Alcohol Sin Taxes*

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Abstract

The externality costs generated by excessive alcohol consumption warrant the imposition of alcohol specific excise taxes. For all U.S. States, average alcohol taxes are significantly below estimates of average externality costs, suggesting the current excise tax regime is inefficiently low relative to the Pigovian benchmark. However, with heterogeneous consumption patterns, this benchmark may be sub-optimal if it fails to consider the welfare losses imposed on non-abusers. Here, using a model calibrated at the State level, we show that once these welfare losses are considered, current U.S. wine and spirit taxes are too high, while beer taxes, on average, are about right.

Key Words: Optimal Taxation, Sin Taxes, Externalities, Alcohol Policy

JEL Codes: H21, H23

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1 Introduction

Excessive alcohol consumption is associated with a range of negative health outcomes, and WHO et al. (2011, p.29;54) attribute 3.8 percent of all global deaths and 4.5 percent of total global disease and injury burden to alcohol. In cost terms, the studies summarized in WHO et al. (2011, p.37) suggest that the total social costs (private and external costs combined) of excessive alcohol consumption are around 2.5 percent of GDP in high income countries, and around 2.1 percent of GDP in middle income countries. When looking at externality costs only, a review of 15 studies related to Europe found average alcohol related externality costs are likely to be at least 0.7 percent of GDP (Cnossen, 2007). It is therefore clear that excessive alcohol consumption is associated with substantial externality costs.

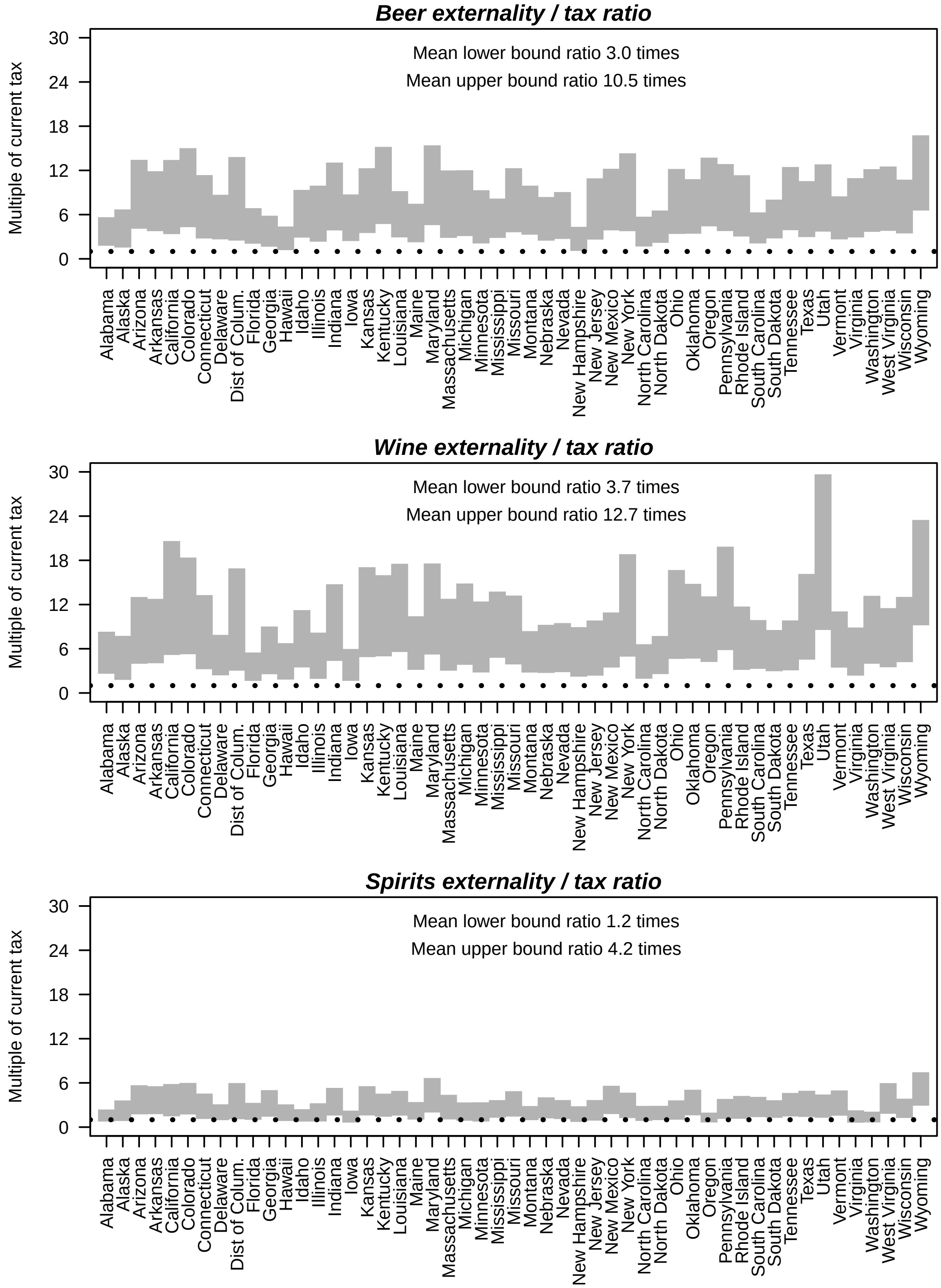
A canonical policy response to remedy externalities is to levy a Pigovian tax, and an intuitive first-order approximation of the optimal Pigovian tax is the average externality cost per unit of ethanol consumed. If marginal externalities are constant with quantity consumed, for taxes to be optimal the ratio: per gallon of ethanol externality cost / per gallon of ethanol tax rate should be one. If externalities are increasing in quantity consumed, then average externality cost would be an under-estimate of the ideal tax, and this ratio should be less than one.

Figure 1.1 plots, for the high to low range of State level externality cost estimates, the relevant tax / externality cost ratio. Taking the mid-point of the externality cost estimate range for each State as a reference point, the figure shows that, on average, for taxes to be optimal, beer taxes need to increase by a factor of seven, wine taxes by a factor of eight, and spirits taxes by a factor of three. It is this kind of comparison between externality cost estimates and alcohol tax revenue that leads Naimi (2011) to conclude that the alcoholic beverage industry receives a substantial public subsidy. However, this approach implicitly assumes that rates of alcohol consumption and abuse are homogeneous across society. In fact, as we document, there is considerable variation in alcohol consumption patterns across individuals, and across States. The majority of American adults consume alcohol in moderation, whilst a relatively small portion of individuals contribute to a disproportionately large fraction of alcohol sales. If overall community welfare is to be maximized, both externality costs and the welfare losses due to alcohol taxes must be considered; and in such a framework it is not clear whether current tax rates are too high, too low, or about right.

This paper builds on the framework introduced in Pogue and Sgontz (1989) for assessing the overall welfare implications of alcohol taxes, and determines both the first-best alcohol tax policy as well as the optimal taxes that preserve the government's current revenue stream. Our model divides consumers into three groups: moderates, whose consumption generates no externalities, informed heavy drinkers (abusers) whose consumption is privately optimal but who generate externalities, and uninformed heavy drinkers whose consumption is both privately and socially sub-optimal. The optimal tax trades-off the social welfare gain of reducing externalities and deterring destructive behavior by abusers against the deadweight losses from distorting the choices of moderates.

The framework is then used to estimate optimal tax rates for beer, wine, and spirits for each State, and optimal taxes for beer, wine, and spirits subject to a tax revenue neutrality constraint. Focusing the analysis at the State-level is appropriate, both because of the heterogeneity in existing State policies, and because differences in the consumption profile across States implies potentially different optimal taxes. When looking at first-best alcohol tax policy settings, for beer, the analysis provides no clear cut finding. Depending on the assumptions made, current beer taxes could be too high, too low, or about right. For wine and spirits, however, the results are unambiguous: relative to the optimal tax rates, current tax rates are universally too high, and imposing the revenue neutrality constraint does not change this result.

Figure 1.1: A simple approach to setting alcohol taxes



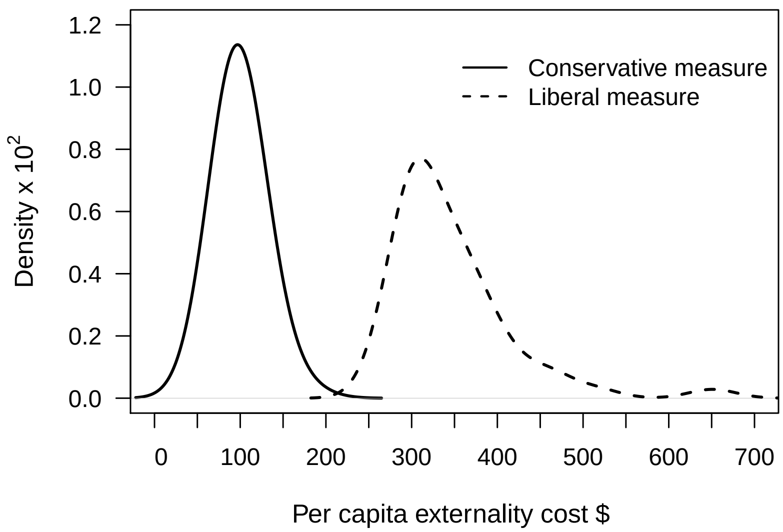
2 Background

2.1 Externality costs

Determining what constitutes an externality cost is complicated. For example, consider the case of a premature death due to alcohol induced liver cirrhosis. First, consider total health related costs. These costs must be separated into costs that fall directly on the individual, and costs borne by the publicly funded health care system, or private insurance pools, where the costs that fall on the other participants in the insurance pool and the public health care system are externalities. Next, consider the question of lost earnings. A premature death has several impacts. First, there is the direct loss of income to the individual. To the extent that the individual has lost income this is not an externality cost. To the extent that the individual was part of a family unit, and the family unit has lost income, it could be argued that an externality cost has been imposed on the other family members. Now consider the issue of marginal productivity. There is a substantial literature that shows both moderate and heavy drinkers earn more than abstainers (see Lye and Hirschberg (2010) for a review). Conditional on being alive, both heavy and moderate drinkers, on average, contribute more to tax revenue than non-drinkers. If the cost of drinking related deaths, in terms of lost revenue to the Department of Treasure, are to be included in externality cost calculations, the additional revenue that the Treasury collects from drinkers over their lifetime should also be considered. Further, a premature death, while resulting in lost tax revenue to the Treasury, may also result in savings in terms of reduced pension payments.

The point of the above discussion is not to make a definitive case for the inclusion / exclusion of some costs, or to argue for a specific definition of externality costs. Rather, the point is that reasonable people can disagree about how externality costs should be determined. As such, it can be more useful to frame externality cost estimates as lying within a range. Here, two estimates of externality costs are used. The first estimate relies on a narrow definition of costs, and is based on estimates of actual costs incurred, i.e. lost potential productivity issues are excluded. The second set of estimates, which are the upper bound or liberal cost estimates, include lost productivity effect estimates. The estimates are based on the data in Sacks et al. (2015), inflated from 2010 to 2012 using the consumer price index (CPI). Full externality cost estimate information is detailed in the appendix, but Figure 2.1 plots the distribution of the State level estimates, expressed on per capita basis, for both the liberal and conservative measure. As can be seen, for both the conservative measure and the liberal measure there is substantial variation in per capita externality cost estimates across States. The mean (unweighted) liberal externality cost estimate is $345 (S.D. $69), and the mean unweighted conservative estimate is $100 (S.D. $20).

Figure 2.1: Distribution of State level per capita alcohol externality cost estimates



2.2 Alcohol taxes

There are a number of different ways to express alcohol tax rates, but here, combined State and Federal tax rates are expressed in U.S. dollars per gallon of pure alcohol. By volume conversion rates of 4.8 percent for beer, 12.5 percent for wine, and 40 percent for spirits were used for the calculations. Figure 2.2 plots the beer, wine, and spirits tax rates for each State. In the plots the vertical scale is the same, and as can be seen, in the U.S., spirits are more heavily taxed than either wine or beer.

To place U.S. tax rates in perspective, Figure 2.3 provides information on alcohol tax rates in 28 European countries, plus Canada. There is significant heterogeneity in alcohol tax policy across the comparison countries, but averaged across Europe and Canada, and similar to the U.S., spirits are taxed at least twice as heavily as wine or beer. Unlike the U.S., in many of the comparison countries wine is afforded a special status, and no wine specific tax applied in about half the sample. By comparing Figure 2.2 and Figure 2.3 it can be seen that in the U.S., the average tax rates by beverage type are about half the average of the international comparison group: beer $40 v $19; wine $30 v $15; spirits $89 v $45.

Given the skewed distribution and small sample size, it seems more appropriate to test for a statistically significant difference in medians rather than means, and using the method of Schaarschmidt and Gerhard (2015), the 95 percent confidence intervals for the differences in the medians between the U.S. and the sample countries are: $1.9 to $19.8 for beer; -$15.3 to $12.2 for wine, and $12.9 to $44.2 for spirits. So, median tax rates for beer and spirits are higher in the comparison countries than in the U.S., but for wine the median tax rates are not different. Such results tend to reinforce perceptions that current U.S. alcohol taxes are are too low.

