Does Heavy Drinking by Adults Respond to Higher Alcohol Prices and Taxes? A Survey and Assessment

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Abstract: Higher alcohol prices and taxes are frequently proposed as a policy tool to deal with abusive consumption and adverse alcohol-related outcomes. Its success depends on price responsiveness of drinkers, especially heavy drinkers. This survey examines empirical studies of the price responsiveness of heavy-drinking adults. Additionally, the survey examines the relationship between alcohol prices and mortality due to liver cirrhosis. A review is conducted of 19 individual-based studies that examine price responses by heavy-drinking adults and nine studies of prices and cirrhosis mortality. The review finds only two studies of heavy drinking with a significant and substantial negative price response. For cirrhosis mortality, only two studies find a significant negative price response. Overall, the role of price and taxes as a significant deterrent to heavy drinking by adults is uncertain.

I. INTRODUCTION

The consumption of alcohol by some individuals creates external costs for others in the form of drink-driving accidents, crime, violence, family strife, and other physical, financial, and psychological costs. Increasing alcohol taxes to correct for external costs – as prescribed originally in 1920 by Pigou – is thus advocated as a means of reducing alcohol consumption to a socially optimal level (Babor *et al*. 2010, Cook 2007). Calculation of social costs has been carried out for a wide variety of developed and developing countries (Cnossen 2007, Thavorncharoensap *et al*. 2009). A portion of health-related costs also are borne by taxpayers generally for publicly-supported health care or through higher private health insurance premiums. If damage costs are proportional to consumption, it is possible to divide costs by quantity to yield an average corrective tax as demonstrated by Phelps (1988), Manning *et al*. (1989), and others.[1] However, while the average-tax approach is simple and attractive, it hides a number of

[1] Because excise taxes are levied on a per unit basis, real revenues decline over time as the general price level rises unless the nominal tax rate is increased, indexed for inflation, or consumption grows rapidly. In the current fiscal climate, many governmental units are considering proposals to raise alcohol taxes or are loosening laws on alcohol sales in an attempt to boost consumption. In the US in 2009, at least 24 states were considering proposals to raise alcohol taxes and several states revoked laws that limited the time, place or manner of sale, such as Sunday-sales bans and grocery store bans; see http://www.drugfree.org/join-together/drugs/state-loosening-alcohol-law.

details, some of which are associated with varying levels and manner of alcohol consumption or what are commonly referred to as "drinking patterns" (Grant and Litvak, 1998). This paper examines the price (or tax) responses of adult drinkers and drinking patterns, and is the first comprehensive survey attempted on the topic.

Suppose there is some moderate level of alcohol consumption for adults that generates no external costs and which may yield health benefits, such as a glass of wine per day. Suppose also there is a category of adult drinkers who drink to excess, and who are responsible for all external costs. Given heterogeneous drinking patterns, an optimal tax structure is necessarily complex. In order to model this problem, Pogue and Sgontz (1989) divide alcohol consumers into "abusers" and "nonabusers," who differ only in terms of their demand for alcohol. As they point out, a first-best tax would tax only abusers. They demonstrate that it is still possible for a second-best average tax to improve overall social welfare, provided the decrease in external costs is larger than losses of consumer surpluses by abusers and nonabusers. The correct tax depends on the proportion of abusers in the drinking population and relative price elasticities of abusers and nonabusers.[2] A worst case scenario is that the demand for alcohol by heavy drinkers is perfectly price inelastic, while the demand by moderate drinkers has some degree of elasticity. In this case, a tax imposes welfare losses on moderate drinkers and has no effect on heavy drinkers' consumption or on social costs. In general, other rules and regulations would be preferred policy alternatives, such as severe fines for drink-driving and public drunkenness and stiffer penalties for crime and violence. Restrictions on supply (availability of outlets, server interventions, etc.) and limits on the time, place or manner of consumption might yield welfare improvements, but some of these regulations also impose costs on moderate drinkers. Providing additional information on the adverse health effects of heavy drinking is another policy alternative.

An open question is the variation in the price elasticity due to heterogeneity of adult drinkers. Do heavy-drinking adults respond to higher alcohol prices and taxes? While a number of empirical studies address this question, no literature review seems to exist. In contrast, prices and drinking patterns for youth and young adults have been studied and reviewed many times (Bonnie and O'Connell 2003, Chaloupka 2003).[3] The studies reviewed below use survey data to examine individual responses to alcohol prices or taxes, which can vary by age, gender, race, income, education, marital status, health status, and so forth. While information about these responses is potentially useful for social programs, the focus here is the price (or tax) response or elasticity according to level of alcohol consumption by adults. For example, a recent study by Ayyagari *et al*. (2013) uses data from the US Health and Retirement Study and a finite mixture model to recover two latent groups of alcohol consumers. The first group is completely unresponsive to price, drinks more heavily on average, and is more likely to

[2] Lacking empirical evidence, Pogue and Sgontz (1989) simply assumed that abusive and nonabusive drinkers have equal price elasticities. The present paper provides the missing evidence on relative elasticities for adults. The potential welfare loss to moderate drinkers has been pointed out by a number of observers (Cnossen 2008, Grossman *et al*. 1993, Kenkel and Manning 1996, Smith 2005).

[3] The price elasticity for youth and the effect of taxes on social costs has been the subject of considerable research that is beyond the scope of the present paper; see Xu and Chaloupka (2011) for a recent review. For alcohol consumption by youth, intervention is warranted due to information failures, peer effects, internal costs imposed by underage drinkers on themselves, and external costs.

engage in "binge" drinking. The second group is responsive to price (elasticity of – 1.69) and drinks lightly or moderately. The second group also is more disadvantaged in terms of education, health, and financial resources. Ayyagari *et al*. (2013) conclude that attention to drinker heterogeneity is critical in welfare analyses because higher taxes could well fail to reduce alcohol-related externalities in a substantial manner.

The objective of this study is to test the robustness of this result by conducting a review of empirical studies on price (or tax) response/elasticity of adult drinkers, ages 26 years and older. Starting with a database of 573 studies of alcohol demand and alcohol-related outcomes, primarily in the field of economics, the review examines two sets of relevant studies. First, a set of 19 individual-based studies that report empirical results for price responses by heavy-drinking adults. Second, a set of nine studies that report empirical results for alcohol prices and liver cirrhosis mortality. As is well known, cirrhosis develops in about 10-20% of individuals who drink heavily over a decade or more (NIAAA 1998). It is generally irreversible, but can be interrupted. At least half of cirrhosis fatalities are alcohol-related. In 2007, it was the 12th leading cause of death in the US (Yoon and Yi 2010). Mortality rates worldwide are higher for men and declining in North America, Japan, Australia, and southern Europe, but rising in Eastern Europe and the UK (Bosetti *et al*. 2007). Examination of two sets of studies provides evidence regarding price responses of heavy drinkers and a closely-related adverse health outcome.

The remainder of the paper is divided into five parts. The next section provides a brief review of the aggregate price elasticity literature, including averages reported in several recent meta-analyses. This information provides a benchmark for closer examination of drinking patterns. This is followed by a section that explains the details of the survey and comments on two important measurement issues. Two sections contain surveys of the studies of price responses for adult drinking and studies of alcohol prices and cirrhosis mortality. The last section assesses limitations of the studies and policy implications of the review. Two appendices provide additional details on the studies.

