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To address the critical need for understanding the efficacy of pricing policies in reducing excessive drinking, this dissertation examines beverage-specific price elasticities and the pass-through rates of alcohol excise taxes. Using a Poisson Pseudo Maximum Likelihood model, this dissertation reveals varying price elasticities across different alcohol consumption behaviors. Additionally, this dissertation uses the synthetic control procedure to show that a beer excise tax increase in Illinois in 2009 is substantially overshifted. This dissertation provides evidence that excise taxes can serve as an effective and potentially efficient control policy for excessive alcohol consumption. However, tax hikes should be concurrent across all alcoholic products to avoid substitution behaviors that could drive overall consumption in the wrong direction.

THE EFFECTS OF PRICING POLICIES AND EXCISE TAXES ON ALCOHOL CONSUMPTION

by

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____
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DEDICATION

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APPROVAL PAGE

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The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

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CHAPTER I: INTRODUCTION

Excessive alcohol consumption is costly to individuals, the healthcare system, and governmental agencies (Bouchery et al., 2011). Excessive drinking is estimated to cause one in eight deaths among 20 to 64 year-old US adults, and one in five deaths among 20 to 49 year-old US adults (Esser et al., 2022). Moreover, excessive drinking cost the U.S. $249 billion in 2010, with over 70% of the cost attributable to binge drinking—defined as 4 or more on one occasion for women or 5 or more per occasion for men (Sacks et al., 2015). Of the binge drinking-related cost, over 40% is paid by the government through expenses such as specialty care and criminal justice corrections (Sacks et al., 2015). Given the substantial costs that excessive drinking imposes on society, governments have searched for effective policies and interventions to reduce alcohol consumption.

Alcohol pricing policies are a common approach used by governments to reduce alcohol consumption (Blanchette et al., 2019). These policies include both taxes, such as excise or ad valorem taxes, and direct pricing interventions such as minimum unit prices. Many studies find these policies successful at curbing overall alcohol consumption and alcohol-related harms (Chisholm et al., 2018; Elder et al., 2010; Wagenaar et al., 2009). Despite this evidence, concerns have been raised that alcohol pricing policies are unfair to individuals who do not drink excessively (Naimi et al., 2018).

While there is some evidence that most of the cost of pricing policies is borne by excessive drinkers, there is almost no evidence on whether these policies are differentially effective at reducing excessive drinking. Specifically, it remains unclear if the reduction in overall consumption is a result of less quantity consumed per drinking occasion or a result of a drinking less often. Moreover, there is limited understanding of whether the reduction in total consumption is associated with a reduction in the number of bingeing episodes. Pricing policies aim not for complete abstinence in the population but rather a reduction in excessive drinking. Therefore, a significant literature gap exists in understanding how pricing policies affect specific drinking behaviors such as the quantity and frequency of typical consumption or the frequency of bingeing. Chapter Four in this dissertation aims to address these gaps.

In addition to understanding the effect of price on different consumption behaviors, it is imperative we also understand how tax policies interact with alcohol prices. A tax may be implemented with the intention of influencing alcohol consumption through price changes, but the key question remains: will a price change occur? If so, to what extent does the tax affect the real price? Furthermore, does tax affect the price differently depending on the type of alcoholic beverage? The existing literature on this subject is inconclusive. Chapter Five in this dissertation aims to bridge these gaps by examining tax pass-through rates for the two most popular beer products using the innovative synthetic control method.

This dissertation makes a substantial contribution to understanding the effectiveness of pricing and tax policies in reducing excessive alcohol consumption. It informs evidence-based policy decisions by addressing the difference in price elasticities across non-aggregate drinking outcomes and the interaction between tax and alcohol prices. By combining the results from Chapter Three and Chapter Four, this dissertation provides valuable insights that have important policy implications. The contribution of this dissertation is crucial for designing targeted interventions that can effectively reduce excessive drinking and associated costs, thereby promoting public health and quality of life.

This dissertation is structured as follows: Chapter Two reviews the importance of alcohol consumption research, the past literature on alcohol price elasticity, and the past literature on alcohol tax pass-through rates. Chapter Three discusses the data used in this dissertation. This is followed by the price elasticity chapter (Chapter Four) and the pass-through chapter (Chapter Five). Finally, Chapter Six concludes the dissertation.