Figure 2.2: US alcohol tax rates by State

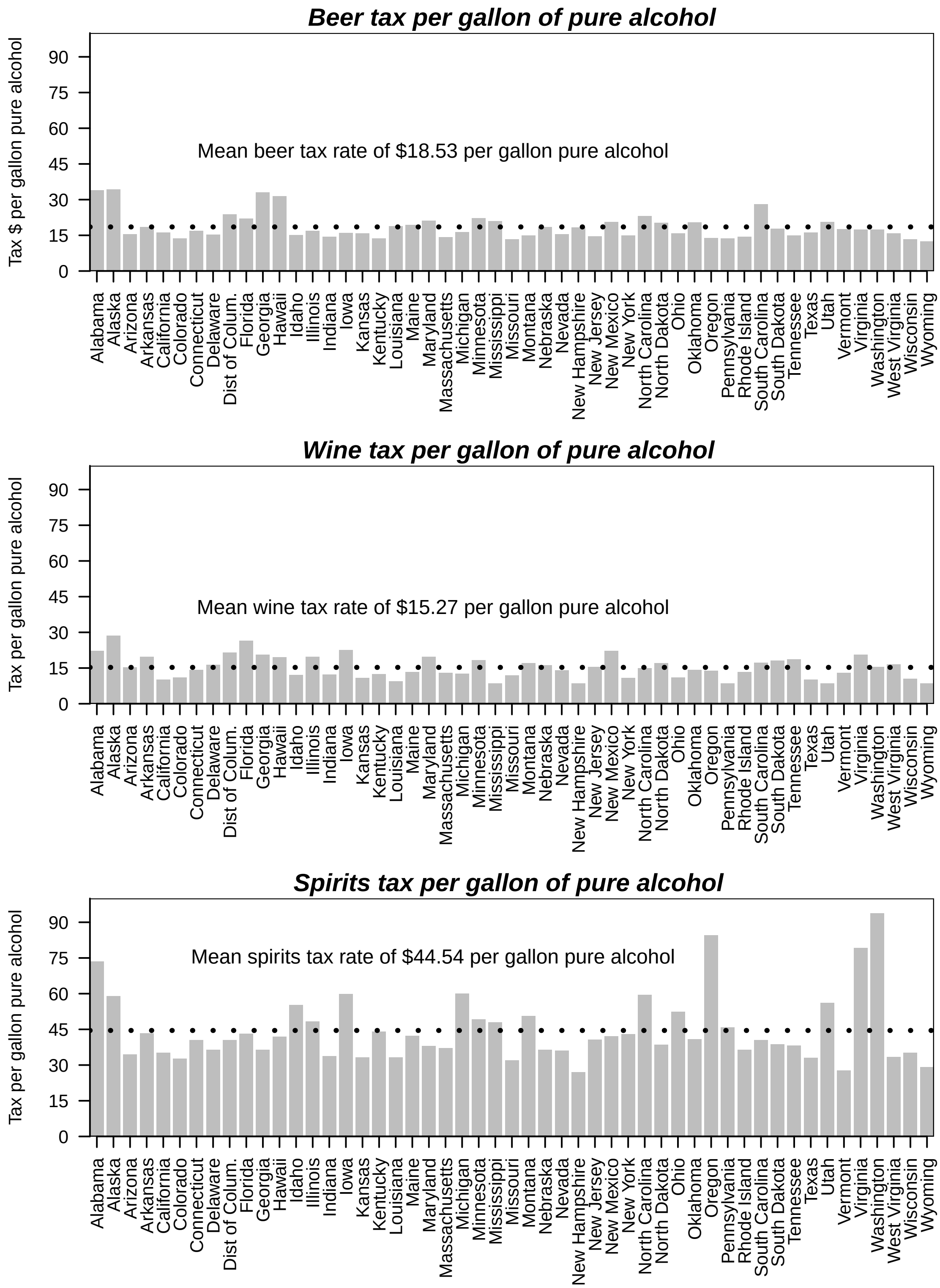
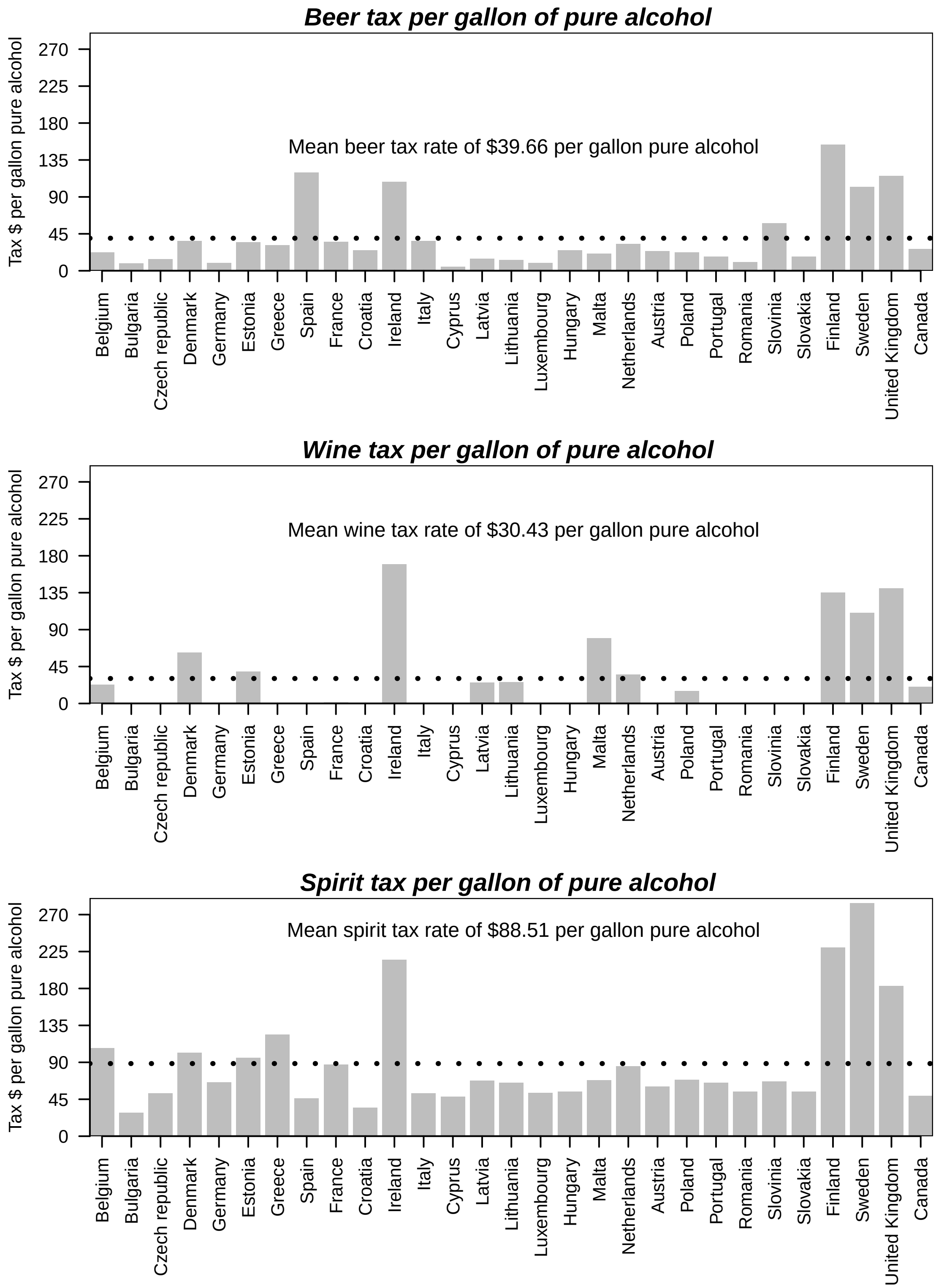


Figure 2.3: Alcohol tax rates in comparison countries



3 Welfare maximizing tax rates

The core elements of the model we present were first presented in Pogue and Sgontz (1989), which considers alcohol as a group. One way of extending the approach to more than one beverage was then developed in Saffer and Chaloupka (1994). The idea of an uninformed consumer group, in the context of an alcohol only model was then introduced in Kenkel (1996). The presentation here synthesizes and generalizes this earlier work in several important directions. First, we integrate the concepts previously introduced into a single unified framework. Second, the model we develop uses Marshallian own-price and cross-price effects for beer, wine, and spirits. Third, the framework is extended to consider the case of optimal alcohol taxes subject to an overall alcohol tax revenue constraint.

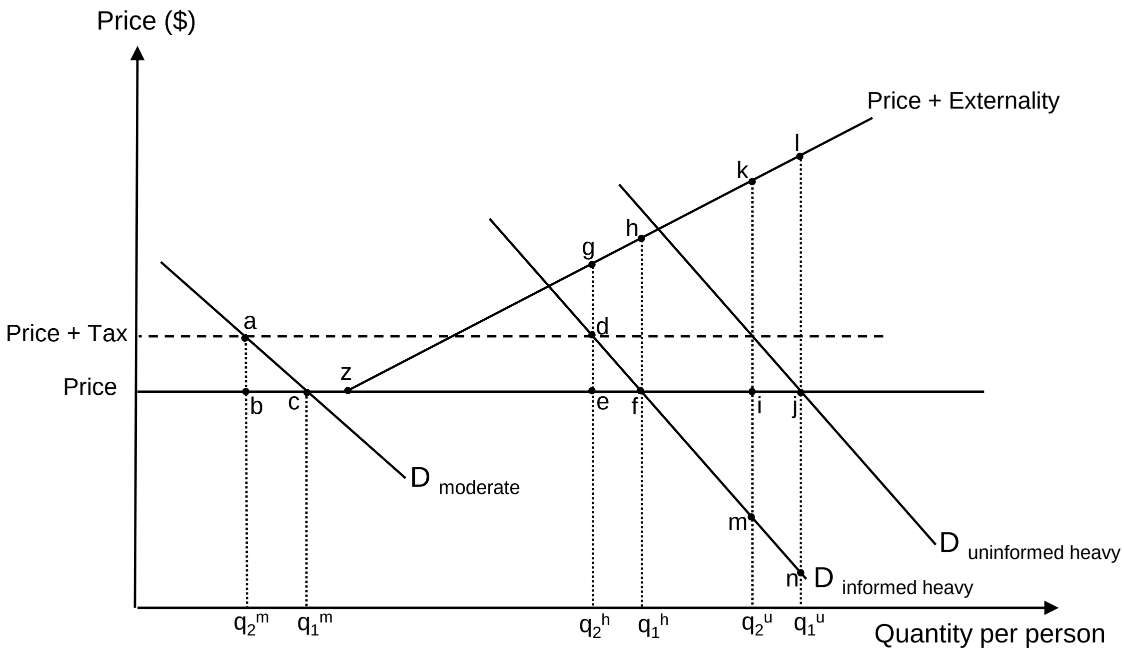
3.1 An optimal tax model

The model assumes there are two types of drinkers: moderate drinkers and heavy drinkers. Moderate drinkers impose no externality costs on the community: heavy drinkers do. The heavy drinker category is further divided into two consumer types: informed heavy drinkers and uninformed heavy drinkers. Informed heavy drinkers comprehend all private costs and benefits associated with their drinking and consume at a level that maximizes *their* welfare. Uninformed heavy drinkers, on the other hand, fail to recognize some of the private costs of heavy drinking, and so consume at a level beyond their individual welfare maximizing level of consumption. Although characterized as uninformed consumers, this group is analogous to a group with time- inconsistent preferences, or a group trapped in destructive habitual behavior. The model further assumes that, above a threshold level of consumption, externality costs are increasing with consumption; that the beer, wine, and spirits markets are competitive, with price equal to long run marginal cost; that tax increases are fully passed through to consumers; and that alcohol tax revenue can be returned to consumers in the form of a lump sum payment. These simplifying assumptions do not detract from the key insights presented below.

Figure 3.1 presents the intuition of the model at the individual consumer level. When there are no alcohol specific taxes, moderate drinkers, informed heavy drinkers, and uninformed heavy drinkers (of a given beverage type) purchase quantities: $q_1^m < q_1^h < q_1^u$ respectively. Moderate drinkers impose no externality costs on society and informed heavy drinkers impose an externality cost on the community equal to the area *fhz*. Uninformed heavy drinkers, when fully informed, are assumed to consume at the same level as informed heavy drinkers. As such, for every unit of consumption between q_1^h and q_1^u the marginal benefit gained by uninformed heavy drinkers is less than the marginal cost. By consuming at q_1^u uninformed heavy drinkers impose an externality cost on the community equal to *jlz*, and receive welfare below the optimal level by an amount equal to *njf*.

Following the introduction of an alcohol tax, moderate, informed heavy, and uninformed heavy drinkers reduce consumption to $q_2^m < q_2^h < q_2^u$, respectively. Moderate drinkers therefore suffer a welfare loss equal to *abc*. Informed heavy drinkers suffer a welfare loss equal to *def*, but society gains *efgh* due to lower externality costs. Uninformed heavy drinkers enjoying a welfare gain equal to *ijmn*, with society gaining *ijkl* due to lower externality costs. The optimal tax balances the welfare gains against the welfare losses.

Figure 3.1: Welfare implication of an alcohol tax



From Figure 3.1 it is possible to see the factors that influence the optimal tax rate. If there are many moderate drinkers and few heavy drinkers a tax generates large welfare losses and small externality cost savings: the optimal tax is therefore low. Reducing the consumption of uninformed heavy drinkers provides a welfare gain to these consumers and generates an externality cost saving. So, the greater the number of uniformed drinkers the greater the optimal tax. The more price responsive moderate drinkers are, the greater the welfare loss. So, as the own-price elasticity for moderate consumers increases in absolute value, the lower the optimal tax rate. Similarly, the closer the heavy drinker own-price elasticity is to zero, the smaller the externality cost savings, and so the lower the optimal tax rate.

With Figure 3.1 providing an intuitive understanding of the way the model works, we now formally set out the problem in terms of parameter values that are known or can be calculated.

The model setup

Let T_j denote the tax on beverage $j \in \{b, w, s\}$, and let $T = (T_b, T_w, T_s)^T$ be a vector of taxes. Let Q_j^k be the quantity of beverage j consumed by type $k \in \{m, h, u\}$ agents, and let $\mathcal{Q}^k = diag\left\{Q_b^k, Q_w^k, Q_s^k\right\}$. Let P_i denote the price of beverage i, and let $P = diag\{P_b, P_w, P_s\}$. Let $\eta_{ji}^k = \frac{\partial Q_j^k}{\partial P_i}\frac{P_i}{Q_j^k}$ be the elasticity of demand for beverage j with respect to price i for type k agents, and let $\mathcal{N} = \left\{\eta_{ji}^k\right\}$. (Note that rows represent beverages and columns represent prices.) Finally, let E_j^k denote the marginal external cost from a type $k \in \{h, u\}$ agent consuming beverage j, and let H_j^u denote the uninternalized private cost from type-u agents consuming beverage j. We have $\mathcal{E}^k = \left(E_b^k, E_w^k, E_s^k\right)^T$ and $\mathcal{H}^u = (H_b^u, H_w^u, H_s^u)^T$.

Given a vector of taxes, the social welfare loss W_j stemming from the consumption of beverage j is:

$$W_j = -\frac{1}{2}T_j Q_j^m \sum_i \frac{T_i}{P_i}\eta_{ji}^m + \left[E_j^h - \frac{1}{2}T_j\right] Q_j^h \sum_i \frac{T_i}{P_i}\eta_{ji}^h + \left[E_j^u + H_j^u\right] Q_j^u \sum_i \frac{T_i}{P_i}\eta_{ji}^u$$

and so the total social welfare loss is $W = W_b + W_w + W_s$. In matrix notation, we have:

$$W = b^T T - \frac{1}{2}T^T A T$$

where,

$\mathcal{A} = \left[\mathcal{Q}^m\mathcal{N}^m + \mathcal{Q}^h\mathcal{N}^h\right] P^{-1}$, $A = \frac{1}{2}\left(\mathcal{A} + \mathcal{A}^T\right)$, and $b^T = \left[\left(\mathcal{E}^h\right)^T \mathcal{Q}^h\mathcal{N}^h + \left(\mathcal{E}^u + \mathcal{H}^u\right)^T \mathcal{Q}^u\mathcal{N}^u\right] P^{-1}$.

The first term in the social welfare loss expression is the welfare loss associated with the dead-weight costs of taxation. It is a quadratic form in T, reflecting the fact that deadweight costs are quadratically increasing in the size of taxes. The second term is the welfare gain associated with causing abusers to internalize externalities (and personal harms) which is, by construction, linear in taxes. Note that A is symmetric (by construction). We assume that A is negative definite, which guarantees both that it is invertible and that standard calculus techniques find the unique global maximum.