II. REVIEW OF AGGREGATE PRICE ELASTICITY ESTIMATES

Numerous studies have been conducted by applied researchers that estimate demand relationships for alcohol beverages. Older studies tend to use aggregate (population-level) time-series data from which price elasticities are easily obtained or which can be calculated with some degree of confidence. More recent studies have used individual-level and household survey data, where price responses by different groups of consumers are conceptually possible. Averages for aggregate elasticity estimates are contained in a number of past reviews, including three recent meta-analyses (Fogarty 2009, Gallet 2007, Wagenaar *et al*. 2009a). The reviews tend to focus on broad comparisons, such as average elasticities by beverage, country, and time period. Table 1 displays the averages found in ten reviews and three country-level studies. Two regularities are apparent: first, beer has a price elasticity of about – 0.30 to – 0.40, and is clearly the least elastic of the beverages; and, second, the price elasticity for total alcohol is about – 0.50 to – 0.60. With regard to other beverages, early reviews suggested that wine and spirits had elasticities close to or slightly greater than unity, but these reviews relied on studies for the UK and US. More recent reviews cover a broader range of countries and more recent

Table 1: Average Aggregate Price Elasticity Estimates[a]

Study/Date/Type	Beer	Wine	Spirits	Alcohol
Ornstein (1980):				
aggregate data studies	-0.40 (19)		– 1.00 (18)	
Ornstein & Levy (1983):				
aggregate data studies	-0.45 (19)	-1.01 (24)	-0.89 (18)	
Clements & Selvanathan (1991):				
aggregate data	-0.17 (8)	-0.42 (8)	-0.36 (8)	-0.59 (3)
Selvanathan (1991):				
country-level data	-0.22 (9)	-0.38 (9)	-0.37 (9)	
pooled countries	-0.19 (9)	-0.53 (9)	-0.28 (9)	
Leung & Phelps (1993):				
aggregate data studies	-0.39 (19)	-0.99 (15)	-0.82 (18)	-0.50 (1)
Edwards *et al*. (1994):				
aggregate data studies	-0.36 (36)	-0.86 (44)	-0.75 (37)	
Berggren (1997):				
aggregate data studies	-0.26 (10)	-0.46 (10)	-0.68 (10)	
Selvanathan & Selvanathan (2005):				
country-level data	-0.37 (10)	-0.46 (10)	-0.57 (10)	
Selvanathan & Selvanathan (2006):				
developed countries				-0.44 (24)
developing countries				-0.57 (19)
all countries				-0.50 (43)
Gallet (2007): meta-analysis				
median	-0.37 (311)	-0.70 (300)	-0.69 (290)	-0.50 (263)
mean	-0.55 (311)	-0.76 (300)	-0.80 (290)	-0.56 (263)
individual-level median	-0.76 (18)	-0.25 (19)	-1.04 (7)	-0.68 (41)
Wagenaar *et al*. (2009a):				
mean	-0.46(105)	-0.69 (93)	-0.80 (103)	-0.51 (91)
Fogarty (2009): meta				
median	-0.33(154)	-0.55 (155)	-0.76 (162)	
mean	-0.45(154)	-0.65 (155)	-0.73 (162)	
UK studies – mean	-0.47 (42)	-0.72 (39)	-0.76 (40)	
US studies – mean	-0.52 (36)	-0.55 (31)	-0.60 (40)	
Collis *et al*. (2010): UK				
median	-0.40 (31)	-0.86 (30)	-0.72 (32)	
mean	-0.56 (31)	-0.90 (30)	-0.75 (32)	

a Figures in parentheses are the number of observations. Unless indicated, unweighted mean values are shown. Averages in some studies were obtained by setting positive price elasticities equal to zero; when a range was reported the least elastic value was used; and estimates for narrower beverage categories were ignored (e.g., vodka).

time periods. The three meta-analyses suggest that wine and spirits have average elasticities in the range – 0.70 to – 0.80. This range of estimates is in line with other summaries (Cook and Moore 2000). Studies that use data for multiple countries yield less elastic demands for individual beverages, but not for total alcohol. Finally, the reviews and studies in *Table 1* rely almost exclusively on population-level data or summarize a small sample of individual-level studies.[4] Using data from Gallet (2007), median values for individual-level studies are reported in *Table 1*. Three of four comparisons by beverage suggest that individual-level data yield somewhat more elastic demands. However, the meta-regressions in Gallet (2007) fail to confirm this relationship.

The aggregate estimates in *Table 1* have been widely used for calculation of optimal taxes, simulations of alcohol-related regulations, and other policy discussions. Costs and benefits to moderate or nonabusive drinkers rarely enter these calculations, in part due to the absence of information on drinking patterns and relative price elasticities. Elasticities for heavy – and moderate-drinking adults are not identified. Analyses that can provide this empirical information cannot be performed using population-level data, but rather require survey data on households or individuals. These studies provide the basis for this review.

III. SURVEY METHODS

A search of the literature on alcohol demand was conducted by the author during the months of August-September 2012, with several meta-analyses providing a useful starting point. In addition to the three meta-analyses in *Table 1*, there are several other analyses that focus on alcohol-related adverse outcomes (Elder *et al*. 2010, Karlsson *et al*. 2011, Patra *et al*. 2012, Wagenaar *et al*. 2010). Articles, chapters, books, reports, dissertations, and working papers were examined on alcohol demand and alcohol-related outcomes, such as liver cirrhosis, traffic fatalities, crime, labor productivity and wages, and other outcomes. Some econometric studies on alcohol harms include first-stage or structural demand estimates, which are easily overlooked. Among the search terms used were combinations of "alcohol" AND "tax" (OR "price" OR "elasticity)." Complementary searches also were conducted using "beer," "wine" "liquor," "distilled spirits," "cirrhosis" and "alcohol mortality." Among the databases searched were EconLit, RePEc, SSRN, JSTOR, AgEcon Search, and on-line retrieval engines for EBSCO Host, ProQuest, ScienceDirect Journals, and Wiley Online Library. References in the studies were used for ancestral-based retrievals. The literature search was restricted to materials in the English language, but not limited to articles in peer-reviewed journals. Numerous Google searches also were conducted, which was especially helpful in locating unpublished materials. *Table 2* summarizes the search process, where a total of 573 studies were retrieved. Hard copies were obtained for all studies in entirety. The abstracts and other summaries were screened to select alcohol-consumption studies with individual or household-level data for adults.

[4] It is important to note that tax and price elasticities are not identical, which is a potential source of confusion in prior surveys and analyses (e.g., Wagenaar *et al*. 2009a). Conversion of tax elasticities requires an average price and the derivative of price with respect to the tax rate, i.e., the pass-through rate. Suppose the estimated tax elasticity for spirits is – 0.05, the mark-up is 20%, and the average price is $20 per bottle. Hence, the estimated price elasticity for spirits is E = ($20*-0.05) /1.2 = – 0.83. The present study avoids this problem by concentrating on statistical significance of effects in each study.

Similar procedures were used for studies of cirrhosis mortality, except this search yielded only population-level studies. These procedures narrowed the search to 48 studies of alcohol demand and 51 studies of alcohol – related mortality. Finally, these studies were read in full to determine if they had useable information on price responses of adult drinkers or cirrhosis mortalities. *Table 2* provides the exclusion criteria used. The final results from this appraisal are summarized in two appendix tables.

Table 2: Results of Literature Search[a]

Total alcohol-related studies examined in search: 573 studies
Excluded aggregate (population-level) alcohol demand studies: 350
Remaining individual-level or mortality studies: 223
Excluded survey studies focused on youth or young adults (< 26 yrs.): 70
Excluded survey studies focused on gender differences: 54
Remaining adult or mortality studies: 99
Adult-survey studies examined: 48
Excluded studies: 29 – reasons
No alcohol demand results: 10
No price/tax results reported: 15
No std. errors reported: 1
Other (duplicate, etc.): 3
Included in review, adult-survey studies: 19
Cirrhosis mortality studies examined: 51
Excluded studies: 42 – reasons
No price/tax results reported: 17
Total mortality study: 10
Other (duplicate, reviews, etc.): 15
Included in review, cirrhosis mortality studies: 9

[a] A complete bibliography of the 573 studies is available on the author's academic institution web-page or by request.

Measurement issues. Many alcohol demand studies employ large surveys, such as the US Behavioral Risk Factor Surveillance System, National Health Interview Survey, and the Health and Retirement Study. Alcohol consumption data are self-reported, which introduces response errors. Response and measurement errors will bias regression coefficients, but the direction and magnitude of this bias is unknown (Cook and Moore 2000). There also are a number of methodological concerns for survey-based alcohol data (Byrnes *et al*., 2013; Martinic 1998, Sindelar 1993). Many surveys report information on the number of drinks consumed during a specific time period, but the definition of a "drink" is not fixed across countries (see Dufor 1999, ICAP 2013). "Heavy" or "frequent" drinking can be defined in alternative ways (Abel *et al*. 1998, Sindelar 1993), and investigators have adopted different definitions for a variable with this label. Definitions used in each study are reported in the appendix tables and summarized below.