CHAPTER II: BACKGROUND

As defined by the CDC (CDC, 2022), excessive alcohol use comprises two separate behaviors: binge drinking, defined as 4 or more drinks on an occasion for a woman or five or more drink on an occasion for men; and heavy drinking, defined as 8 or more drinks per week for women or 15 or more drinks per week for men. Other public health agencies use different terminology with slightly different definitions. For example, NIAAA (NIAAA, 2023) defines binge drinking using the same limits on the number of drinks but stipulates that they be consumed within "about 2 hours," and defines heavy drinking as more than 3 drinks per day or 7 drinks per week for women or 4 drinks per day or 14 drinks per week for men. One common element across most terms and definitions, however, is a differentiation between typical daily consumption behaviors and atypical episodes of heavier consumption. Thus, almost all public health agencies recognize that alcohol harms are fundamentally related to the core drinking behaviors of typical quantity, typical frequency, and the frequency of binge drinking.

Regardless of the exact definition or term, excessive drinking is associated with short-term and long-term harms, such as injuries, damages suffered from violence or crime, alcohol poisoning, the development of alcohol-use disorders, and the development of chronic diseases or mental health issues (CDC, 2022). These harms impact the drinker, the drinker's family and friends, businesses, and governmental institutions. Alcohol use is also a leading cause of preventable death in the United States (Murray, 2013), and excessive drinking is believed to be the third leading actual cause of death (Mokdad et al., 2004). By the late 2000s, the annual average number of alcohol attributable deaths was 87,798. Among working-age adults, excessive alcohol consumption accounted for 9.8% of total deaths and made up more than two-thirds of all alcohol attributable deaths (Stahre, 2014). Mortality related to excessive drinking includes death by one’s own alcohol consumption, such as alcohol poisoning or alcohol-attributable chronic diseases, as well as deaths by other peoples’ alcohol consumption, such as car accidents caused by drunk drivers.

Alcohol price and tax policies are a common approach for reducing consumption and related harms because they are feasible and cost-effective (Chisholm et al., 2018), and alcohol taxes have been the primary method for controlling alcohol consumption in the U.S. (Nelson et al., 2013). A systematic review on alcohol tax policy interventions finds that increased alcohol taxes decrease total consumption (Elder et al., 2010). Furthermore, in a 2010 Delphi panel, U.S alcohol policy experts identified alcohol excise tax as the most effective control policy for binge drinking and alcohol-impaired driving among the general population and the youth population (Nelson et al., 2013). Additionally, the World Health Organization considers alcohol tax one of the core interventions for population-based harmful alcohol use, along with policies that restrict marketing and retail availability. In addition to alcohol taxes that impact consumption by indirectly increasing the price of alcohol, minimum unit pricing policies are gaining popularity as a way to directly impact the price of alcohol (Ludbrook et al., 2012).

This dissertation focuses on the main pricing policy, specific excise tax, since this tax is still the primary control method for drinking. It bridges literature gaps by presenting critical insights for formulating precise interventions aimed at curbing excessive alcohol consumption, subsequently mitigating its economic burdens.

Alcohol taxes affect alcohol consumption by raising the price of alcohol and so the price elasticity of demand is a critical economic parameter in determining the overall effectiveness of these policies in reducing consumption. Almost all existing studies report negative price elasticities, which means a higher cost is associated with a lower demand. The magnitudes of the elasticities are quite consistent within each type of alcohol and across studies (Elder et al., 2010). Systematic reviews on alcohol price elasticities suggest that the median price elasticities of beer and wine are -0.50 and -0.64 respectively (Elder et al., 2010), and the mean price elasticities of beer and wine are -0.46 and -0.69 (Wagenaar et al., 2009). Results from meta-analyses of relevant research indicate an inverse relationship exists between tax/price and demand for beer or wine, despite a small number of studies reporting non-negative or insignificant results (Wagenaar et al., 2009).

Several studies also emphasize heavy drinking or binge drinking beyond general consumption. A systematic review concludes that all but one study (out of 10 total studies) find negative relationships between alcohol tax or price and heavy drinking. The average price elasticity for heavy drinking is -0.28, a smaller magnitude than the general consumption price elasticity (Wagenaar et al., 2009). Furthermore, Ayyagari et al. (2009) found evidence that people who are more responsive to alcohol price changes are typically the ones who consume less and are less likely to generate alcohol-related externalities. Heterogeneity across studies in the definition of heavy drinking may limit the generalizability of these results, however. For example, Chaloupka (1994) defines frequent/heavy drinking as “40 or more drinking occasions during the previous year”, “10 or more drinking occasions during the past 30 days”, or “at least one drinking occasion during the past two weeks by a youth”, which does not match the current definition of heavy drinking used by CDC (CDC, 2022) or NIAAA (NIAAA, 2023). Another issue in understanding how price and tax policies may affect alcohol consumption is possible substitution behaviors in which drinkers change the type of alcohol consumed (Gehrsitz et al., 2020). Despite these concerns, these studies suggest that price elasticities may vary by the level of alcohol consumption, and thus motivate research on specific drinking behaviors that underlie all definitions of excessive or heavy drinking.

