Kenkel 1996) primarily focused on measuring externalities, such as drunk-driver crashes and lifetime medical burdens on third parties from alcohol-related illness. Little attention has been paid to the fiscal rationale for alcohol taxes; that is, that they reduce revenue needed from other taxes to finance the government's budget over time, especially those on current (or future) labor income. Theoretical literature in public finance and environmental economics shows that a tax shift off labor and on to a commodity can increase labor supply and thereby justify an excise tax greater than any Pigouvian tax, if that commodity is a relative leisure complement (Sandmo 1975; Bovenberg and Goulder 2002; Parry and Small 2005). However, this framework has not been applied specifically to alcohol policy, leaving a number of unanswered questions.

Most obvious is how much additional taxation of alcohol might be warranted on fiscal grounds and whether this is important or not relative to the externality rationale for taxation. Another issue is how the alcohol/leisure complementarity argument for taxation is related to empirical studies on the health-

induced workplace productivity effects of alcohol abuse. A broader issue is whether the fiscal rationale for alcohol taxation is undermined if extra revenues ultimately finance more public spending instead of reductions in current (or future) taxes (Becker and Mulligan 2003).

A second set of issues revolves around the priority for alcohol tax increases over other policies, particularly when large tax increases might be impractical. In this regard, raising a moderate amount of extra revenue through higher expected drunk-driver penalties might yield larger welfare gains, as this targets drunk drivers directly, rather than penalizing all alcohol consumers. And what if the alternative is stiffer non-pecuniary penalties, such as increased likelihood and duration of jail terms? Unlike fines, these penalties impose a first-order deadweight loss on households that is not offset by a transfer to the government (Becker 1968), they forgo potential efficiency gains from revenue recycling, and their implementation may involve significant policing, judicial, and other government resource costs. Do these inefficiencies imply that moderately higher alcohol taxes produce greater welfare gains than higher non-pecuniary, drunk-driver penalties? And how does the level of drunk-driver penalties affect the optimal alcohol tax?

A final issue is whether or not differential taxation of individual beverages is efficient. Saffer and Chaloupka (1994) show that there is not much basis for uneven taxation on externality grounds alone unless there are strong cross-price effects among beverages. To what extent might fiscal considerations modify this result if individual beverages have different own-price and leisure cross-price elasticities?

This paper develops an analytical framework to conceptualize these issues and implements it by compiling evidence on underlying parameters. One caveat is that various labor-supply dimensions of alcohol policies currently are uncertain in the empirical literature, and, therefore, we cannot pin down the optimal policy with confidence. Instead, our purpose is to identify useful policy implications that appear robust across broad parameter scenarios and to develop intuitive formulas for optimal policies and welfare effects that are updated readily in light of new empirical evidence. We summarize the main findings as follows.

We put the Pigouvian component of the optimal alcohol tax at $68 per alcohol gallon (roughly $1.60 for a typical six-pack of beer or bottle of wine); drunk-driver crashes account for 91 percent of costs.

Alcohol appears to be a relative complement for leisure (for a given health status), implying a positive fiscal component to the optimal alcohol tax when the tax is revenue-neutral; this component exceeds the Pigouvian tax in most of our parameter scenarios. To the extent that alcohol abuse also reduces tax revenue from effective labor supply through illness or auto injuries, this reinforces the case for setting taxes above the Pigouvian level, though this effect typically is smaller than the fiscal component. These results are somewhat robust to allowing for alternative revenue uses because even if

there are no efficiency gains from revenue recycling, there still can be significant gains due to alcohol/leisure complementarity (though the fiscal basis for additional taxation would be undermined if revenues financed pork-barrel spending with social value well below the dollars spent). Overall, we put the optimized alcohol tax at anything from three to more than ten times the prevailing tax.

As regards more incremental reforms, welfare gains from increasing expected drunk-driver fines significantly exceed those from imposing the same tax burden on all alcohol consumers, while those from higher expected jail terms are moderately higher. Even though these policies involve significant implementation costs, possible first-order deadweight costs, and fiscal interactions are far less important in relative terms, these drawbacks are offset by their advantage in targeting the road safety externality more directly.[1] This underscores that higher alcohol taxes should complement, rather than substitute for, stiffer drunk-driver penalties. We also find that although the optimal alcohol tax declines with drunk-driver fines, paradoxically it is not affected by the level of non-pecuniary penalties, and optimized expected drunk-driver penalties are between $0.8 and $1.9 per mile of drunk driving, compared with prevailing penalties of $0.3 per mile.

Finally, fiscal considerations suggest that beer should be taxed relatively heavily and sprits relatively lightly on an alcohol-equivalent basis; in contrast, current policy taxes spirits most heavily and wine and beer roughly the same.

The rest of the paper is organized as follows. The next three sections develop our analytical framework, discuss parameter values, and present the results. A final section offers conclusions and discusses limitations and future applications of this type of analysis at the intersection of health economics and public finance.

2. Analytical Framework
A. Model Assumptions
(i) Preferences. Given our focus on economy-wide policies and that distributional issues are beyond our scope (see Section 5), it is reasonable to employ a representative agent framework. The behavioral responses of this agent to policy changes represent an aggregation of responses over different population

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[1] Although we do not model increased duration of license suspensions or mandated use of vehicle breathalyzer interlock technologies, welfare gains from these policies are likely larger than those for the equivalent additional jail penalty, as they prevent recidivism over a longer period of time.

subgroups in the real economy (e.g., heavy drinkers and abstainers) and are later calibrated to econometric studies that account for such heterogeneity.[2]

We use a one-period model representing an agent's life cycle. The utility function is:

(1a) $U = U(A^m, A^h, D, C, l, H, \tau_D D, \overline{M}, \overline{G}^P)$, $A^m + A^h = A$

(1b) $H = H(A^h, D, \overline{D}, M)$, $T(H) = l + L$

Variables are per capita, present values over the period, expressed on an annualized basis; a bar denotes an economy-wide variable exogenous to individual agents.

In (1a) A denotes gallons of alcohol consumption, consisting of alcohol consumed in moderation A^m and during bouts of heavy drinking A^h (individual beverages are disaggregated later). D is driving trips taken after heavy drinking, C is a general consumption good, l is leisure, H is fatal and non-fatal health/injury risks, τ_D is (expected) non-pecuniary penalties incurred per drunk-driver trip from jail terms and license suspensions, M is spending on medical services, and G^P is government spending on public goods. U is a well-behaved function, decreasing in H and $\tau_D D$, weakly increasing in $\overline{M}$, and strictly increasing in other arguments. $U_{\overline{M}}$ is possible marginal utility from paternalistic preferences over medical care received by other individuals that are a possible, though contentious, justification for medical care subsidies.

In 1(b) health effects are increasing in the agent's own heavy drinking and drunk driving and the drunk driving of others and decreasing with own consumption of medical services. T is an agent's expected lifespan, which declines with the risk of premature mortality; time is allocated between leisure and work, L.

(ii) Production. All goods are produced under constant returns by competitive firms employing labor as the only (primary) input, so there are no pure profits. Firms pay a gross wage of w equal to the value marginal product of labor. $W = wL$ is "effective" labor supply where $\partial W / \partial H < 0$ if alcohol abuse reduces on-the-job productivity or the ability to obtain and maintain stable employment.

The government pays for fraction s of medical services, representing tax exemptions for medical insurance and direct spending, such as Medicaid; the remainder is covered by insurance companies charging a lump-sum premium K_M and a variable fee per dollar of services $v_M < 1$, representing uncovered costs. Similarly, for auto repair, firms charge a lump-sum insurance premium of K_D and an (expected)

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[2] 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 apply in our case; these are that alcohol is an average leisure substitute and that all external costs reduce the marginal value of work relative to that of leisure (Williams 2005).

variable cost equivalent to v_D per drunk-driver trip, reflecting deductibles and elevated future premiums following an auto accident; $v_D < c_D$ where c_D is the (expected) cost of auto repair to firms per drunk-driver trip.[3] v_M and v_D are given while K_M and K_D adjust so firm profits are zero in equilibrium. Other third-party costs of alcohol abuse, such as group life insurance, are incorporated in the model parameterization.

(iii) Government. The government budget constraint is:

$$(2) \qquad G^P + G^T + sM = t_L W + t_A A + (t_D - r)D$$

where G^T is lump-sum transfer spending or spending that is a close substitute for private goods, such as education. t_L, t_A and t_D denote, respectively, a proportional tax on labor income, a specific tax on alcohol consumption, and an expected fine per drunk-driver trip equal to the fine per conviction times the probability of arrest and conviction. r denotes average government resource costs per drunk-driver trip, including police costs associated with breathalyzer testing and arrests, judicial costs, and the cost of accommodating jail sentences. We assume both r_{τ_D} and $r_{t_D} > 0$; even if t_D is increased through higher fines per conviction, rather than higher arrest rates, this may protract legal process.

(iv) Agent optimization. The household budget constraint is:

$$(3) \qquad (p_A + t_A)A + (v_D + t_D)D + v_M M + p_C C = I + \tilde{W}$$

where p denotes a pre-tax price, $I = G^T - K_M - K_D$ is lump-sum income net of lump-sum insurance payments, and $\tilde{W} = \tilde{w}L$ is labor earnings, where $\tilde{w} = (1 - t_L)w$ is the net wage.

Optimizing (1) subject to (3) yields the agent's first order conditions:

$$(4) \qquad \frac{U_{A^h}}{\lambda} = p_A + t_A + mpc \cdot H_{A^h}, \qquad \frac{U_D}{\lambda} = v_D + t_D + \tau_D + mpc \cdot H_D,$$

$$-mpc \cdot H_M = v_M, \qquad\qquad \frac{U_l}{\lambda} = \tilde{w}$$

where λ is the marginal utility of income, and we have normalized $-U_{\tau_D D}/\lambda = 1$ so that the non-pecuniary penalty is expressed in monetary equivalents. $mpc = -(U_H/\lambda + \tilde{w}T_H + \tilde{W}_H)$ is the marginal private cost of health risks, consisting of direct disutility from suffering $-U_H/\lambda$, the value of reduced life expectancy $-\tilde{w}T_H$, and lost wages from lower productivity $-\tilde{W}_H$.

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[3] Other private costs of driving, such as fuel and time costs, are netted out implicitly from the benefit of driving in the utility function. We ignore other auto externalities (e.g., pollution, national security, congestion), as they are small relative to accident costs per mile of drunk driving (see Parry and Small 2005 and below).

From (4), agents equate the marginal private benefit from heavy drinking with the tax-inclusive alcohol price and the own-heath cost, and they equate the marginal benefit from drunk driving with the expected out-of-pocket expenses for auto crashes, government penalties, and own health risks. They also equate the marginal private benefit from medical care with the variable cost and the marginal value of leisure with the net wage, which is below the marginal value product of labor due to the labor tax.