Price data are not obtained from survey respondents and are imputed (or proxied) based on respondents' place of residence. For the US, researchers have tended to use one of two approaches to price measurement. First, alcohol prices are contained in the ACCRA Cost of

Living Index, which is published quarterly for 300 medium and large US cities, and which reports shelf prices for one brand each of beer, wine, and blended whiskey. These data ignore opportunities for substitution across the price spectra, including off – vs. on-premise consumption (Gruenewald *et al*. 2006, Treno *et al*. 1993). Second, many US researchers instead use state beer taxes as a proxy for prices. Both approaches to price measurement have a number of well-known problems. The ACCRA data cannot capture the full spectra of alcohol prices and geographic details are limited. Young and Bielinska-Kwapisz (2003) examine the effects of measurement errors and possible endogeneity of ACCRA prices for the composite demand for alcohol for a panel of 49 states for 1982-1997. Depending on model specification and econometric method, they find substantial variation of price elasticity estimates (-1.24 to 0.027), which they conclude is evidence of measurement error. Only one of their six estimates compares favorably with the consensus average of –0.50 in *Table 1*. Ruhm *et al*. (2012) compare ACCRA prices to prices from UPC scanner data on grocery store alcohol sales.[5] They show that in most markets ACCRA prices are higher for beer and spirits and lower for wine. Using alcohol data from the National Epidemiological Survey, they demonstrate that ACCRA prices fail to yield stable estimates of the price elasticity for beer. Using scanner data, they find a statistically insignificant beer price elasticity of – 0.28.

A widely adopted alternative, especially in the alcohol-harms literature, is to use state beer taxes as an empirical proxy for beverage prices. A prime attraction is that taxes are policy variables. The assumption is that taxes are fully passed through to prices. Most studies of this relationship report some over-shifting (Bergman and Hansen, 2010; Kenkel, 2005; Young and Bielinska-Kwapisz 2002). However, state taxes are a small percent of beer prices and tax rates have changed infrequently over time. This suggests that cross-sectional variation in prices is likely dominated by non-tax factors and any temporal variation in real tax rates is largely due to general inflation (Dee 1999b). State alcohol taxes also may be endogenously determined (Kubik and Moran, 2001) or might capture state-to-state variation in drinking sentiment (Dee 1999b). Young and Bielinska-Kwapisz (2002) report that beer taxes are poor predictors of alcohol prices. Ruhm *et al*. (2012) find that beer taxes are poor predictors of alcohol consumption compared to scanner price data. They estimate three regressions for beer consumption conditional on beer taxes. All of the tax elasticities are positive and statistically insignificant. These results present a quandary for researchers, and cast doubt on empirical studies using ACCRA prices or alcohol tax variables.[6] Ruhm *et al*. (2012) suggest that the wide variation in elasticities also may reflect the sensitivity of statistical estimates to the selected sample or a tendency by researchers to report only their most "favorable" results (i.e., publication selection bias). These cautions appear to be borne out in the survey results reported below.

[5] In the US, eighteen states have monopoly control over the wholesaling or retailing of alcohol beverages. For the control states, Ruhm *et al*. (2012) use shelf price data from the National Alcohol Beverage Control Association. The information on prices is condensed into average prices per ethanol equivalent using data on the sales and ethanol content of 231 brands of beer, 314 brands of wine, and all brands of spirits.

[6] Some past studies on alcohol-harms report null results for beer taxes as a proxy for prices (Dee 1999a, Freeman 2000, Mast *et al*. 1999, Sen 2003); improbably small or large elasticities (Freeman 1999, Sen and Lee 2002); or conflicting results for ACCRA prices and beer taxes (Young and Bielinska-Kwapisz 2006). See Dee (1999a, 1999b) for discussion of state taxes and identification issues in studies using cross-sectional survey data or longitudinal panel data.

IV. SURVEY RESULTS FOR PRICES AND HEAVY-DRINKING BY ADULTS

The review of 19 studies of heavy drinking by adults is found in appendix *Table A1*. This section describes the data and methods used in the studies and summarizes the key empirical results in tabular form.

Sample features. Thirteen studies use individual-level data for the US, while the remaining studies cover Australia (2 studies), Canada (2), China (1), and Switzerland (1). The US studies use data from seven different national surveys, including the US Behavioral Risk Factor Surveillance System (6 studies), National Health and Retirement Study (2), and supplements to the Health Interview Survey (2). Two studies employ different data sets: Nelson (2008) uses survey data for the US aggregated to the state level; and Heeb *et al*. (2003) use a special two-part survey in Switzerland to examine effects of a tax change for spirits. Many sample sizes are substantial (10,000-plus observations), but smaller samples are found in two Canadian studies, the Switzerland study, and two US studies. The average age of survey respondents is generally around 40-45 years, but older respondents are found in two US studies that use the Retirement Study. All studies based exclusively on youth or young adults (ages 21-26) are excluded. Also excluded is a study by Purshouse *et al*., (2010). While very detailed, the study covers all age groups (16 years and older) and does not correctly account for zero consumption observations by price-level, beverage, or drinking locations.

Drinking measures. The studies employ different measures of drinking as a dependent variable as the studies and surveys define "moderate" and "heavy" drinking in different manners.[7] This complicates the review task. *Table A1* reports the definitions used by the investigators. The surveys generally ask questions on drinking frequency during a past period (no. of drinks during past week, month or year) and drinking intensity (no. of drinks per occasion). This information is combined to create drinking categories by frequency or intensity, but categorizations differ. For example, Kenkel (1996) defines "moderate" drinking as consumption levels below four drinks a day and "heavy" drinking as five or more drinks a day. Kenkel's dependent variable is the number of drinking days at moderate or heavy intensities in the past two weeks or year. However, intensity data are used in different ways, with heavy ("chronic") drinking defined as 2+ drinks daily in Dave and Saffer (2008) to as high as 8+ drinks on a single occasion in the Canadian studies by Auld (2005) and Hamilton and Hamilton (1997). This measurement issue is discussed further below.

Price measures. For the US, eight studies use ACCRA price data and five studies use alcohol tax rates. The limitations of these data are discussed above. The US studies employ the price/tax data in different manners, so there is experimental variation. The non-US studies use government price indexes or average prices for broad geographic areas, with some adjustments for beverage or regional differences. Typically these indexes pertain to off-premise consumption. However, there is little geographic information available, so price elasticities mostly reflect variation over time. No study reviewed here attempts to measure on-premise prices and consumption or to separate off – and on-premise consumption. The study for China

[7] Two studies are less representative on drinking patterns: Farrell *et al*. (2003) base "heavy drinking" on survey responses that are subject to interpretation; and Shi (2011) does not specifically identify heavy drinkers.

by Shi (2011) uses community-level prices for local brands of beer and spirits, but little is known about the quality of these data.

Econometric models. A standard feature of survey data on alcohol use is the presence of zero observations, reflecting outcomes for abstainers and non-drinkers. When presented with data with this feature, many econometric studies use a double-hurdle or two-part model, consisting of a discrete choice model (probit, logit, or tobit) for drinking participation (extensive margin) and a continuous model for alcohol demand by those respondents with some consumption (intensive margin). It is possible in two-part models for alcohol prices to affect participation or alcohol consumption or both decisions. Price response and elasticities in two-part models reflect this hierarchy of choices.[8] Some studies restrict the sample to only drinkers (e.g., Stout *et al*. 2000). Two recent studies employ more advanced econometric models for discrete choices (Ayyagari *et al*. 2013, Harris *et al*. 2006) and two studies estimate quantile regressions for drinking levels (Manning *et al*. 1995, Shi 2011). In studies that examine wages and earnings, alcohol use and income are jointly endogenous variables (Auld 2005, Hamilton and Hamilton 1997). A recommended research practice is to report empirical results that exclude possibly endogenous variables, which a few studies employ (Ayyagari *et al*. 2013, Farrell *et al*. 2003, Kenkel 1996). Two studies contain results with the price variable interacted with a second variable, using health status or income (Manning *et al*. 1995, Kenkel, 1996).

Special covariates. Almost all of the studies include a standard list of explanatory variables for age, gender, race, marital status, income, and so forth, which are excluded from *Table A1*. Three studies examine longitudinal panel data using fixed-effects models (Ayyagari *et al*. 2012, McLellan 2011, Nelson 2008), but true panels are not common in large surveys. Greater interest is associated with variables that do not appear in other studies or which are not common, especially policy-related variables. Several studies contain results for state-level regulations regarding alcohol sales or drink-driving. Only one study includes border state prices (Kenkel 1996) and only one study includes outlet density (Nelson 2008). Among studies with other special variables, those that contain variables for health status or health knowledge are notable: An and Sturm (2011), Auld (2005), Ayyagari *et al*. (2013), Dave and Saffer (2008), Hamilton and Hamilton (1997), Kenkel (1996), and Shi (2011).