Optimal Taxes

Our problem is to choose T to minimize the social welfare loss W. By the first order condition, the optimal tax vector solves $AT - b = 0$. Hence, we have:

$$\begin{aligned} T^* &= A^{-1}b \\ &= 2\left[\left[\mathcal{Q}^m\mathcal{N}^m + \mathcal{Q}^h\mathcal{N}^h\right]P^{-1} + P^{-1}\left[\left(\mathcal{N}^m\right)^T\mathcal{Q}^m + \left(\mathcal{N}^h\right)^T\mathcal{Q}^h\right]\right]^{-1} \\ &\quad\times\left[\left(\mathcal{E}^h\right)^T\mathcal{Q}^h\mathcal{N}^h + \left(\mathcal{E}^u + \mathcal{H}^u\right)^T\mathcal{Q}^u\mathcal{N}^u\right]P^{-1} \end{aligned}$$

where $T^* = A^{-1}b$ is the first best tax policy — it minimizes the social welfare loss. In principle, if substitution effects are large enough the first best tax policy may include a subsidy to some beverage types. Since alcohol subsidies are typically not politically feasible, we impose the feasibility constraint that $T \geq 0$. If $T_j^* < 0$ for some j, then we must search for a constrained optimal tax policy.

Unfortunately, the properties of the matrix A and vector b are difficult to understand in the abstract — they depend on the interaction between the elasticities η_{ij}^k and the externalities E_j^k (and uninternalized personal cost H_j^u). Hence, it is difficult to give the terms A and b a direct interpretation, and to give meaning to the solution more generally. However, we do provide a special case below:

Example 1 (No cross price effects). Suppose $\mathcal{N}^k$ is a diagonal matrix so that all (Marshallian) cross-price elasticities are zero. Then, the first order condition (w.r.t T_j) becomes:

$$\left[Q_j^m\eta_{jj}^m + Q_j^h\eta_{jj}^h\right]\frac{T_j}{P_j} = \frac{1}{P_j}\left[\eta_{jj}^h Q_j^h E_j^h + \eta_{jj}^u Q_j^u\left(E_j^u + H_j^u\right)\right]$$

for each $j \in \{b, w, s\}$. This implies that:

$$T_j^* = \frac{\eta_{jj}^h Q_j^h E_j^h + \eta_{jj}^u Q_j^u\left(E_j^u + H_j^u\right)}{Q_j^m\eta_{jj}^m + Q_j^h\eta_{jj}^h}$$

Assuming $\eta^k_{jj} < 0$ in all cases (i.e. there are no Giffen goods), then we must have $T^*_j > 0$, and so T^* is optimal.

To parse this expression, note that the numerator quantifies the welfare gain from a 1 percent increase in prices, stemming from both a reduction in externalities and lower self-harm by abusers. The denominator is the decrease in consumption by the moderate and informed abusers from a 1 percent increase in prices. (Recall, the deadweight loss is increasing in both the size of the tax and the drop in quantity.) Hence, the optimal tax should equal the marginal welfare gain per unit of consumption deterred. Such a tax optimally trades-off the social welfare gains from reduced externalities against the harms stemming from higher deadweight losses.

Finally, note that if all consumers are informed abusers (i.e. if $Q^m = Q^u = 0$), then $T^*_j = E^h_j$, which is simply the standard Pigovian tax that internalizes an externality. From this baseline, increasing the number of moderates will cause the optimal tax to decrease, as taxes impose costs on these consumers without an off-setting reduction in externalities. By contrast, increasing the number of uninformed abusers will cause the optimal tax to increase, to both internalize the higher average externality as well as to deter self-harm.

Revenue Neutral Taxes

Now suppose we add the constraint that the optimal tax regime must satisfy the government's revenue requirement. For concreteness, we assume that current government policy actually achieves the desired revenue, and ask whether this policy is (revenue constrained) optimal. Let t be the current tax policy (distinct from the optimal policy T), so that current alcohol tax revenue is $R^0 = \sum_i t_i \sum_k Q^k_i$. Let $dT = T - t$ and let dR denote the change in revenue associated with the policy change dT. We have:

$$
\begin{aligned}
dR &= \sum_i dT_i \left[\sum_k Q_i^k \right] + \sum_i t_i \left[\sum_k dQ_i^k \right] \\
&= \sum_i dT_i \left[\sum_k Q_i^k \right] + \sum_i t_i \left[\sum_k \sum_j \eta_{ij}^k \frac{Q_i^k}{P_j} dT_j \right]
\end{aligned}
$$

In matrix form, this becomes:

$$
dR = \sum_k \left[i^T \mathcal{Q}^k + t^T \mathcal{Q}^k \mathcal{N}^k P^{-1} \right] dT
$$

where $i = (1, 1, 1)^T$ is the vector of ones. Feasibility requires that $dR = 0$. Again, for notational simplicity, define $c = \left\{ \sum_k \left[i^T \mathcal{Q}^k + t^T \mathcal{Q}^k \mathcal{N}^k P^{-1} \right] \right\}^T$, and so $dR = c^T dT = 0$. Writing $dT = T - t$, gives:

$$
\begin{aligned}
c^T T &= R^0 + \sum_k t^T \mathcal{Q}^k \mathcal{N}^k P^{-1} t \\
&= d
\end{aligned}
$$

Hence, the revenue neutrality constraint is defined by a linear function on the tax rate. We assume that increasing taxes cause revenue to increase (i.e. we aren't on the wrong side of the Laffer Curve), which implies that all the components of vector c are positive. If so, the set of revenue neutral taxes will be 'down-ward sloping'.

Optimality

The policy maker's problem is to choose T to minimize $\frac{1}{2} T^T A T + b^T T$ subject to $c^T T \geq d$, where the inequality allows that the optimal tax may raise *more* revenue than current taxes, but they may not raise less revenue. There are two possibilities. If the first best tax policy $T^* = A^{-1} b$ (from the previous section) weakly satisfies the revenue requirement (i.e. if

$c^T A^{-1} b \geq d$), then the revenue constraint is non-binding, and the first best tax policy is the optimal policy. However, if (as the data suggests for most States) the first best policy does not satisfy the revenue requirement, then the constraint must bind in equilibrium. The policy maker faces a trade-off between efficiency and revenue. Solving the Lagrange problem gives:

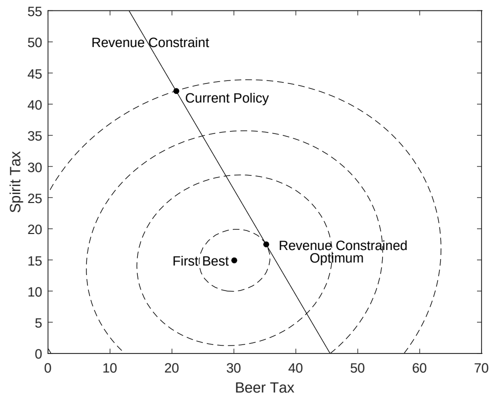
$$\hat{T} = T^* + \frac{d - c^T A^{-1} b}{c^T A^{-1} c} A^{-1} c$$

where $\hat{T}$ is the revenue constrained optimal tax policy, and T^* is the first best policy. Hence, the revenue-constrained optimal policy is the first best policy shifted in a way that reflects the marginal revenue of taxation.

To provide some intuition for the nature of the solution, note that the level sets of the objective function ($\frac{1}{2} T^T A T - b^T T$) are a series of concentric ellipsoids, centered at $A^{-1}b$. These are the social planner's indifference curves. Ellipses closer to the center are associated with lower levels of social welfare loss. Clearly, the loss is minimized at $A^{-1}b$, which corresponds to the first best tax policy. The revenue constraint is linear in taxes. If the first best tax policy lies below the revenue constraint, then it does not raise the required revenue. The revenue constrained optimum is the policy on the level set tangent to the revenue constraint.

We see this in the following diagram, where for representational simplicity, we focus on the case of two beverage classes: beer and spirits. The diagram is calibrated to the environment in New Mexico. As we see, the first best and revenue constrained optimal tax rates may be relatively similar for one class of beverages (spirits in this case), but quite different for others (beer).

Figure 3.2: First Best and Revenue Constrained Optimal Taxes



4 Model calibration values

To estimate optimal alcohol taxes requires information on: own-price and cross-price elasticities for each beverage and consumer type; consumption information for each beverage and consumer type; externality cost estimates for both types of heavy consumer for each beverage; estimates of the uninternalized cost for uniformed heavy drinkers for each beverage; and price information for each beverage.

Summary information on the baseline data used for model calibration is provided below, with detailed information on how baseline calibration values were determined provided in the appendix.

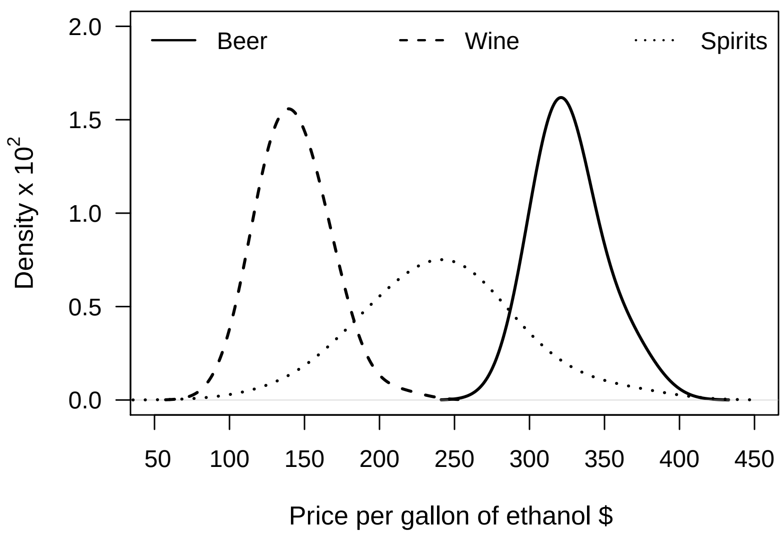
4.1 Prices

The beer and wine price data is based on information in the The Council for Community and Economic Research Cost of Living Index, and spirit price data is based on the inflation adjusted sale price of spirits from an online source.[1] Prices were then converted to per gallon of pure ethanol equivalent prices using alcohol by volume conversion factors of 4.8 percent for

[1] http://gizmodo.com/how-much-a-bottle-of-whiskey-costs-in-every-state-1650381482 [Accessed 23 June 2015]

beer, 12.5 percent for wine, and 40 percent for spirits. Estimated per gallon of pure ethanol taxes were then deducted from these values to arrive at the ex-tax alcohol prices. Figure 4.1 provides a summary of the price data, and as can be seen, on a per unit of ethanol basis, beer is the most expensive beverage and wine the least expensive.

Figure 4.1: Alcohol price distributions



4.2 Price elasticity

4.2.1 Population level price elasticity

Alcohol demand has been a popular research topic, and the global alcohol demand literature has been summarized in a number of meta studies, for example: Fogarty (2006; 2010), Gallet (2007), and Nelson (2013b; 2013c; 2014). Although the existing research provides many useful insights, the existing literature summaries do not address the issue of observation dependence due to common underlying data sources, and nor do they provide information on cross-price effects. As such, a primary meta study was undertaken to obtain calibration values for the beer, wine, and spirits own-price and cross-price elasticities. The appendix provides greater detail on the approach taken, but in brief, the steps used to obtain calibration values were as follows.

Single equation single beverage models that feature in the early alcohol demand literature are likely to suffer from omitted variables bias. As such, only studies that use a demand system approach were considered. The model is calibrated using the unconditional Marshallian elasticities, so the sample was then restricted to studies that either report unconditional estimates or provide sufficient information to derive approximate unconditional Marshallian elasticities using the formulas in Okrent et al. (2011). To address the issue of estimate dependence due to the use of common underlying data sources a two level model was used. The top level of the model is the data source; and the second level is a single elasticity estimate from each study. There is a separate equation for each elasticity value, and estimation relies on Fisher and Tipton (2015).

Table 4.1 provides a summary of the unconditional Marshallian price elasticity estimates for alcoholic beverages in the U.S., as a whole, allowing for observation dependence due to common underlying data sources, and the own-price elasticity estimates are: beer -0.41, wine -0.64, and spirits -.49. As can be seen, the unconditional Marshallian cross-price elasticity estimates are all positive, but in no case is it possible to reject the null hypothesis that cross-price effects are zero. The key message from Table 4.1 is that following a price rise for an alcoholic beverage, aggregate consumption of that beverage falls, but consumers engage in little to no beverage substitution. This result is consistent with the findings of Clements et al. (1997). For model calibration, the base case relies on the own-price elasticity point estimates shown in Table 4.1, with cross-price elasticity values set to zero. As part of the sensitivity testing the impact of increasing and decreasing the own-price elasticity values by 20 percent is considered; as is the impact of allowing beer, wine, and spirits to be Marshallian substitutes.

Table 4.1: Price Elasticity Estimates

η_{ij}	Est.	S.E.
Beer-Beer	-0.41**	(0.16)
Beer-Wine	0.06	(0.06)
Beer-Spirits	0.06	(0.05)
Wine-Wine	-0.64**	(0.20)
Wine-Beer	0.12	(0.11
Wine-Spirits	0.06	(0.05)
Spirits-Spirits	-0.49**	(0.03)
Spirits-Wine	0.10	(0.06)
Spirits-Beer	0.10	(0.06)

Note: **, * significant at 1% and 5% level.

4.2.2 Demand heterogeneity

At the population level, the elasticity estimates for beer, wine, and spirits shown in Table 4.1 accurately describe consumption changes when prices change. However, as alcohol is addictive, it is possible that heavy drinkers and moderate drinkers respond differently to price changes. Various models have been proposed for addictive goods – habit formation / myopic addiction Pollak (1970); rational addiction (Becker and Murphy, 1988); and time inconsistent preferences O'Donoghue and Rabin (2006) – but regardless of the modeling approach, given the addictive properties of alcohol, the possibility that heavy (addicted) consumers are less price responsive than moderate drinkers should be considered. As explained in the appendix, the evidence in Manning et al. (1995), An and Sturm (2011), and Ayyagari et al. (2013) that the heavy and moderate drinker price elasticity is different is compelling. The detail for the calculations is provided in the appendix, but reflecting the available evidence, for the base case the moderate and heavy drinker price elasticity values are set at: beer -0.63 and -0.09; wine -0.85 and -0.15; and spirits -0.62 and -0.09. The impact of a range of alternative assumptions are also explored as part of the sensitivity analysis.

