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Fiscal and Externality Rationales for Alcohol Policies*

Ian W. H. Parry, Sarah E. West, and Ramanan Laxminarayan

Abstract

Alcohol taxes are typically justified as a means to address externalities from alcohol abuse and to raise government revenue. Prior literature has focused on measuring the Pigouvian tax but has paid little attention to the fiscal rationale. This paper presents an analytical and simulation framework for assessing the optimal levels, and welfare effects, of alcohol taxes and drunk driver penalties, accounting for both externalities and how policies interact with the broader fiscal system.

Under plausible parameter values and recycling possibilities, the fiscal component of the optimal alcohol tax may be as large, or larger, than the externality-correcting component. Therefore, fiscal considerations can significantly strengthen the case for higher alcohol taxes. They also raise the welfare gains from alcohol taxes relative to those from drunk driver penalties, and they warrant differential taxation of individual beverages on an alcohol equivalent basis.

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

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1. Introduction

Although alcohol excise taxes raised $12 billion in revenue for federal and state governments in 2000, tax rates are low by historical standards. Alcohol taxes were 12 percent of pre-tax prices in 2000 compared with 50 percent in 1970 (see Kenkel 1996 and below). Budget deficits at the federal and state level have heightened interest in alcohol taxes as a means to raise government revenues, while at the same time deterring alcohol abuse.

Previous literature in health economics on the appropriate level of alcohol taxes mainly focuses on measuring externalities, such as the costs of drunk driving, and medical burdens on third parties from alcohol-induced illness (e.g., Manning et al. 1989, 1991; Phelps 1988; Pogue and Sgontz 1989; and Kenkel 1996). Less attention has been paid to the other rationale for taxing alcohol frequently invoked by policymakers, namely that this raises government revenue. In principle, this extra revenue reduces the need to raise revenue from other taxes—particularly those on income that distort factor markets—to finance a given amount of public spending.

A well-known literature in public finance uses general equilibrium models to study the welfare effects of partially shifting taxes off labor income and onto individual products. A familiar result from this literature is that the optimal tax on a commodity may exceed any amount that might be justified on externality grounds alone, if the commodity is a weaker substitute for leisure than the average consumption good, the more so the more inelastic the demand for the taxed commodity (e.g. Sandmo 1975).[1] This type of public finance framework has not been applied, quantitatively, to alcohol policy, which leaves the following policy questions unanswered.

First, is the fiscal component of alcohol taxes quantitatively important relative to the externality rationale? In other words, to what extent might estimates of Pigouvian taxes understate (or overstate) the overall optimal alcohol

[1] Recent literature on green tax swaps provides more intuition on this finding by decomposing two different linkages between taxes on products (or inputs) and the broader fiscal system (e.g., Bovenberg and Goulder 2002; Parry and Oates 2000). First is the efficiency gain from using new revenue sources to reduce pre-existing, distortionary taxes elsewhere in the economy. Second is a counteracting effect, due to the impact of commodity taxes on driving up the general price level, thereby reducing real household wages and, slightly, reducing the overall level of labor supply. For the average good, the second effect dominates the former, so fiscal considerations warrant setting commodity taxes below (rather than above) marginal external costs. However, the second effect is weaker, and possibly reverses sign, when the commodity in question is a relatively weak substitute (or complement) for leisure.

Sgontz (1993) discusses the efficiency gains from recycling alcohol tax revenues in labor tax reductions. However, his partial equilibrium framework excludes impacts on labor supply from the increase in price of alcohol relative to the price of leisure.

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tax? As a practical matter, unless tax-neutrality is specified in legislation, it is possible that extra alcohol tax revenues may ultimately end up funding more public spending rather than other tax reductions. So it is also important to check whether or not any fiscal rationale for higher alcohol taxes is undermined, under alternative possibilities for recycling of the revenues.

Second, to what extent do fiscal considerations alter the relative welfare effects of alcohol taxes, drunk driver fines, and non-pecuniary drunk driver penalties like jail terms? Although drunk driver penalties target the road safety externality more directly, they involve significant implementation costs (policing costs, judicial costs, etc.). A further drawback of non-pecuniary penalties is that they impose a first-order deadweight loss on households that is not offset by a revenue transfer to the government (Becker 1968). Kenkel (1993a), for example, showed that the costs of reducing drunk driving by 20 percent might be roughly similar under higher alcohol taxes as under some combination of higher drunk driver fines and non-pecuniary penalties. However, it would be useful to know how this analysis changes when policy impacts on broader fiscal distortions are taken into account, and how the optimal alcohol tax in this framework varies with the level of drunk driver penalties.

Third, is differential taxation of individual beverages (on an alcohol-equivalent basis) warranted or not? In earlier literature, Saffer and Chaloupka (1994) showed that there is not too much basis for uneven taxation on externality grounds alone, unless there are strong cross-price effects among beer, wine, and spirits. However fiscal interactions may alter this result, if individual beverages have different own-price and leisure cross-price elasticities, as this effects their efficiency at raising government revenues.

Addressing these questions requires reliable values for a diverse range of parameters. For the most part, plausible parameter values can be obtained. However, available empirical evidence on one critical parameter—the alcohol/leisure cross-price elasticity—is more suggestive than solid. Nonetheless, even if definitive quantitative results to the above questions cannot be pinned down at present, there is still value to laying out what policies are implied under alternative scenarios, and exploring qualitative policy implications that are robust to different assumptions.

We therefore develop an analytical model that integrates a model of alcohol externalities into a general equilibrium model that accounts for interactions between alcohol policies and broader tax distortions in the economy. After deriving formulas for the optimal levels and welfare effects of alcohol taxes and drunk driver penalties, with different revenue recycling possibilities, we then

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simulate these formulas based on an extensive compilation and updating of parameter values.[2]

Our main conclusions are as follows. Across a wide range of plausible scenarios the fiscal component of the optimal (revenue-neutral) alcohol tax is positive and quantitatively important. In many cases it is larger than the externality-correcting component of the optimal tax, particularly if (as recent evidence suggests) alcohol demand is fairly inelastic. Therefore, under most parameter scenarios, fiscal considerations significantly reinforce the case for raising alcohol taxes, given that current taxes are only about a third of marginal external costs. Even modest increases in alcohol taxes can produce substantial welfare gains; for example, doubling the current tax from 12 to 24 percent of producer prices generates estimated annual welfare gains of around \$3–\$10 billion or more. These findings are fairly robust to other possibilities for revenue recycling (aside from more extreme scenarios for government wastage of new revenues).

For a given reduction in drunk driving, revenue-neutral alcohol taxes may easily generate larger welfare gains than stiffer drunk driver penalties, due to the possibly large fiscal dividend in the former case and various implementation costs and deadweight losses in the latter. For example, tripling the alcohol tax reduces drunk driving by 8–18 percent, with estimated welfare gains of around \$5–15 billion. Under higher expected fines for drunk drivers the same reduction in drunk driving generates estimated welfare gains of about \$2–5 billion, or about \$1–3 billion under non-pecuniary penalties.

Even if drunk driver penalties are substantially increased, the case for higher alcohol taxes is not necessarily undermined. We show that the welfare gains from alcohol taxes are de-coupled from the level of non-pecuniary penalties like jail terms when changes in the first-order deadweight losses associated with these penalties are taken into consideration. And even if drunk driver fines were

[2] Many previous papers have derived analogous formulas for optimal tax policies in other contexts. Our approach differs from that in standard models in the public finance by separating out the effects of revenue recycling from those due to changes in the price of commodities relative to leisure. This decomposition is needed to consider other possibilities for recycling commodity tax revenues, beyond cutting other distortionary taxes. In this regard, our approach is similar to that in recent literature on environmental tax shifts (e.g., Bovenberg and Goulder 2002, Parry and Oates 2000). However, it differs from these analyses with respect to the model and its application to alcohol taxes. For example, the nature of alcohol externalities is more complex than a single damage function for pollution; we encompass a broader range of revenue uses; we model pecuniary and non-pecuniary drunk driver penalties in addition to product taxes; we account for policy implementation costs; we consider optimal taxes on individual beverages; and we integrate alcohol-induced workplace productivity effects.