Empirical results for heavy drinking. Empirical results from 19 studies are summarized in *Table 3*. Heavy-drinking adults are significantly and substantially responsive to prices in only two studies (Dave and Saffer 2008, Rhoads 2010), and even these studies contain mixed results. The other 17 studies indicate that heavy drinkers have statistically insignificant responses to changes in alcohol prices or taxes. However, several studies find that moderate drinkers are price responsive. For example, Harris *et al*. (2006, p. 794) report that for Australia, "whilst an increase in alcohol price decreases the utility of occasional and moderate drinkers, its effect on frequent drinkers' utility is statistically insignificant." Similar results for Australia are found in Byrnes *et al*. (2013). In a few studies in *Table 3*, there is some indication that the youngest group of adult drinkers might be price responsive (Dave and Saffer 2008, Gius 2002, Heeb *et al*. 2003). Price effects for adult drinking-participation also cannot be ruled out (Dave and

[8] Ayyagari *et al*. (2013) argue that two-part models are not required for adults because occasional drinkers go back and forth between no drinks and light drinking. Their finite mixture model allows for a degenerate distribution at zero, so two-part models emerge as a special case.

Saffer 2008, Sloan *et al*. 1995). However, based on the results in *Table 3*, it cannot be argued convincingly that heavy drinking by adults can be curbed extensively by higher alcohol prices or higher taxes. On the other hand, the evidence is consistent with price being important for moderate drinkers and possibly for participation and drinking by the youngest adult respondents.

Table 3: Results in 19 Studies on Alcohol Prices and Heavy Drinking by Adults[a]

Study, Country, Time period	Ave. age (yrs.)	Main findings
An & Sturn (2011), USA, 1984-2009	44.8	At 21 or more drinks per month, beer taxes are insignificant at 4 of 6 levels. Insignificant at highest level. Light drinking is responsive to taxes.
Auld (2005), Canada, 1985 & 1991	37.9	Relative to moderate drinkers, alcohol price index is insignificant for heavy drinkers and non-drinkers. Price is insignificant for alcohol participation.
Ayyagari *et al*. (2013), USA, 1996-2004	65 (est.)	Heavy drinking latent group is unresponsive to alcohol prices. Moderate drinking latent group is price responsive. Heavy drinkers more likely to binge.
Byrnes *et al*. (2013), Australia, 2001-2007	45	Frequency of use is price responsive at two lowest intensity levels (0, 1-4 drinks per occasion), but insignificant at higher levels (5-9, 10+ drinks).
Dave & Saffer (2008), USA, 1999-2004	39.6 & 67.9	For alcohol participation, beer tax is significant for risk adverse and risk tolerant individuals. Beer tax is insignificant for heavy drinking (2+ drinks daily) in Health and Retirement Study sample.
Dee (1999b), USA, 1984-1995	45.5	Chronic alcohol use and binge drinking are insignificantly affected by taxes (beer, liquor) in full sample and nine subsamples. Models rely on state-fixed effects for identification.
Farrell *et al*. (2003), USA, 1991-1992	40.3	Price elasticity for heavier drinking is insignificant for 5 of 8 factor scores. Price of alcohol has an insignificant impact on" increased salience of drinking" (highest level of consumption).
Gius (2002), USA, 1994	31	Alcohol taxes (beer, wine, spirits) are insignificant in 5 of 6 OLS regressions and insignificant for binge drinking in four probit regressions
Hamilton & Hamilton (1997), Canada, 1985	37.6 & 33.4	Alcohol price indexes (beer, wine, spirits) are insignificant for heavy drinkers and non-drinkers.
Harris *et al*. (2006), Australia, 1995-2001	37.9	Alcohol price index is insignificant for heavy drinkers, but significantly negative for moderate drinkers. Participation elasticities are insignificant or positive for moderate and heavy drinkers, but negative and significant for occasional drinkers.
Heeb *et al*. (2003), Switzerland, 1999	45 (est.)	For high-volume drinkers and binge drinkers at baseline, spirits consumption shows no change for a reduction in spirits tax. Price responses are mostly among younger persons and among lighter drinkers.

Kenkel (1996), USA, 1985	43.3 & 45.7	Price elasticity is insignificant for heavy drinkers overall, but significantly negative for those with more complete health information. Moderate drinkers are price responsive.
Manning *et al*. (1995), USA, 1983	39.5	In quantile regressions for drinking intensity, price is insignificant at the 90th and 95th percentiles. For heavy drinking, the conditional and combined elasticities are insignificant. Heaviest drinkers have perfectly price inelastic demands.
McLellan (2011), USA, 2001-2006	45 (est.)	ACCRA beer price is less than one (for odds ratios) for binge and heavy drinking in regional fixed-effects models, but insignificant in state-fixed effects models.
Nelson (2008), USA, 1999-2003	44 (est.)	Beer tax is insignificant in two regressions for binge drinking by adults.
Rhoads (2010), USA, 1991-2004	45	Price is insignificant for binge drinking in the full sample and binge participation by age groups. For binge intensity, price is negative and significant for two older groups. ages 40-64 and ages 65+, but not for younger adults, ages 25-39 years.
Shi (2011), China, 1993-2006	45.1	For males, price is significant in OLS and one tobit regression, but not in two-part regression. For females, price is significant in OLS and two-part regression, but not in logit model. All elasticities are small (-0.1 or less) in quantile regressions. Heavy drinking is not defined in this study.
Sloan *et al*. (1995), USA., 1984-1990	45.3	ACCRA price is significant for probability of any drinking in past month, but not for probability of binge drinking or number of binge episodes. Marginal effects or elasticities are small in all instances for alcohol prices.
Stout *et al*. (2000), USA, 1984-1995	42	Alcohol prices are insignificant for heavy drinkers in both drinking and drink-driving regressions.

[a] Statistical significance is based on a t-statistic of 1.96 or more, two-tailed test at the 5% significance level.

V. SURVEY RESULTS FOR PRICES AND CIRRHOSIS MORTALITY RATES

Table A2 summarizes nine studies of the effects of alcohol prices (or taxes) on mortality rates due to liver cirrhosis. Studies of total mortality, alcohol-related accidents, or alcohol dependence are excluded from the review. Not all cirrhosis deaths are due to alcohol consumption, but alcohol is a primary cause in many cases. Several related studies demonstrate a close relationship between alcohol sales and cirrhosis mortality (Bentzen and Smith 2011, Gruenewald and Ponicki 1995, Wilson 1984). A general finding is that aggregate mortality rates respond almost immediately to changes in alcohol consumption. The explanation is that reductions in consumption reduce the "reservoir" of individuals who are about to die from a chronic alcohol-related disease;

see Edwards *et al*. (1994), Cook and Tauchen (1982), and Sloan *et al*. (1994). Conceptually, prices affect alcohol consumption (demand or consumption relationship) and chronic alcohol consumption results in cirrhosis deaths (mortality relationship). In the empirical literature, researchers estimate reduced-form models, where determinants of alcohol demand are substituted for alcohol consumption in the mortality relationship. Hence, some covariates in reduced-form relationships, such as income, have indeterminate signs (Nelson and Young 2001).

Sample features. Six studies employ annual US state-level data (one study uses a single state) for different time periods, ranging from seven years to 28 years in duration. Two studies use an international panel of 17 developed countries and one study uses time-series data for Poland. Time-series data raise issues of non-stationarity, but only the study for Poland addresses this concern (Bielinska-Kwapisz and Mielecka-Kubien 2011). Sample sizes range from 45 observations to 1224 observations. The literature search did not locate any studies that employ individual – or household-level data for prices and cirrhosis mortality.

Dependent variables and prices. Most of the studies use annual age-adjusted state – or country-level mortality rates. The study by Sloan *et al*. (1994) examines alcohol primary-cause fatalities, which includes cirrhosis. The Alaska study by Wagenaar *et al*. (2009b) also uses a broader definition of alcohol-related fatalities that includes all deaths in which alcohol is a primary cause. Two studies use alcohol taxes and three studies use ACCRA prices or prices for specific brands of spirits. Three studies use price indexes or average prices constructed from sales data. The Alaska study uses an interrupted ARIMA model for quarterly data and state tax changes in 1983 and 2002.