The efficiency of tax policies as interventions for excessive drinking depends on consumers' response to price changes, while their effectiveness hinges on whether tax hikes lead to price increases. The extent to which a tax increase imposed on producers is passed on to consumers in the form of a higher price is called the tax pass-through rate. It measures the share of tax burden borne by customers. For example, if the tax is increased by $1 per unit and the price of the product subsequently increase by $0.60, the pass-through rate is 0.6, or 60%. If a pass-through rate is lower than 100%, the tax is considered “undershifted”, whereas if the pass-through rate is higher than 100%, the tax is considered “overshifted”. An exact 100% pass-through rate is referred as a one-to-one pass-through. The fourth chapter in this dissertation investigates the alcohol excise tax pass-through rate to determine the effectiveness of tax policies as drinking intervention.

Several studies have previously examined the pass-through rate for beer beverages in the United States. Since these studies either employ different identification strategies of product and price, or investigate different time periods and geographic areas, the results of pass-through rate studies span a wide range.

A study in 2015 by Hanson and Sullivan focuses on popular beer products (Bud Light and Miller Lite). Using store level price data collected through phone surveys, the authors find a negative pass-through rate of beer excise taxes. Interestingly, the results from the same study show sales taxes, unlike excise taxes, are passed on to the consumers (Hanson & Sullivan, 2015). Another study at the product level, conducted by Harding et al., finds that beer excise taxes have a small effect on beer prices. However, the pass-through rates are positively related to the store-to-lower-tax-state border distance (Harding et al., 2012).

One of the early studies of excise tax pass through rates in the U.S. is conducted by Kenkel in 2005. This study uses brand level prices collected from establishments through phone surveys. Contrary to the results of papers discussed above, Kenkel finds the beer excise tax is substantially overshifted for on-premises beer (pass through rates range from 1.96 to 2.50) and mostly overshifted for off-premises beer (pass through rates are 1.57 or above, except for one). It is important to note that his pass-through rates are calculated directly from the real price hike and do not rely on any statistical models (Kenkel, 2005).

Furthermore, a few studies on this topic find evidence suggesting that beer excise tax pass-through rates may be influenced by various factors, including economic downturns (recessions), the level of government implementing tax (federal or state), and changes in market structure (mergers), no matter the results suggesting under- or overshift of tax (Hunt et al., 2018; Young & Bielinska-Kwapisz, 2002; Shrestha & Markowitz, 2016)

Overall, previous literature has found mixed results on excise tax pass-through rates for beer. A systematic review on this subject by Nelson and Moran revel that over half of the discussed studies find evidence suggesting beer excise tax is fully shifted or overshifted, while the rest find evidence of undershifted excise tax or mixed results. The meta-analysis suggests the beer excise tax pass-through rates range from 0.56 to 3.84, or - 0.25 to 3.84 accounting for studies with negative results, with a median estimation of 1.28. Among the 24 studies on beer products included in the systematic review, 12 focus on the US market. Five of these papers find overshifted excise taxes, while four find undershifted excise taxes, with one reporting negative pass-through rates due to border effects. In addition, three studies report both under- and overshift of excise taxes (meaning the tax increase dollar amount can be passed on to prices of products under or over 100%), with variations attributed to beer types, governmental level, and policy trends (Nelson & Moran, 2019). The mixed findings based on various factors and identifying strategies suggest the need for more in-depth research on this topic.

This dissertation adds to the literature by providing new perspectives and incorporating innovative approaches in understanding the effectiveness and efficiency of pricing and tax policies in reducing excessive alcohol consumption. It accomplishes this by investigating how pricing policies impact non-aggregate level drinking outcomes and the interaction between tax increases and alcohol prices. These insights pave the way for more targeted strategies to combat excessive drinking.

CHAPTER III: DATA

To investigate price elasticities and tax pass-through rate, we require data on sub-level alcohol consumption behaviors, prices of different types of alcoholic products, and excise taxes. Additionally, time and location variables are needed to match data across different sources. Considering the relevance, coverage, completeness, and availability of data, this dissertation uses three main datasets: the Behavioral Risk Factor Surveillance System (BRFSS), the NielsenIQ Retail Scanner Data (Scanner), and the Alcohol Policy Information System (APIS).