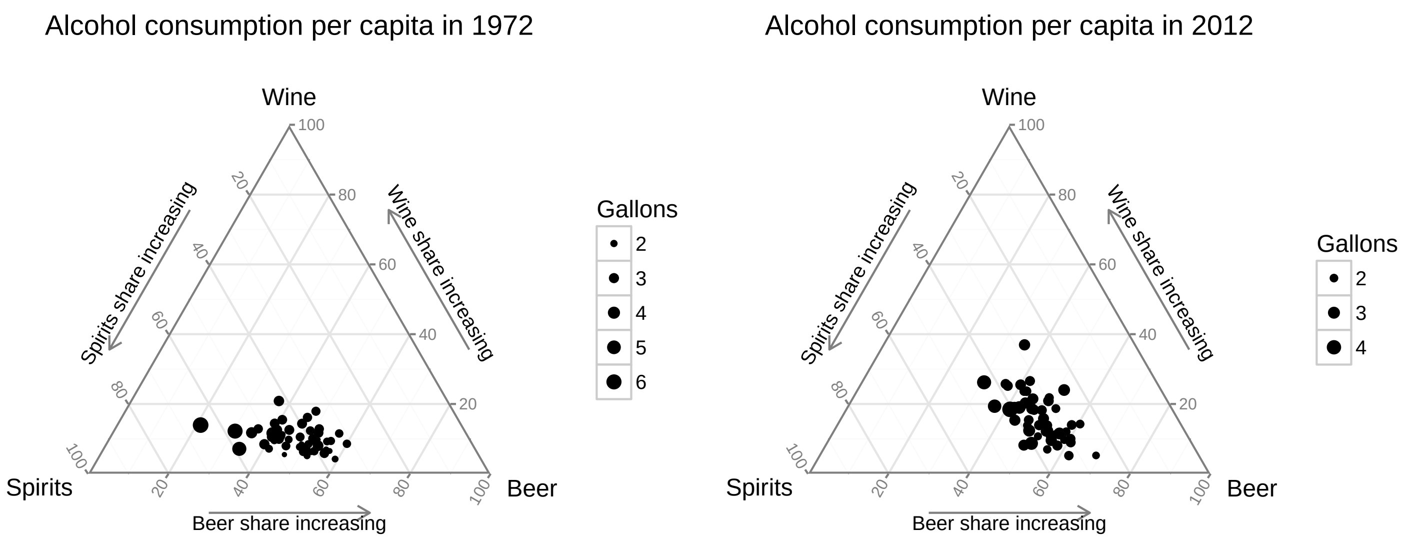
4.3 Consumption

Alcohol consumption data for each State is based on LaVallee et al. (2014). For model calibration this information is then adjusted to implied ex-tax consumption. The ex-tax consumption level is established by calculating the percentage price reduction that would follow the removal of excise taxes and multiplying by the relevant own-price elasticity value reported in Table 4.1. Specific detail on alcohol consumption by State is provided in the appendix, but Figure 4.2 uses the ternary plot format to show current, and for perspective, historical U.S. consumption patterns. In each plot the location of the dot reflects the relative consumption share for each beverage, and the size of the dot reflects the level of per capita total alcohol consumption. The plot was created using Hamilton (2016).

State level per capita alcohol consumption data can be distorted by cross-border sales, but even with this caveat, Figure 4.2 reveals several important features of the U.S. alcohol market. First, over the period 1972 to 2012, there has been a reduction in drinking in those States that have historically had the highest level of alcohol consumption. Second, the dots shift up and to the right, indicating an increase in the relative importance of beer and wine at the expense of spirits. Third, in 2012, in no State is the per capita ethanol share for wine or spirits greater than 50 percent, but beer accounts for at least 50 percent of consumption in 24 states. The beer ethanol share is also above 45 percent in a further 11 States; while in no State is the wine or spirits ethanol share above 45 percent. As beer is the dominant beverage in 35 States, it seems reasonable to describe the U.S. as a beer drinking nation.

For model calibration total alcohol consumption must be allocated to: informed heavy drinking, uniformed heavy drinking, and moderate drinking. Globally, the definition of heavy drinking is variable. For example, the U.S. maximum recommended daily drink standard for males is approximately equal to the OECD average, while the U.S. female maximum recommended daily drink standard is about half the OECD average (of Australia, 2009). As such, defining heavy drinking is not straight forward. Here, two approaches are used to

Figure 4.2: Apparent per capita consumption of alcohol: US States



estimate State level heavy drinking shares, and both approaches rely on the Behavioral Risk Factor Surveillance System data: BRFSS (2013). The BRFSS (2013) captures information on alcohol consumption at the individual consumer level, and sampling for the BRFSS is proportional to State population. In the first approach, if a survey respondent indicated they had engaged in heavy drinking at least once in the past month – defined as five or more drinks on a single occasion for men and four or more drinks for women – the respondent was deemed a heavy drinker and their total alcohol consumption was attributed to the heavy drinker category. The second approach identified all respondents that had average daily consumption above the U.S. recommended threshold of two standard drinks for men and one standard drink for women, and allocated the consumption of these respondents to the heavy drinker category. In Figure 4.3, the dark grey bars represent the heavy drinking share calculated using the binge drinking metric and the light grey bars represent the heavy drinking share calculated using the number of standard drinks metric. Using the binge drinking metric the mean heavy drinking share across States is 30 percent, and ranges from 12 percent

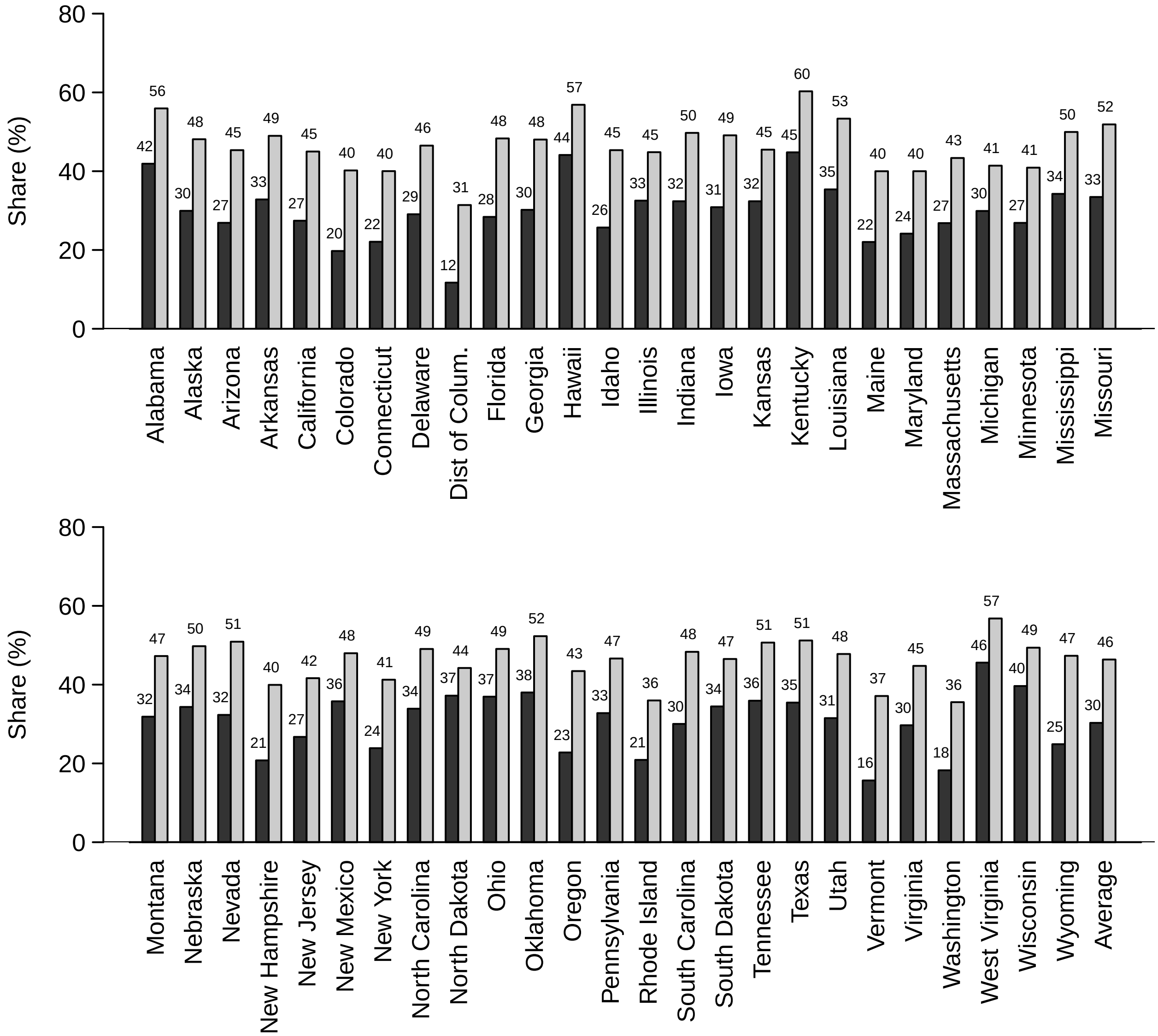
(District of Columbia) to 46 percent (Western Virginia). When using the standard drink metric the mean heavy drinking share is 46 percent, and ranges from 31 percent (District of Columbia) to 60 percent (Kentucky).

As explained in the appendix, the detail in Naimi et al. (2007), Siegel et al. (2011), and Naimi et al. (2015) was then used to map the overall alcohol heavy drinking share information shown in Figure 4.3 to beverage specific shares. For the binge drinking metric the average shares for moderate, informed heavy, and uniformed heavy drinking categories are: 0.757, 0.219, and 0.024 for spirits; 0.848, 0.149, 0.003 for wine; and 0.605, 0.367, and 0.028 for beer. The impact of using the heavy drinking metric is considered as part of the sensitivity analysis and for this approach to calculating the heavy drinking share the respective values are: 0.626, 0.337, and 0.037 for spirits; 0.766, 0.229, and 0.005 for wine; and 0.392, 0.565, and 0.043 for beer.

4.4 Externality costs

Total externality costs for each State are based on Sacks et al. (2013) and Sacks et al. (2015), and the issues with defining externality costs were discussed above. The base case calibration uses the conservative definition of externality costs, with the impact of using the liberal definition considered as part of the sensitivity testing. As detailed in the appendix, some beverages are disproportionately present in some activities associated with significant externality costs. For example, relative to its overall consumption share, beer is over-represented in driving while intoxicated incidents. The evidence on beverage specific relationships to externality costs is discussed in the appendix, and on average, externality costs are highest for beer and lowest for wine. In the base case, the marginal externality cost associated with uninformed heavy consumption is also assumed to be 20 percent higher than for informed heavy drinking. The distribution of State level externality costs, per gallon of ethanol, for informed and uninformed heavy drinkers is shown in Figure 4.4. So that the differences

Figure 4.3: Heavy drinking share of total consumption

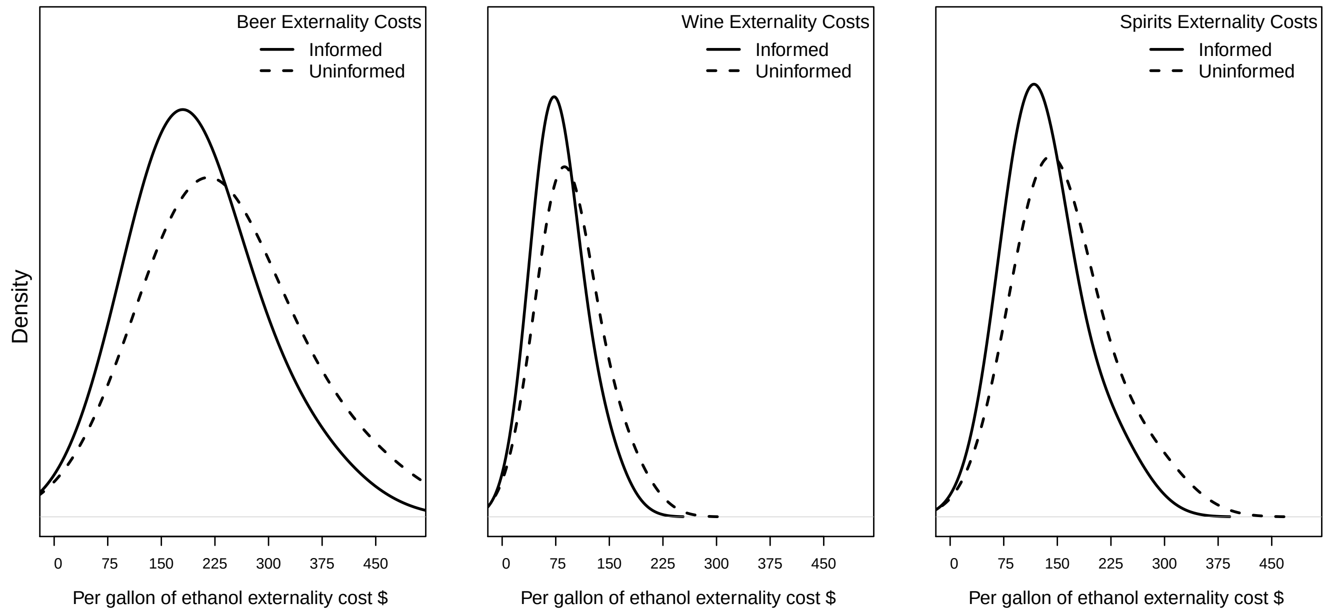


across beverage types can be seen, in each plot the horizontal scale is the same.

4.5 Uninformed user costs

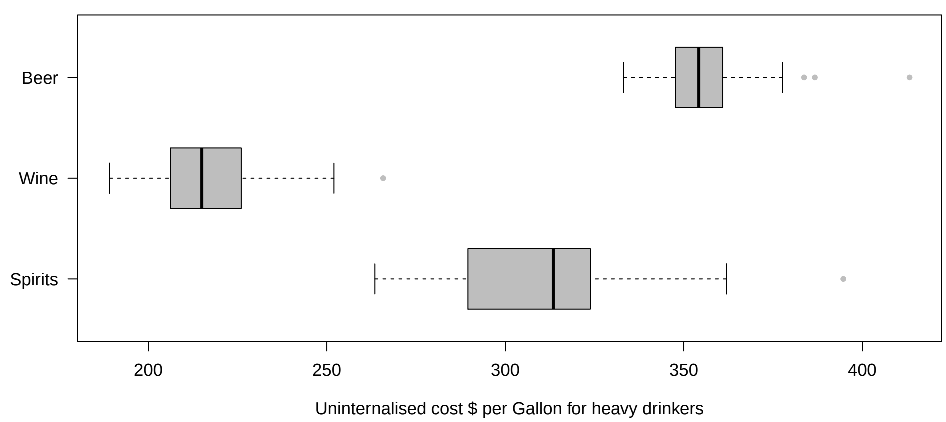
The approach used to estimate the marginal gain to uniformed heavy drinkers from reduced consumption is motivated by Figure 3.1, where the relevant distance is jm. Specifically, by assuming demand is linear around the point of actual consumption, the distance jm can be calculated. The detail for the calculation is provided in the appendix, but across the States

Figure 4.4: Externality cost distributions



the estimates of the marginal uninternalized damage cost range from: $333 to $413 for beer; $189 to $266 for wine; and $263 to $395 for spirits. The distribution of uninternalized costs for each beverage category is shown in Figure 4.5.

Figure 4.5: Uninternalized cost of excess consumption



4.6 Sensitivity scenarios

The base case calibration relies on considered best estimate values. There is, however, significant uncertainty regarding these values. As such, sensitivity testing is also undertaken. The specific scenarios investigated as part of the sensitivity analysis are:

(i) Category level own-price elasticity values set at 20 percent larger and smaller (in absolute value) than the base case

(ii) Beer, wine, and spirits as slight Marshallian substitutes rather than independent goods

(iii) Moderate drinker demand less elastic and heavy drinker demand more elastic

(iv) Moderate drinker demand more elastic and heavy drinker demand less elastic

(v) Externality costs estimated using the liberal definition of costs (higher externality costs)

(vi) Heavy drinking consumption share based on the standard drink metric (heavy drinking share of total consumption is larger)

(vii) Uninternalized costs for uninformed heavy drinkers higher and lower by 20 percent

(viii) Pooling the informed heavy drinker category and the uniformed heavy drinker category, and assuming no uninternalized costs.