Econometric models. Several state – and country-level studies use panel data econometrics, but some results are sensitive to this specification (Sloan *et al*., 1994).[9] Several studies use logit models for the log odds ratio of mortality rates. This is a natural specification to use when the dependent variable can be interpreted as a probability of occurrence. Three studies test for rational addiction in alcohol consumption and include lagged and leading values of the dependent variable and prices (Bielinska-Kwapisz and Mielecka-Kubien 2011, Grossman 1993, Sloan *et al*. 1994). Other studies use lagged values for prices on the assumption that mortality may not respond immediately to price or tax changes (Cook and Tauchen 1982, Ponicki and Gruenewald 2006). Using this specification, short – and long-run changes in mortality due to a change in state taxes on spirits are reported in Cook and Tauchen (1982). Heien and Pompelli (1987) report that stress variables, such as unemployment and divorce, are more important in their study of cirrhosis mortalities and alcohol abuse.

Empirical results for cirrhosis mortality. The empirical results are summarized in *Table 4*. Taken as a whole, the results in the nine studies present a mixed picture of the effect of alcohol prices on cirrhosis mortality. Three studies report insignificant results for prices: Bielinska-Kwapisz and Mielecka-Kubien (2011), Heien and Pompelli (1987), and Sloan *et al*. (1994). Four studies contain mixed results for different regressions or combinations of variables: Cook and Tauchen (1982), Grossman (1993), Ponicki and Gruenewald (2006), and Wagenaar *et al*.

[9] State fixed-effects control for time-invariant differences among states, such as public attitudes toward drinking. Sloan *et al*. (1994) argue this specification greatly reduces endogeneity concerns, so the more important empirical issue is inclusion or exclusion of time fixed-effects; see also Dee (1999a, 1999b) on longitudinal panel data econometrics.

Table 4: Results in Nine Studies on Alcohol Prices and Liver Cirrhosis Mortality[a]

Study, Country, Time period	Data type, Dep. variable measure, Sample size (N)	Main findings
Bielinska-Kwapisz & Mielecka-Kubien (2011), Poland, 1950-2005	National time series data. Annual cirrhosis mortality rate (ages 20 and over). N = 45.	Price variable is statistically insignificant (t = 1.40).
Cook & Tauchen (1982), USA, 1962-1977	16-year panel of 30 license states. Annual cirrhosis mortality rate (ages 30 and over). N = 480.	Current spirits tax rate is negative and insignificant (t = 1.76) and once-lagged tax rate is insignificantly positive. Sum of coefficients is significantly negative (t = 2.45).
Grossman (1993), USA, 1961-1984	24-year panel of 51 states. Annual cirrhosis mortality rate (ages 30 and over). N = 1224.	Price of spirits is significant in regression with income and demographics, but insignificant in a state fixed-effects model (t = 1.37).
Heien & Pompelli (1987), USA, 1968-1977	9-year panel of 45 states. Annual cirrhosis mortality rate (ages 44+), logit model. N = 405.	Price of spirits is statistically insignificant (t = 0.07).
Nelson & Young (2001), 17 countries, 1977-1994	18-year panel of OECD countries. Annual cirrhosis mortality rate, logit model. N = 306.	Price index variable is significantly negative for cirrhosis mortality, but may reflect omitted variable bias or drinking sentiment.
Ponicki & Gruenewald (2006), USA, 1971-1998	28-year panel of 30 license states. Annual cirrhosis mortality rate (ages 15 and over). N = 840.	Spirits tax is significant in regression without other taxes, but insignificant in regressions that also include beer & wine taxes (t = 1.79 & 1.70). Beer and wine taxes are always insignificant.
Saffer (1991), 17 countries, 1970-1983	14-year panel of OECD countries. Annual cirrhosis mortality rate, logit model. N = 238.	Price index variable is significantly negative for cirrhosis mortality, but may reflect omitted variable bias or drinking sentiment.
Sloan *et al*. (1994), USA, 1982-1988	7-year panel of 48 states. Alcohol primary-cause fatalities in four areas. N = 336.	In two regressions with state fixed-effects, ACCRA price is insignificant. Excluding fixed-effects, the alcohol price is negative and significant (t = 2.95).
Wagenaar *et al*. (2009b), Alaska, 1983 & 2002	Tax increases on all beverages in Alaska in August 1983 and October 2002. All deaths in which alcohol is the primary cause (liver, pancreatic, psychoses, dependence, etc.). N = 116.	Alcohol-caused mortality was significantly reduced by the tax hike in 1983 in three of four regressions. The step function coefficients for 2002 are insignificant in four regressions.

[a] Statistical significance based on a t-statistic of 1.96 or more, two-tailed test at the 5% significance level.

(2009b). The two country-level studies contain significant negative coefficients for alcohol prices, but higher prices in these studies might also act as proxies for other (omitted) alcohol policies, such as severe penalties for drink-driving in the Nordic countries (see Nelson 2010). The study by Ponicki and Gruenewald (2006) suggests that taxes on distilled spirits are important, but this result is not replicated in Grossman (1993) or Heien and Pompelli (1987). Overall, this is a mixed set of results for alcohol prices or taxes. Other variables, such as unemployment, are important in some studies, including the cross-country studies.

VI. DISCUSSION

The review found only two of nineteen empirical studies where there was a significant and substantial price/tax response by heavy-drinking adults (ages > 26 years), and even these two studies present mixed results. On the other hand, many studies show that moderate-drinking adults have significant and substantial price/tax elasticities, including both studies for Australia (Brynes *et al*. 2012, Harris *et al*. 2006) and several of the US studies. The review of cirrhosis mortality found only two of nine studies obtained significant negative price/tax effects, but prices in these studies might be proxies for other (omitted) alcohol policies or drinking sentiment generally. The other cirrhosis studies contain mixed results or are sensitive to econometric specifications. Several limitations of the studies should be kept in mind, which also provide a basis for future research in this area.

Drinking measures. In general, heavy episodic ("binge") drinking has been used to distinguish between moderate and heavy drinking categories. The most common approaches are: (1) number of days drinking at a given intensity or number of drinks over a given time period (An and Sturm 2011, Byrnes *et al*. 2013, Dave and Saffer 2008, Harris *et al*. 2006, Kenkel 1996, Manning *et al*. 1995); (2) separate variables for number of days or drinks and frequency of binge drinking (Dee 1999b, Gius 2002, McLellan 2011, Rhoads 2010, Sloan *et al*. 1995); and (3) binge drinking frequency only (Ayyagari *et al*. 2013, Heeb *et al*. 2003, Nelson 2008, Stout *et al*. 2000). The remaining studies combine the information on frequency and bingeing (Auld 2005, Hamilton and Hamilton 1997) or use other definitions (Farrell *et al*. 2003, Shi 2011). Five studies use two measures of heavy drinking and four of these studies obtain null results for price responses. Overall, the results do not appear to be sensitive to alternative definitions of heavy drinking or the number of covariates for heavy drinking. For future research, it would be useful to adopt standard definitions or show results for alternative definitions of heavy drinking and binge drinking.

Price measures. The US studies use ACCRA price data or alcohol tax rates, which contain limited information on the price spectra or limited geographic variation. The non-US studies use government price indexes for broad geographic areas, with some adjustments for beverage or regional differences. While these indexes are widely used in aggregate studies, their use for individual-level consumption is questionable. There is little geographic information available, so price elasticities mostly reflect variation over time. No study reviewed here attempts to measure on-premise prices and consumption or to separate off – and on-premise consumption. It would be highly desirable for researchers to make use of UPC scanner price data or surveys with individualized data on prices. A study focusing on home-consumption

could capture any price substitution resulting from higher on-premise prices and restrictive regulations. As demonstrated by Ruhm *et al*. (2012), additional information on prices can be critical for measured responses.

Cirrhosis results. Given the insignificant results for heavy drinking by adults in *Table 3*, it is worth asking if the cirrhosis results in *Table 4* present a different outcome. First, none of the mortality studies use individual – or household-level data, so they suffer from all of the shortcomings associated with aggregate data (causality issues, correlated data, non-stationary time-series, etc.). Second, the price data are weak and need to be supplemented with data with more geographic variation (Treno *et al*. 1993). Third, it may be that reductions in mortality are due to changes in drinking behavior by moderate or nonabusive drinkers, who are price responsive. Studies with survey data are needed to determine if price is a causal factor for mortality among heavy drinkers. Fourth, the models in mortality studies need to be supplemented with state fixed-effects (Dee 1999a, 1999b, Stout *et al*. 1994). Fifth, as suggested in Cook and Tauchen (1982), it may be that cirrhosis studies capture a marginal response by heavy drinkers that is missed in studies of alcohol consumption, possibly due to measurement issues discussed above. A research study that examines the joint effect of scanner prices on alcohol demand and cirrhosis mortality for heavy – and moderate-drinking adults would be an important addition in this area.