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to be two orders of magnitude larger than at present, current alcohol taxes are still far below their optimal (revenue-neutral) level in most cases.

Finally, in contrast to current policy, we also find that fiscal considerations suggest that beer should be taxed more heavily than wine on an alcohol equivalent basis, and that wine should be taxed more heavily than spirits.

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 briefly concludes the paper.

2. Analytical Framework

We follow the traditional externality literature on alcohol taxes in assuming that impacts within the family (e.g., fetal alcohol syndrome) are internal and that individuals do not undervalue future costs of addiction because of hyperbolic discounting. Using alternative models of household behavior that relaxed these assumptions would further strengthen the welfare gains from higher alcohol taxes. Nonetheless, it seems reasonable to leave these issues aside given that they remain contentious in the broader substance abuse literature (e.g., Gruber 2002 and Viscusi 2002) and our main focus is on conceptualizing fiscal linkages.

We adopt a highly simplified treatment of the broader fiscal system, by collapsing the rest of the tax system into a single tax on labor income. Accounting for additional distortions from the US tax system, particularly those in the capital market, and distortions between ordinary and tax-favored spending (e.g., on home ownership, employer medical insurance), would further strengthen the efficiency gains from recycling alcohol tax revenues in income tax reductions (e.g., Bovenberg and Goulder 1997; Parry and Bento 2000). In this regard, our analysis may understate the fiscal component of the optimal alcohol tax.

We employ a representative agent framework, which is appropriate for efficiency analysis, with some caveats. One is that the model should allow for the possibility of different behavioral responses of alcohol consumption and drunk driving to policy. Another is that, in gauging the labor supply response to higher alcohol prices, parameters that are representative of drinking-intensive households should be used.[3]

[3] Aggregation bias could still occur in our framework if there were some correlation between alcohol or labor income taxes and the behavioral responses to those taxes across different income groups. Roughly speaking however, households face uniform alcohol taxes, and the dispersion in effective income tax rates across different income groups is fairly limited (Kotlikoff and Rapson 2007, Tables 4.2, 4.3). This suggests that aggregation bias may not be too serious.

Distributional equity is beyond our scope. Lyon and Schwab (1995) found that alcohol taxes are regressive, even when income is measured on a lifetime basis. In future work it would be informative to explore, as Metcalf (2007) does for carbon taxes, how the broader income tax

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A. Model Assumptions

(i) Preferences. We adopt a static model where an agent, representing an aggregation over all households in the real economy, has utility:

(1a) $U = U(A, D, \tau_D D, C, l, G^P, H)$

(1b) $H = H(A, D, \overline{D}, M)$

Variables are expressed on a per capita basis and a bar denotes an economy-wide equilibrium value that individuals take as given when making their own decisions. U is a continuous, quasi-concave function, increasing in all arguments other than $\tau_D D$ and H.

In (1a) A is total gallons of alcohol consumption (individual beverages are disaggregated later). D is driving trips taken under the influence of alcohol (we assume alcohol and drunk driving are complements). τ_D is non-pecuniary penalties per drunk-driver trip, for example, from jail terms and license suspensions; implicitly, τ_D is the probability of being arrested and convicted per intoxicated trip, times the penalty per conviction. C is a general consumption good.[4] l is leisure time. G^P is government spending on public goods. Finally, H is health or injury risks caused either by heavy drinking (over the lifecycle), or by alcohol-involved traffic accidents.

These health risks are defined by the continuous, quasi-concave function H(.) in 1(b). This function is increasing in the agent's own alcohol consumption (through long-term health effects) and drunk driving. It also increases with the amount of drunk driving by others $\overline{D}$, as this raises injury risks to agents in their role as pedestrians or as sober car drivers. Lastly, H(.) decreases with the agent's consumption of medical services M, as this reduces suffering from a given illness or injury.

(ii) Production. Alcohol, the general good, medical services, and auto services (to repair property damage from drunk driver collisions) are all produced under constant returns to scale by competitive firms using labor as the only primary input. Therefore, there are no pure profits, and producer prices are fixed (producer

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schedule might be adjusted to counteract these regressive effects, and possible costs in terms of less efficient revenue recycling.

[4] We do not consider cross-price effects between alcohol and other taxed commodities that may affect the welfare effects, and optimal levels, of alcohol taxes. The most obvious example is cigarettes. However, there is disagreement on whether cigarettes are currently over-taxed or under-taxed from a market failure perspective (e.g., Cnossen and Smart 2005). Therefore, it is not clear whether this cross-price effect would increase or decrease the optimal alcohol tax.

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prices for medical services and the general good are normalized to unity). Firms pay a gross wage of w equal to the value marginal product of labor. We denote "effective" labor supply by $W = wL$, where L is time at work. $\partial W / \partial H < 0$ if health effects reduce on-the-job productivity, the amount of time agents are available for work, or if employers are more likely to fire alcoholic workers.

The government pays for fraction s of medical care costs, while fraction $1-s$ is borne by private insurance companies. Implicitly, the government subsidy represents spending programs like Medicare/Medicaid and the favorable tax treatment of employer-medical benefits. Private insurance companies cover their costs through charging a lump-sum premium to households of K_M and also a variable payment amounting to fraction v_M of medical expenses. Similarly, auto insurance companies cover property damage costs through charging households a lump-sum premium of K_D and a variable cost that amounts to v_D per drunk-driver trip. This variable cost represents deductibles and elevated future premiums following an auto accident—thus, to a modest degree, the costs of drunk driving are internalized through the risk of higher future premiums. $v_D < c_D$ where c_D is the (expected) cost of auto repair to insurance companies per drunk-driver trip. v_M and v_D are given while K_M and K_D adjust so insurance company profits are zero in equilibrium.

(iii) Government. The government is subject to the budget constraint:

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

G^T is lump-sum transfer spending. 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 probability of arrest and conviction per trip times the fine per conviction). $r = r(\tau_D, t_D)$ denotes resource costs expended by the government from implementing drunk driver penalties. These include policing costs associated with road patrols, breathalizer testing, arrests, etc., judicial costs from hearing drunk driver cases, and the cost of accommodating jail sentences. $r(.)$ is increasing in both arguments; for example, an increase in τ_D may increase the costs of supplying incarceration facilities, while an increase in either τ_D or t_D may increase judicial costs through protracting the legal process.

(iv) Agent optimization. Agents are subject to the following budget and time constraints

$$(1-t_L)W + G^T = (p_A + t_A)A + C + K_M + v_M M + K_D + v_D D + t_D D \tag{3a}$$

$$l + L = T(H) \tag{3b}$$

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In (3a), net of tax labor income, and the government transfer payment, equal expenditures on alcohol, general consumption, lump-sum and variable costs paid to medical and auto insurance companies, and drunk driver fines (p_A is the producer price of alcohol). In (3b), work and leisure are equal to available time T. The latter declines with H representing, for example, time lost due to incapacitating injury or premature mortality.

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

$$(4) \qquad \frac{U_A}{\lambda} = p_A + t_A + mpc \cdot H_A, \qquad \frac{U_D}{\lambda} = v_D + t_D + \tau_D + mpc \cdot H_D,$$
$$-mpc \cdot H_M = v_M, \qquad \frac{U_l}{\lambda} = (1 - t_L)w$$

where λ is the marginal utility of income, and we have normalized $-U_{\tau_D D} / \lambda = 1$ so that the expected non-pecuniary penalty per drunk driver trip is expressed in monetary equivalents. $mpc = -(U_H / \lambda + (1 - t_L)(wT_H + W_H))$ is the marginal private cost of health risks, which are internal to households. These consist of direct disutility from suffering $-U_H / \lambda$, the value of lost time from incapacitation or premature mortality $-(1 - t_L)wT_H$, and forgone private earnings from lower workplace productivity $-(1 - t_L)W_H$.

According to (4), agents equate the marginal private benefit from alcohol consumption 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, (monetized) 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.

In equilibrium, consumption and labor supply depend on the following reduced form functions (see Appendix A):

$$(5) \qquad y = y(t_A, t_L, G^T, G^P, s - v_M, c_D - v_D), \qquad y = A, D, C, M, L$$

These functions differ, albeit very slightly, from the demand/supply functions of the representative agent, as they account for feedback effects from changes in $\overline{M}$ and $\overline{D}$ on the equilibrium, lump-sum medical and auto premiums charged by insurance companies.