5 Results

5.1 Base case

A summary of the base case results is presented in Figure 5.1, and the conclusions drawn regarding the appropriateness of current tax rates based on Figure 5.1 contrast sharply with those drawn from Figure 1.1. In Figure 5.1, the plot on the left shows that beer taxes, rather than being too low by a factor of about seven, are about right, on average. For spirits and wine, rather than being too low by a factor of three and eight, respectively, current tax rates are too high. The plot on the right in Figure 5.1 shows the optimal and current beer, wine, and spirits taxes for the individual States, with the actual difference between current tax rates and optimal tax rates detailed in Table 5.1.

In Table 5.1 negative values indicate the size of the reduction in the current tax rate needed to bring tax rates down to the optimal rate, and positive values indicate the increase required to bring the current tax rate up to the optimal tax rate. The final row of Table 5.1 provides information on the average difference between current and optimal tax rates and shows that on average, beer taxes are about right, but to bring current wine and spirits tax rates into line with optimal tax rates requires decreases in tax rates of around $13 per gallon of ethanol for wine and around $37 per gallon of ethanol for spirits.

In terms of units of measurement that are more common to the consumer, the average tax rate for a 750ml bottle of spirits across the U.S. is about $13.36, while the average optimal tax rate is estimated to be around $1.61 per bottle. As the average person consumes 2.6 bottles of spirits per year, the difference between average current spirits tax rates and the optimal tax rates works out to be about $30.55 per person per year. For wine, when expressed in per 750ml bottle terms, the difference between the average optimal tax rate and the current average tax rate is around $1.19. Given average per capita consumption of 4.4 bottles of wine per year, the average difference is around $5.29 per person per year. In aggregate, the difference between optional taxes and current taxes is around $7.7bn for spirits and around $1.3bn for wine.

Figure 5.1: Comparison of actual and base case optimal tax rates

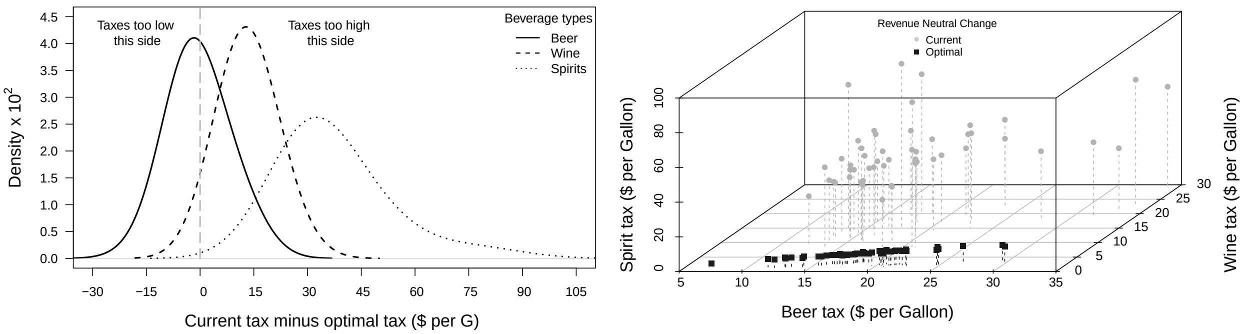


Table 5.1: Tax rate comparison: optimal tax minus current tax (per gallon ethanol)

State	Beer	Wine	Spirits	State	Beer	Wine	Spirits
Alabama	-9.25	-19.84	-64.88	Montana	1.80	-15.24	-44.18
Alaska	-12.88	-26.26	-50.79	Nebraska	-3.00	-14.54	-30.43
Arizona	6.28	-12.80	-26.48	Nevada	2.33	-12.34	-29.47
Arkansas	2.51	-17.41	-35.46	New Hampshire	-11.03	-7.72	-23.86
California	5.13	-7.80	-27.41	New Jersey	1.55	-13.80	-34.54
Colorado	5.11	-8.74	-25.38	New Mexico	9.08	-19.09	-31.85
Connecticut	0.21	-12.31	-33.87	New York	5.15	-8.60	-35.33
Delaware	2.25	-14.45	-29.77	North Carolina	-2.23	-12.74	-51.77
Dist of Colum.	-12.18	-20.06	-35.88	North Dakota	-5.83	-15.68	-33.17
Florida	-5.12	-24.70	-36.91	Ohio	3.63	-9.15	-45.22
Georgia	-14.66	-18.64	-29.52	Oklahoma	4.32	-11.79	-32.15
Hawaii	-10.76	-17.90	-34.53	Oregon	6.57	-11.48	-76.74
Idaho	4.41	-10.00	-47.81	Pennsylvania	3.43	-6.72	-39.45
Illinois	-1.11	-18.06	-42.47	Rhode Island	-0.13	-11.62	-30.64
Indiana	6.61	-10.09	-25.92	South Carolina	-9.09	-15.08	-33.38
Iowa	-3.02	-21.16	-54.73	South Dakota	0.00	-16.40	-32.04
Kansas	2.52	-8.97	-26.42	Tennessee	7.05	-16.50	-30.11
Kentucky	16.28	-9.90	-34.02	Texas	1.20	-8.41	-26.64
Louisiana	1.58	-7.35	-25.86	Utah	5.96	-5.64	-46.30
Maine	-5.98	-11.75	-37.12	Vermont	-4.73	-11.28	-22.61
Maryland	0.92	-17.15	-29.72	Virginia	1.60	-18.61	-72.09
Massachusetts	2.30	-11.13	-30.66	Washington	3.14	-12.97	-85.83
Michigan	2.23	-10.63	-53.00	West Virginia	6.61	-14.48	-25.15
Minnesota	-10.03	-16.92	-44.47	Wisconsin	6.99	-8.65	-27.92
Mississippi	-2.02	-6.52	-40.96	Wyoming	12.11	-5.60	-19.83
Missouri	4.91	-10.03	-25.28	Average	0.45	-13.23	-37.45

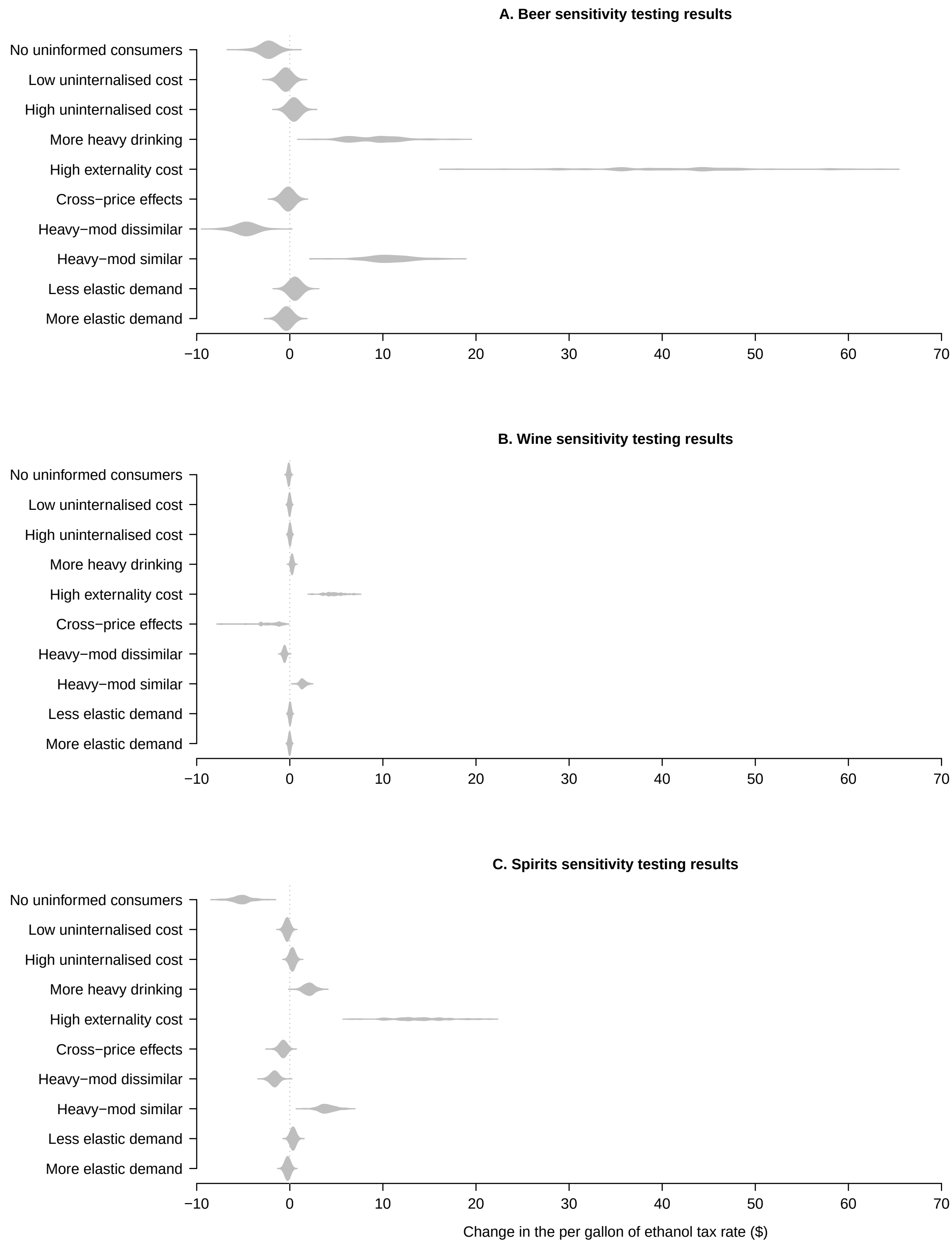
5.2 Sensitivity analysis

As there are ten sensitivity scenarios, three beverages, and 51 jurisdictions, a series of bean plots are used to summarize the sensitivity analysis findings. The bean plots show the difference between the base case results and each sensitivity scenario, where the summary metric is the difference in the per gallon of ethanol tax rate.

The key points from Figure 5.2 can be summarized as follows. For beer, the assumptions that matter are the assumptions about how the heavy drinking share of the population is defined; the difference between the own-price elasticity for moderate and heavy consumers; and how externality costs are defined. For wine, the impact of assumption changes are about an order of magnitude smaller than for beer, but the two assumptions that do seem to matter are the assumption regarding how externality costs are defined, and whether or not cross-price effects are present. For spirits, the assumptions that matter are: how externality costs are calculated; the difference between the moderate and heavy drinker price elasticity; and whether or not the uninformed heavy drinker category is included in the model.

Figure 5.1 clearly shows that the base case optimal tax rates, on average, are not different to the current tax rates for beer, but are different for wine and spirits. To formally test whether the tax rates for each sensitivity scenario (and the base case) are statistically different to current tax rates the Dunnett method, available in Hothorn et al. (2008), is used. To account for the paired State level data comparison and non-constant error variance the methods available in Pinheiro et al. (2016) are used. Formal test results are summarized in Table 5.2, and for wine and spirits the key insight from the base case remains unchanged: under all sensitivity scenarios current wine and spirit taxes are always too high. For beer the picture is more complex. For the base case, and five sensitivity scenarios current tax rates and optimal taxes rates are not different; for three sensitivity scenarios – the liberal externality cost scenario, the standard drink definition of heavy drinking scenario, and the scenario where the heavy drinker and moderate drinker own-price elasticities are more similar

Figure 5.2: Model sensitivity result: difference to the base in levels



– current tax rates are, on average, too low; and for one scenario – the moderate drinker and the heavy drinker own-price elasticity more dissimilar – current tax rates are, on average, too high.

That optimal wine and spirit tax rates are much lower than current tax rates is a robust result. For beer, however, the result is not clear. Current tax rates are, on average, either: about right, too high, or too low, depending on the assumptions made.

Table 5.2: Tax rate comparison: optimal minus actual (per gallon ethanol)

Scenario comparison	Beer		Wine		Spirits	
	Diff	SE	Diff	SE	Diff	SE
Base case	0.45	(0.93)	-13.23**	(0.68)	-37.36**	(1.49)
Less elastic demand	1.00	(0.93)	-13.20**	(0.68)	-37.04**	(1.49)
More elastic demand	0.08	(0.93)	-13.25**	(0.68)	-37.58**	(1.49)
Cross-price effects	0.26	(0.93)	-15.46**	(0.71)	-37.93**	(1.49)
Heavy-Moderate more dissimilar	-4.27**	(0.94)	-13.80**	(0.68)	-38.63**	(1.49)
Heavy-Moderate more similar	11.26**	(0.99)	-11.84**	(0.68)	-33.71**	(1.49)
High externality cost	41.68**	(1.62)	-8.46**	(0.69)	-23.68**	(1.54)
High heavy drinker share	9.59**	(1.01)	-12.98**	(0.68)	-35.39**	(1.49)
High uninternalized cost	0.89	(0.93)	-13.21**	(0.68)	-37.10**	(1.49)
Low uninternalized cost	0.00	(0.93)	-13.25**	(0.68)	-37.62**	(1.49)

Note: Dunnett pair-wise comparison table for paired observations allowing for heteroskedasticty.
**, * significant at 1% and 5% level.

5.3 Comparison to previous literature

It is valuable to place the current results within the context of the original optimal tax literature from the 1980s and 1990s. To make the comparison with earlier works clear, Table 5.3 provides information on the optimal tax rates, and the key parameter values from the historical studies and the current study. In Table 5.3 all dollar values are expressed in 2012 values, and for comparison purposes the focus is on the implied average overall alcohol tax rates.

By reading across the first row of Table 5.3 it can be seen that the average optimal alcohol tax rate from the current study is at least an order of magnitude lower than the estimates from the original literature. Although there is some variation in key parameter values across studies, the parameter setting that largely explains the difference in the optimal tax estimates is the moderate drinker to heavy drinkers price elasticity ratio (see the final row of Table 5.3). Due to a lack of evidence at the time, earlier studies assume average price responsiveness for heavy drinkers and moderate drinkers is either the same or approximately the same. The current study incorporates the subsequently published evidence on demand heterogeneity that shows heavy drinkers are much less price responsive than moderate drinkers.[2]

Some insight into the impact of the elasticity ratio assumption can be seen from the sensitivity analysis results presented in both Pogue and Sgontz (1989) and the current study. For example, in Pogue and Sgontz (1989), when the moderate to heavy drinker price elasticity is increased from one to four, the optimal tax rates fall from \$121 to \$45 for the two group model, and from \$723 to \$207 for the three group model. In the current study, when the elasticity ratio was reduced from seven to four, the average optimal alcohol tax increases by over 50 percent to around \$19. So the incorporation of new information of demand heterogeneity explains much of the difference between the current estimate of optimal tax rates and the historical estimates.