Policy assessment. The case for higher alcohol taxes has been debated extensively by economists (Cook and Moore 1993, 1994, Heien 1995/96), but much of the debate has revolved around related issues, such as the measurement of social costs, tax regressiveness, and incentives for illicit alcohol production and sale. The price responses by youth and young adults were not analyzed in the present paper, but clearly are important for the debate. The lack of a response by heavy-drinking adults may be due to the additive nature of drinking, which also has implications for youth drinking patterns and alcohol policies directed at youth. By analyzing price responses, the present study casts doubt on the effectiveness of alcohol taxes as a means of reducing heavy drinking by adults and its related social costs. Hence, it is useful to summarize results in one study for a non-tax policy variable. Results in Kenkel (1996) suggest that better health information is an effective policy to reduce the health costs of heavy drinking. He finds that the least-informed drinkers have a perfectly inelastic demand for alcohol, but the better-informed heavy drinkers have demands that are more elastic than moderate drinkers. Using alcohol taxes to target poorly-informed heavy drinkers is not a practical economic policy, suggesting that provision of better health information is needed along with or as an alternative to any changes in prices or taxes.

In recent years, attention by policymakers in some countries has shifted away from alcohol taxes and toward direct control of prices, especially minimum prices, with such laws under consideration or adopted in Australia, Canada, England, Ireland, Northern Ireland, and Scotland (Ludbrook 2009, Walker 2009). While the evidence-base is limited, the supporters of minimum pricing have argued that heavy drinkers tend to choose the least-costly alcohol brands and beverages. Empirical support for an effect of minimum pricing is limited to two Canadian studies, where minimum pricing at the provincial level has been in effect for a number of years (Stockwell *et al*. 2011, 2012). However, these studies examine population-level alcohol consumption and not consumption of targeted brands or consumption by youth, young adults,

or heavy-drinking adults. The results of the present survey covered 19 studies of heavy-drinking adults, and fail to provide support for minimum pricing policies. The results from nine studies of liver cirrhosis mortality, while based on population-level data, are equally non-supportive.

In summary, a review of two sets of related studies casts doubt on public policies that rely extensively on price controls or higher alcohol taxes as a means to reduce abusive drinking by adults, adverse health outcomes, and related social costs. The price/tax elasticity for heavy drinkers appears to approach zero in most instances. This result is robust across countries, time periods, drinking measures, and model specifications. Improvements in price data in empirical studies might remove some uncertainty associated with this evidence.

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Table A1: Empirical Review – Nineteen Studies on Alcohol Prices and Heavy Drinking by Adults

Study/Country	Data source (N = obs.), Ave. age of sample.	Definition of key terms, Measures used	Econometric model, Special variables incl.	Main findings
An & Sturm (2011), USA	Behavioral Risk Factor Surveillance System, 1984-2009 (N = 3.9 mil & 1.9 mil). Age = 44.8 yrs. Among drinkers, ave. no. of drinks per mth. is 22.6.	Any alcohol consumption (participation) and no. of standard drinks in last 30 days. Federal and state excise taxes per gallon of beer.	Two-part model: probit and OLS. Disability status included. Results for nine levels of drink quantity. Tax effects differ among race/ethnic groups.	At 21+ drinks per month, tax is insignificant at 4 of 6 levels. Insignificant at highest level. Light drinking is responsive to taxes. Concludes higher taxes are least effective among heavy drinkers.
Auld (2005), Canada	General Social Survey, 1985 & 1991, men only (N = 3891). Age = 37.9 yrs. Heavy drinkers are 9.3% of sample.	Abstain, Moderate (drinks at least once per month), and Heavy (drinks at least once per week & binged 8+ drinks in past week). Alcohol beverage price index by province.	Two-stage simultaneous model for income and substance use: multinomial probit model for drinking status. Health status & religion included.	Relative to moderate drinkers (normalized to zero), alcohol price is insignificant for non-drinkers and Heavy drinkers (t = 1.69). Concludes price has little effect on drinking abstention.
Ayyagari *et al*. (2013), USA	Health and Retirement Study, 1996-2004, under 51 yrs. excluded (N = 65,002). Age = 65 yrs. (est.). Average no. of drinks for drinkers is 2.08 per day when they drink. Heavy drinkers are 27.2% of sample.	No. of Drinks per day when drink and Binge drink (no. of days with 4+ drinks on one occasion in last 3 mths.). ACCRA price at state level, adjusted for ethanol content per drink.	Two – and three-component finite mixture model, with Poisson-distributed sub-populations. Robusteness checked with state laws on drink driving. Health status and cognitive ability score included.	Two latent groups are recovered. Moderate drinking group is price responsive and more likely to be older, non-white, female, married, and less educated. Concludes that Heavy drinking group is insensitive to price, and more likely to binge drink.
Byrnes *et al*. (2013), Australia	National Drug Strategy Household Surveys, 2001, 2004 & 2007 (N = 79, 545). Age = 45 yrs. Sample ave. is 3.2 standard drinks (10 g of alcohol) per occasion.	No. of days alcohol consumed at four drinking intensities, defined as no. of std. drinks on one occasion (0, 1-4, 5-9, 10+) National ave. sales prices, adjusted for state CPI.	Pooled 3SLS for four intensity levels, with coefficients constrained to sum to zero. Unemployed status included.	Frequency of consumption is price responsive for two lowest drinking intensity levels (0, 1-4). Concludes there is no significant change at two highest intensity levels (moderate, high).

Table A1: Empirical Review – Nineteen Studies on Alcohol Prices and Heavy Drinking by Adults (contd)

Dave & Saffer (2008), USA	Panel Study of Income Dynamics, 1999-2003 (ages 21-54) & Health and Retirement Study, 1992-2004 (ages 55+) (N = 27,531 & 101,477). Age = 39.6 yrs. & 67.9 yrs. 66% of PSID sample & 35% of HRS sample are drinkers.	Abstain, Drinks, and ave. no. of drinks consumed daily. "Chronic" or Heavy drinking in HRS sample is 2+ drinks daily, on average. State excise tax on beer.	Two-part model: probit and OLS. Models include variables for risk aversion, health status, & selected state-level regulations.	For alcohol participation, beer tax is significant for both data sets for risk averse and risk tolerant respondents. Tax coefficients for Heavy drinking in HRS sample are not significant (t = 1.52 & 1.39). Concludes risk preferences help explain drinking patterns.
Dee (1999b), USA	Behavioral Risk Factor Survey, 1984-1995 (N = 742,202). Age = 45.5 yrs. 50% of sample are drinkers and ave. drinks per month is 21. Only 4% of sample is chronic drinkers and 13% engaged in binge drinking in previous month.	Drinks is no. of drinks per month; Chronic is 60+ drinks in last month; and Binge is 5+ drinks on one occasion or more in last month. State and federal beer tax; state and federal liquor tax; wt. excise tax per gal. ethanol.	Separate OLS regressions for Drinks, Chronic, and Binge, with and without state fixed-effects & state time trends. Reports results by demographic groups (race, gender, age). Concludes state fixed-effects are important.	For full sample, with state fixed-effects, tax rates are insignificant (liquor tax is positive) for Chronic and Binge. For Binge in full sample and demographic subsamples, taxes are insignificant, incorrect positive signs or are very small effects. Concludes most patterns of alcohol use are unresponsive to taxation.
Farrell *et al*. (2003), USA	National Longitudinal Alcohol Epidemiologic Survey, 1991 and 1992, ages 18 & older (N = 38,098). Age = 40.3 yrs. Self-reported data on alcohol dependence and misuse is used in a three-factor score model: (1) heavier drinking; (2) physical & other consequences of drinking; and (3) increased salience of drinking (highest level of drinking).	Logged factor scores from a three-factor measurement model. Price elasticities computed for each latent factor, with and without state alcohol policy variables. ACCRA price data, adjusted for alcohol content of standard drinks, beverage sales (national), and state sales taxes. Real prices adjusted for ACCRA COL index.	Three-part model: participation (logit), symptoms of alcohol dependence (logit), and degree of dependence (GLM model). Includes regional fixed-effects, family health history (incl. alcoholism), state drink-driving laws, & availability laws. Adjusts for clustering by state.	Price elasticities for increased salience of drinking are not statistically significant ($p = 0.34$ for overall elasticity). The effect of price on level of factor scores is never significant. For heavier drinking, price elasticities are insignificant for 5 of 8 reported outcomes ($p > 0.05$). Concludes the overall price elasticity for increased salience is not statistically significant.