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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 any changes in t_L, G^T and G^P to maintain government budget balance. The result is (see Appendix A for derivation and definition of elasticities)

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

$$(6b) \qquad E^A = (1 - v_M)M_A + E^D D\eta_{DA}/(A\eta_{AA})$$

$$(6c) \qquad E^D = mpc \cdot H_{\overline{D}} + c_D - v_D + (1 - v_M)(M_D + M_{\overline{D}}) + r - t_D$$

$MEG_{G^P} = U_{G^P}/\lambda - 1$ is the marginal efficiency gain (or loss) from spending on public goods, that is, the value to households per dollar of extra spending, minus the dollar. $\eta_{AA} < 0$ and $\eta_{DA} < 0$ denote elasticities of alcohol consumption and drunk driving with respect to the price of alcohol.[5]

The marginal welfare effect in (6a) has three components. First is the reduction in alcohol, times the marginal external cost of alcohol E^A (defined below), net of the alcohol tax. Second is the change in effective labor supply, times the labor tax. This tax creates a wedge between the value marginal product of effective labor supply and the marginal opportunity cost of effective labor supply in terms of foregone leisure. The third welfare component is MEG_{G^P}, times any extra spending on public goods.

In (6b) the marginal external cost of alcohol consumption E^A has two components. First is the (lifetime) medical burden due to the health risks from additional alcohol consumption M_A multiplied by $1 - v_M$. The latter is the portion of medical costs that are paid by third parties, rather than individuals (the government pays fraction s and insurance companies pay fraction $1 - s - v_M$). The second component of E^A is the external cost per drunk-driver trip, E^D, multiplied by η_{DA}/η_{AA}, to account for the price responsiveness of drunk driving, relative to that for alcohol consumption, and by D/A, to convert costs per trip into costs per gallon of alcohol.

In (6c), the external cost per drunk driver trip E^D has five components. First is the private cost of injury risks to other road users and pedestrians posed by an additional drunk-driver trip, $mpc \cdot H_{\overline{D}}$. Second is the expected automobile

[5] We assume that indirect changes in medical and auto insurance premiums, and in government spending and labor taxation, have a small impact on alcohol consumption and drunk driving, relative to the direct impact of alcohol taxes and drunk driver penalties. Thus, we later use evidence on uncompensated elasticities to parameterize alcohol and drunk driver elasticities.

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property damages per trip c_D, less variable costs v_D that are borne by individuals. The third component is the medical burden on third parties from injury risks to both drunk drivers and other road users, $(1-v_M)(M_D + M_{\bar{D}})$. Fourth is the cost to the government of implementing drunk driver policies, expressed per trip, *r*. Finally, E^D is defined net of the expected drunk driver fine per trip t_D, which is an internal cost.

On the other hand, E^D is gross rather than net of the non-pecuniary penalty, τ_D. This means that the optimal level of and welfare gains from alcohol taxes will be independent of the level of non-pecuniary penalties. To see this consider Figure 1 which shows deadweight losses under the drunk driver demand curve from the government penalties per trip $t_D + \tau_D$ (excluding externality benefits). These losses include the usual Harberger triangle from the distortion of demand. However they also include the shaded rectangle $\tau_D D$ or the first-order utility loss from the non-pecuniary penalty, which (unlike for the fine) is not offset by a revenue transfer to the government. Higher alcohol taxes shift in the demand curve for drunk driving and thereby increase overall deadweight loss by the black rectangle, or t_D per unit reduction in *D*. (Although τ_D is part of the price distortion, there is an offsetting saving of τ_D in first-order deadweight costs per unit reduction in *D*).

(ii) Labor supply effects. The change in effective labor supply in (6) can be decomposed into three effects (from totally differentiating (5)):[6]

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

The first component is the increase in workplace productivity due to the effect of lower alcohol consumption on reducing illness or road injuries. The second component arises from the labor supply effect of raising the price of alcohol

[6] We assume that $\partial L / \partial G^P$ = 0. More generally, 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 available evidence on this, our assumption represents a neutral case.

We also ignore the possibility that savings in employer medical costs (in response to higher alcohol taxes) will cause a positive feedback effect on labor supply to the extent they are passed on to employees in the form of higher wages. Most likely this effect is relatively small, given that medical costs are a minor portion of total external costs, that only a fraction of the population has employer medical insurance, and that a large portion of any savings accrue to the government in the form of reduced tax expenditures.

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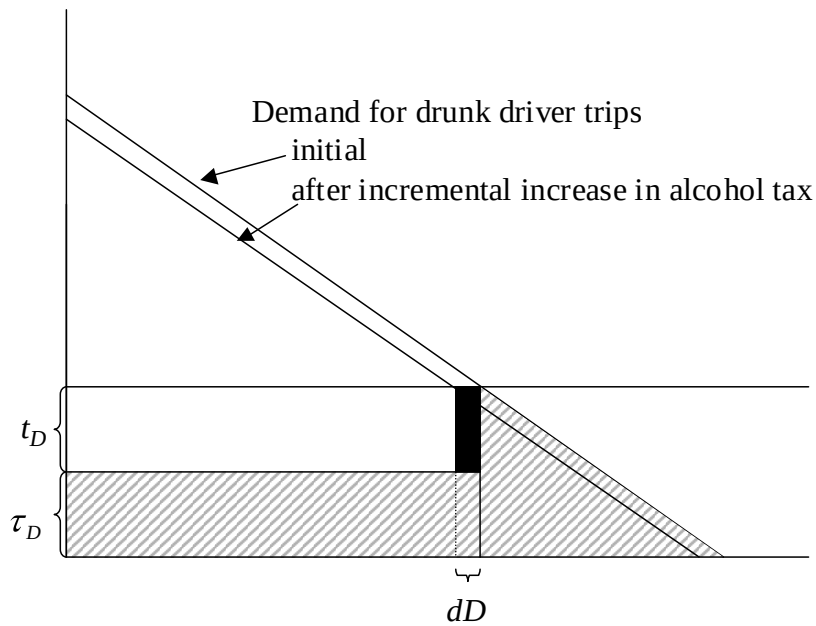
relative to leisure (for given health status), which depends on the degree of substitution or complementarity between alcohol and leisure. Third is the effect of revenue recycling: using revenues to reduce t_L will increase labor supply, while using them to increase transfer income G^T will have the opposite effect because leisure is a normal good.

Figure 1. Deadweight Losses from Drunk Driver Penalties



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

$$\text{(8a)} \qquad t_A^* = \overbrace{E^A}^{\text{Pigouvian tax}} + \overbrace{MEG_{t_L}\left\{\frac{p_A + t_A}{(-\eta_{AA})} - t_A + g^A\right\}}^{\text{Revenue–recycling effect}} - \overbrace{\frac{(1+MEG_{t_L})t_L(p_A+t_A)(\eta_{Al}^c+\eta_{LI})}{(1-t_L)(-\eta_{AA})}}^{\text{Tax–interaction effect}} + \overbrace{(1+MEG_{t_L})t_L(-W_H H_A)}^{\text{productivity effect}}$$

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(8b) $$MEG_{t_L} = \frac{-t_L \dfrac{\partial L}{\partial t_L}}{L + t_L \dfrac{\partial L}{\partial t_L}} = \frac{\dfrac{t_L}{1-t_L}\varepsilon_{LL}}{1 - \dfrac{t_L}{1-t_L}\varepsilon_{LL}},$$

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

In these expressions 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, $\eta_{LI} < 0$ denotes the income elasticity of labor supply (as it pertains to the income effect of higher alcohol prices), and c denotes a compensated elasticity (all elasticities are defined in Appendix A). $MEG_{t_L} > 0$ is the efficiency gain from using a dollar of revenue to cut the labor tax. This is equivalent to the marginal efficiency cost of increasing the labor tax $t_L \partial L / \partial t_L$ divided by the marginal labor tax revenue $L + t_L \partial L / \partial t_L$. g^A is savings in government medical and resource expenses, net of reduced revenue from drunk-driver fines, per gallon reduction in alcohol (g^A plays only a minor role in our simulations so we do not belabor its interpretation).