From (1), (3) and (4) we can express the demand and labor supply functions as:[4]

(5) $\qquad y = y(t_A, t_L, H, G^T, G^P),$ $\qquad\qquad\qquad y = A^m, A^h, D, C, M, L$

B. Optimal Tax and Penalty Formulas

(i) Marginal welfare effect from an increase in t_A. This is obtained by totally differentiating the indirect utility function, accounting for changes in t_L, G^T and G^P to maintain government budget balance; the result is (see Appendix A)

(6a) $\qquad (E^A - t^A)\left(-\dfrac{dA}{dt_A}\right) + t_L\dfrac{dW}{dt_A} + MEG_{G^P}\dfrac{dG^P}{dt_A}$

(6b) $\qquad E^A = (E^h A^h \eta_{hA} + E^D D \eta_{DA})/(A\eta_{AA}),$ $\qquad\qquad E^h = (1 - v_M - U_{\overline{M}}/\lambda)M_{A^h},$

$\qquad E^D = (mpc \cdot H_{\overline{D}} + c_D - v_D + (1 - v_M - U_{\overline{M}}/\lambda)(M_D + M_{\overline{D}}) + r - t_D),$

$\qquad MEG_{G^P} = \dfrac{U_{G^P}}{\lambda} - 1$

where η_{AA}, η_{hA} and $\eta_{DA} < 0$ denote elasticities of alcohol consumption, heavy drinking, and drunk driving with respect to the alcohol price, and MEG_{G^P} is the marginal efficiency gain (or loss) from public goods (i.e., the value to households per dollar of extra spending minus the dollar).

The marginal welfare effect consists of (i) the reduction in alcohol times the marginal external cost of alcohol E^A, net of the alcohol tax; (ii) the change in effective labor supply times the labor tax; and (iii) MEG_{G^P} times any increase public goods. E^A equals the external cost per gallon of heavy drinking, E^h, and per drunk-driver trip, E^D, each expressed in costs per alcohol gallon, and multiplied by η_{hA}/η_{AA} and η_{DA}/η_{AA} to account for the responsiveness of A^h and D relative to that for overall alcohol consumption (Pogue and Sgontz 1989; Kenkel 1996).

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[4] Income effects from changes in K_M and K_D are very small and are ignored. We also assume that the effect of a given increase in alcohol tax on alcohol consumption and drunk driving (though not labor supply) is the same, regardless of how alcohol tax revenues are used; this is reasonable given their small budget shares.

E^h is the lifetime medical burden from additional heavy drinking multiplied by $1 - v_M$, which is the portion of marginal costs paid by the government (s) and by insurance companies ($1 - s - v_M$). Portion $-U_{\overline{M}} / \lambda$ of medical costs is excluded from external costs because of the positive consumption externality; for example, if medical subsidies are fully justified by paternalistic preferences ($-U_{\overline{M}} / \lambda = s$), only the medical burden to insurance companies is an external cost (Browning 1999).

E^D consists of (i) injury risks to other road users from a drunk-driver trip $mpc \cdot H_{\overline{D}}$; (ii) expected property damages from the trip net of costs internal to individuals $c_D - v_D$; (iii) external costs of the added medical burden from injury risks to the driver and other road users; and (iv) government resource costs per trip. E^D also is defined net of the expected drunk-driver fine but *not* the non-pecuniary penalty. To see this, consider Figure 1 where the (gross of externality) deadweight loss from combined penalties, $t_D + \tau_D$, is shown by the gray shaded area and comprises the usual second-order effect from the distortion of demand, and rectangle $\tau_D D$, equal to the first-order utility loss from non-pecuniary penalties, which is not offset by a revenue gain to the government. Higher alcohol taxes shift in the drunk driving demand curve and increase the combined deadweight loss by the black rectangle, or t_D per unit reduction in D, rather than $t_D + \tau_D$ (although τ_D is part of the price distortion, there is a saving of τ_D in the first-order deadweight costs of the non-pecuniary penalty per unit reduction in D).

(ii) Disentangling labor supply effects. The change in effective labor supply can be decomposed into three effects (from totally differentiating (5)):

$$(7) \quad \frac{dW}{dt_A} = \frac{\partial W}{\partial H} \frac{dH}{dt_A} + w \frac{\partial L}{\partial t_A} + w \left\{ \frac{\partial L}{\partial t_L} \frac{dt_L}{dt_A} + \frac{\partial L}{\partial G^T} \frac{dG^T}{dt_A} + \frac{\partial L}{\partial G^P} \frac{dG^P}{dt_A} \right\}$$

First is productivity increases from improved health, encompassing increases in w and in hours worked L. Second is the effect of higher alcohol prices (for given health), as determined by the degree of substitution between alcohol and leisure. Third is the effect of revenue recycling: using revenues to reduce t_L will increase labor supply, while using them to increase G^T will have the opposite effect because leisure is a normal good. Expanding the provision of public goods may increase or decrease labor supply depending on whether it increases or decreases the marginal utility of consumption relative to leisure (Atkinson and Stern 1974); given there is little evidence on this either way, we adopt the neutral case where $\partial L / \partial G^P = 0$.

(iii) Optimal tax when revenues finance reductions in t_L. From (6a) and (7) the optimal, revenue-neutral, alcohol tax can be expressed (see Appendix A):

(8a)
$$t_A^* = \overbrace{E^A}^{\substack{\text{Pigouvian}\\\text{tax}}} + \overbrace{MEG_{t_L}\left\{-\frac{p_A+t_A}{\eta_{AA}}-t_A+g^A\right\}}^{\substack{\text{Revenue–recycling}\\\text{effect}}}$$

$$-\overbrace{MEG_{t_L}\left(-\frac{p_A+t_A}{\eta_{AA}}\right)\frac{\eta_{Al}^c+\eta_{LI}}{\varepsilon_{LL}}}^{\substack{\text{Tax–interaction}\\\text{effect}}}+\overbrace{(1+MEG_{t_L})t_L\theta_{WH}^A}^{\substack{\text{productivity}\\\text{effect}}}$$

(8b)
$$MEG_{t_L}=\frac{-t_L\dfrac{\partial L}{\partial t_L}}{L+t_L\dfrac{\partial L}{\partial t_L}}=\frac{\dfrac{t_L}{1-t_L}\varepsilon_{LL}}{1-\dfrac{t_L}{1-t_L}\varepsilon_{LL}}, \qquad \theta_{WH}^A=-\frac{\partial W}{\partial H}\frac{dH}{dA},$$

$$g^A=\{sM_{A^h}A^h\eta_{hA}+s((M_D+M_{\bar{D}})+(r-t_D))D\eta_{DA}\}/(A\eta_{AA})$$

η_{Al} is the elasticity of demand for alcohol with respect to the price of leisure (or household wage), $\varepsilon_{LL}>0$ is the labor supply elasticity, $\eta_{LI}<0$ is the income elasticity of labor supply, and c denotes a compensated elasticity. $MEG_{t_L}>0$ is the marginal efficiency gain from using a dollar of revenue to cut the labor tax, equivalent to the marginal efficiency cost from increasing t_L per dollar of extra revenue. g^A is savings in government medical and resource outlays, net of the reduction in revenue from drunk-driver fines, per gallon reduction in alcohol. The optimum alcohol tax differs from the Pigouvian tax, defined as the marginal external cost with no labor tax, due to three effects.

First is the "revenue-recycling" effect, or efficiency gain from using extra revenues to cut the labor tax, and equals MEG_{t_L} times marginal revenue per gallon reduction in alcohol, including savings in government medical and resource expenditures (note that $(p_A+t_A)/\eta_{AA}=A\cdot dt_A/dA$). This effect is greater the more inelastic the demand for alcohol, as this implies a larger first order revenue gain per unit reduction in consumption.

Second is the "tax-interaction" effect, or welfare impact from the change in labor supply, caused by the increase in price of alcohol relative to leisure (for given health status) per unit reduction in alcohol; it is derived from $t_L w(\partial L/\partial t_A)/(dA/dt_A)$, multiplied by $(1+MEG_{t_L})$ to account for the value of lost revenue that is made up through higher labor taxes. The tax-interaction effect incorporates the pure substitution effect between alcohol and leisure, which reduces/increases labor supply if η_{Al}^c is

positive/negative, and a negative income effect, which increases labor supply because leisure is a normal good ($\eta_{LI} < 0$). We call the difference between the revenue-recycling and tax-interaction effects the fiscal component of the optimal tax; substituting $\eta_{LI} = \varepsilon_{LL} - \varepsilon_{LL}^{c}$ from the Slutsky equation, and leaving aside g^{A}, this component can be positive if alcohol is a relative leisure complement, $\eta_{Al}^{c} < \varepsilon_{LL}^{c}$.[5]

Finally, the "productivity effect" is the efficiency gain from the health-induced increase in effective labor supply. It equals t_L times the increase in gross earnings per unit reduction in alcohol, θ_{WH}^{A}, times $1 + MEG_{t_L}$ to account for the value of additional labor tax revenue (reductions in net of tax earnings are internal to individuals).

(iv) Optimal tax when revenues finance additional public spending. In this case the optimal tax is (see Appendix A):

$$
(9a) \quad t_A^* = \overbrace{E^A}^{\substack{Pigouvian \\ tax}} + \overbrace{MEG_i\left\{-\frac{p_A + t_A}{\eta_{AA}} - t_A + g^A\right\}}^{\substack{Revenue-recycling \\ effect}}
$$

$$
\qquad\qquad - \overbrace{\beta_i MEG_{t_L}\left(-\frac{p_A + t_A}{\eta_{AA}}\right)\frac{\eta_{Al}^{c} + \eta_{LI}}{\varepsilon_{LL}}}^{\substack{Tax-interaction \\ effect}} + \overbrace{(1 + MEG_{G^i})t_L\theta_{WH}^{A}}^{\substack{productivity \\ effect}}
$$

$$
(9b) \quad MEG_{G^T} = \frac{t_L w \dfrac{\partial L}{\partial I}}{1 - t_L w \dfrac{\partial L}{\partial I}} = \frac{t_L \eta_{LI}}{1 - t_L \eta_{LI}}, \qquad \beta_i = \frac{1 + MEG_{G^i}}{1 + MEG_{t_L}},
$$

for $i = T$ or P. MEG_{G^T} is the efficiency change per dollar increase in the transfer payment, which is (slightly) negative due to the reduction in labor supply from the income effect. In a more general framework, MEG_{G^T} might be positive overall if transfer spending is motivated by, for example, distributional or social insurance objectives. Comparing (8) and (9), the revenue recycling effect is larger or smaller, depending on whether the marginal efficiency gain from increased public spending is larger or

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[5] ε_{LL}^{c} is equivalent to the elasticity of aggregate consumption with respect to the price of leisure in our model. The revenue-recycling and tax-interaction effects previously have been discussed in the context of environmental policies (e.g., Goulder et al. 1997, Parry and Oates 2000), though they have not been expressed in an optimal tax formula as above. In the context of alcohol taxes, Sgontz (1993) discusses the revenue-recycling effect, but not the tax-interaction effect.

smaller than the marginal efficiency gain for cutting other taxes.[6] For the remaining policies below, we focus just on the revenue-neutral case.