3a. Behavioral Risk Factor Surveillance System

BRFSS is one of the world's largest behavioral health data sets and is collected by the CDC (CDC, 2023). BRFSS conducts telephone interviews annually with over 400,000 adults from all 50 states, the District of Columbia, and U.S. territories to collect data on respondents' health-related risky behaviors and relevant health information. We use data from base surveys conducted in 2006 through 2012. The years of BRFSS data used is restricted by lack of specific geographic information (county level) in BRFSS post 2012, as well as the availability of price data (see section 3b of this Chapter).

During the survey, the respondents are given explicit instructions on how to define a single drink and binge behavior. Then, the respondents are asked how many days during the past 30 days they had at least one alcoholic beverage, how many drinks they consumed on average per drinking day, and how many times a binge episode occurred. These answers are coded to be used as "frequency," "quantity," and "binge" respectively, in this dissertation. In addition, interviewers gather respondents' demographics such as age, gender, race, income, education, and marital status, which are used as control variables. The interview date is also recorded and used to merge with price data by week at the county level (using county FIPS code). This is especially beneficial since the survey only covers drinking behaviors during a 30-day span.

Table 1 presents the unweighted demographic characteristics of our analysis sample for the full sample and for drinkers and nondrinkers separately. Our analysis sample is approximately evenly split between people who drank in the past 30 days (drinkers) and those who did not (nondrinkers). The average age of our sample is about 54 years old, with drinkers being slightly younger than nondrinkers. The full sample is approximately two-thirds female, while the drinker sample is closer to half female. The drinker sample has just over half of respondents in the highest income category, compared to well under half of nondrinkers. The drinker sample is also more concentrated in the highest education category and the married category. Finally, the drinker sample has a higher proportion of White respondents while the nondrinker sample has a higher proportion of Black respondents.

Table 1: Unweighted demographic characteristics of analysis sample. BRFSS 2006-2012

	All	Drinkers	Nondrinkers
N	1,518,084	802,066	716,018
Mean age	54.39	52.27	56.77
(standard deviation)	(16.41)	(15.73)	(16.82)
Sex			
Male	39.45	45.48	32.69
Female	60.55	54.52	67.31
Annual income			

< $15,000	11.01	5.74	16.90
$15,000 - < $25,000	17.00	11.54	23.12
$25,000 to < $35,000	11.91	9.99	14.05
$35,000 to < $50,000	15.23	15.18	15.28
$50,000 or more	44.86	57.55	30.65
Education			
Did not graduate High School	8.15	4.07	12.71
Graduated High School	27.42	22.09	33.38
Attended College or Technical School	26.99	26.85	27.15
Graduated from College or Technical School	37.45	46.99	26.76

Marital status			
Married	55.14	59.45	50.31
Divorced	14.95	14.25	15.74
Widowed	12.29	8.32	16.74
Separated	2.19	1.82	2.62
Never married	12.8	13.01	12.57
A member of an unmarried couple	2.62	3.15	2.03
Race			
White	79.46	84.49	73.82
Black or African American	8.88	6.20	11.88
Asian	1.38	1.14	1.66
Native Hawaiian or Other Pacific Islander	0.16	0.14	0.17

American Indian, Alaska Native	1.10	0.74	1.51
Other	0.61	0.55	0.67
Don’t know or not sure	1.37	1.23	1.53
Multiracial but preferred race not asked	7.05	5.52	8.76

3b. Retail Scanner Data

The Retail Scanner Data is a NielsenIQ data set distributed by the Kilts Center at the University of Chicago. It contains information on weekly pricing and sales from over 90 participating retail chain stores across the United States, collected via point-of-sale systems. The products recorded in Scanner range from groceries to beauty aids. Additionally, the data also include product characteristics and store demographics.

A county-level sales-weighted average weekly price is created for each type of alcoholic beverage sold in stores based on the Scanner data price, sales entry, store information, and product description. Extreme values are limited by winsorizing 5 percentile at each end of the price entries. Prices for all beer types are standardized to be per 72 oz (a standard 6-pack of 12 oz beers). All wine prices are standardized to 750 ml (the size of a standard bottle of wine). The Scanner data include details product categories for both beer and wine (e.g., ales, porters, dessert wine, etc.). Given the limited sales of many of these categories, we focus on the two highest selling beer types (light beer and regular beer) and the two highest selling wine types (dry domestic and dry imported) to limit the loss of observations due to missing price data.