Gius (2002), USA	National Longitudinal Survey of Youth, 1994, ages 29-33 yrs. in 32 states (N = 893 & 595). Age = 31 yrs. Ave. no. of drinks per month is 15.3 and 30.8% of sample has binged.	Drinks is no. of drinks in past month. Binge is 6+ drinks on at least one occasion in past month. State beer tax, wine tax, and spirits tax separately as variables.	OLS model for Drink and probit model for Binge, fitted to full sample and drinkers-only sample. Aggregate variables for crime & unemployed.	Alcohol taxes are insignificant or positive in five regressions for log of Drinks, except for one negative value for beer tax. Taxes are insignificant for Binge in four probit regressions.
Hamilton & Hamilton (1997), Canada	1985 General Social Survey, ages 25-59 for working males (N = 1741). Age = 37.6 yrs. for full sample and 33.4 yrs. for heavy drinkers. Heavy drinkers are 10% of sample and average 20 drinks per week.	Abstain, Moderate (drinks regularly, ave. 3 per week), and Heavy (drinks weekly & binged 8+ drinks in past week). Prices are beer, wine, and spirits province-specific indexes based on sales revenue and volume.	Multinomial logit for non-drinkers & Heavy drinkers relative to Moderate group. Drinking status treated as an endogenous variable in determination of earnings. Religion & health status included.	Price indexes are insignificant for non-drinkers. Price indexes are insignificant for Heavy drinkers (t = 1.693 for beer tax) or positive and insignificant. Results not fully reported for alternative definitions of heavy & binge drinking.
Harris *et al*. (2006), Australia	Drug Strategy and Household Survey for 1995, 1998, and 2001 pooled (N = 39,872). Age = 37.9 yrs. Frequent ("heavy") drinkers are 21.4% of sample. Data show a higher probability of frequent drinking among older individuals.	Abstain, Occasional (drinks 2 or 3 days per month), Moderate (drinks 1-4 days per week), and Heavy (drinks 5 or more days per week). State-specific alcohol price index, deflated by state CPI.	Ordered Generalized Extreme Value (OGEV) model for multiple discrete choices. Unemployed status and education level are included.	Alcohol price coefficient is significantly negative for Moderate drinkers (t = 2.30), but insignificant for Heavy drinkers (t = 0.06). Probability elasticity is insignificant for Moderate drinkers and significantly positive for Heavy drinkers. Occasional drinkers have a probability elasticity of – 0.783.
Heeb *et al*. (2003), Switzerland. Earlier results in Kuo *et al*. (2003) for a similar sample are not reviewed here.	General population survey, 3 months before and after a tax-induced reduction in price of foreign spirits in 1999 (N = 1347). Age = 45 yrs. (est.). Age categories are 15-29 yrs., 30-59 yrs., and 60+ yrs. Study restricted to current drinkers at both baseline & follow-up. Percent of high-volume or binge drinkers changed little over time.	Volume of alcohol obtained by converting quantities of each beverage and related frequencies to grams (g) of pure alcohol per day. Heavy is drinking 40g of pure alcohol per day for men and 20g for women. Binge is defined as 6+ drinks for men and 4+ for women on one or more occasions in past 6 months.	OLS regression for spirits consumption (g/day) only; no change for beer, wine, or total alcohol. Variables for gender, change in volume, and change in binge drinking. Change in spirits due to a shift of low-volume males to higher – volume drinking. Price of foreign spirits declined.	Spirits consumption rose by 30%. Females showed no significant change; males showed a 38% increase, mostly in the younger age group and among lighter drinkers. For high-volume drinkers at baseline, spirits consumption showed no change (t = 0.14). Binge drinkers at baseline showed no change (t = 0.04). Some changes are consistent with regression to the mean.

Table A1: Empirical Review – Nineteen Studies on Alcohol Prices and Heavy Drinking by Adults (contd)

Kenkel (1996), USA. Earlier results in Kenkel (1993) for a similar sample are not reviewed here.	Health Promotion and Disease Prevention supplement to 1985 Health Interview Survey (N = 12,169 males & 15,827 females). Age = 43.3 yrs. for males & 45.7 yrs. for females. Heavy drinkers are 38.2% of males & 13.8% of females.	Abstain, Moderate (no. of days with 1-3 drinks & typical no. of drinks), & Heavy (no. of days with 5 or more drinks in past yr.). ACCRA prices aggregated to state-average price. Price is interacted with health information variable.	Tobit model, comparison with two-part probit-OLS model. Includes variable for health knowledge about risks of Heavy drinking. Includes border-price & state laws on drink driving.	Alcohol price is significant for frequency and intensity of Moderate drinking by males and females, with elasticities between – 0.5 and – 1.0. Price is insignificant for Heavy drinking overall, but significantly negative for drinkers with more complete health information.
Manning *et al.* (1995), USA	Alcohol and Health Practices supplement to 1983 Health Interview Survey (N= 18,844). Age = 39.5 yrs. Current drinkers are 60.4% of sample and 23% engaged in heavy drinking. Ave. daily consumption among drinkers is 0.36 oz. of ethanol (10.6 ml.).	Abstain, Drink (ave. daily consumption of ethanol), and Heavy (no. of days in past year with five or more drinks). ACCRA price per unit of ethanol (weighted), adjusted for state sales tax and ACCRA and BLS COL indexes.	Two-part model: logit and OLS, with selected results for quantile regressions. Price & income are interacted.	Price is significant in the overall model for participation, but not for Drink. Price-income interaction is significant. In the quantile regression for Drink, price is insignificant for 90th and 95th percentiles. For Heavy, price elasticities are insignificant. Concludes heaviest drinkers have perfectly price inelastic demands.
McLellan (2011), USA	Behavioral Risk Factor Surveillance System for 2001-2006 (N = 1.3 million). Age = 45 yrs. (est.). About 15% are binge drinkers. For men, 63% are current drinkers and women, 48%.	Abstain, Drink (at least one drink in month), Heavy (more than two drinks per day), and Binge (5+ drinks on one occasion in past month). ACCRA price for beer, aggregated to state level.	Logistic and linear probability models, but does not account for non-drinkers. Models fitted with regional-fixed effects, state-level variables, and state-fixed effects	Price is significantly less than one for Binge for regional-fixed effects model, but not for state-fixed effects. Price is significantly less than one for Heavy for regional fixed-effects, but not for state fixed-effects model.
Nelson (2008), USA	National Survey on Drug Use and Health, aggregated to the state-level for 1999-2003 (N= 225). Age = 44 yrs. (est.). Drink prevalence for adults (ages 26+) is 51% and Binge prevalence is 20%.	Drink is estimated state-level prevalence (any alcohol use in past month). Binge is bingeing in past month (5+ drinks on a single occasion). State beer tax rate, CPI deflated.	Linear probability models for panel data. Variables include state-level poverty rate, unemployment, state – availability laws, tourism, & outlet density.	Beer taxes have significant negative effects in Drink regressions for adults with state-fixed effects, but are incorrectly signed when availability laws are included. Beer tax is insignificant in both Binge regressions for adults.