(v) Optimal (expected) penalties per drunk-driver trip. These are given by (see Appendix A):

(10a)
$$j^* = \overbrace{\tilde{E}^j}^{\substack{Pigouvian \\ penalty}} + \overbrace{MEG_{t_L}\left\{(\sigma^j - r_j)\left(-\frac{t_D + \tau_D}{\eta_{DD}}\right) - t_D + g^j\right\}}^{\substack{Revenue-recycling \\ effect}}$$

$$- \overbrace{MEG_{t_L}\left(-\frac{t_D + \tau_D}{\eta_{DD}}\right)\frac{\eta_{Dl}^c + \eta_{Ll}}{\varepsilon_{LL}}}^{\substack{Tax-interaction \\ effect}} + \overbrace{(1 + MEG_{t_L})t_L\theta_{WH}^D}^{\substack{productivity \\ effect}},$$

(10b) $\quad E^{t_D} = \tilde{E}^D + r_{t_D}(t_D + \tau_D)/\eta_{DD}, \qquad E^{\tau_D} = (\tilde{E}^D - t_D)(-\eta_{DD})/(1 + r_j) - t_D,$

$\quad g^j = s(M_D + M_{\bar{D}}) + r, \qquad \theta_{WH}^D = -\frac{\partial W}{\partial H}\frac{dH}{dD}, \qquad \sigma^{t_D} = 1, \qquad \sigma^{\tau_D} = 0$

where $j = t_D$ or τ_D, and η_{DD} and η_{Dl} are the elasticity of drunk driving with respect to penalties and the price of leisure respectively, $\tilde{E}^D = E^D + t_D$ is the external cost per trip defined gross of the expected fine, and we have ignored cross-price effects on alcohol consumption, which are small (see Appendix A).

E^{t_D} is the Pigouvian fine, equal to the (gross) external cost per trip, less the marginal increase in resource costs needed to raise the expected fine, $r_{t_D}(t_D + \tau_D)/\eta_{DD} = \tau_{t_D}D/(dD/dt_D)$. Leaving aside resource costs and assuming the initial fine is zero, the Pigouvian equivalent for the non-pecuniary penalty, E^{τ_D}, is smaller than the Pigouvian fine if the demand for drunk driving is inelastic; in this case the first-order addition to the height of the deadweight loss rectangle in Figure 1 exceeds the reduction in its width from the reduction in trips. Terms g^j and θ_{WH}^D are analogous to before, though they are expressed per trip, and exclude heavy drinking effects.

As before, the optimal expected fine per trip differs from the Pigouvian tax due to the revenue-recycling, tax-interaction and productivity effects. The revenue-recycling effect is smaller the larger the incremental increase in resource costs r_j and likely is negative under the non-pecuniary penalty that does not generate any first-order increase in revenue.

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[6] The β_i term adjusts the tax-interaction effect for the efficiency effects of neutralizing induced changes in labor tax revenues by adjusting G^T or G^P, rather than t_L.

(vi) Taxation of individual beverages. We now assume:

(11a) $A^m = A^m(A_{BE}^m, A_{WI}^m, A_{SP}^m)$, $A^h = A^h(A_{BE}^h, A_{WI}^h, A_{SP}^h)$

(11b) $E^{A_i} = E^A$, $\theta_{WH}^{A_i} = \theta_{WH}^A$, $i = BE, WI, SP$

In (11a), A^m and A^h are now composites for moderate and heavy alcohol consumption that are (weakly quasi-concave) functions of individual beverages: beer (*BE*), wine (*WI*) and spirits (*SP*). In (11b) we assume that marginal external costs and productivity effects per alcohol gallon are the same across these beverages.[7]

Optimal beverage taxes are given by (see Appendix A):

(12) $\hat{t}_i = t_i^* - \Sigma_{k \neq i}(t_k^* - \hat{t}_k)\left(-\dfrac{\eta_{ki}A_k}{\eta_{ii}A_i}\right)$

where *i, k = BE, WI, SP* and η_{ii} and η_{ki} denote own- and cross-price beverage elasticities. t_i^* is the optimal tax in the absence of cross-price effects among beverages and is analogous to that in (8a); thus, the optimal tax on one beverage likely is higher than that for another if it is more inelastic and more complementary to leisure. To the extent that beverages are substitutes ($\eta_{ki} > 0$), the optimal tax $\hat{t}_i$ is likely somewhat lower than t_i^* because as one beverage tax is increased above its initial level, the substitution into other beverages reduces efficiency, assuming all beverage taxes initially are below their optimal levels. Given the lack of solid evidence on beverage cross-price effects, and that they only moderately affect optimal taxes (Saffer and Chaloupka 1994), our discussion below focuses on differences in t_i^*.

(vii) Welfare effects. For increasing the overall alcohol tax from an initial level t_A^0 to t_A, and drunk-driver penalties from j^0 to j ($j = t_D$, τ_D), welfare effects are given by (see Appendix A):

(13) $(1 + MEG_i) \displaystyle\int_{v=t_A^0}^{t_A} \dfrac{dA}{dv}(v - t_A^*)dv$, $(1 + MEG_j) \displaystyle\int_{v=j^0}^{j^*} \dfrac{dD}{dv}(v - j^*)dv$

where $MEG_{t_D} = MEG_{t_L}$ and $MEG_{\tau_D} = 0$. The welfare gain from a marginal increase in the tax or penalty is the induced quantity reduction times the difference between the optimum and prevailing

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[7] This is a standard assumption (Saffer and Chaloupka 1994) because data on auto accidents, health, and productivity impacts are not decomposed by beverage type.

penalty, times $1 + MEG_{t_L}$ if extra revenue is raised and used to cut the labor tax; integrating over the entire tax increase gives the total welfare gain. Alternatively, welfare effects can be expressed in terms of quantities and elasticities by substituting for the price coefficients.

To compute optimal taxes/penalties, we assume external costs per unit of drunk driving and heavy drinking are constant. We also assume constant price elasticities, so quantities are given by:

$$(14) \qquad A = A^0 \left(\frac{p_A + t_A}{p_A + t_A^0} \right)^{\eta_{AA}}, \quad D = D^0 \left(\frac{t_D + \tau_D}{t_D^0 + \tau_D^0} \right)^{\eta_{DD}} \left(\frac{p_A + t_A}{p_A + t_A^0} \right)^{\eta_{DA}}$$

3. Parameter Values

We now discuss parameter values used to implement the above formulas. These values are for year 2000 and are (mostly) summarized in Table 1; Appendix B provides a detailed justification, and documentation, for chosen values where it is not provided below. For critical parameters that are uncertain, we consider ranges of values.

A. Baseline Data

Initial alcohol consumption $A^0 = 493$ million gallons of pure alcohol (or ethanol), with beer, wine, and spirits accounting for 56 percent, 14 percent, and 30 percent, respectively, of alcohol gallons. Excise tax rates (at federal and state level) for these beverages are $20.1, $17.5 and $34.8 per alcohol gallon, respectively, with an average rate of $24.2 per alcohol gallon or 12 percent of the pre-tax price $p_A = 197 per alcohol gallon. We assume initial drunk-driver trips $D^0 = 1,287$ million, and the probability of conviction is 1/1,562 per trip.

B. External Costs

Drunk-driver costs and penalties. We put the marginal external cost of drunk driving at $E^D D/A = 61.9 per alcohol gallon, or $23.7 per (14-mile) trip; injuries to other road users and pedestrians, property damages, medical costs, and government resource costs account for 53 percent, 27 percent, 10 percent, and 11 percent of these costs, respectively, while expected drunk-driver fines internalize just 1 percent of costs (Appendix B). Only 17 percent of injuries in crashes with alcohol involvement are counted as external (from Levitt and Porter 2001), as the added risk to other road users is the excess rate above the normal risk for sober drivers and excludes injuries in single-vehicle crashes that are internal and account for about two-thirds of all alcohol-related injuries. The private cost per fatality, *mpc*, is the value of life

(assumed to be \$4.0 million for the average drunk driver) and for non-fatal injuries it mainly is quality-adjusted life years. External costs from property damage apply to all excess single- and multi-vehicle crashes; the risk of elevated future insurance premiums internalizes 17 percent of these costs. We assume that 20 percent of medical costs are borne by individuals in variable costs and 40 percent by the government in tax subsidies and Medicare and that half of the government subsidy is justified by paternalistic preferences; overall, 60 percent of medical costs (which also apply to excess injuries in single- and multi-vehicle crashes) are external.[8]

Drunk-driver penalties are obtained by aggregating state-level data on arrests and penalties; non-pecuniary penalties (from jail terms and license suspensions) are valued at \$9.9 per alcohol gallon, or \$3.8 per trip; however, as discussed above, they do not affect the optimal alcohol tax.

Heavy drinking costs. Two widely cited studies have estimated these costs. Harwood et al. (1998), updated in Harwood (2000), put the annualized medical cost of alcohol abuse at \$12.0 billion or \$24 per alcohol gallon (excluding auto injuries) using estimates of the fraction of alcohol-related illnesses due to alcohol use. This figure likely is too high for our purposes as it excludes savings in medical costs from premature mortality and health benefits to moderate drinkers. Instead, we rely on Manning et al. (1989), who put lifetime medical costs for all individuals at equivalent to \$6.5 per alcohol gallon from comparing outcomes for heavy and moderate drinkers over time.[9] Netting out altruism and variable costs gives \$3.9 per alcohol gallon. Manning et al. (1989) also estimate external costs from life insurance and retirement pensions at the equivalent of \$1.0 and \$1.4 per alcohol gallon, respectively; including these gives our benchmark value $E^h A^h / A$ = \$6.3 per alcohol gallon.

C. Elasticities

Labor supply elasticities. Based on expert views in Fuchs et al. (1998) and the review of empirical evidence in Blundell and MaCurdy (1999), we choose $\varepsilon_{LL} = 0.15$, $\varepsilon_{LL}^c = 0.35$, and hence $\eta_{LI} = -0.20$.[10]

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[8] Earlier estimates of drunk-driver external costs include Manning et al. (1989), Miller and Blincoe (1994), and Kenkel (1993a). Levitt and Porter (2001) put the external cost for 1994 at \$8,000 per arrest, which converts to \$22.3 per alcohol gallon using our assumption about the value of life. This is for fatality costs alone; our corresponding estimate is \$23.0 per gallon.

[9] This figure is the total medical cost to individuals and third parties, scaled to exclude auto injuries, and updated to year 2000.