To study excise tax pass-through rates, the price is aggregated to the state level by taking the mean of county-level sale-weighted prices. Since the tax hike is a statewide policy change, a monthly state-level price for each type of alcoholic beverage is more suitable for a unified analysis. We focus our investigation on the two most popular types of beer, regular beer and light beer, and the prices are CPI adjusted at monthly level instead of yearly level to further eliminate the impact of inflation.

3c. Alcohol Policy Information System

The Alcohol Policy Information System (APIS) is database maintained by the National Institute of Alcohol Abuse and Alcoholism (NIAAA), a part of the National Institute of Health. It contains detailed information on a wide range of alcohol related policy topics, including pricing policies, tax, blood alcohol concentration, retail sales, transportation, and others. We utilize this platform to extract data on tax policies at the state level for this dissertation.

The Alcohol Policy Information System (APIS) provides data on alcohol sales regulations and excise taxes in each state. We gather specific excise tax rates for 5% alcohol (beer tax) and for 12% alcohol (wine tax) from APIS's "policy on a specific date" information tab. Due to policy differences, some states may be missing an excise tax rate but control the sales of alcoholic products. A dummy variable is created for observations under state control that have valid missing data on excise taxes. This affects about 5% of the sample on beer tax and about 22% on wine tax.

Additionally, information on alcohol policy changes, particularly any changes of beer excise tax over the study period, is gathered from APIS. A set of policy changes during the study period is identified through APIS's "changes over time" information tab. We choose to focus on a tax hike in Illinois in September 2009, although North Carolina and New York also increased excise taxes in 2009. According APIS, the states of North Carolina and New York experienced changes in September 2009 and May 2009, respectively, and are therefore excluded from the synthetic donor pool used in Chapter 5.

It is noteworthy that excise tax hikes are quite rare. In addition to the three mentioned above (Illinois, North Carolina, and New York in 2009), there are only two other changes to excise taxes during the study period: once in Connecticut in May 2011, and another in

Washington in December 2011. Excluding changes to ad valorem or other taxes, this means the U.S. experienced, on average, fewer than 0.8 excise tax changes per year from 2006 to 2012. Since excise taxes lack variation, it is more feasible to study the effects of prices and use the findings to inform expected changes in drinking outcomes associated with tax hikes.

3d. Combined data

Chapter 4 uses data from all three data sources while Chapter 5 combines the Retail Scanner Data with information from APIS. Table 2 shows the alcohol consumption, prices, and regulatory environment of the analytic sample used in Chapter 4. Drinkers consumed a total of approximately 21 drinks in the last 30 days. They drank on about 9 out of the last 30 days and consumed about 2 drinks per drinking day. They binge drank on about 1 day in the past 30 days. Table 2 also shows that the average county-level price among the drinker sample is slightly higher than the average price among the nondrinker sample across all products, while the beer and wine excise tax rates are slightly lower among the drinker sample.

Table 2: Unweighted descriptive statistics for alcohol consumption, prices, and regulatory environment variables. BRFSS, Scanner, and APIS 2006-2012

	All	Drinkers	Nondrinkers
N	1,518,084	802,066	716,018
Total alcohol drinks in past 30 days	11.09	21.00	0.00
(standard deviation)	(32.03)	(41.64)	

Frequency (days) of alcohol use in past 30 days	4.87	9.23	0.00
(standard deviation)	(8.06)	(9.10)	
Usual quantity per drinking day	1.11	2.11	0.00
(standard deviation)	(1.89)	(2.16)	
Days of binge drinking in past 30 days	0.50	0.95	0.00
(standard deviation)	(2.42)	(3.27)	
Price per 6-pack of light beer	4.10	4.12	4.08
(standard deviation)	(0.35)	(0.35)	(0.35)
Price per 6-pack of regular beer	4.60	4.64	4.56
(standard deviation)	(0.49)	(0.48)	(0.49)
Price per bottle of dry domestic wine	4.84	4.92	4.75

(standard deviation)	(0.98)	(0.98)	(0.97)
Price per bottle of dry imported wine	6.08	6.11	6.04
(standard deviation)	(0.79)	(0.77)	(0.81)
Beer excise tax	0.27	0.26	0.30
(standard deviation)	(0.24)	(0.22)	(0.25)
Wine excise tax	0.58	0.57	0.59
(standard deviation)	(0.59)	(0.58)	(0.60)
Beer control state			
No	93.81	93.26	94.42
Yes	6.19	6.74	5.58
Wine control state			
No	76.39	76.6	76.15
Yes	23.61	23.4	23.85

Table 3 lists the monthly nominal and real prices for beer and light beer in Illinois from August through December 2009. The raw data shows a small dip for all prices when the policy change occurs in September, followed by a larger jump in October that drives price beyond pre-treatment level.