Another important difference between the current study and the historical literature is the assumption regarding the proportion of the population that would benefit from a reduction in their own consumption. In both Pogue and Sgontz (1989) and Kenkle (1996), for the model variants that incorporate a sub-group of heavy drinkers that would benefit from lower consumption, both studies assume that this group is responsible for most heavy drinker consumption. Historically, such an assumption may be have been appropriate, but with the possible exception of young consumers, today most heavy consumers in developed countries are well informed of the consequences of heavy drinking, and so fall in to the category of

[2]Evidence on demand heterogeneity was starting to emerge a the time of the original work. For example, for three of the eight heavy drinker groups considered in Kenkel (1996), (accounting for 54% of total heavy drinker consumption) the results reported show that the own-price elasticity is not statistically different from zero.

Table 5.3: Comparison of historical model results and current model

Detail	Pouge & Sgontz (1989)	Kenkle (1996)	Saffer & Chaloupa (1994)	Current Study[8]
Optimal Tax ($ G E)	121, (723)[1]	154, (210)[2]	132[6]	12 (1-30)
Price alcohol ($ G E)	$238	198	NA	265 (107-130)
Heavy drink share	0.41	0.36	0.40	0.30 (0.11-0.46)
Non-optimal share	0, (0.735)[1]	0, (0.96)[2]	0	0.10
Externality ($ G E)	294	333[2]	294[7]	172 (38-490)
Health ($ G E)	1,022	33 - 308[4]	NA	316 (189-413)
Elasticity ratio	1.0	1.3[5]	1.0	7.0

Note:[1] three group model with alcohol as a disease;[2] model with uniformed consumers; [3] includes adding back drunk driving costs without this component externality costs fall to $170; [4] estimate varies with knowledge of disease impacts; [5] share weighted average across all heavy drinker consumer classes; [6] share weighted average tax, actual tax rates are: beer $144, wine $124, spirits $116; [7] uses the Pouge & Sgontz estimate; [8] central value is the beverage share weighted mean, with the range presented in parenthesis.

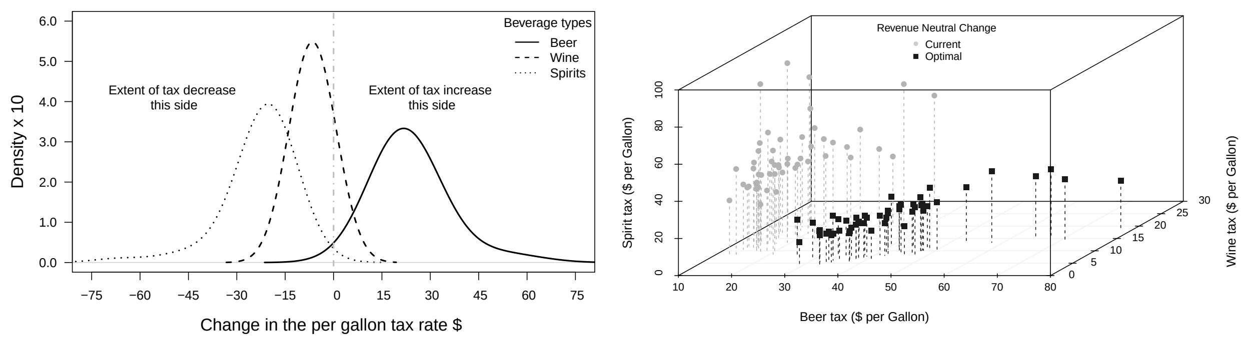
informed heavy consumers.

5.4 Revenue neutral changes maximizing tax rates

We now consider welfare maximizing alcohol tax rates subject to the constraint that total alcohol tax revenue in each State is held constant. Note that for these scenarios the revenue constraint was binding in all cases: total alcohol taxes in all States are too high relative to the first best. In terms of specific results, Figure 5.3 provides a summary of the key findings. In Figure 5.3, the plot on the left shows the distribution of changes in tax rates separately for beer, wine, and spirits; and the plot on the right shows the specific mapping from current tax rates to optimal revenue neutral tax rates.

Under the optimal tax model, current beer taxes were found to be about right. However, for the revenue neutral model, optimal beer taxes, on average, are $42 per gallon of ethanol, which is just over double the current rate of $19 per gallon of ethanol. For spirits and wine, the implications under the revenue neutral model are the same as under the optimal tax model: taxes should be reduced substantially. Specifically, for wine, the average revenue neutral tax wine tax is $9 (down from $15) per gallon of ethanol; and for spirits it is $22 (down from $45) per gallon of ethanol. Under the revenue neutral model the relative emphasis of taxation remains the same as under the optimal tax model: beer faces the highest taxes and wine the lowest.

Figure 5.3: Comparison of actual and revenue neutral constrained optimal tax rates



5.5 Implications and discussion

The results lead to three key policy conclusions. First, as optimal taxes vary with beverage type, a common uniform tax rate for alcohol is not an optimal strategy. Second, as externality costs and consumption patterns vary across States, alcohol taxation policy should be be set at the State, or lower level. Third, under all plausible scenarios, including the revenue neutral scenario, wine and spirits taxes in the U.S. are too high.

A move towards setting alcohol tax rates in line with the model presented here also implies an overall philosophy for alcohol policy that is constructive. For example, at the moment the disincentive for alcoholic beverage producers to see their product in the hands of underage drinkers is modest. Firms need a social license to operate, and can not overtly target youth and underage drinkers, but at the margin there is a financial incentive to allow advertising to reach underage consumers, and there is evidence underage drinkers can access industry messaging on new social media platforms (Barry et al., 2016). Under a taxation model of the kind outlined here, allowing alcohol messages to reach youth such that they take up underage drinking would result in higher taxation rates, and so act as a disincentive to current questionable approaches to marketing.

The situation regarding drink driving is similar. Over many years the alcoholic beverage industry has funded a wide range of activities that have as their stated goal the reduction of drink driving. However, a systematic review of over 266 industry funded programs found that industry sponsored programs are: generally not evaluated for effectiveness (56%); generally not consistent with recommendations for actions flowing from the public health literature (68%); and overwhelming are actions that also serve a brand marketing function (88%) (Esser et al., 2016). With taxation rates linked directly to beverage specific harm estimates industry would have a direct financial incentive to fund programs that are effective and report formal evaluations of program effectiveness.

More generally, the philosophy of matching costs with taxation for alcoholic beverages could have broader application. For example, if specific venues or entertainment precincts can be identified as locations whose patrons are disproportionately associated with vandalism events or police call out events it suggests raising the licensing cost for these establishments or precincts.

6 Conclusion

Excessive alcohol consumption results in both private and external costs, and these costs are substantial. Alcohol specific excise taxes are therefore a legitimate policy tool. The focus of this research has been to identify, at a State level, optimal beer, wine, and spirits tax rates, where both the benefit of alcohol taxes, in terms of lowering externalities, and the cost of alcohol taxes, in terms of lowering consumer welfare, are considered. Unlike the approach of dividing total externality costs by total consumption, the model captures the dead-weight loss alcohol specific taxes impose on moderate consumers, who are both the main consumer category, and whose consumption imposes no externality costs on society. For the preferred model calibration, and all sensitivity scenarios, the results show that both spirits and wine taxes in the U.S. are too high. For beer, under the preferred model calibration taxes are about right. These finding contrasts sharply with earlier research that has suggested alcohol tax rates in the U.S. are too low.

The finding that alcohol tax rates are generally too high does not diminish the scale of the externality and social costs due to excessive alcohol consumption. Rather, the finding highlights the need to rely on multiple tools and policies to address the problem of excess alcohol consumption. Education activity, venue opening hours, enforcement of drink driving laws, planning laws for the build environment, and alcohol taxes all need to be considered as part of a comprehensive government strategy to address harm due to excessive alcohol consumption.

Appendix

A Model calibration values

Below is a detailed description of both the model calibration values and the method used to calculate these values.

A.1 Prices

The reference product for beer is a six-pack of Heineken 12-oz containers, excluding any deposit. The reference product for wine is a 1.5-liter bottle of Livingston Cellars or Gallo Chablis or Chenin Blanc. The reference product for spirits is a 750ml bottle Jack Daniels whiskey. The beer and wine prices are based on the data collected for The Council for Community and Economic Research Cost of Living Index. For this data set, samples are taken from multiple locations in each State, in each quarter of each year. For 2012 there are 1,218 beer price observations and 1,218 wine price observations. For each State the value used is the simple average of reported values. Spirit price data is based on the inflation adjusted sale price of spirits from a single store in each State.[3] Retail prices were then converted to per gallon of pure ethanol equivalent prices using alcohol by volume conversion factors of 4.8 percent for beer, 12.5 percent for wine, and 40 percent for spirits.

To derive tax exclusive prices, estimated per gallon of pure ethanol taxes were calculated by combining the Tax Foundation State level data[4] with Federal alcohol tax rate data[5]. The prices shown in Table A.1 are therefore exclusive of both State and Federal alcohol taxes. Note, for control States, the Tax Foundation provides an implied tax rate estimate.

[3] http://gizmodo.com/how-much-a-bottle-of-whiskey-costs-in-every-state-1650381482 [Accessed 23 June 2015]

[4] https://taxfoundation.org/state-sales-gasoline-cigarette-and-alcohol-tax-rates

[5] https://www.ttb.gov/tax_audit/atftaxes.shtml

Table A.1: Per gallon of pure alcohol price ($): exclusive of State and Federal excise taxes

State	Beer	Wine	Spirits	State	Beer	Wine	Spirits
Alabama	324.75	135.02	217.73	Montana	327.11	129.33	272.56
Alaska	380.34	176.81	363.50	Nebraska	304.60	124.58	253.02
Arizona	320.52	127.78	170.89	Nevada	327.28	145.03	205.42
Arkansas	322.10	156.59	252.78	New Hampshire	304.49	176.30	285.90
California	339.77	107.29	182.16	New Jersey	314.53	126.91	260.85
Colorado	328.09	124.05	244.52	New Mexico	314.36	129.05	151.64
Connecticut	361.39	136.65	261.08	New York	368.89	177.05	306.56
Delaware	353.28	212.29	229.04	North Carolina	318.81	161.28	266.46
Dist of Colum.	316.86	138.83	249.15	North Dakota	355.62	110.79	262.84
Florida	311.41	125.54	174.56	Ohio	313.14	150.10	240.90
Georgia	324.13	148.43	228.96	Oklahoma	300.92	158.32	183.27
Hawaii	346.59	155.44	319.64	Oregon	337.33	131.96	218.73
Idaho	325.89	140.20	234.66	Pennsylvania	368.80	156.89	231.95
Illinois	303.41	116.85	193.67	Rhode Island	319.94	169.21	301.08
Indiana	332.55	117.95	255.56	South Carolina	309.79	161.33	235.98
Iowa	315.66	112.71	290.55	South Dakota	368.20	149.80	250.21
Kansas	308.36	135.86	208.04	Tennessee	332.57	158.53	263.31
Kentucky	335.02	139.43	269.63	Texas	322.22	135.91	184.30
Louisiana	308.43	151.89	208.04	Utah	322.98	164.79	252.29
Maine	323.66	147.95	199.36	Vermont	305.22	142.70	261.29
Maryland	333.03	144.91	251.35	Virginia	322.57	147.12	223.17
Massachusetts	333.98	160.02	312.24	Washington	354.06	127.34	126.58
Michigan	316.34	120.32	285.97	West Virginia	293.55	128.25	363.74
Minnesota	332.94	128.64	192.88	Wisconsin	300.96	132.94	206.25
Mississippi	318.01	170.58	233.88	Wyoming	326.79	143.14	240.95
Missouri	315.26	129.56	209.22	Average	327.11	129.33	272.56

A.2 Price elasticity

A.2.1 Population level price elasticity

As noted in the body text, although there are several existing meta studies of alcohol demand, due to concern about underlying data dependence, and a lack of information on cross-price effects, a primary meta study was undertaken to obtain model calibration values. The method used to do this was to: (i) apply a quality filter and select only studies that use a demand system approach; and (ii) use the R routines of Fisher and Tipton (2015) to address the issue of underlying data dependence via a two level model. If not reported in the primary study, unconditional Marshallian elasticities were derived using the formulas in Okrent et al. (2011).

So that the data structure can be seen, Table A.2 provides summary information on both the conditional and unconditional Marshallian estimates for each study. As can be seen: (i) the difference between conditional and unconditional Marshallian estimates can be substantial; and (ii) there is underlying data dependence across some studies which has not been accounted for in earlier work. For model estimation, the weight for study j was related to sample size as: $[(n_j/N) + (1/J)] \times 1/2$, where n_j denotes the sample size for study j, and $N = \sum_j^J n_j$. Where a study reported multiple estimates, the estimates preferred by the author were used.

Summary meta-regression results are reported in Table A.3 for the contrasting cases of what is generally discussed in the literature (conditional Hicksian estimates) and what is relevant for public policy and model calibration (unconditional Marshallian estimates). On average, the unconditional Marshallian own-price estimates are more elastic by 0.15 than the conditional Hicksian estimates. Expressed in percentage difference terms, the differences are: beer (-.35 -.41)/-.35 = 17 percent; wine (-.43 -64)/-. 43 = 49 percent, and spirits (-.32 -.49)/- .43 = 53 percent, so the differences are material. Further, the results for the conditional Hicksian cross-price elasticities suggest that beer, wine, and spirits are substitutes, but for the unconditional Marshallian cross-price elasticity estimates in no case is it possible to reject the null that the cross-price elasticity is zero. These difference highlight the need to be clear regarding the specific type of elasticity value that is being reported.

Table A.2: Elasticity estimate data

Data nesting structure	η_{bb}	η_{bs}	η_{bs}	η_{ww}	η_{wb}	η_{ws}	η_{ss}	η_{sb}	η_{sw}
Data/ study					A. Conditional Marshallian Estimates				
Jobson Handbooks; Brewers Almanac									
Nelson (1997)	-0.495	-0.082	-0.111	-0.630	-0.492	0.195	-0.946	-0.545	-0.005
Nelson and Moran (1995)	-0.414	-0.263	-0.032	-0.381	-0.254	-0.268	-0.630	-0.625	-0.109
Brewers Ass. Canada, Distilled Spirit Council									
Selvanathan and Selvanathan (2005)	-0.540	-0.209	-0.050	-0.363	-0.424	-0.273	-0.675	-0.496	-0.019
Selvanathan and Selvanathan (2007)	-0.483	-0.270	-0.063	-0.360	-0.355	-0.415	-0.810	-0.330	-0.090
Household Food Survey 1977-78									
Hein and Pompelli (1989)	-0.978	0.076	-0.027	-0.598	-0.046	0.081	-0.580	-0.020	-0.029
Household Food Survey 1987-88									
Gao et al. (1995)	-0.187	0.111	0.164	-0.897	-2.134	-1.999	-0.751	-0.434	-0.022
					B. Unconditional Marshallian Estimates				
Jobson Handbooks, Brewers Almanac									
Nelson (1997)	-0.275	-0.030	-0.073	-0.576	-0.181	0.270	-0.825	-0.043	0.082
Nelson and Moran (1995)	-0.192	-0.167	0.006	-0.333	0.029	-0.145	-0.445	-0.199	-0.035
Brewers Ass. Canada, Distilled Spirit Council									
Selvanathan and Selvanathan (2005)	-0.296	-0.084	-0.017	-0.319	-0.100	-0.107	-0.480	-0.117	0.033
Selvanathan and Selvanathan (2007)	-0.252	-0.043	-0.015	-0.293	-0.036	-0.101	-0.467	0.018	-0.017
Household Food Survey 1977-78									
Hein and Pompelli (1989)	-0.840	0.134	0.018	-0.550	0.103	0.144	-0.500	0.169	0.032
Household Food Survey 1987-88									
Gao et al. (1995)	-0.231	0.088	0.169	-1.184	0.378	-0.701	-0.439	0.169	-0.091

Table A.3: Meta regression comparison

Quantity-Price	Cond. Hicksian		Uncond. Marshallian	
	Est.	SE	Est	SE
Beer-Beer	-0.35	(0.18)	-0.41**	(0.16)
Beer-Wine	0.07	(0.05)	0.06	(0.06)
Beer-Spirits	0.11**	(0.02)	0.06	(0.05)
Wine-Wine	-0.43**	(0.06)	-0.64**	(0.20)
Wine-Beer	0.18*	(0.07)	0.12	(0.11)
Wine-Spirits	0.15**	(0.03)	0.06	(0.05)
Spirits-Spirits	-0.32**	(0.09)	-0.49**	(0.03)
Spirits-Wine	0.07*	(0.02)	0.10	(0.06)
Spirits-Beer	0.16**	(0.01)	0.10	(0.06)

Note: **, * significant at 1% and 5% level.