[10] These values represent an average over males and females and hours worked and participation elasticities. There is much variation across different empirical studies; however, if anything, we believe our values are conservative, as far greater responses are needed to explain, at least in part, business cycle fluctuations and large differences in work

Alcohol elasticities. Numerous studies have estimated own-price elasticities for alcohol, though there are serious methodological challenges (Cook and Moore 2000); we consider a range for all beverages of η_{AA} = –0.4 to –1.0.[11] Evidence on whether heavy alcohol consumption is more or less price elastic than alcohol as a whole is mixed;[12] however, our results are not very sensitive to this parameter given the relatively small contribution of heavy drinking costs in E^A, and we set $\eta_{hA} = \eta_{AA}$. Based on reviews by Clements et al. (1997) and Leung and Phelps (1993), we illustrate cases where the own-price elasticity for beer is up to 50 percent below the wine price elasticity, while the spirits elasticity is up to 50 percent above that for wine; the wine price elasticity is taken as –0.7.

We use two pieces of information to gauge a range for η_{Al}^c. First, this elasticity can be separated into two components (see Appendix A):

$$(15) \qquad \eta_{Al}^c = \eta_{A\widetilde{W}} \varepsilon_{LL}^c + \eta_{Al}^{c,\widetilde{W}}$$

where $\eta_{A\widetilde{W}}$ is the expenditure elasticity for alcohol and $\eta_{Al}^{c,\widetilde{W}}$ is the alcohol/leisure cross-price elasticity for given labor income. The first component reflects the allocation of extra labor income (following the reduction in leisure) to alcohol, while the second reflects possible changes in the marginal utility from alcohol relative to other goods as leisure falls. Estimates of income elasticities (which approximate expenditure elasticities) averaged across all beverages are positive but typically below 0.5.[13] A priori, we might expect $\eta_{Al}^{c,\widetilde{W}} < 0$ if people spend less time at places of hospitality or lingering over dinner with a bottle of wine with less leisure, although a counteracting effect is that people may drink to relax after work. Setting $\eta_{Al}^{c,\widetilde{W}} = 0$, and assuming $\eta_{A\widetilde{W}} = 0.1$–0.6, gives a (conservative) range of $\eta_{Al}^c = 0.04$–0.21.

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effort between Americans and Europeans (Prescott 2004). In addition, effective labor supply responses are greater over the longer term when human capital investments are endogenous (Kapicka 2005).

[11] Recent estimates for the United States include –0.74 in Baltagi and Goel (1990), –0.69 in Baltagi and Griffin (1995), –0.72 in Lee and Tremblay (1992), –0.80 in Manning et al. (1995), –0.87 in Manning and Mullahy (1998), –.50 in Nelson and Moran (1995), –0.10 in Selvanathan (1991), and –0.34 in Yan (1994). (In some cases we have averaged over individual beverage elasticities.)

[12] See Manning et al. (1995), Grossman et al. (1987), Cook and Tauchen (1982), Pogue and Sgontz (1989), Kenkel (1993a), Becker et al. (1991) and Farrell et al. (2003).

[13] Recent estimates (averaging over all beverages) include 0.10 in Baltagi and Griffin (1995), below 0.10 in Farrel et al. (2003), 0.11 in Lee and Tremblay (1992), 0.25 in Manning et al. (1995), 0.40 in Nelson and Moran (1995), 0.18 in Ruhm (1995), 0.89 in Selvanathan (1991), and 0.4 in Yen (1994).

Second, West and Parry (2006) directly estimate η_{Al}^c from an Almost Ideal Demand System over alcohol, leisure, and other consumption estimated with household data. Their central value is −0.09, with a 95 percent confidence interval of −0.40 to 0.20, though their central value for $\eta_{A\tilde{W}}$ is at the lower end of the above range (their central value for $\eta_{Al}^{c,\tilde{W}}$ is –0.1). As a compromise, we illustrate a range of η_{Al}^c = −0.20 to 0.20.[14] Typical income elasticity estimates for beer are lower than for wine and higher for spirits; we illustrate cases where all beverages are equally complementary to leisure and where beer is moderately more complementary to leisure than wine and vice versa for spirits.

Drunk-driver elasticities. We assume $\eta_{DA} = \eta_{AA}$ and $\eta_{DD}= -0.4$ to -1.0 based on estimated responses of drunk driving and highway fatalities to alcohol prices (see Appendix B). There is little empirical basis for gauging the drunk-driver/leisure cross-price elasticity; however, as explained below, it is generally of only moderate importance for our results. We illustrate a range of $\eta_{Dl}^c = 0$ to 0.35.[15]

D. Productivity Effects

From our accident data we estimate productivity losses from auto injuries at $12.5 per alcohol gallon or θ_{WH}^D = $4.8 per drunk-driver trip. As regards other productivity effects, it seems plausible that heavy drinkers suffer from difficulty of finding and retaining employment, while for moderate drinkers there might be little effect (Cook and Moore 2000; Cook and Peters 2005). However, as discussed in Appendix B, empirical evidence on this is highly conflicting and some studies implicitly estimate the productivity, revenue-recycling, and tax-interaction effects combined, rather than isolating the productivity effect. Manning et al. (1989) and Harwood (2000) are representative of a small and a substantial productivity impact respectively (for auto injuries and illness combined), and we use them (after updating) to infer an overall range of θ_{WH}^A = $12.0–$174 per alcohol gallon; for the revenue-neutral alcohol tax this implies a productivity effect of $6–$80 per alcohol gallon.[16]

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[14] West and Parry (2006) also estimate that $\eta_{Al}^c < \varepsilon_{LL}^c$; that is, alcohol is a relative (if not absolute) leisure complement, over a 95 percent confidence interval. And they find little correlation among η_{Al}^c, η_{AA}, and ε_{LL}^c, providing a justification for varying these elasticities independently in sensitivity analysis.

[15] We use a somewhat higher value than for the alcohol/leisure cross-price elasticity because the alcohol expenditure elasticity likely is larger for drunk drivers, who are dominated by younger, single individuals.

[16] The Harwood estimate implies annual productivity losses of $86 billion, or about 40 percent of annual earnings, for the typical heavy drinker. This excludes productivity losses from premature mortality, as we assume that the loss of tax revenues would be offset by a reduction of government spending, to keep per capita spending constant. The

E. Other Parameters

Following others (e.g., Ballard 1990; Goulder et al. 1997; Prescott 2004), we assume a labor tax (which combines federal and state income taxes, payroll taxes, broad sales taxes) of $t_L = 0.4$ along with labor supply elasticities; this implies $MEG_{t_L} = 0.11$. In addition, $MEG_{G^T} = -0.07$, though as noted, transfer spending may have broader social benefits. We illustrate a range where the marginal efficiency gain from public spending (either transfers or public goods) is -0.1 to 0.2.

Based on the assumption that half of the increase in an expected drunk-driver penalty is due to an increase in that penalty per conviction and half is due to an increase in the arrest rate (holding the expected cost of other penalties fixed), we obtain $r_{t_D} = 0.25$ and $r_{\tau_D} = 0.58$ (Appendix B). Finally, the g^A and g^j terms are inferred from other parameters but play a minor role in the simulations.

4. Results

A. Alcohol Tax

We begin by underscoring the potential importance of fiscal considerations for the overall optimal alcohol tax. Figure 2 shows the fiscal component, expressed relative to the Pigouvian tax, for different own- and leisure-cross price elasticities for alcohol (and our mid-range value for the productivity effect). For the revenue-neutral case in panel (a), the fiscal component is relatively large and exceeds the Pigouvian tax in most scenarios; in fact, the tax-interaction effect is a welfare gain that reinforces the revenue-recycling effect when the alcohol/leisure cross-price elasticity is below 0.2. Overall, when the own-price alcohol elasticity is –0.7, the fiscal component is 100 percent and 200 percent of the Pigouvian tax if the alcohol/leisure cross-price elasticity is 0.12 and 0, respectively. Even when the alcohol/leisure cross-price elasticity is 0.2, the fiscal component is still sizeable, amounting to 28–120 percent of the Pigouvian tax.

Panel (b) illustrates the case when alcohol tax revenues finance additional public spending given an alcohol demand elasticity of –0.7. When the marginal efficiency gain from public spending exceeds that from cutting other taxes (i.e., it exceeds 0.11), the fiscal component is larger than in the revenue-neutral case due to the larger revenue-recycling effect. But even when the marginal efficiency gain is zero

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above figures should be viewed with caution, as they come from comparing labor market outcomes of alcohol-dependent individuals to other individuals and are subject to problems of unobserved confounding factors (e.g., motivation) and errors in self-reported drinking.

and there is no revenue-recycling effect, the fiscal component still may be large—it varies from 0 to 3 times the Pigouvian tax—due to the positive tax-interaction effect.

Table 2 summarizes optimal alcohol taxes and welfare gains from various tax reforms under alternative parameter scenarios for the revenue-neutral case and, to be conservative, when the marginal efficiency gain from public spending is zero. The Pigouvian tax is $68 per alcohol gallon, with 91 percent and 9 percent of this due to the drunk-driver and heavy drinking externalities respectively.[17] The productivity effect adds another $6 to $80 per alcohol gallon to the optimal tax but is less than the fiscal component in most cases. Under revenue neutrality, the fiscal component adds anything from roughly $20 to well over $300 per alcohol gallon, while with increased spending it adds between $0 and $168 per alcohol gallon. Overall, the optimal tax is anywhere from three to more than ten times the current tax of $24 per alcohol gallon.

Welfare gains, shown in the lower part of Table 2, are $1.1 to $6.6 billion for a 50 percent increase in the alcohol tax above its current level; $1.8 to $12.9 billion for a doubling of the tax; $2.4 to $24.9 billion for a trebling of the tax, and, in many cases, much larger for optimizing over tax rates.

B. Drunk-Driver Penalties

Table 3 shows optimal drunk-driver penalties and welfare gains from raising penalties under alternative parameter scenarios. We note the following points.

First, resource costs and first-order deadweight losses from non-pecuniary penalties play a significant role in reducing the Pigouvian tax or tax equivalent. Even though the external cost per drunk-driver trip is $23.5, the Pigouvian fine is $7.3 to $18.8 per trip, depending on the drunk-driver elasticity, while the Pigouvian equivalent for the jail penalty is $5.7 to $14.6 per trip.

Second, the fiscal component generally is much smaller relative to the Pigouvian component for drunk-driver fines as opposed to alcohol taxes, and the revenue-recycling advantage of fines over non-pecuniary penalties also is relatively small (aside from when own- and cross-price elasticities both take on their lower bound values). The drunk-driver external cost is about six times current drunk-driver penalties, so welfare gains in this market from higher penalties typically swamp those in the labor market; in contrast, external costs for alcohol are "only" 30 percent of the consumer price, so welfare gains in this market from higher taxes can be dominated by those in the labor market.[18] A related point is that welfare

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[17] The Pigouvian tax is somewhat sensitive to alternative parameter choices. For example, it varies from $64.8 to $71.7 as paternalistic preferences justify 0 to 100 percent of medical subsidies; from $56.7 to $79.7 as the value of life varies from $2 to $6 million; and from $39.0 to $97.5 as drunk-driver and heavy drinking elasticities take low and high values given the mid-range value for the own-price alcohol elasticity.