In equation (8a) the optimal alcohol tax consists of the marginal external cost of alcohol consumption, or Pigouvian tax, and three additional components stemming from broader fiscal interactions.

First is the "revenue-recycling" effect. This is equal to MEG_{t_L} times the marginal revenue to the government from raising the alcohol tax, expressed per gallon reduction in alcohol, and including any indirect savings in government medical and resource expenditures, g^A. Note that $\eta_{AA} = (dA/dt_A)(p_A + t_A)/A$, so the term in parentheses is $-A \cdot dt_A / dA - t_A + g^A$, or extra revenue per unit reduction in A. The revenue-recycling component is greater the more inelastic the demand for alcohol, as this magnifies the first-order revenue gain to the government ($-A \cdot dt_A / dA$) per unit reduction in alcohol.

The second extra component is the "tax-interaction" effect. This is the efficiency change from the change in labor supply as the alcohol price rises relative to the price of leisure (for given health status). It is multiplied by $1 + MEG_{t_L}$ to account for the change in labor tax revenue, which implies t_L must be changed to maintain government budget balance. The tax-interaction effect incorporates the pure substitution effect between alcohol and leisure, which reduces or increases labor supply depending on whether η^c_{Al} is positive or negative. It also includes the income effect from higher alcohol prices, which reduces labor supply because leisure is a normal good ($\eta_{LI} < 0$). If alcohol were

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an average substitute for leisure then $\eta_{Al}^{c} + \eta_{LI} = \varepsilon_{LL}$.[7] Using (8a and b), and ignoring g^A, the net impact of the revenue-recycling and tax-interaction effects in this case is $-MEG_{t_L} \cdot t_A$. That is, there would be a downward adjustment to the optimal alcohol tax. Thus, the fiscal argument for higher alcohol taxes hinges on the assumption that alcohol is a relative complement for leisure (η_{Al}^{c} is relatively small or negative).

Finally, the third extra component of the optimal alcohol tax is termed the "productivity effect". This is the health-induced increase in productivity per unit reduction in alcohol $-W_H H_A = -(\partial W / \partial H)(dH / dA)$, times the labor tax, times $1 + MEG_{t_L}$ to account for the change in revenue.

(iv) Optimal tax with increased public spending. For this case, the optimal tax is (see Appendix A):

$$\text{(9a)} \qquad t_A^* = \overbrace{E^A}^{\text{Pigouvian tax}} + \overbrace{MEG_{G^i}\left\{\frac{p_A + t_A}{(-\eta_{AA})} - t_A + g^A\right\}}^{\text{Revenue–recycling effect}} - \overbrace{\frac{(1+MEG_{G^i})t_L(p_A + t_A)(\eta_{Al}^{c} + \eta_{LI})}{(1-t_L)(-\eta_{AA})}}^{\text{Tax–interaction effect}} + \overbrace{(1+MEG_{G^i})t_L(-W_H H_A)}^{\text{productivity effect}}$$

$$\text{(9b)} \qquad MEG_{G^T} = \frac{t_L w \dfrac{\partial L}{\partial G^T}}{1 - t_L w \dfrac{\partial L}{\partial G^T}} = \frac{t_L \eta_{LG^T}}{1 - t_L \eta_{LG^T}}$$

for $i = T$ or P. $\eta_{LG^T} < 0$ is the elasticity of labor supply with respect to an increase in the economy-wide transfer payment (we note why η_{LG^T} might differ from η_{LI} below). MEG_{G^T} is the efficiency change per dollar increase in the transfer payment, which is (slightly) negative as transfer spending reduces labor supply,

[7] This follows because alcohol would change in the same proportion to aggregate consumption, or labor supply, following an increase in the labor tax. See Parry (1995) for more discussion.

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given that leisure is a normal good.[8] Comparing (8) and (9), the main difference is that the revenue-recycling effect is larger or smaller, depending on whether the marginal efficiency gain from increased public spending is larger or smaller than the marginal efficiency gain from cutting distortionary taxes. For the remaining policies below, we focus just on the revenue-neutral case.

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

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

$$- \overbrace{\frac{(1+MEG_{t_L})t_L(t_D+\tau_D)(\eta^c_{Dl}+\eta_{LI})}{(1-t_L)(-\eta_{DD})}}^{\textit{Tax–interaction effect}} + \overbrace{(1+MEG_{t_L})t_L(-W_H H_D)}^{\textit{productivity effect}}$$

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

$$\tilde{E}^D = E^D + t_D, \qquad g^D = s(M_D + M_{\bar{D}}) + r, \qquad \sigma^{t_D} = 1, \qquad \sigma^{\tau_D} = 0$$

In these expressions j indexes the fine or non-pecuniary penalty ($j = t_D$ or τ_D) and σ^j is a dummy variable. η_{DD} and η_{Dl} denote the elasticity of drunk driving with respect to the combined penalty $t_D + \tau_D$, and with respect to the price of leisure respectively. The g^D term is analogous to g^A in equation (8) (though now it is expressed per drunk driver trip). We also ignore the effects of drunk driver penalties on alcohol demand, as the resulting efficiency changes in the alcohol market are small relative to those in the drunk driver "market" (see Appendix A).

E^{t_D} is the Pigouvian fine on drunk driving. It equals the external cost per drunk driver trip as defined previously in (6b), but with two minor adjustments. First it is gross (rather than net) of the drunk driver fine itself. Second it is net of the (first-order) increase in resource costs to the government from raising t_D (e.g., higher fines might encourage more use of lawyers, thereby lengthening the judicial process). These extra resource costs, per unit reduction in drunk driving,

[8] In a more general model, transfer spending might generate significant social benefits if it were motivated by, for example, distributional or social insurance objectives. However, our purpose here is to investigate to what extent the case for alcohol taxes is undermined, if there is a risk that revenues are not used productively.

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are $-(\partial r/\partial t_D)D/(dD/dt_D)$; substituting $\eta_{DD} = (dD/dt_D)(t_D + \tau_D)/D$ gives $r_{t_D}(t_D + \tau_D)/\eta_{DD}$ in the above expression.

E^{τ_D} is the Pigouvian equivalent for the non-pecuniary penalty. Leaving aside additional resource costs, and setting $t_D = 0$, the Pigouvian equivalent is $-E^D\eta_{DD}$. Assuming the demand for drunk driving is inelastic (see below), or $-\eta_{DD} < 1$, this is smaller than the Pigouvian fine. This follows because, under these conditions, increasing the non-pecuniary penalty increases the area of the shaded deadweight loss rectangle in Figure 1.

Again, the optimal expected fine per trip differs from the Pigouvian penalty, because of the revenue-recycling, tax-interaction, and productivity effects (where these effects are now defined per unit reduction in drunk driving). One slight difference is that the revenue-recycling effect is net of the increase in policy implementation costs r_{t_D}. For the non-pecuniary penalty, the revenue-recycling effect may be approximately zero, or even negative, as this policy does not directly raise any government revenues.

(vi) Taxation of individual beverages. Now suppose:

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

(11b) $E^{A_i} = E^A, \qquad H_{A_i} = H_A, \qquad i = BE, WI, SP$

In (11a), $A(.)$ is now a composite for alcohol consumption that is a (weakly quasi-concave) function 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.[9]

Optimal taxes on these individual beverages are given by (see Appendix A):

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

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

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

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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 and functional forms. 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 ($j = t_D,\ \tau_D$), welfare effects are given by (see Appendix A):

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

where $i = t_L,\ G^T$, or G^P, $MEG_{t_D} = MEG_{t_L}$, and $MEG_{\tau_D} = 0$. The welfare gain from a marginal increase in the tax or penalty is the induced change in alcohol or drunk driving, times the difference between the prevailing and the optimum tax/penalty, times $1+MEG_{t_L}$ if extra revenue is raised and used to cut the labor tax, or $1+MEG_{G^T}$ if used to finance transfer spending, etc. Integrating over the entire tax/penalty increase gives the total welfare gain. Price coefficients dA/dv and dD/dv are easily obtained from data on own-price elasticities, prices, and quantities.