A.2.2 Moderate and heavy consumer elasticity

One of the first studies to investigate demand heterogeneity for alcoholic beverages was Manning et al. (1995). The study used a quantile regression approach and found that price responsiveness in the tails of the distribution is different to price responsiveness for the median consumer; and that the price elasticity for consumers at the 90th percentile and above was not statistically different from zero. An and Sturm (2011) use the use BRFSS data for the period 1984 to 2009 to estimate alcohol price elasticities for different groups in the U.S. They find significant heterogeneity in price responsiveness, and for consumers that drink over 40 standard drinks per month it is not possible to reject the null hypothesis that the price elasticity is zero. Ayyagari et al. (2013), using a mixture model, report results similar to those of An and Sturm: moderate consumers exhibit price elastic demand; and for heavy drinkers it is not possible to reject the null hypothesis that the own-price elasticity is zero. Although here, the focus is specifically on price elasticity measures, there is also a broader literature, reviewed in Nelson (2013a) that demonstates heavy drinkers are not price responsive. The overall evidence is therefore clear. The own-price elasticity for heavy drinkers and moderate drinkers is different, with heavy drinkers much less price responsive than moderate drinkers.

The ratio of the elasticity estimates for moderate drinkers to heavy drinkers is one way to quantify the difference between the two consumer groups. For Manning et al. (1995) the ratio is around two; for An and Sturm (2011) the ratio is between 13 and 22; and for Ayyagari et al. (2013), as the point estimate for heavy drinkers is positive, the ratio is undefined. The absolute difference in the heavy drinker elasticity and the moderate drinker elasticity is another way to understand the extent of the difference in demand responsiveness for these two groups, and for Manning et al. (1995) the difference is 1.31; for An and Sturm (2011) the difference is 0.33; and for Ayyagari et al. (2013) the difference is 1.09.

For model calibration, the beverage specific moderate drinker and heavy drinker elasticity values were found as follows. First, let $R_A = \eta_A^M / \eta_A^H$ denote the ratio of the moderate drinker to heavy drinker alcohol own-price elasticity, and reflecting the above studies, let $R_A = 7$ for the base case. Next, let s_i^M denote the national moderate consumption share for beverage i, with $\left(1 - s_i^M\right) = s_i^H$ denoting the heavy drinking share. The base case own-price elasticity values satisfy the constraints $R_A = 7$ and $\eta_{ii} = s_i^M \eta_{ii}^M + \left(1 - s_i^M\right) \eta_{ii}^H$, where consumption shares are defined using the the binge drinking definition of heavy drinking; and the own-price elasticity values are the values from Table A.3. The sensitivity analysis then considers the case where: moderate and heavy drinkers are more similar ($R_A = 4$) and less similar ($R_A = 10$); the overall beverage price elasticity values are 20 percent more and 20 percent less responsive; and the standard drink metric is used to calculate the heavy drinking share (high heavy drinker share). The specific own-price elasticity values for the different scenarios are detailed in Table A.4.

Table A.4: Moderate and heavy drinker own-price elasticity values

	Beer		Wine		Spirits	
	Moderate	Heavy	Moderate	Heavy	Moderate	Heavy
Base Case	-0.626	-0.089	-0.734	-0.105	-0.619	-0.088
High heavy drinker share	-0.866	-0.124	-0.802	-0.115	-0.723	-0.103
Less elastic demand	-0.501	-0.072	-0.587	-0.084	-0.495	-0.071
More elastic demand	-0.751	-0.107	-0.881	-0.126	-0.743	-0.106
Heavy-Moderate more similar	-0.587	-0.147	-0.721	-0.180	-0.599	-0.150
Heavy-Moderate more dissimilar	-0.643	-0.064	-0.739	-0.074	-0.627	-0.063

A.3 Consumption data

In terms of the beverages that are most commonly associated with binge drinking in the U.S., based on a sample of 14,150 binge drinkers, Naimi et al. (2007) found beverage specific binge drinking shares of: 67.1 percent for beer, 21.9 percent for spirits, and 10.9 percent for wine. The overall beverage consumption shares for the US reported in LaVallee et al. (2014) are: beer 48 percent, wine 18 percent, and spirits 33 percent, and if the binge drinking share information in Naimi et al. (2007) is divided by the ethanol share information in LaVallee et al. (2014) the ratios are: beer (67.1/48.5) = 1.38; wine (10.9/17.5) = 0.62; and spirits (21.9/33.5) = 0.65; so in terms of the expected binge drinking share, beer is over-represented, and both spirits and wine are underrepresented.

For youth in the U.S., spirits are the beverage of choice for both general consumption and binge drinking. For example, based on an eight State survey of 7,723 grade nine through grade 12 students that had consumed alcohol in the past 30 days, Siegel et al. (2011) report that youth prefer: spirits (43.8 percent), followed by beer and malt beverages (26.6 percent); with wine and cooler type drinks a distant third (7.1 percent). Additionally, Seigal et al. report that among those that drink, binge drinking was much more common for those drinking spirits, with binge drinking negligible for those drinking wine. Naimi et al. (2015) also found spirits to be the clear beverage of choice for binge drinking episodes involving US youth.

The process used to determine the moderate and heavy drinker consumption shares can be understood as follows. Let $\bar{h_{jk}}$ denote the overall alcohol heavy drinking share for State k, calculated using metric j, where j is the binge drinking metric or standard drink metric (see Figure 4.3). Let r_i denote the 'relative' heavy drinking share for beverage i, where, by combining the youth and general heavy drink preferences discussed above we have: $r_b = 1.3$, $r_w = 0.5$, and $r_s = 0.8$, where values greater then one indicate that the beverage is over-represented in heavy drinking relative to the beverage's total consumption share. Finally, let s_{ik} denote the ethanol share for beverage i in State k. Using this notation the beverage specific heavy drinking share for beverage i, in State k, using method j, denoted h_{ijk}, is found as $h_{ijk} = r_i s_{ij} \alpha_{jk}$, where α_{jk} is a scaling parameter used to ensure the weighted sum of the beverage specific heavy drinking shares sum to the ethanol based heavy drinking share. To illustrate the calculations, let k = Alabama and let j = the binge drinking metric. In Alabama, when the binge drinking metric is used to estimate heavy drinking we have $\bar{h_{jk}} = 0.42$, $s_{bk} = 0.58$, $s_{wk} = 0.12$, and $s_{sk} = 0.30$. As $[(0.58\times1.3) + (0.12\times0.5) +(0.30\times0.8)]\times0.87 = 0.42$, the scaling parameter α_{jk} is $= 0.87$, and $h_{bjk} = 0.52$, $h_{wjk} = 0.20$, and $h_{sjk} = 0.32$.

The intuition of the model suggests that the uniformed heavy drinkers are largely young binge drinkers. This group has a strong preference for spirits, followed by beer, and lastly wine. In the base case the uninformed consumption share is set at 10 percent of total heavy spirit consumption, 7 percent of total heavy beer consumption, and 2 percent of heavy wine consumption. The uniformed consumption shares for beer, wine and spirits are thus: $h_{ijk}u_i$, where, $u_b = 0.07$, $u_w = 0.02$, and $u_s = 0.10$. The base case consumption share data is shown in Table A.5 through Table A.7.

Table A.5: Spirits base case consumption share data

State	Moderate	Heavy	Uniformed	State	Moderate	Heavy	Uniformed
Alabama	0.679	0.289	0.032	Montana	0.755	0.22	0.024
Alaska	0.746	0.229	0.025	Nebraska	0.744	0.231	0.026
Arizona	0.779	0.199	0.022	Nevada	0.728	0.245	0.027
Arkansas	0.747	0.228	0.025	New Hampshire	0.825	0.158	0.018
California	0.762	0.214	0.024	New Jersey	0.763	0.213	0.024
Colorado	0.833	0.15	0.017	New Mexico	0.717	0.255	0.028
Connecticut	0.803	0.177	0.02	New York	0.796	0.184	0.020
Delaware	0.747	0.227	0.025	North Carolina	0.729	0.244	0.027
Dist of Colum.	0.892	0.097	0.011	North Dakota	0.709	0.262	0.029
Florida	0.764	0.212	0.024	Ohio	0.719	0.253	0.028
Georgia	0.764	0.212	0.024	Oklahoma	0.713	0.259	0.029
Hawaii	0.639	0.325	0.036	Oregon	0.808	0.173	0.019
Idaho	0.761	0.215	0.024	Pennsylvania	0.754	0.222	0.025
Illinois	0.734	0.239	0.027	Rhode Island	0.825	0.158	0.018
Indiana	0.738	0.235	0.026	South Carolina	0.769	0.208	0.023
Iowa	0.766	0.211	0.023	South Dakota	0.736	0.238	0.026
Kansas	0.754	0.221	0.025	Tennessee	0.719	0.253	0.028
Kentucky	0.649	0.316	0.035	Texas	0.729	0.244	0.027
Louisiana	0.724	0.249	0.028	Utah	0.749	0.226	0.025
Maine	0.823	0.159	0.018	Vermont	0.872	0.115	0.013
Maryland	0.796	0.184	0.02	Virginia	0.755	0.221	0.025
Massachusetts	0.766	0.21	0.023	Washington	0.842	0.142	0.016
Michigan	0.756	0.219	0.024	West Virginia	0.676	0.292	0.032
Minnesota	0.777	0.201	0.022	Wisconsin	0.683	0.285	0.032
Mississippi	0.749	0.226	0.025	Wyoming	0.804	0.176	0.020
Missouri	0.734	0.24	0.027				

Table A.6: Wine base case consumption share data

State	Moderate	Heavy	Uniformed	State	Moderate	Heavy	Uniformed
Alabama	0.799	0.197	0.004	Montana	0.847	0.150	0.003
Alaska	0.841	0.156	0.003	Nebraska	0.840	0.157	0.003
Arizona	0.862	0.136	0.003	Nevada	0.830	0.166	0.003
Arkansas	0.842	0.155	0.003	New Hampshire	0.890	0.107	0.002
California	0.851	0.146	0.003	New Jersey	0.852	0.145	0.003
Colorado	0.896	0.102	0.002	New Mexico	0.823	0.174	0.004
Connecticut	0.877	0.121	0.002	New York	0.872	0.125	0.003
Delaware	0.842	0.155	0.003	North Carolina	0.830	0.166	0.003
Dist of Colum.	0.932	0.066	0.001	North Dakota	0.818	0.178	0.004
Florida	0.853	0.144	0.003	Ohio	0.825	0.172	0.004
Georgia	0.852	0.145	0.003	Oklahoma	0.820	0.176	0.004
Hawaii	0.775	0.221	0.005	Oregon	0.880	0.117	0.002
Idaho	0.851	0.146	0.003	Pennsylvania	0.846	0.151	0.003
Illinois	0.834	0.163	0.003	Rhode Island	0.890	0.107	0.002
Indiana	0.837	0.160	0.003	South Carolina	0.855	0.142	0.003
Iowa	0.854	0.143	0.003	South Dakota	0.835	0.162	0.003
Kansas	0.846	0.151	0.003	Tennessee	0.825	0.172	0.004
Kentucky	0.780	0.215	0.004	Texas	0.830	0.166	0.003
Louisiana	0.827	0.169	0.003	Utah	0.843	0.154	0.003
Maine	0.890	0.108	0.002	Vermont	0.920	0.078	0.002
Maryland	0.872	0.125	0.003	Virginia	0.847	0.150	0.003
Massachusetts	0.854	0.143	0.003	Washington	0.901	0.097	0.002
Michigan	0.848	0.149	0.003	West Virginia	0.797	0.198	0.004
Minnesota	0.860	0.137	0.003	Wisconsin	0.802	0.194	0.004
Mississippi	0.843	0.154	0.003	Wyoming	0.878	0.120	0.002
Missouri	0.833	0.163	0.003				

Table A.7: Beer base case consumption share data

State	Moderate	Heavy	Uniformed	State	Moderate	Heavy	Uniformed
Alabama	0.478	0.485	0.037	Montana	0.602	0.370	0.028
Alaska	0.587	0.384	0.029	Nebraska	0.583	0.387	0.029
Arizona	0.640	0.335	0.025	Nevada	0.558	0.411	0.031
Arkansas	0.588	0.383	0.029	New Hampshire	0.715	0.265	0.020
California	0.614	0.359	0.027	New Jersey	0.615	0.358	0.027
Colorado	0.729	0.252	0.019	New Mexico	0.539	0.428	0.032
Connecticut	0.680	0.297	0.022	New York	0.668	0.309	0.023
Delaware	0.589	0.382	0.029	North Carolina	0.559	0.410	0.031
Dist of Colum.	0.824	0.163	0.012	North Dakota	0.527	0.440	0.033
Florida	0.617	0.356	0.027	Ohio	0.544	0.424	0.032
Georgia	0.616	0.357	0.027	Oklahoma	0.533	0.434	0.033
Hawaii	0.414	0.545	0.041	Oregon	0.688	0.290	0.022
Idaho	0.611	0.361	0.027	Pennsylvania	0.600	0.372	0.028
Illinois	0.568	0.402	0.030	Rhode Island	0.715	0.265	0.020
Indiana	0.575	0.395	0.030	South Carolina	0.624	0.350	0.026
Iowa	0.620	0.354	0.027	South Dakota	0.570	0.400	0.030
Kansas	0.600	0.372	0.028	Tennessee	0.544	0.424	0.032
Kentucky	0.429	0.531	0.040	Texas	0.559	0.410	0.031
Louisiana	0.551	0.418	0.031	Utah	0.592	0.379	0.029
Maine	0.713	0.267	0.020	Vermont	0.792	0.193	0.015
Maryland	0.668	0.309	0.023	Virginia	0.601	0.371	0.028
Massachusetts	0.621	0.353	0.027	Washington	0.744	0.238	0.018
Michigan	0.604	0.368	0.028	West Virginia	0.473	0.490	0.037
Minnesota	0.637	0.337	0.025	Wisconsin	0.485	0.479	0.036
Mississippi	0.591	0.380	0.029	Wyoming	0.682	0.296	0.022
Missouri	0.567	0.403	0.030				

A.4 Externality costs

Model calibration relies on externality cost estimates per gallon of ethanol. As noted in the main text, the externality cost estimates are based on Sacks et al. (2015) and Sacks et al. (2013), where the narrow definition of costs excludes estimates of lost productivity and the liberal estimate includes these costs. To determine beverage specific externality costs the relative importance of each beverage, in terms of contributing to externality costs was then considered.