[18] A parallel result applies in the context of environmental policies. Welfare effects from fiscal interactions are relatively large when internalizing pollution damages through (freely allocated) emissions permits would reduce

gains in Table 3 increase as drunk driving becomes more price-elastic, while in Table 2 they fall with greater price elasticity. More elastic responses imply greater externality benefits from a given price increase, but they also diminish the revenue-recycling and tax-interaction effects (see above); the former effect dominates for drunk-driver penalties.

Third, even though non-pecuniary penalties impose first-order deadweight losses, implementation costs, and forgo gains from fiscal interactions compared with higher alcohol taxes, these drawbacks are offset by their advantage in targeting the drunk-driver externality more directly. Welfare gains from an increase in expected non-pecuniary penalties of $4 per trip (which would yield about $5 billion in revenue if it were a fine) yields welfare gains of $3.3 to $8.3 billion; the equivalent revenue-neutral tax on all alcohol users yields welfare gains of $1.9 to $6.6 billion (Table 2). The equivalent increase in expected drunk-driver fines yields somewhat larger welfare gains of $8.4 to $12.4 billion.

Fourth, the optimized fine is $19.0 to $26.0 per trip, or $1.4 to $1.9 per mile of drunk driving, while the optimized non-pecuniary penalty is $11.2 to $13.8 per trip, or $0.8 to $1.0 per mile; prevailing penalties amount to $0.3 per mile.

C. Individual Beverage Taxes

Finally, Table 4 shows the optimal tax on beer and spirits relative to that for wine under alternative scenarios (estimates are approximate as we ignore cross-price effects among beverages). Optimal taxes on beer may substantially exceed those for wine to the extent that the own- and leisure-cross price elasticities are smaller for beer than for wine, implying a larger fiscal component to the optimal tax; the optimal beer tax is anything from 13 percent to 360 percent greater than that for wine for the scenarios illustrated. For converse reasons, the optimal tax for spirits is 53 to 93 percent of that for wine. In contrast, spirits currently are taxed more heavily than wine and beer (Table 1).

5. Conclusion

Our results suggest there is a solid efficiency case for shifting some of the tax burden off labor and onto alcohol, or more generally, for including higher alcohol taxes in any package of deficit-reduction measures to offset the need for future labor tax increases to pay for projected growth in entitlement spending. However, higher alcohol taxes should be seen as a complement to, rather than substitute for, stiffer drunk-driver penalties as, for more incremental changes, the latter policies yield welfare gains that are at least moderately, if not substantially, larger.

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emissions by a modest amount (for example, carbon) as opposed to a relatively large amount (for example, sulfur dioxide). See Goulder et al. (1997) and Parry et al. (1999).

One limitation of our analysis is that it does not distinguish between different quality beverages. While externalities call for the same tax on beverages with the same alcohol content, beyond this additional revenues should be raised without distorting choice among, for example, inexpensive and fine wines, implying that the ideal structure contains a mix of specific and ad valorem taxes.

Distributional issues also are beyond our scope. Incidence studies suggest that alcohol taxes are regressive, even when income is measured on a lifetime basis (e.g., Lyon and Schwab 1995). However, regressivity is partly offset by benefits from revenue recycling from improved health and fewer drunk-driver accidents and automatic indexing of benefits and income tax thresholds to the general price level; nonetheless, additional adjustments to the broader tax and benefit system would be required to more fully address distributional concerns.[19]

On the other hand, accounting for additional distortions from the tax system, particularly those in the capital market, and distortions between ordinary and tax-favored spending (e.g., on home ownership), could increase significantly the optimal alcohol tax, as there would be greater efficiency gains from reducing income taxes (e.g., Bovenberg and Goulder 1997; Parry and Bento 2000,). Further issues beyond our scope include possible inefficiencies from misperceptions over the risks of alcohol addiction (Kenkel 1996); whether excise taxes are over- or under-shifted into alcohol prices (e.g., Young and Bielinska-Kwapisz 2002; Kenkel 2005); the broader social costs of alcohol abuse, such as crime and violence; and simultaneous optimization with other commodity taxes and the level of public spending.

The type of analysis developed here might be applied to other problems at the nexus of public finance and health economics, most obviously cigarette taxation. Another possible application is the growing problem of obesity, where corrective taxes (e.g., on fatty foods) or subsidies (e.g., for exercise) might be warranted if obesity increases third-party medical costs over the lifecycle or if people lack self-control (O'Donoghue and Rabin 2006). However, the fiscal component may flip sign in this case if fast food and exercise are, respectively, leisure substitutes and complements.

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[19] A related issue is that, in theory, some of the fiscal component of the optimal alcohol tax might be incorporated into the income tax system rather than into the excise tax (Atkinson and Stiglitz 1976). However, this possibility is compromised to the extent that (a) leisure is non-separable from consumption goods in utility, as suggested by empirical studies (e.g., Barnett 1979; Blundell and Walker 1982; and Browning and Meghir 1991); (b) individuals have different preferences; and (c) for practical reasons, tax rates for different income brackets differ from those that would minimize the equity-weighted deadweight costs of the tax system (Saez 2002).

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Appendix A. Analytical Derivations

Deriving equation (6)

      Using (1) and (3), agents solve the following optimization problem:

(A1) $V(t_A, t_L, I, G^P, \overline{D}, \overline{M}) = MAX\ U(A^m, A^h, D, C, l, H, \tau_D D, \overline{M}, G^P)$

$$+ \lambda\{I + (1 - t_L)w(H)(T(H) - l) - (p_A + t_A)A - (v_D + t_D)D - v_M M - p_C C\}$$

where $H = H(A^h, D, \overline{D}, M)\}$, $T - l = L$, and λ is a Lagrange multiplier. From partially differentiating (A1):

(A2) $\dfrac{\partial V}{\partial t_A} = -\lambda A$, $\dfrac{\partial V}{\partial t_L} = -\lambda wL$, $\dfrac{\partial V}{\partial I} = \lambda$, $\dfrac{\partial V}{\partial G^P} = U_{G^P}$, $\dfrac{\partial V}{\partial \overline{D}} = -\lambda H_{\overline{D}} mpc$, $\dfrac{\partial V}{\partial \overline{M}} = U_{\overline{M}}$

where *mpc* is defined in the text. Totally differentiating $V(.)$ with respect to t_A, and using (A2), gives:

(A3) $\dfrac{1}{\lambda}\dfrac{dV}{dt_A} = -A - wL\dfrac{dt_L}{dt_A} + \dfrac{dI}{dt_A} + \dfrac{U_{G^P}}{\lambda}\dfrac{dG^P}{dt_A} - H_{\overline{D}} mpc\dfrac{dD}{dt_A} + \dfrac{U_{\overline{M}}}{\lambda}\dfrac{dM}{dt_A}$

      Totally differentiating the government budget constraint (2) with respect to t_A, allowing t_L, G^T and G^P to vary, gives:

(A4) $\dfrac{dG^T}{dt_A} - W\dfrac{dt_L}{dt_A} = t_L\dfrac{dW}{dt_A} + A + t_A\dfrac{dA}{dt_A} - s\dfrac{dM}{dt_A} + (t_D - r)\dfrac{dD}{dt_A} - \dfrac{dG^P}{dt_A}$

From the zero profit condition for medical and auto insurance companies, $K_M = (1 - s - v_M)M$ and $K_D = (c_D - v_D)D$. Substituting into $I = G^T - K_M - K_D$, and totally differentiating with respect to t_A gives

(A5) $\dfrac{dI}{dt_A} = \dfrac{dG^T}{dt_A} - (1 - s - v_M)\dfrac{dM}{dt_A} - (c_D - v_D)\dfrac{dD}{dt_A}$

Substituting (A4) and (A5) in (A3) and grouping terms gives:

(A6) $\dfrac{1}{\lambda}\dfrac{dV}{dt_A} = -\left(1 - v_M - \dfrac{U_{\overline{M}}}{\lambda}\right)\dfrac{dM}{dt_A} - (mpc \cdot H_{\overline{D}} + c_D - v_D - t_D + r)\dfrac{dD}{dt_A}$

$$+ t_A\dfrac{dA}{dt_A} + t_L\dfrac{dW}{dt_A} + \left(\dfrac{U_{G^P}}{\lambda} - 1\right)\dfrac{dG^P}{dt_A}$$

From (5), assuming that demand for medical care operates through changes in health:

(A7) $\dfrac{dM}{dt_A} = M_{A^h}\dfrac{dA^h}{dt_A} + M_D\dfrac{dD}{dt_A} + M_{\overline{D}}\dfrac{d\overline{D}}{dt_A}$

In addition we define:

(A8) $\eta_{AA} = \dfrac{dA}{dt_A}\dfrac{(p_A + t_A)}{A}$, $\qquad \eta_{DA} = \dfrac{dD}{dt_A}\dfrac{(p_A + t_A)}{D}$, $\qquad \eta_{hA} = \dfrac{dA^h}{dt_A}\dfrac{(p_A + t_A)}{A^h}$

Substituting (A7) and (A8) in (A6) gives, after some manipulation, equations (6a and b).