To compute optimal taxes/penalties, we assume the external costs per unit of drunk driving and alcohol consumption are constant over the relevant range. 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

Parameter values used to implement the above formulas are for year 2000 or thereabouts and are (mostly) summarized in Table 1. Appendix B provides an extensive discussion of how we compiled and estimated parameter values, along

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with data sources. In measuring external costs, we mainly update procedures developed by others (e.g., Manning et al. 1989, Kenkel 1993a and b). For important parameters that are uncertain, we consider wide ranges of values.

A. Baseline Data

Initial alcohol consumption A^0 is 493 million gallons of pure alcohol (or ethanol), with beer, wine, and spirits accounting for 56 percent, 14 percent, and 30 percent, respectively, of this total. 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 of \$197 per alcohol gallon. We put initial drunk-driver trips D^0 at 1,287 million, and the probability of conviction is 1/1,562 per trip.

B. External Costs

Drunk-driver costs and penalties. We estimate the marginal external cost of drunk driving at \$23.7 per trip (where the average trip length is 14 miles); expressed as a cost of total alcohol consumption these external costs, $E^D D/A$, are \$64.1 per alcohol gallon. Injuries to other road users and pedestrians, property damages, medical costs, and government resource costs account for 51 percent, 26 percent, 13 percent, and 10 percent of these costs, respectively, while expected drunk-driver fines internalize just 1 percent of costs.

Only 17 percent of injuries in alcohol-involved crashes are external (Levitt and Porter 2001). This is because the risk to other road users is net of the normal risk posed by sober drivers and, more importantly, the two-thirds of injuries that occur in single-vehicle crashes are assumed to be internal. The private cost, *mpc*, for a fatality, 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 single- and multi-vehicle crashes (in excess of the normal crash risk); 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; overall, 80 percent of medical costs (which also apply to excess injuries in single- and multi-vehicle crashes) are external.[10]

[10] 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 value of life. This is for fatality costs alone. Our corresponding estimate of the fatality cost component is \$23.0 per gallon.

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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 \$3.8 per trip or \$9.9 per alcohol gallon, though they do not affect the optimal alcohol tax (see above).

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), by attributing observed illnesses to alcohol as opposed to other factors. This figure likely is too high for our purposes as it excludes savings in medical costs over the life cycle from premature mortality. Instead, we use regression results from Manning et al. (1989), who put lifetime medical costs for all individuals at equivalent to \$6.5 per alcohol gallon (updated to 2000 and excluding auto injuries), by comparing outcomes for heavy and moderate drinkers over time.[11] Netting out variable costs gives \$5.2 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 E^A = \$7.6 per alcohol gallon.

C. Elasticities

Labor supply elasticities. It is appropriate to use economy-wide labor supply elasticities in the MEG terms, as these reflect economy-wide responses to changes in income taxes and public spending. Based on reviews in Blundell and MaCurdy (1999), Nickell (2004) and Fuchs et al. (1998), we choose a labor supply elasticity (averaged over all male and female workers and over the hours worked and participation decision) of $\varepsilon_{LL} = 0.15$, and a value of $\eta_{LG^T} = -0.20$ for the income elasticity of labor supply in response to higher transfer spending.

[11] This estimate does not take account of the possibility of external health benefits from light drinking. In fact, to the extent these benefits exist, the above approach of comparing health outcomes for moderate and heavy drinkers will actually attribute these benefits as a cost of heavy drinking. However, most likely this has little quantitative importance for our optimal tax results, given that the health impacts of drinking costs are small relative to the costs of drunk driver crashes.

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Table 1. Benchmark Values for Selected Parameters
(for year 2000 or thereabouts)

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		64.1
injuries to other road users	32.8	
property damage	16.5	
medical costs	8.5	
government resource costs	6.7	
pecuniary drunk driver penalty		0.5
non-pecuniary drunk driver penalties		9.9
Heavy drinking cost		7.6
Elasticities		
Labor supply with respect to		
net wage (uncompensated)		0.15
net wage (compensated)		0.35
income effect from labor tax cut		-0.20
income effect from alcohol price increase		-0.10
Alcohol		
own price (all beverages)		-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 expected penalty		
fine		0.25
non-pecuniary penalty		0.58

Source: See text and Appendix B.

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Own-price alcohol elasticities. Numerous studies have estimated own-price elasticities for alcohol, though there are significant methodological challenges (Cook and Moore 2000). We consider a range for all beverages of η_{AA} = –0.4 to –1.0; however, in the view of at least one leading expert, this range is conservative.[12] Based on reviews by Clements et al. (1997) and Leung and Phelps (1993), we illustrate cases where the size of the beer price elasticity is up to 50 percent smaller than, and the spirits price elasticity is up to 50 percent larger than, the wine price elasticity, where the latter is taken as –0.7.

Alcohol-leisure cross-price elasticity. As noted earlier, available evidence on this parameter is limited and therefore is more suggestive than definitive. Nonetheless, based on a compromise between two pieces of information, we believe a plausible illustrative range for this elasticity is η_{Al}^{c} = –0.20 to 0.20. First, West and Parry (2009) obtained a direct estimate of η_{Al}^{c} from an Almost Ideal Demand System defined over alcohol, leisure, and other consumption and estimated with household data; their estimate accounts for differing behavioral responses across households with different drinking intensities. Their central value is –0.09 though the confidence interval at the 95 percent level is very wide (–0.40 to 0.20). Second, we obtain a range of η_{Al}^{c} = 0.04–0.21 based on decomposing this elasticity into an expression containing the alcohol expenditure elasticity (for which there is substantial empirical evidence) and two other elasticities, for which we use conservative values (see Appendix B). As for individual beverages, we illustrate cases where they are equal substitutes for leisure, and where beer is moderately more complementary to leisure than wine, and vice versa for spirits, based on the lower (higher) expenditure elasticities for beer (spirits).

Finally, in practice η_{LI} could differ from η_{LG^T} (assumed above to be –0.20) as the former reflects the income elasticity of labor supply for alcohol-consuming households, rather than all households. While still negative (as leisure is a normal good), η_{LI} maybe smaller in size than η_{LG^T}, as the latter is disproportionately influenced by labor supply participation responses of married females who are relatively light drinkers. We use a compromise value of η_{LI} = –0.1 (alternative values have the same effect as varying η_{Al}^{c}).

[12] Willard Manning (personal communication, 2006) put the "best value" at about –0.4, and using this value greatly strengthens the fiscal component of the optimal alcohol tax below. Recent published estimates 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), –0.50 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.)

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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 only of moderate importance for our results. We illustrate a range of $\eta_{Dl}^{c} = 0$ to 0.35.[13]

D. Productivity Effects

From our accident data we estimate productivity losses from auto injuries at \$12.5 per alcohol gallon, or $-W_H H_D$ = \$4.8 per drunk-driver trip. As regards productivity effects from general alcohol consumption, 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 conflicting. 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 $-W_H H_A$ = \$12.0–\$174 per alcohol gallon. For the revenue-neutral alcohol tax this implies a productivity effect of \$6–\$80 per alcohol gallon.[14]

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 our labor supply elasticities, this implies $MEG_{t_L} = 0.11$ and $MEG_{G^T} = -0.07$. We illustrate a range where the marginal efficiency gain from public spending (either transfers or public goods) is −0.1 to 0.2.

[13] 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.

[14] 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 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.

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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^D terms are inferred from other parameters but are small.

4. Results

A. Alcohol Tax

(i) Relative importance of fiscal interactions. Figure 2 shows the "fiscal component" of the optimal alcohol tax, which we define by the revenue-recycling component net of the tax-interaction effect. Here, the fiscal component is expressed relative to the Pigouvian tax, for different own- and (compensated) leisure-cross price elasticities for alcohol (the productivity effect is excluded from these calculations).

For the revenue-neutral case in panel (a), the fiscal component can be relatively large and exceeds the Pigouvian tax under a number of parameter combinations. For example, when the own-price alcohol elasticity is –0.7, the fiscal component exceeds 100 percent of the Pigouvian tax if the alcohol/leisure cross-price elasticity is in the lower half of our assumed range. And when the own-price alcohol elasticity is –0.4, the fiscal component exceeds 100 percent of the Pigouvian tax across three-quarters of our assumed range for the alcohol/leisure cross price elasticity.