For the U.S., the existing literature on cirrhosis mortality, drunk driving, and homicide and suicide is summarized in Tables A.8, A.9 and A.10. Table A.8 provides solid evidence of a relationship between spirits consumption and cirrhosis; moderate evidence of a relationship between beer consumption and cirrhosis; and no evidence of a relationship between wine consumption and cirrhosis. The early literature on beverage specific relationships and drunk driving is reviewed in Berger and Snortum (1985, p. 232), and this literature finds beer drinkers are over represented in terms of driving after drinking, and driving while intoxicated. The more recent evidence on drunk driving – summarized in Table A.9 – is consistent with the early findings: there is strong evidence of a disproportionate relationship between beer consumption and drunk driving; weaker evidence of a relationship for spirits; and no evidence of a relationship for wine. Beer is also the beverage of choice for the group that White and Gasperin (2007) characterize as hard core drunk drivers. The evidence on homicide and suicide – summarized in Table A.10 – is not as clear cut as the evidence for drunk driving and cirrhosis, but on balance the evidence suggests spirits and beer consumption are more problematic than wine consumption.

As there is clear evidence that some beverages are disproportionately present in some activities associated with significant externality costs, for example, driving while intoxicated, it is not appropriate to assume a uniform marginal externality cost for all beverages. Here, beverage specific externality costs are calculated are follows.

Let E_{jkm} denote the total externality cost estimate for State k, calculated using externality cost definition j, ($j =$ liberal or conservative definition), divided by total heavy consumption in State k, calculated using metric m, ($m =$binge drinking or standard drink metric); and let a_{ikm} denote the heavy drinking conditional budget share for beverage i, State k, heavy drinking share metric m, where $\sum_i a_{ikm} = 1$. The overall beverage specific externality cost estimates, denoted E_{ijkm}, are found as the values that satisfy $\sum_i a_{ikm} E_{ijkm} = E_{jkm}$, and $E_{bjkm} = 2.5E_{wjkm} = 1.5E_{sjkm}$; where the second constraint reflects a subjective, but nevertheless genuine attempt to incorporate the information reviewed in Tables A.8 through Table A.10 into the externality cost framework.

Table A.8: Summary cirrhosis mortality information

Study	Data and approach	Key findings
Ye and Kerr (2011)	State level data for 1950-2002. ARIMA and panel data models for cirrhosis. Separate total alcohol, beer, wine, and spirits models.	The strongest relationship is for spirits consumption, then beer. No consistent relationship for wine (positive, negative and Not Significant) is found.
Ponicki and Gruenewald (2006)	Data for 1971-98 for 30 States. Panel data model for cirrhosis with beer, wine, spirits tax variables.	Marginally significant result for spirits only. Note that with lagged tax values multicollinearity issues are present, so SEs are inflated.
Cohen et al. (2004)	Data for 1996-97 for 92 municipalities in Louisiana. Least squares cross-section regression with beer consumption variable.	Controlling for socioeconomic status and the proportion of the population that is black, there is a correlation between beer sales and liver disease.
Gruenewald and Ponicki (1995)	State level data for 1975-1986. Panel data model for cirrhosis with beer, wine, and spirits sales variables	Significant relationship for spirits; marginally significant and less pronounced effect for beer; negative and not significant relationship for wine.
Roizen et al. (1999)	National data for 1949-1994. ARIMA and correlation models. Separate total alcohol, beer, wine, and spirits models.	Spirits relationship stronger than the total alcohol relationship. No evidence of a relationship for beer and wine.

Table A.9: Summary drunk driving information

Study	Data and approach	Key findings
Kerr and Ye (2011)	Data for 1957-02 for 48 States. Panel data model for fatalities. Separate beer, wine, and spirits models.	For 1957-80 no effect for any beverage. For 1981-02 a significant relationship for beer and spirits (same magnitude), but not wine.
Berger and Snortum (1985)	Survey in 1983 across 48 States (n= 546). Least squares drink driving regression with a prefer beer (to spirits or wine) dummy variable.	The prefer beer, relative to spirits and wine, dummy predicts driving with a high BAL. Strongest contrast is between beer drinkers and wine drinkers.
Colón and Cutter (1983)	State level data from 1976. Least squares fatal accident rate regression with a beer consumption variable.	Beer consumption is related to fatal accidents and fatalities. Wine, spirits, and total alcohol variables were excluded from the model as not significant.
Gruenewald and Ponicki (1995)	Data for 1975-86 for 38 States. Panel data model for fatalities with spirit and beer relative frequency variable.	Strong positive relationship for beer, weaker but significant relationship for spirits, no relationship for wine.
Greenfield and Rogers (1999)	National survey in 1995, n = 1,260. Least squares and logistic drunk driving regression with beer, wine, and spirits heavy drinking variables.	For the least squares model there is a relationship between drunk driving and heavy beer drinking, but not for wine or spirits; no beverage specific effect is found for the logistic regression model.
Gruenewald et al. (1999)	California and South Carolina. Probit model. Driving after drinking model n= 2,275; driving intoxicated model n=985.	For driving after drinking the strongest relationship is for beer, then spirits, (relative to wine); no significant beverage specific effects are identified for intoxicated driving.

Table A.10: Summary Homicide and suicide information

Study	Data and approach	Key findings
Kerr et al. (2011)	Panel data for 1950-02 $\times$ 50 states. Beer, wine, spirits variables for male, female, all suicides.	Relationships are found: for beer only in the all gender model; for beer and wine in the males only model; for spirits in the female only model.
Landberg (2009)	National data for 1950-02. Separate ARIMA models for total alcohol, beer, wine, and spirits by gender for suicide.	No relationships identified for males for any beverage, and for females modest evidence of a relationship for spirits.
Cohen et al. (2004)	Data for 1996-97 for 92 municipalities in Louisiana. Least squares cross-section regression with beer consumption variable.	Controlling for socioeconomic status and proportion of the population that is black, there is a correlation between beer sales and homicide.
Sorenson and Berk (2001)	Data for 1972-93 for 32 age group $\times$ gender $\times$ ethnicity groups in California.	There is a correlation between beer sales and homicide rates in California.
Parker and Cartmill (1997)	National data for 1935-94. Multiple vector ARMA models for both black and white homicide rates.	For white homicides moderate evidence of a positive relationship with spirits; solid evidence of a negative relationship for wine. For black homicides moderate evidence for a positive relationship with beer.
Gruenewald et al. (1995)	Panel data models for suicide. Data for 1976-89 (38 States) and 1970-89 (50) states. Beverage sales variables.	Across both models a significant positive relationship for spirits only.
Lester (1980)	Correlation time series analysis for the period 1940-73 and correlation cross-section analysis for 1972 for suicides and homicides.	For the time series analysis a significant correlation for all beverages for homicides only. For the cross-section analysis a significant correlation for all beverages for suicide only.

To illustrate, if k = Alaska, j = the conservative definition of externality costs, and m =the binge drinking metric, we have $E_{jkm} = \$83.67M/0.49M = \$169$; $a_{bjk} = 0.56$, $a_{wjk} = 0.10$, and $a_{sjk} = 0.34$. This then implies that: $E_{bjk} = \$205$, $E_{wjk} = \$85$, and$E_{sjk} = \$137$.

Externality costs for uniformed heavy drinkers are set 20 percent higher than for informed heavy drinkers, subject to the constraint that the heavy consumption share weighted average of the uniformed heavy drinker externality cost and the informed drinker externality cost equal E_{ijkm}. Continuing with the Alaska example, and noting that for beer the uniformed consumption share out of total heavy drinking is set at 7 percent, the final values for beer are $E^u_{bjkm} = \$243$ and $E^h_{bjkm} = \$203$.

Base case per gallon of ethanol externality costs for heavy drinkers and uniformed drinkers are detailed in Table A.11 and Table A.12. Note that for the sensitivity scenario that uses the standard drink metric to determine the heavy drinking share, as the heavy drinking share is larger, the per gallon of ethanol externality cost estimates fall. Similarly, for the sensitivity scenarios that uses the liberal externality cost definition the per gallon of ethanol externality cost estimates increase.

Table A.11: Heavy drinker externality cost ($) per gallon of ethanol: base case

State	Beer	Wine	Spirits	State	Beer	Wine	Spirits
Alabama	154	62	102	Montana	166	67	110
Alaska	203	82	134	Nebraska	141	57	93
Arizona	263	106	174	Nevada	147	59	97
Arkansas	203	82	135	New Hampshire	109	44	72
California	230	93	152	New Jersey	169	68	112
Colorado	343	139	227	New Mexico	244	99	162
Connecticut	241	98	160	New York	271	110	180
Delaware	165	66	109	North Carolina	178	72	118
Dist of Colum.	361	146	239	North Dakota	98	40	65
Florida	180	73	120	Ohio	154	62	102
Georgia	197	80	130	Oklahoma	195	79	129
Hawaii	93	38	62	Oregon	305	123	202
Idaho	207	84	137	Pennsylvania	168	68	111
Illinois	135	54	89	Rhode Island	237	96	157
Indiana	192	78	127	South Carolina	211	85	140
Iowa	134	54	89	South Dakota	153	62	102
Kansas	184	74	122	Tennessee	176	71	117
Kentucky	159	64	105	Texas	145	58	96
Louisiana	168	68	111	Utah	267	108	177
Maine	218	88	145	Vermont	327	132	217
Maryland	304	123	201	Virginia	191	77	127
Massachusetts	177	72	117	Washington	408	165	270
Michigan	188	76	125	West Virginia	135	55	90
Minnesota	134	54	89	Wisconsin	128	52	85
Mississippi	182	74	121	Wyoming	361	146	239
Missouri	158	64	105				

Table A.12: Uninformed drinker externality cost ($) per gallon of ethanol: base case

State	Beer	Wine	Spirits	State	Beer	Wine	Spirits
Alabama	185	75	122	Montana	199	80	132
Alaska	243	98	161	Nebraska	169	68	112
Arizona	315	127	209	Nevada	177	71	117
Arkansas	244	98	161	New Hampshire	131	53	87
California	276	111	183	New Jersey	202	82	134
Colorado	412	166	273	New Mexico	293	118	194
Connecticut	290	117	192	New York	326	132	216
Delaware	197	80	131	North Carolina	213	86	141
Dist of Colum.	433	175	287	North Dakota	118	48	78
Florida	217	87	144	Ohio	185	75	122
Georgia	236	95	157	Oklahoma	234	94	155
Hawaii	112	45	74	Oregon	366	148	243
Idaho	248	100	164	Pennsylvania	201	81	133
Illinois	162	65	107	Rhode Island	284	115	188
Indiana	230	93	153	South Carolina	253	102	167
Iowa	161	65	107	South Dakota	184	74	122
Kansas	221	89	146	Tennessee	212	86	140
Kentucky	190	77	126	Texas	174	70	115
Louisiana	201	81	133	Utah	320	129	212
Maine	262	106	173	Vermont	392	159	260
Maryland	364	147	241	Virginia	229	93	152
Massachusetts	213	86	141	Washington	490	198	324
Michigan	226	91	149	West Virginia	162	66	108
Minnesota	161	65	107	Wisconsin	154	62	102
Mississippi	219	88	145	Wyoming	433	175	287
Missouri	190	77	126				

A.5 Uninternalized cost for uniformed drinkers

The approach used to estimate the gain to uniformed heavy drinkers from lower consumption of beverage type j in State k, and denoted H_{jk}, is motivated by the representation of the problem presented Figure 3.1. Specifically, let q_{jk}^h denote the average consumption for an informed heavy drinker of beverage type j in State k, and let the average consumption level for an uninformed heavy drinker be $q_{jk}^u = \alpha q_{jk}^h$ where $\alpha > 1$. Given the representation of Figure 3.1, the distance jm represents the value of the uninternalized marginal cost, and this value can be calculated as: $H_{jk} = 1/\eta_{jj} \times p_{jk}/q^h_{jk} \times \alpha q^h_{jk} = 1/\eta_{jj} \times p_{jk} \times \alpha$. The relevant value depends on the own-price elasticity, the beverage price, and the assumption regarding the extent of 'excess' consumption by uninformed drinkers, which in the base case is assumed to be 10 percent. As there is considerable uncertainty regarding these values, each State × beverage uninternalized cost estimate is 'shrunk' towards a common value. Specifically, if $\bar{H}_k = J^{-1} \sum_j H_{jk}$ denotes the average within State uninternalized cost estimate across beverages; and $\bar{H}_j = K^{-1} \sum_k H_{jk}$ denotes the average beverage specific uninternalized cost estimate across States; the actual State × beverage specific calibration values used in the model are found as: $\ddot{H}_{jk} = J^{-1}\left(H_{jk} + \bar{H}_j + \bar{H}_k\right)$, with the specific values used in the base case detailed in Table A.13.

Table A.13: Implied health cost per gallon of ethanol

State	Beer	Wine	Spirits	State	Beer	Wine	Spirits
Alabama	315	218	363	Montana	329	215	357
Alaska	395	266	413	Nebraska	309	206	343
Arizona	269	198	339	Nevada	290	211	349
Arkansas	319	226	357	New Hampshire	326	231	351
California	274	189	348	New Jersey	316	209	348
Colorado	305	204	350	New Mexico	263	200	338
Connecticut	323	219	373	New York	352	244	387
Delaware	313	252	374	North Carolina	334	230	361
Dist of Colum.	314	218	354	North Dakota	320	207	369
Florida	275	204	341	Ohio	314	217	349
Georgia	305	221	361	Oklahoma	280	213	338
Hawaii	356	239	384	Oregon	319	213	359
Idaho	312	214	353	Pennsylvania	313	224	374
Illinois	284	197	335	Rhode Island	340	234	360
Indiana	311	203	354	South Carolina	309	225	353
Iowa	339	212	354	South Dakota	320	227	378
Kansas	286	203	338	Tennessee	323	228	361
Kentucky	326	217	360	Texas	275	201	342
Louisiana	288	210	342	Utah	325	227	360
Maine	290	212	350	Vermont	311	213	345
Maryland	316	221	362	Virginia	320	223	356
Massachusetts	346	232	367	Washington	279	204	358
Michigan	337	210	354	West Virginia	362	220	350
Minnesota	290	207	354	Wisconsin	284	200	333
Mississippi	312	226	355	Wyoming	301	233	358
Missouri	286	201	340				

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