Deriving (8)
From totally differentiating the government budget constraint (2) with respect to t_A, with t_L variable and G^T and G^P fixed, and using (7), we can obtain:

(A9) $\dfrac{dt_L}{dt_A} = -\dfrac{A + t_A\dfrac{dA}{dt_A} + (t_D - r)\dfrac{dD}{dt_A} - s\dfrac{dM}{dt_A} + t_L\left\{w\dfrac{\partial L}{\partial t_A} + \dfrac{\partial W}{\partial H}\dfrac{dH}{dt_A}\right\}}{w\left\{L + t_L\dfrac{\partial L}{\partial t_L}\right\}}$

From (A9) and (8b):

(A10) $t_L w\dfrac{\partial L}{\partial t_L}\dfrac{dt_L}{dt_A} = MEG_{t_L}\left\{A + t_A\dfrac{dA}{dt_A} + (t_D - r)\dfrac{dD}{dt_A} - s\dfrac{dM}{dt_A} + t_L\left\{w\dfrac{\partial L}{\partial t_A} + \dfrac{\partial W}{\partial H}\dfrac{dH}{dt_A}\right\}\right\}$

Substituting (7) and (A10) into (6a), with $dG^T/dt_A = dG^P/dt_A = 0$, gives:

(A11) $(E^A - t^A)\left(-\dfrac{dA}{dt_A}\right) + MEG_{t_L}\left\{A + t_A\dfrac{dA}{dt_A} - s\dfrac{dM}{dt_A} - (r - t_D)\dfrac{dD}{dt_A}\right\}$

$\qquad\qquad\qquad + (1 + MEG_{t_L})t_L w\dfrac{\partial L}{\partial t_A} + (1 + MEG_{t_L})t_L\dfrac{\partial W}{\partial H}\dfrac{dH}{dt_A}$

From the Slutsky equations:

(A12) $\dfrac{\partial L}{\partial t_A} = \dfrac{\partial L^c}{\partial t_A} - \dfrac{\partial L}{\partial I}A$, $\qquad \dfrac{\partial L}{\partial t_L} = -\dfrac{\partial L^c}{\partial \tilde{w}}w - \dfrac{\partial L}{\partial I}wL$

where superscript c denotes a compensated coefficient. From the Slutsky symmetry property:

(A13) $\dfrac{\partial L^c}{\partial t_A} = -\dfrac{\partial A^c}{\partial \tilde{w}}$

Equating (A11) to zero, and substituting (A12) and (A13) gives (8a), where g^A and θ_{WH}^A are defined in (8b), η_{AA} is defined in (A8), and additional elasticities are:

$$(A14) \quad \varepsilon_{LL} = \frac{\partial L}{\partial \tilde{w}} \frac{\tilde{w}}{L}, \quad \eta_{Al} = \frac{\partial A}{\partial \tilde{w}} \frac{\tilde{w}}{A}, \quad \eta_{LI} = \frac{\partial L}{\partial I} \frac{\tilde{w}L}{L}$$

Deriving (9)
Following the derivation of (A10) above, with G^P or G^T variable and t_L fixed gives:

$$(A15) \quad t_L w \frac{\partial L}{\partial G^i} \frac{dG^i}{dt_A} = MEG_{G^i} \left\{ A + t_A \frac{dA}{dt_A} + (t_D - r) \frac{dD}{dt_A} - s \frac{dM}{dt_A} + t_L \left\{ w \frac{\partial L}{\partial t_A} + \frac{\partial W}{\partial H} \frac{dH}{dt_A} \right\} \right\}$$

where $i = P, T$ and MEG_{G^T} and MEG_{G^P} are defined in (6b) and (9b). Following the analogous derivation for equation (8) but using (A15) in place of (A10) gives (9).

Deriving (10)
We simply our formulas for optimal drunk-driver penalties by assuming $dA/dj = dA^h/dj = 0$ ($j = t_D, \tau_D$). To justify this, suppose that the average drunk driver consumes 0.03 gallons of alcohol (equivalent to one liter of red wine) and that 50 percent of the reduction in drunk driving in response to higher penalties comes from reduced heavy drinking (as opposed to people continuing to drink but using other transportation or drinking at home). Given an alcohol tax of \$24.2 and a heavy drinking cost of \$6.3 per alcohol gallon, the welfare loss from the induced reduction in heavy drinking per drunk-driver trip is $0.03 \times 0.5 \times (24.2–6.3) = \$0.27$ which is very small relative to the externality benefit of \$23.7 per avoided trip (see also Kenkel 1993b).

Differentiating the government budget constraint (2) with respect to $j = t_D, \tau_D$, with G^T and G^P fixed but t_L variable and $dA/dj = 0$ gives:

$$(A16) \quad -W \frac{dt_L}{dj} = t_L \frac{dW}{dj} + \sigma_j D - s \frac{dM}{dj} + (t_D - r) \frac{dD}{dj} - r_j D$$

where $\sigma_{t_D} = 1$, $\sigma_{\tau_D} = 0$. The welfare effect from an incremental increase in penalty j can be obtained by following the same derivation for equation (6) above for an increase in t_A, using (A16) in place of (A4), and with $dA/dj = dA^h/dj = 0$. The result is:

$$(A17) \quad (\tilde{E}^D - t_D) \left(-\frac{dD}{dj} \right) - (r_j + 1 - \sigma_j)D + t_L \frac{dW}{dj}$$

where $\tilde{E}^D$ is the external cost gross of the fine. The analogous equations to (A9) and (A11) above are:

$$(A18) \quad \frac{dt_L}{dj} = -\frac{(\sigma_j - r_j)D + (t_D - r)\dfrac{dD}{dj} - s\dfrac{dM}{dj} + t_L\left\{ w\dfrac{\partial L}{\partial j} + \dfrac{\partial W}{\partial H}\dfrac{dH}{dj} \right\}}{w\left\{ L + t_L\dfrac{\partial L}{\partial t_L} \right\}}$$

and

$$(A19) \quad (E^D - t_D)\left(-\frac{dD}{dj} \right) - (r_j + 1 - \sigma_j)D + MEG_{t_L}\left\{ (\sigma_j - r_j)D - s\frac{dM}{dj_A} - (r - t_D)\frac{dD}{dj} \right\}$$
$$+ (1 + MEG_{t_L})t_L w\frac{\partial L}{\partial j} + (1 + MEG_{t_L})t_L \frac{\partial W}{\partial H}\frac{dH}{dj}$$

Following the analogous steps in deriving (8) above, using (A18) and (A19), gives (10).

Deriving equation (12)

As discussed below the welfare effect from an incremental increase in the alcohol tax with just one alcohol aggregate is $(1 + MEG_i)(t_A - t_A^*)dA/dt_A$. Therefore, with three beverages each with their own tax rate, the welfare effect from incrementally increasing one of them is given by:

$$(A20) \quad (1 + MEG_i)(t_k - t_k^*)\Sigma_k dA_k / dp_i$$

Equating (A20) to zero and substituting the own- and cross-price elasticities $\eta_{ii} = (dA_i / dp_i)p_i / A_i$ and $\eta_{ki} = (dA_k / dp_i)p_i / A_k$, gives (12).

Deriving equation (13)

Here we illustrate welfare effects for the revenue-neutral alcohol tax: derivations for the welfare effects of drunk-driver penalties and alternative forms of revenue recycling are analogous. From manipulating (8a), using the definition of η_{AA} and using the Slutsky equation for ε_{LL}:

$$(A21) \quad -E^A\frac{dA}{dt_A} = -(1 + MEG_{t_L})t_A^*\frac{dA}{dt_A} + MEG_{t_L}\left\{ g^A - \frac{A(\varepsilon_{LL}^c - \eta_{Al}^c)}{\varepsilon_{LL}} \right\} - (1 + MEG_{t_L})t_L\theta_{WH}^A\frac{dA}{dt_A}$$

From (6a), (7) and (A10):

$$(A22) \quad -E^A\frac{dA}{dt_A} + (1 + MEG_{t_L})t_A\frac{dA}{dt_A} + (1 + MEG_{t_L})t_L\theta_{WH}^A\frac{dA}{dt_A} + (1 + MEG_{t_L})t_L\tilde{w}\frac{\partial L}{\partial t_A}$$
$$+ MEG_{t_L}(A - g^A)$$

Substituting (A21) in (A22) gives:

(A23) $\quad (1+MEG_{t_L})(t_A - t_A^*)\dfrac{dA}{dt_A} + (1+MEG_{t_L})t_L\tilde{w}\dfrac{\partial L}{\partial t_A} - MEG_{t_L}A\left\{\dfrac{\varepsilon_{LL}^c - \eta_{Al}^c}{\varepsilon_{LL}}\right\}$

The last two terms cancel, after using (A12)–(A14) to substitute out for $\partial L/\partial t_A$, and noting that $1+MEG_{t_L} = MEG_{t_L}t_L\varepsilon_{LL}/(1-t_L)$. Integrating over the entire tax increase gives (13).

Deriving Equation (15)

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

(A24) $\quad \dfrac{\partial A^c}{\partial \tilde{w}} = \dfrac{\partial A^{c,\tilde{W}}}{\partial \tilde{w}} + \dfrac{\partial A}{\partial \tilde{W}}\tilde{w}\dfrac{\partial L^c}{\partial \tilde{w}}$

Multiplying by $\tilde{w}/A$, and using $\tilde{W} = \tilde{w}L$ gives (15), where $\eta_{A\tilde{w}} = (\partial A/\partial \tilde{W})\tilde{W}/A$ is the expenditure elasticity for alcohol (equivalent to the income elasticity with labor supply fixed).

Appendix B. Additional Documentation for Parameter Values

Alcohol consumption, taxes, and prices. Consumption of beer, wine, and spirits, in gallons of pure alcohol, is from NIAAA (2003). Alcohol tax revenue by beverage accruing to federal, state, and local governments is from TTB (2004), and TPC (2004). Dividing total tax revenue by beverage consumption gives the excise tax rates. The pre-tax price of alcohol is calculated by total spending on alcohol (from the US Bureau of Economic Analysis website), less tax revenue, divided by alcohol consumption.

Drunk-driver trips and conviction rate. Following NHTSA (2005) we assume that drivers with BAC above the legal limit account for 1/140 of nationwide passenger vehicle miles. This is based on a study that estimates drunk-driver miles using data on auto crashes involving alcohol, and the relative crash risk for sober and drunk drivers. Multiplying by passenger vehicle miles for 2000 (from BTS 2005, Table 1.32) and dividing by an assumed average trip length of 14 miles (Gallup 2003), gives initial drunk driver trips of 1,287 million. There were 823,424 drunk-driver convictions in 2000 (US NHTSA 2002a, Summary Table 2), implying a conviction rate of 1/1,562 per trip.

External costs of drunk driving. Levitt and Porter (2001) estimate that in 1994 only 16.8 percent of fatalities in auto accidents where one or more drivers have been drinking are external; the bulk of deaths occur in single-vehicle crashes where risks are internal, and external costs are also net of the "normal" fatality risk (i.e. that posed by sober drivers, bad weather and road conditions, etc.). Applying the same ratio to alcohol-related fatalities in 2000 (from US NHTSA 2002b, Table 6) gives 2,821 external fatalities. For fatalities, the marginal private cost *mpc* corresponds to estimates of the value of life, which captures the discounted value of foregone market and non-market time, grief to relatives, etc. US NHTSA (2002b) assumes a value of life of $3.2 million for all highway fatalities; Aldy and Viscusi (2006) estimate a higher average value, though it depends on age—$3.8 and $6.0 million for a 20- and 30-year-old, respectively. As a compromise, we adopt a value of $4 million.

Non-fatal injuries in alcohol-related crashes for seven injury classes (MAIS 0 to MAIS 5 and property damage only) are from US NHTSA (2002b), Table 10; again, we multiply by 0.168 to obtain

external injuries. For a given class of non-fatal injury, we obtain *mpc* using estimated quality-adjusted life years, forgone (net of tax) wages, and foregone non-market time, from US NHTSA (2002b), Table A-1. Aggregating over the value of fatal and non-fatal injuries, and dividing by alcohol consumption, gives a value for $mpc \cdot H_{\bar{D}} D / A$ = \$32.8 per alcohol gallon.