Panel (b) illustrates the case when alcohol tax revenues finance additional public spending, for an assumed 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 in panel (a) (middle curve) due to the larger revenue-recycling effect. But even when there are no efficiency gains from extra public spending (as indicated by the middle curve in panel (b)), the case for taxing alcohol is not really undermined. In fact, across three quarters of our range for the alcohol/leisure cross-price elasticity, the fiscal component of the optimal tax is still positive; that is, when this elasticity is below 0.10, the tax-interaction effect contributes positively, rather than negatively, to the optimal tax (or $\eta^c_{AL} + \eta_{LI} < 0$ in equation (9a)). The case for taxing alcohol is only reversed—that is the optimal tax is well below the Pigouvian tax—if the alcohol/leisure cross price elasticity is in the top half of our assumed range *and* revenues are spent in a socially wasteful way (in our figure, this is when the social benefits of extra spending fall short of the dollars spent by 10 percent).

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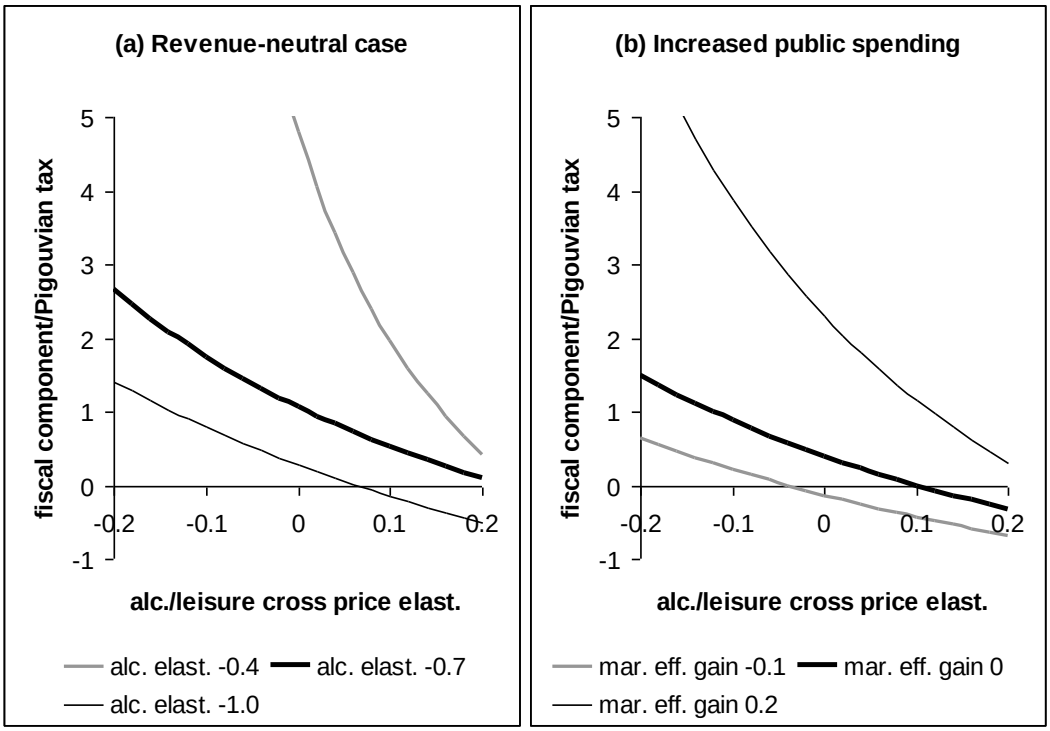
(ii) Overall optimal alcohol tax and welfare gains from policy reform. Table 2 summarizes optimal alcohol taxes and welfare gains from various tax reforms under selected values for own-alcohol and alcohol/leisure elasticities and for different assumptions about the productivity effect. Results are shown for the revenue-neutral alcohol tax and (to be conservative) when the marginal efficiency gain from public spending is zero. There are several noteworthy points.

Figure 2. Fiscal Component of Optimal Alcohol Tax
(relative to Pigouvian tax)



The Pigouvian tax is $72 per alcohol gallon, with 91 percent and 9 percent of this due to the drunk-driver and heavy drinking externalities respectively.[15] The

[15] The Pigouvian tax is somewhat sensitive to alternative parameter choices. For example, it varies from $60.7 to $83.7 as the value of life varies from $2 to $6 million and from $43.0 to $101.5 as drunk-driver and heavy drinking elasticities take low and high values, given the mid-range value for the own-price alcohol elasticity. Some have argued against counting medical burdens as an external cost if medical subsidies might be warranted by paternalistic preferences (e.g., Browning 1999). Excluding all third-party medical costs reduces the Pigouvian tax to $60.4 per alcohol gallon.

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productivity effect adds anything from $5 to $80 per alcohol gallon to the optimal tax.

Under revenue neutrality, the fiscal component of the optimal alcohol tax (the combined revenue-recycling and tax-interaction effects) is $77 to $90 per alcohol gallon, or moderately larger than the Pigouvian tax, under mid-range assumptions for the alcohol demand elasticity (–0.7) and the alcohol/leisure cross-price elasticity (0). In this case the optimal alcohol tax overall is $154 to $239 per alcohol gallon, or 6 to 10 times the current tax. Under this scenario, optimizing the tax reduces alcohol consumption by 28 to 38 percent, increases government revenue by $43 to $61 billion, and produces large annual welfare gains of $13 to $33 billion. Note however, that substantial welfare gains can still be obtained by far more modest (and perhaps more practical) tax increases. For example, increasing the tax by $24 per gallon to $48 per gallon produces welfare gains of $4.7 to $8.1 billion.

As regards other scenarios, the fiscal component of the optimal tax becomes extremely large when the alcohol demand elasticity is –0.4 and the alcohol/leisure cross price elasticity is –0.15. On the other hand, the fiscal component is far more moderate, $10 to $13 per alcohol gallon, when the own-price elasticity is unity and we use a higher value of 0.15 for the alcohol/leisure cross-price elasticity. Nonetheless, even in this case the optimal tax overall is $90 to $159 per gallon, or roughly 4-6 times the current tax. And optimizing over the tax still produces significant welfare gains of $5 to $19 billion per annum.

As regards the case when recycling alcohol tax revenues does not produce efficiency gains, the optimal alcohol tax is still well above current levels. It is anything from $68 to $177 per gallon when the (size of) alcohol elasticities take their mid-range or relatively high values, and is much higher still if these elasticities are at the lower end of our assumed ranges.

B. Drunk-Driver Penalties and Implications for Alcohol Taxes

(i) Optimal penalties and welfare gains. Table 3 shows optimal drunk-driver penalties, and welfare gains from raising penalties, using values for own-price drunk driver, and drunk driver/leisure, elasticities that are at the bottom, at the middle, or at the top of the ranges mentioned above. Any government revenue effects of policies are offset by adjusting the labor tax. We note the following points.

First, as emphasized earlier by Kenkel (1993a), resource costs and first-order deadweight losses from non-pecuniary penalties play a significant role in reducing the Pigouvian tax, or the Pigouvian tax equivalent, component of the overall optimal penalty level.

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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		72			72	
Productivity effect		6 - 80			5 - 70	
Fiscal component						
own-price alc. elast.	-0.4	-0.7	-1.0	-0.4	-0.7	-1.0
alc./leisure cross-price elast.	-0.15	0	0.15	-0.15	0	0.15
	528 - 651	77 - 90	10 - 13	195 - 241	29 - 36	(8.8) - (11)
Overall optimal tax	605 - 799	154 - 239	90 - 159	271 - 382	105 - 177	68 - 130
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.	6.8 - 9.0	2.5 - 4.3	1.8 - 3.7	2.6 - 3.7	1.4 - 2.7	1.0 - 2.6
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.	13.2 - 17.8	4.7 - 8.1	3.0 - 6.9	4.9 - 7.2	2.5 - 5.1	1.6 - 4.8
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.	25 - 34.3	8.2 - 14.8	4.5 - 12.0	9.2 - 13.7	4.0 - 9.0	na - 8.0
to optimal level						
% reduction in alc. consumption	40 - 45	28 - 38	23 - 38	26 - 32	20 - 31	17 - 33
net increase in revenue, $ bn.	166 - 203	43 - 61	22 - 37	87 - 116	30 - 49	16 - 31
welfare gain, $bn.	134 - 227	13 - 33	5 - 19	24 - 49	5 - 16	2 - 11

Note. Parentheses indicates a negative value.