Rhoads (2010), USA	Behavioral Risk Factor Surveillance System, 1991-2004. (N = 1,446,891 for binge drinking prevalence & 199,077 for binge drinking number). Age = 45 yrs. About 52% of BRFSS sample are drinkers and 11% have binged.	Drink participation (at least drink); Drink Intensity (no. of drinks), Binge participation (at least once), & Binge Intensity (no. of times). ACCRA price data converted to a wt. ave. price per unit of ethanol. Sensitivity tests with beer price only.	Two-part model: probit and OLS for Drink and Drink Intensity. Two-part model for binge drinking: probit and OLS. Reports that alcohol price does not have a significant effect on decision to binge, but does affect Binge Intensity.	Reports full results for Drink model and Binge drink model for five age groups: age 18-20; age 21-24; age 25-39; age 40-64; & age 65+. For Binge participation, all price coefficients are insignificant (or positive), regardless of age. For Binge Intensity, price is significantly negative for ages 40-64 yrs. & ages 65+ yrs.
Shi (2011), China. See also Tian & Liu (2011) for comparable results.	Health and Nutrition Survey, 1993-2006 (N = 47,685 obs. for 18,266 individuals in 234 communities). Age = 45.1 yrs. 60.6% of males & 9.6% of females are drinkers. Ave. consumption is 22.6% beer, 3.5% wine, and 73.9% liquor.	Frequency of drinking in a week or month & Quantity of each beverage if the individual drinks. Converted to pure ethanol consumption in ml. per week. Ave. quantity for male drinkers is 249.2 ml. per week (8.4 oz.) of pure alcohol. Prices for local beer & liquor from community-level agencies (source not reported).	OLS, Tobit (males), logit (females), two-part model (probit-OLS), and quantile regressions. Variables include meals at home, health status, labor force status, & community environment.	For males, price is significant in OLS & one Tobit regression, but not in two-part regressions. Significant elasticities are small (-0.09, – 0.11). For females, price is significant in OLS & two-part regressions, but not in logit model. Significant elasticities are small (-0.05, – 0.07). Coefficients & standard errors not reported for quantile regressions, but elasticities are small at all drink levels (males, – 0.06, females, – 0.10).
Sloan *et al*. (1995), USA	Behavioral Risk Factor Surveillance System, 1984-1990, for 15% random sample for age > 18 (N = 49,199). Age = 45 yrs for entire sample; 40 yrs for drinkers, and 34 yrs for binge drinkers. Binge drinkers are 28% of sample.	Drink (any in past month), any Binge drink (5+ drinks on an occasion in past month); and No. of Binge episodes. ACCRA prices, weighted mean price for all three beverages, converted to an index relative to California.	Probit models for probability of Drink and Binge drink. OLS and Tobit models for No. of Binge episodes. Includes family income, minimum legal age, and 12 variables for enforcement of drink – driving laws.	Alcohol price is significant for probability of drinking, but not for probability of binge drinking (marginal effect is zero) or number of binge episodes in OLS model. Marginal effect is small in Tobit model. Price is significant for fraction of binge episodes that involved drink driving, but the marginal effect is small.
Stout *et al*. (2000), USA	Behavioral Risk Factor Surveillance System, 1984-1995, for 25% random sample for age > 21 for those who drink at all (N = 86,273). Age = 42 yrs. Heavy drinkers are 26% of sample.	Drink (any in past month) and Heavy (at least one heavy drinking episode of 5+ drinks on one occasion). ACCRA prices, converted to a state index using national weights.	Logit model for binary dependent variables. Results reported for odds ratio for Heavy drinking and for Heavy drinking and driving. Includes laws on drink driving, availability laws, other health behaviors, & religion. Robust std. errors by state.	Alcohol price is insignificant for Heavy drinking. In drinking and driving regressions, price is insignificant for both Drink and Heavy. Concludes the effects of price are insignificant for probability of heavy episodic drinking and drinking and driving among heavy drinkers.

Table A2. Empirical Review – Nine Studies on Alcohol Prices and Liver Cirrhosis Mortality

Study/Country	Time period for sample (N = obs.)	Definition of key terms, Measures used	Econometric model, Special variables incl.	Main findings
Bielinska-Kwapisz & Mielecka-Kubien (2011), Poland	National time-series data, 1959-2005 (N = 45). Alcohol consumption from official records; total ethanol in liters per capita (ages 15 and older).	Annual cirrhosis mortality rate (ages 20 and over). Real beverage price indexes and total alcohol price index.	All series are first differenced and tested for consistency with myopic and rational addiction models. Variables include lagged consumption, prices, income, & free market binary.	OLS regression for cirrhosis mortality is not significant overall, and the price term is statistically insignificant (t = 0.002). The consumption and mortality series follow each other closely, but the regression on stationary data performs poorly.
Cook & Tauchen (1982), USA	16-year panel of 30 license states, 1962-1977 (N = 480). Apparent consumption of spirits (gallons of ethanol per capita).	Annual cirrhosis mortality rate (ages 30 and over). Current and one-year lagged state liquor tax rate.	Two-step GLS model for mortality, conditional on state liquor taxes, income, & state and yr. fixed-effects. Hausman test for random – vs. fixed – effects.	Current tax rate is negative and insignificant (t = 1.76), but the lagged tax rate is insignificantly positive. The sum of the coefficients is significant, – 0.054 (t = 2.45). Empirical results identify the short – and long-run reductions in mortality.
Grossman (1993), USA	24-year panel of 51 states, 1961-1984 (N = 1224).	Annual cirrhosis mortality rate (ages 30 and over). Prices of leading brands of spirits, 1958-84.	Restricted 2SLS model for rational addiction, leading and lagging cirrhosis rate & prices.	Price is significant in first regression with income and demographics, but insignificant in a state fixed-effects model. First model yields substantial price elasticities.
Heien & Pompelli (1987), USA	9-year panel of 45 states, 1968-1977, but 1972 omitted (N = 405). Also reports selective results for Ontario, CN, but omits price.	Annual cirrhosis mortality rate (ages 44 and over). Spirits price index constructed from brand-specific prices, adjusted for state CPI.	Reduced-form logit model for log-odds of cirrhosis mortality. Variables for ethnic-racial groups, state controls, divorce rate, unemployment, & income.	Price index of spirits is statistically insignificant (t = 0.07). Unemployment rate has the greatest impact on cirrhosis death rates.
Nelson & Young (2001), 17 OECD countries	18-year panel, 1977-1994 (N = 306).	Annual mortality rate from liver cirrhosis (UN data). Real price of a liter of alcohol in 1990 US dollars.	Reduced-form logit and log-linear probability models, with population weights. Variables for ad bans, age, income, wine sentiment, & fixed effects.	Price index variable is significantly negative for cirrhosis mortality; variables for income, age, and wine sentiment are positive; and the unemployment rate and age > 65 are negative. Advertising bans are insignificant.

Ponicki and Gruenewald (2006), USA	28-year panel of 30 license states, 1971-1998 (N = 840).	Annual cirrhosis mortality rate (ages 15 and over), logged. Real tax rates for beer, wine, and spirits.	Random-effects regressions, with current and once lagged tax rates. Variables for income, age, health, etc.	Beer and wine taxes are always insignificant. Spirits tax is significant, but not in regressions that also include beer and wine taxes (t = 1.79 & 1.70).
Saffer (1991), 17 OECD countries	14-year panel, 1970-1983 (N = 238).	Annual cirrhosis mortality rate (UN data). Real price index for a liter of pure alcohol in US dollars.	Reduced-form logistic regressions, with population weights. Variables for ad bans, beer-wine sentiment, income, & time fixed-effects.	Price index is significantly negative for cirrhosis mortality. Beer-wine sentiment is significantly positive and income is insignificant. Advertising bans are insignificant.
Sloan *et al*. (1994), USA	7-year panel of 48 states, 1982-1988 (N = 336). Alcohol primary-cause fatalities in four areas: alcoholic cirrhosis, alcoholic liver damage, chronic liver disease and other cirrhosis, & other fatalities not specifically alcoholic.	Vital statistics data on mortality aggregated to the state level. Rates of death for population ages 25 to 64 years. ACCRA price index by state.	WLS regressions, with state population weights. Variables for income, urbanization, race, availability laws, & state and time fixed-effects. Lagged cirrhosis excluded in reported regressions.	In two regressions with fixed-effects, the alcohol price is insignificant. Excluding fixed-effects, the alcohol price is negative and significant (t = 2.95). The authors argue that the fixed-effects specification negates possible endogeneity due to unobserved state-level heterogeneity.
Wagenaar *et al*. (2009b), Alaska, USA	Quarterly death rates (ages 15 and over) for 29 years, 1976-2004 (N = 116). All deaths in which alcohol is the primary cause (liver, pancreatic, psychoses, abuse, dependence, etc.).	Vital statistics on annual deaths, converted to quarterly counts of death. Tax increases on all beverages in Alaska in August 1983 and October 2002.	ARIMA transfer-function model, beginning in 1976 and ending in 2004. Models fitted with step function for tax interventions. Dependent variables are frequency, rate, and log rate. Rate and log-rate regressions also include covariate for control states.	Alcohol-caused mortality was significantly reduced by the tax hike in 1983 in three of four regressions. The step function coefficients for 2002 are insignificant in four regressions. Test for a dissipation effect of the 1983 increase are sensitive to model specification. Analysis of the 2002 increase is incomplete due to limited post change data points.