Total property damages from drunk driving, $c_D D$, was obtained using estimates of the (average) property damage associated with a given injury class (including insurance and legal costs) from US NHTSA (2002b). However, since part of property damages in single-vehicle crashes is an external cost (unlike the own-driver injury risk), these values are multiplied by excess injuries across both single- and multi-vehicle crashes. $v_D D$ was obtained by assuming a convicted drunk driver pays insurance premiums that are three times larger than otherwise for three years (Kenkel 1993a), an annual premium of \$687 (U.S. DOC 2003, Table 1225), and a 5 percent discount rate, and multiplying by drunk-driver convictions. Dividing by alcohol consumption gives $c_D D/A$ = \$19.8, $v_D D/A$ = \$3.3 and net property damages of \$16.5 per alcohol gallon.

Medical costs per injury type (including emergency services) were obtained from NHTSA (2002b); multiplying by the respective number of excess injuries for both single- and multi-vehicle crashes and aggregating gives $(M_D + M_{\bar{D}})D$. Based on out-of-pocket expenditures in U.S. DOC (2003), Table 127, we set $v_M = 0.20$. We assume a medical subsidy $s = 0.4$, which accounts for tax relief on health insurance, and Medicare payments. We are unaware of any empirical evidence on the extent to which medical subsides are warranted by paternalistic preferences; we assume half of the medical subsidy is warranted ($U_{\bar{M}} / \lambda$ = 0.20). Putting these components together and dividing by alcohol consumption gives external medical costs $(1 - v_M - U_{\bar{M}} / \lambda)(M_D + M_{\bar{D}})D / A$ = \$6.4 per alcohol gallon.

Drunk-driver Penalties. Our approach here is roughly based on Kenkel (1993a). US BOJS (2002) provides drunk-driver arrests by state;[20] following Kenkel (1993b, pp. 140) we assume that 80 percent of arrests result in conviction.

Fines, jail sentences, license suspensions and other penalties for driving under the influence convictions by state are available from US NHTSA (2002a), Summary Table 2. We obtain the average penalty per conviction by assuming weights of 0.67, 0.19 and 0.14 for first-, second-, and third-time offenders (based on Maruschak 1999). Nationwide average penalties are obtained by weighting average state penalties by that state's share in total drunk-driver convictions. The average fine per conviction is \$295 while the average jail penalties and license suspensions are 10.4 days and 5.6 months respectively. Most likely, the private cost of day in jail exceeds the value of time forgone in the market or non-market sector due to the disutility from incarceration and stigma. One way to indirectly value a jail penalty is by the cost of community service that is frequently offered to convicted drunk drivers as an alternative to jail. For states that offer community service as an option, on average the service duration is about four times that of the jail penalty; we therefore value the cost of a day in jail at four times the forgone net of tax wage, which leads to an estimate of \$2,554 for the cost of the average jail term.[21] License suspensions are valued at vehicle ownership and operating costs, assumed to be \$20.2 per day (from www.aaamidatlantic.com), or \$3,368 per conviction. Multiplying by total convictions of 1,029,280 for 2000 (US BOJS 2002), the conviction rate, and dividing by alcohol consumption gives pecuniary and non-pecuniary penalties of $t_D D / A$ = \$0.5 and $\tau_D D / A$ = \$9.9 per alcohol gallon.

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[20] In almost all cases data is for 2000; for other cases we used data as close to 2000 as possible.

[21] We assume a gross daily wage of \$112 from www.bls.gov/ncs/ect/home.htm#tables.

Government resource costs. Based on estimates for cases resulting in a guilty plea, Kenkel (1993b) assumes judicial costs per drunk-driver arrest of $500 for 1985, about one-seventh of the cost per arrest averaged over all arrests (which include protracted cases with innocent pleas for which costs per arrest are much higher). We obtain judicial costs of $1,600 per drunk-driver arrest by taking one-seventh of the nationwide average cost per arrest for 2000 (from U.S. BOJS 2004, Table 1 and U.S. BOJS 2002, Table 4.1); dividing by the conviction rate gives a cost of $2,000. We assume police costs of $360 per drunk-driver arrest from updating Kenkel (1993a) for inflation; this represents an average over sobriety checkpoints and (less costly) testing of those pulled over for reckless driving. The ratio of judicial and police costs per conviction to the private value of a jail term is therefore 0.95.

Based on other studies, Kenkel (1993b) assumed a government resource cost of $40 per person per day in jail for 1985; we update this to $80 for 2000 based on the growth in costs per inmate in the prison system (U.S. BOJS 2004, Appendix), which is $832 per sentence, or 33 percent of the private costs to drunk drivers. Combined costs are therefore $3,282; multiplying by drunk-driver convictions and dividing by alcohol consumption gives $rD/A = \$6.7$ per alcohol gallon.

Judicial costs amount to 32 percent of the private cost per conviction. Assuming two-thirds of these costs are fixed and one-third vary in proportion to the total value of penalties per conviction, then $r_{t_D} = 0.11$ when the fine per conviction is increased. Assuming resource costs for jail terms are proportional to the duration of the term, then $r_{\tau_D} = 0.11 + 0.33$ when jail terms per conviction are increased. Now suppose the arrest rate per trip were doubled, that non-pecuniary penalties per conviction are reduced by 50 percent to keep them fixed in expected terms per trip, and that the fine per trip is increased to keep total penalties per conviction fixed. The increase in resource costs per dollar of expected fines would be $r_{t_D} = ((450 + 2{,}000) + 416) - 416)/((2{,}554 + 3{,}368) \times .5 + 295 + (2{,}554 + 3{,}368) \times .5) = 0.39$. Conversely, if the arrest rate were doubled with the fine and license suspension per conviction reduced 50 percent, and the jail penalty per trip increased to keep total penalties per conviction fixed, the increase in resource costs per dollar equivalent of extra expected jail penalties would be $r_{\tau_D} = (.71 \times 832 + (450 + 2000 + 1.71 \times 832))/((295 + 3{,}368) \times .5 + 2{,}554 + (295 + 3{,}368) \times .5) = 0.72$. Therefore, assuming that half of any increase in expected penalty comes from increasing the penalty per conviction, and half from increasing the arrest rate, gives $r_{t_D} = 0.25$ and $r_{\tau_D} = 0.58$.

Drunk-driver elasticities. A study of self-reported data on drunk driving by Kenkel (1993a) implies an alcohol price/drunk-driving elasticity $\eta_{DA} = -0.75$; this is broadly consistent with estimates of the traffic fatality-alcohol price elasticity, which are typically around –0.5 to –1.0 (e.g., Evans et al. 1991, Chaloupka et al. 1993, Ruhm 1996). It therefore seems reasonable to use the same range for η_{DA} as for η_{AA}.

Most, though not all, studies suggest that drunk driving is responsive to stricter deterrence policies; for example, Chaloupka et al. (1993), Kenkel (1993b), and Mullahy and Sindelar (1994) find significant responses, though Evans et al. (1991) do not. Kenkel (1993b), Table 7, estimates that an increase in annual deterrence costs of $1,260 million (after updating to 2000) would reduce drunk driving by 18 percent; using our figures this would represent an increase in drunk-driver penalties of around 25 percent, implying $\eta_{DD} \approx -0.7$. We illustrate a range of $\eta_{DD} = -0.4$ to -1.0.

Productivity effects. Empirical literature on the productivity effects of alcohol is very mixed (Cook and Moore 2000). Although some studies suggest that alcohol abuse causes reduced educational attainment

and likelihood of full time employment (Mullahy and Sindelar 1991, 1993), others find a drinker's bonus, that is, a positive association between earnings and alcohol consumption (e.g., Berger and Leigh 1988, Zarkin et al. 1998). However, one difficulty is controlling for confounding factors such as motivation (Mullahy and Sindelar 1996, pp. 413), while another is reverse causation, that is, higher wages should lead to more drinking given that alcohol is a normal good. Some studies attempt to address these problems by using instrumental variables (e.g., Kenkel and Ribar 1994; Mullahy and Sindelar 1996), while two recent studies by Dave and Kaestner (2001) and Cook and Peters (2005) estimate reduced form models relating labor market outcomes to alcohol taxes, but again reach highly conflicting results. Dave and Kaestner (2001) find that alcohol taxes are unrelated to employment, hours of work, and wages; in contrast, Cook and Peters (2005) find that higher beer taxes substantially increase the prevalence of full-time employment among young adults.

A further complication is that reduced form estimates of the effective labor supply/alcohol tax relation implicitly lump together the productivity, revenue-recycling, and tax-interaction effects. This is not the case for studies, such as West and Parry (2006), that regress alcohol demand on net wages; here, differences in net wages pick up the complementarity between alcohol and leisure, while controlling for alcohol taxes, and hence health status.

Figures and Tables
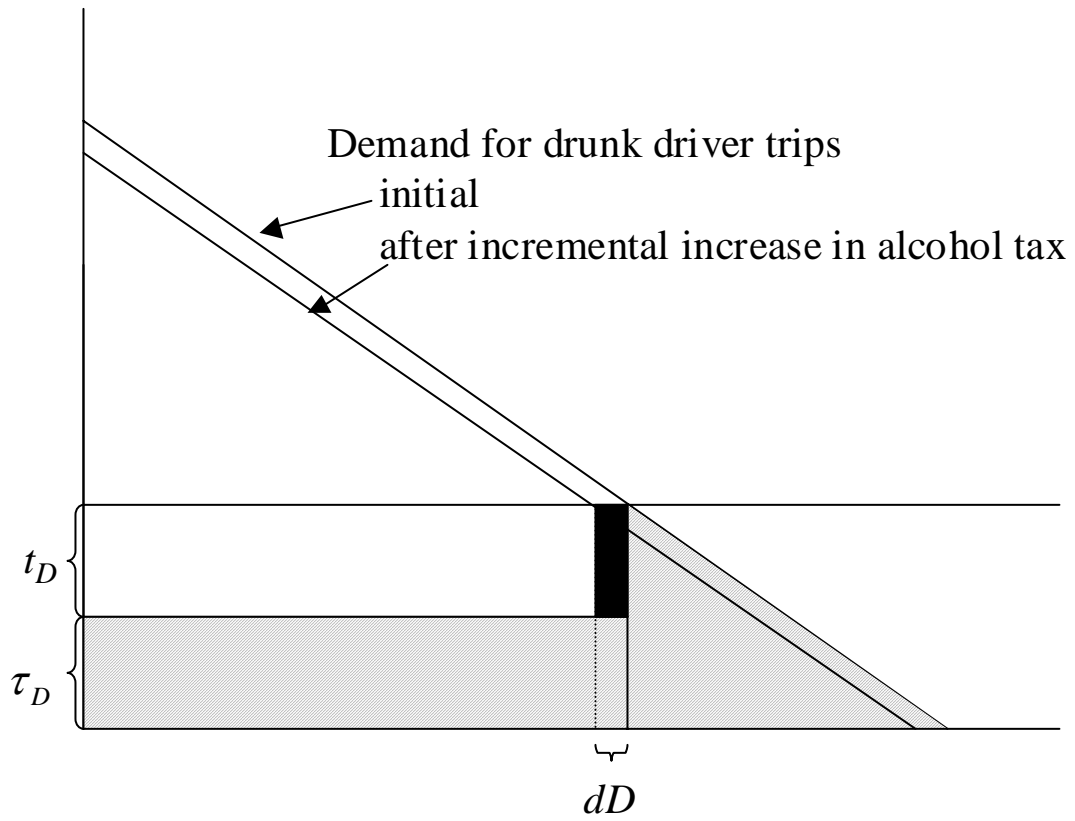
Figure 1. Deadweight Losses from Drunk-Driver Penalties