As mentioned above, we put the external cost per drunk driver trip at $23.5. Under a pecuniary penalty, this would be the Pigouvian tax, if there were no increase in resource costs from raising the expected penalty level. However, in practice, resource costs do go up with penalty level. To the extent that higher expected fines result from an increase in the arrest rate, policing and judicial costs increase. And to the extent that higher fines protract the legal process, judicial costs increase. Under our assumption that each of these responses counts 50 percent to any increase in the expected penalty, these resource costs reduce the Pigouvian penalty per trip to between $7.3 and $18.8 depending on the drunk driver elasticity (the more inelastic the demand the greater the increase in the required expected penalty, per reduced incidence of drunk driving). Under the non-pecuniary penalty (higher expected jail terms), the Pigouvian equivalent is lower still, between $5.7 and $14.6 per drunk driver trip. This is primarily because raising the non-pecuniary penalty also increases the size of the first-order deadweight loss from that policy (refer back to Figure 1).

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Second, the fiscal component typically plays a much smaller role in the overall optimum penalty level than for the alcohol tax. A related point is that the revenue-recycling advantage of fines over non-pecuniary penalties also is relatively small for the following reason.[16] The drunk-driver external cost is about six times current drunk-driver penalties, which means that the welfare gains from higher penalties in the drunk driver market are typically large relative to welfare effects from any interactions with the labor market. In contrast, external costs for alcohol are "only" 30 percent of the consumer price; therefore welfare gains from higher taxes in this market are small relative to welfare effects in the labor market.

Third, the overall optimized drunk driver fine is $19.0 to $26.0 per trip, or $1.4 to $1.9 per mile of drunk driving. The optimized non-pecuniary penalty is equivalent to $11.2 to $13.8 per trip, or $0.8 to $1.0 per mile of drunk driving (given the current fine). Prevailing expected fines and non-pecuniary penalties are small relative to these optimal penalty levels; combined, these penalties amount to $0.3 per mile. Fourth, annual welfare gains from a $4 increase in the expected fine per drunk driver trip are $8.4–$12.4 billion. This policy raises approximately the same amount of revenue as a 50 percent increase in the alcohol tax, however the latter policy generally produces smaller welfare gains of $1.8–$9.0 billion (Table 2, revenue-neutral case). This is because, per dollar of revenue raised, the drunk driver penalty has a more direct impact on reducing externalities than the alcohol tax, and this outweighs its drawback in terms of higher government resource costs. Even though a $4 per trip increase in the non-pecuniary penalty would also impose first-order deadweight losses and forgo gains from revenue recycling, this policy still produces comparable welfare gains of $3.3 to $8.3 billion.

Drunk driver fines are more efficient than taxes because all of the behavioral response to the drunk driver policies comes from reduced drunk driving, which produces substantial externality benefits, while most of the behavioral response to alcohol taxes comes from a reduction in moderate alcohol consumption, which has no externality benefits. If policies were instead compared for about the same reduction in drunk driving, then the alcohol tax is more favorable because it exploits the large fiscal benefit. For example, an increase in the alcohol tax to $72 per gallon, reduces alcohol consumption and hence drunk driving (given our elasticity assumptions) by 7.6–17.9 percent with welfare gains of around $5 to $15 billion or larger (Table 2, revenue-neutral case). In contrast, an increase of $0.9 in the expected penalty per drunk driver trip reduces drunk

[16] The exception to these cases is when own- and leisure cross-price drunk driver elasticities both take on their lower bound values.

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driving by approximately the same amount, but results in a smaller welfare gain of $1.2 to 5.4 billion.

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 22.5% or $0.9 per trip						
% reduction in trips	11.4	13.3	18.5	11.4	13.3	18.5
net change in revenue, $bn.	1.5	1.3	1.1	-0.6	-0.4	-0.1
welfare gain, $bn.	2.3	3.9	5.4	1.2	2.0	2.8
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.	5.5	5.1	4.7	-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

(ii) Optimal alcohol taxes under higher drunk driver penalties. As noted above, the optimal alcohol tax is de-coupled from the level of non-pecuniary drunk driver penalties. Table 4 shows how the (revenue-neutral) optimal tax varies with the level of the expected fine per trip (here we adopt the lower end of our range for the productivity effect). Even if it were feasible to offset a large portion of the drunk driver externality through fines, substantially higher alcohol taxes would still be warranted, at least if they were revenue neutral. For example, suppose that the expected fine per trip were $16, instead of the current fine of $0.19, per trip; this would internalize about 70 percent of the drunk driver externality. But even in

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this case the optimal alcohol tax is $63, $99 or $444 per gallon, across the different cases for alcohol elasticities in Table 4. Even these taxes are much higher than the current level of $24 per gallon.

Table 4. Sensitivity of Optimal Alcohol Tax to Drunk Driver Penalties
(revenue-neutral case)

own-price alc. elast.	-0.4	-0.7	-1.0
alc./leisure cross-price elast.	-0.15	0	0.15
Optimum alcohol tax			
Expected drunk driver fine $4 per trip	507	141	79
Expected drunk driver fine $8 per trip	487	127	68
Expected drunk driver fine $16 per trip	444	99	63

C. Individual Beverage Taxes

Finally, Table 5 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

This paper develops an analytical framework for estimating the optimal levels and welfare effects of alcohol taxes and drunk driver penalties, accounting for how policies interact with pre-existing tax distortions in the labor market. Although more empirical research on some model parameters is needed our analysis suggests that alcohol taxes in the United States are far lower than their optimal levels. These optimal levels are determined not just by externality considerations, which have been the predominant focus of the existing literature but also by fiscal considerations that are likely to be compelling to law makers.

In principle, a similar type of analysis might be usefully applied to other substance abuse policies, like tobacco taxes and, possibly, taxes on unhealthy

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foods to address the rise in obesity. However, empirical research would be needed on the critical leisure cross-price elasticities to pin down optimal taxes with much confidence.

Table 5. 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

More generally, one might wonder what is special about alcohol—why not analyze other commodity taxes in general as replacements for labor taxes? One response is that—unlike for other commodities—alcohol taxes are widespread in practice and are frequently justified as a revenue-raising measure. It therefore behooves economists to assess, insofar as possible, how much alcohol taxation might be warranted on fiscal grounds. Moreover, the potential welfare gains from implementing the optimal level of alcohol taxes are potentially large, given the substantial externalities associated with its consumption. Though there are important exceptions, for other commodities in general externalities are minimal, and on average the Ramsey tax component is zero, given that the average good must be an average substitute for leisure.

Appendix A. Analytical Derivations

Deriving equation (5)
Using (1) and (3), agents solve the following optimization problem:

$$\text{(A1)} \quad V(t_A, t_L, I, G^P, \overline{D}) = MAX\ U(A, D, C, T(H) - L, H, \tau_D D, G^P) + \lambda\{(1-t_L)W + G^T - K_M - K_D - (p_A + t_A)A - (v_D + t_D)D - v_M M - p_C C\}$$

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where $W = w(H)L$, $K_M = (1 - s - v_M)\overline{M}$, $K_D = (c_D - v_D)\overline{D}$, $H = H(A, D, \overline{D}, M)$ and λ is a Lagrange multiplier. $\overline{M}$ and $\overline{D}$ are the economy-wide per capita variables, taken as given in the individual's optimization. The equilibrium is defined by the individual's demand functions and the fact that, since an individual is also the representative individual, privately optimal choices, M^* and D^* equal the per capita $\overline{M}$ and $\overline{D}$:

$$y^* = y^*(t_A, t_L, G^T - (1 - s - v_M)M^* - (c_D - v_D)D^*, G^P, D^*)$$

for $y = A$, D, C, M, L where the $y^*(.)$ are the demand/supply functions for the representative individual who treats per capita $\overline{M}$ and $\overline{D}$ as given and we have substituted M^* and D^* for $\overline{M}$ and $\overline{D}$. Solving for the endogenous equilibrium values as functions of the exogenous variables gives:

$$\hat{y} = \hat{y}(t_A, t_L, G^T, G^P, s - v_M, c_D - v_D)$$

The equilibrium responses of the endogenous variables to the tax and other policy instruments are the partial derivatives of $\hat{y}$ rather than y^*. The former take into account the feedback effects of changes in K_M and K_D (to maintain zero profits for insurance companies) on individual demands.