Demand for drunk driver trips
initial
after incremental increase in alcohol tax

t_D

τ_D

dD

Figure 2. Fiscal Component of Optimal Alcohol Tax
(relative to Pigouvian tax)
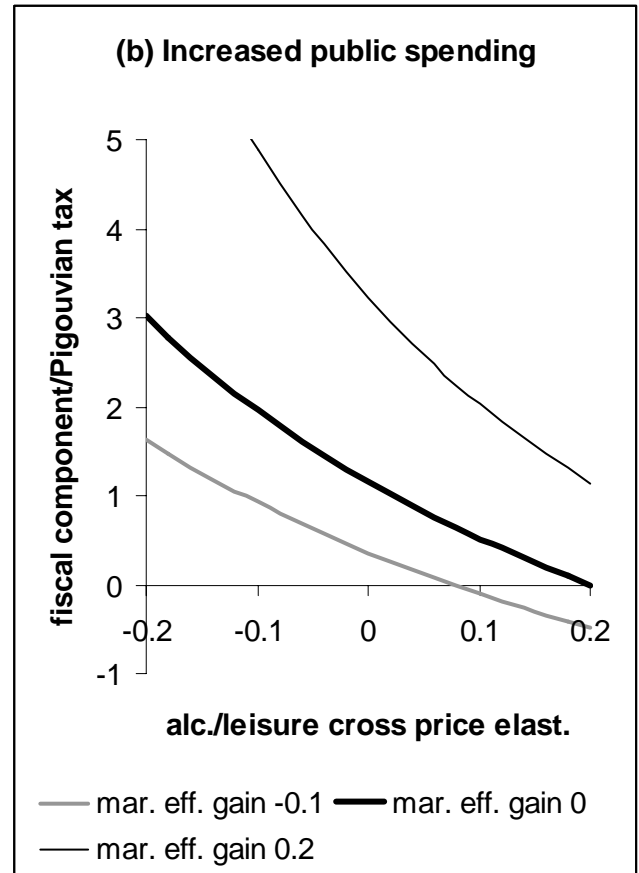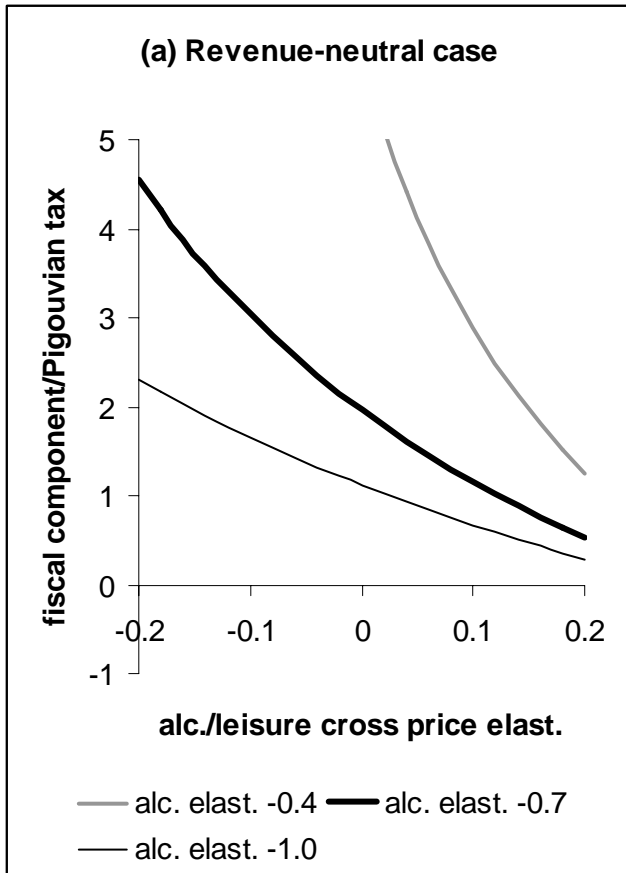
Table 1. Benchmark Values for Selected Parameters

parameter		Value
Baseline data		
Alcohol consumption, mn alc. gals.		493
beer	276	
wine	71	
spirits	146	
Pre-tax alchol price, $/alc. gal.		197
Excise taxes, $/alc. gal.		
all beverages		24.2
beer	20.1	
wine	17.5	
spirits	34.8	
Drunk driver trips, mn		1,287
External Costs, $/alc.gal.		
Drunk driving		61.9
injuries to other road users	32.8	
property damage	16.5	
medical costs	6.4	
government resource costs	6.7	
pecuniary drunk driver penalty		0.5
non-pecuniary drunk driver penalties		9.9
Heavy drinking cost		6.3
Elasticities		
Labor supply with respect to		
net wage (uncompensated)		0.15
net wage (compensated)		0.35
income		-0.20
Alcohol		
own price (all beverages)		-0.4 to -1.0
heavy drinking with respect to alcohol price		-0.4 to -1.0
cross price with respect to leisure		-0.2 to 0.2
Drunk driving		
with respect to alcohol price		-0.4 to -1.0
own price		-0.4 to -1.0
cross price with respect to leisure		-0.2 to 0.35
Alcohol/health impact on earnings, $/alc. gal.		12.0 to 174.0
Marginal efficiency gain		
labor tax reduction		0.11
increased public spending		-0.1 to 0.2
Extra resource costs per $ of exp. penalty		
fine		0.25
non-pecuniary penalty		0.58

Table 2. Simulations of the Optimal Alcohol Tax

	with labor tax adjustment			with govt. spending adjustment, MEG = 0		
Components of opt. tax, $/alc. gal.						
Pigouvian tax		68			68	
Productivity effect		6 - 80			5 - 70	
Fiscal component						
own-price alc. elast.	low	middle	high	low	middle	high
alc./leisure cross-price elast.	middle	middle	high	middle	middle	high
	363 - 447	123 - 145	18 - 21	135 - 168	64 - 79	0
Overall optimal tax	437 - 592	197 - 294	95 - 167	208 - 306	137 - 217	73 - 138
Effects of increasing taxes						
by 50% or to $36 per alc. gal.						
% reduction in alc. consumption	2.1	3.6	5.2	2.1	3.6	5.2
net increase in revenue, $ bn.	5.5	5.3	5.0	5.5	5.3	5.0
welfare gain, $bn.	4.8 - 6.6	3.4 - 5.4	1.9 - 4.0	1.9 - 2.9	2.0 - 3.4	1.1 - 2.8
by 100% or to $48 per alc. gal.						
% reduction in alc. consumption	4.0	7.0	9.8	4.0	4.0	9.8
net increase in revenue, $ bn.	10.9	10.2	9.5	10.9	10.9	9.5
welfare gain, $bn.	9.3 - 12.9	6.7 - 10.7	3.4 - 7.7	3.6 - 5.7	3.6 - 6.5	1.8 - 5.2
by 200% or to $72 per alc. gal.						
% reduction in alc. consumption	7.6	12.9	17.9	7.6	12.9	17.9
net increase in revenue, $ bn.	21.0	19.1	17.3	21.0	19.1	17.3
welfare gain, $bn.	17.8 - 24.9	12.0 - 19.8	5.3 - 13.3	6.6 - 10.6	6.2 - 11.8	2.4 - 8.7
to optimal level						
% reduction in alc. consumption	34.4 - 39.9	33.6 - 42.9	24.9 - 39.7	21.5 - 28.0	25.1 - 35.5	18.2 - 34.1
net increase in revenue, $ bn.	129.1 - 163.4	53.3 - 71.0	23.6 - 38.4	68.6 - 96.4	38.7 - 56.8	17.6 - 33.0
welfare gain, $bn.	70.9 - 128.0	23.1 - 52.7	5.8 - 21.8	13.7 - 31.0	8.9 - 24.5	2.4 - 12.4

Table 3. Simulations of Optimal Drunk Driver Penalties

	fine			non-pecuniary penalty		
Components of opt. penalty, $/trip						
Productivity effect		1.9			1.9	
own-price drunk dr. elast.	low	middle	high	low	middle	high
drunk dr./leisure cross-price elast.	low	middle	high	low	middle	high
Pigouvian penalty						
no increase in resource costs	23.5	23.5	23.5	9.1	16.1	23.1
with increase in resource costs	7.3	16.0	18.8	5.7	10.1	14.6
Fiscal component	16.9	2.7	-1.6	3.3	-0.7	-2.8
Overall optimal penalty	26.0	21.0	19.0	11.2	11.6	13.8
Effects of increasing penalties						
by 100% or $4 per trip						
% reduction in trips	24.3	38.6	50.1	24.3	38.6	50.1
net change in revenue, $bn.	5.1	5.1	5.1	-2.6	-1.5	-0.6
welfare gain, $bn.	8.4	10.6	12.4	3.3	5.5	8.3
by 200% or $8 per trip						
% reduction in trips	35.7	53.8	66.8	35.7	53.8	66.8
net change in revenue, $bn.	8.5	7.5	6.9	-6.8	-4.6	-3.0
welfare gain, $bn.	11.7	13.9	15.6	4.1	6.7	10.0
to optimal level						
% reduction in trips	55.4	72.4	82.7	41.5	61.5	77.6
net change in revenue, $bn.	17.8	11.2	8.5	-10.6	-7.9	-7.2
welfare gain, $bn.	14.7	16.0	17.0	4.3	6.9	10.4

Table 4. Taxes on Individual Beverages
(Approximate optimal tax relative to that on wine)

	wine/leisure cross-price elasticity						
	0			0.2			

Beer

own-price elasticity	-0.35	-0.53		-0.35		-0.53	
beer/leisure cross price elasticity	0	-0.2	0	0	0.2	0	0.2
optimal tax/optimal wine tax	2.79	3.17	1.35	4.64	1.46	2.26	1.13

Spirits

own-price elasticity	-0.88		-1.05		-0.88		-1.05	
spirits/leisure cross price elasticity	0	0.2	0	0.2	0.2	0.4	0.2	0.4
optimal tax/optimal wine tax	0.84	0.56	0.74	0.53	0.93	0.60	0.88	0.61