Differentiating the $\hat{y}(.)$ functions with respect to t_A gives:

$$\frac{d\hat{y}}{dt_A} = \hat{y}_{t_A} + \hat{y}_{t_L}\frac{dt_L}{dt_A} + \hat{y}_{G^T}\frac{dG^T}{dt_A} + \hat{y}_{G^P}\frac{dG^P}{dt_A}$$

We assume that for $y = A$, D, M then $d\hat{y}/dt_A \approx \hat{y}_{t_L}$. That is, the impact of higher alcohol taxes on alcohol consumption, drunk driving and medical consumption (for alcohol-related health impacts) is large relative to the feedback effect from induced changes in labor taxes and public spending through the government budget equation. That is, the change in these quantities is the same irrespective of how extra tax revenues are spent. This seems a reasonable approximation, given that household budget shares for these items are relatively small (Willig 1976) and the huge bulk of any compensation through revenue-recycling will therefore be spent on other goods. For the remainder of Appendix A and B, and in the main text, we drop the ^ notation.

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Deriving equation (6)
From partially differentiating (A1):

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

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

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

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

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

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

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

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

$$\text{(A6)} \quad \frac{1}{\lambda}\frac{dV}{dt_A} = -(1 - v_M)\frac{dM}{dt_A} - (mpc \cdot H_{\overline{D}} + c_D - v_D - t_D + r)\frac{dD}{dt_A} + t_A\frac{dA}{dt_A} + t_L\frac{dW}{dt_A} + \left(\frac{U_{G^P}}{\lambda} - 1\right)\frac{dG^P}{dt_A}$$

To incorporate medical costs into an expression for the external costs of alcohol consumption and drunk driving we assume that medical services can alternatively be expressed as a simple function of alcohol consumption, own drunk driving and the drunk driving of others (as these variables drive medical care demand through their impact on health): $M = M(A, D, \overline{D})$. This form is reasonable if individuals receive a fixed amount of medical care for a given injury/illness, and the

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incidence of injury/illness is a function of A, D and $\overline{D}$. Differentiating the expression with respect to t_A gives:

$$\text{(A7)} \quad \frac{dM}{dt_A} = M_A \frac{dA}{dt_A} + M_D \frac{dD}{dt_A} + M_{\overline{D}} \frac{d\overline{D}}{dt_A}$$

In addition we define:

$$\text{(A8)} \quad \eta_{AA} = \frac{dA}{dt_A} \frac{(p_A + t_A)}{A}, \qquad \eta_{DA} = \frac{dD}{dt_A} \frac{(p_A + t_A)}{D}$$

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:

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

where

$$\frac{dA}{dt_A} = \frac{\partial A}{\partial t_A} + \frac{\partial A}{\partial t_L}\frac{dt_L}{dt_A}, \qquad \frac{dD}{dt_A} = \frac{\partial D}{\partial t_A} + \frac{\partial D}{\partial t_L}\frac{dt_L}{dt_A}, \qquad \frac{dM}{dt_A} = \frac{\partial M}{\partial t_A} + \frac{\partial M}{\partial t_L}\frac{dt_L}{dt_A}$$

From (A9) and (8b):

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

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

$$\text{(A11)} \quad (E^A - t^A)\left(-\frac{dA}{dt_A}\right) + MEG_{t_L}\left\{A + t_A\frac{dA}{dt_A} - s\frac{dM}{dt_A} - (r - t_D)\frac{dD}{dt_A}\right\}$$
$$+ (1 + MEG_{t_L})t_L w\frac{\partial L}{\partial t_A} + (1 + MEG_{t_L})t_L\frac{\partial W}{\partial H}\frac{dH}{dt_A}$$

From the Slutsky equations:

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

where superscript c denotes a compensated coefficient and $\partial L / \partial I$ is the income effect on labor supply. From the Slutsky symmetry property:

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

where $\tilde{w} = (1 - t_L)w$ denotes the net of tax wage. Equating (A11) to zero, and substituting (A12) and (A13) gives (8a), where g^A and θ^A_{WH} are defined in (8b), η_{AA} is defined in (A8), and additional elasticities are:

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

Deriving (9)

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

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

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

Deriving (10)

We simplify our formulas for optimal drunk-driver penalties by assuming $dA/dt_D = dA/d\tau_D = 0$. 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 × 0.5 × (24.2–6.3) = \$0.27 which is very small relative to the externality benefit of \$23.7 per avoided trip (see also Kenkel 1993a).

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

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

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 $dA/dj = 0$. The result is:

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

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

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

and

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

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:

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

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}:

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

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

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

Substituting (A21) in (A22) gives:

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

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).

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-

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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 1993b), 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. Putting these together and

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dividing by alcohol consumption gives external medical costs $(1-v_M)(M_D + M_{\bar{D}})D/A$ = \$8.5 per alcohol gallon.

Drunk-driver Penalties. Our approach here is roughly based on Kenkel (1993b). US BOJS (2002) provides drunk-driver arrests by state;[17] following Kenkel (1993a, 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 and 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.[18] 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.

Government resource costs. Based on estimates for cases resulting in a guilty plea, Kenkel (1993a) 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

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

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

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updating Kenkel (1993b) 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 (1993a) 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_{τ_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) × .5 + 295 + (2,554 + 3,368) × .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_{τ_D} = (.71 × 832 + (450 + 2000 + 1.71 × 832))/((295 + 3,368) × .5 + 2,554 + (295 + 3,368) × .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_{τ_D} = 0.58.

Alcohol/leisure cross-price elasticity: alternative estimate. 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:

$$\text{(B1)} \qquad \frac{\partial A^c}{\partial \tilde{w}} = \frac{\partial A^{c,\tilde{W}}}{\partial \tilde{w}} + \frac{\partial A}{\partial \tilde{W}} \tilde{w} \frac{\partial L^c}{\partial \tilde{w}}$$

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(again ~ denotes a variable net of the labor tax). Substituting into the definition of η_{Al}^{c} gives:

(B2) $\eta_{Al}^{c} = \eta_{A\tilde{W}}\varepsilon_{LL}^{c} + \eta_{Al}^{c,\tilde{W}}$

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), ε_{LL}^{c} is the compensated (own-price) labor supply elasticity for alcohol-consuming households and $\eta_{Al}^{c,\tilde{W}}$ is the alcohol/leisure cross-price elasticity for given labor income. The first component in (B1) 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.[19] A priori, we might expect $\eta_{Al}^{c,\tilde{W}} < 0$ 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. The economy-wide compensated labor supply elasticity, which would be 0.35 given our assumptions for ε_{LL} and η_{LG^T}, is probably an upper bound on ε_{LL}^{c}, as the economy-wide elasticity is largely driven by the (participation) decision of married females, who are relatively light drinkers. Assuming $\eta_{A\tilde{W}}$ = 0.1–0.6 and, to be conservative in the sense of understating the fiscal component of the optimal alcohol tax, we set $\eta_{Al}^{c,\tilde{W}}$ = 0 and ε_{LL}^{c} = 0.35; this gives a range of 0.04 –0.21 for η_{Al}^{c}.

Drunk-driver elasticities. A study of self-reported data on drunk driving by Kenkel (1993b) implies an alcohol price/drunk-driving elasticity η_{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}.

[19] 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).

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Most, though not all, studies suggest that drunk driving is responsive to stricter deterrence policies; for example, Chaloupka et al. (1993), Kenkel (1993a), and Mullahy and Sindelar (1994) find significant responses, though Evans et al. (1991) do not. Kenkel (1993a), 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 (2009), 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.

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