Table 3: Monthly state-level prices for beer products, nominal and real (monthly CPI adjusted) in Illinois, from August to December 2009

	Beer Price	Beer Price (real)	Light Beer Price	Light Beer Price (real)
August 2009	4.25	3.91	3.81	3.50
September 2009	4.21	3.87	3.75	3.44
October 2009	4.34	3.98	3.90	3.58
November 2009	4.32	3.96	3.88	3.56
December 2009	4.36	4.01	3.89	3.57

CHAPTER IV: PRICE ELASTICITY

To understand how pricing policies affect specific drinking behaviors, we estimate price elasticity models separately for typical quantity, typical frequency, and the frequency of binge drinking using data on drinking behaviors from the Behavioral Risk Factor Surveillance System (BRFSS) and on beer and wine prices from the NeilsenIQ retail scanner data. We use Poisson pseudo-maximum likelihood models (PPML) to estimate hurdle models of how drinking outcomes respond to price changes.

We find that specific drinking behaviors respond differently to different product prices. For example, we find a negative relationship between the price of light beer and the decision to drink and possibly the number of binge drinking episodes in a month, while we find a positive relationship between the price of regular beer and these same behaviors. These results are consistent with individuals changing from one beverage to another when relative prices change, and are also consistent with individuals drinking for different reasons as relative prices change (e.g., social interactions versus intoxication).

This research is the first to examine the relationship between alcohol prices and excessive drinking by dividing total consumption into three drinking outcomes: frequency, quantity, and bingeing. Our results advance our understanding of price effects on alcohol consumption behaviors and provide improved policy suggestions aimed at reducing excessive alcohol consumption and its associated externalities. We also identify the possibility of substitution effects among different types of beer and wine, identifying new potentials for policy interventions.

4a. Theory

The Household Production Theory proposed by Gary Becker is offers a fresh perspective on allocations of time and money. It portrays a household as a collective agent making economic decisions that would maximize their utilities (Becker, 1965; Heckman, 2014). In this model, households engage in activities that bundle goods and time. The term "commodity" is used specifically to describe these bundles in this theory. The households both consume (input) goods and time and produce (output) commodities and are subject to traditional budget constraints (Heckman, 2014). Many more microeconomic theories and applications were derived from this analytical framework, including the model in this research.

We assign alcohol three different roles based on the three different types of activities it is associated with based on the Household Productivity Theory. We call these the "applications of alcohol." Each application of alcohol can be viewed as an input to the household production function along with certain goods and some amount of time. The outputs produced from each combination of inputs include a dining commodity, a social/leisure commodity, and an intoxication commodity. These three commodities are likely to cover the majority of activities involving alcohol but are not a complete representation of all possible commodities.

Note that while we do have some identification features regarding households in our data, we will not necessarily focus on households collectively in our research. Rather, the theoretical application of the Becker Model is that alcohol can be viewed as an input to different commodities.

Assuming the traditional budget constraints, a change of the cost of a commodity could induce a substitution between commodities. In the context of this research, that means the price increase in one type of alcohol would drive people away from the corresponding commodity and to the others. This would require the assumption that each alcoholic good is directly associated with one commodity and not any others. For example, to produce a dining commodity, one might just need a single beer to accompany dinner, similar to having a soda with a Big Mac meal. To produce a social commodity, one might consume a few glasses of wine to meet social expectations, but not necessarily too many that could appear as alcohol dependent to colleagues. Lastly, to produce an intoxication commodity, a substantial amount of alcohol would need to be consumed in a short period.

Whereas in reality, it is possible that all alcoholic goods are somewhat involved in all drinking outcomes and all drinking outcomes affect all commodities. We will start with a likely scenario and test different models with alternative identification assumptions:

$$freq(Alc) = F(beer, wine) \text{ .... } (4.1)$$

$$quant(Alc) = Q(beer, wine) \text{ .... } (4.2)$$

$$binge(Alc) = B(beer, wine) \text{ .... } (4.3)$$

Becker's household production model motivates our empirical model:

$$U = u(D, S, I), where\ u' > 0\ and\ u'' < 0 \text{ .... } (4.4)$$

$$D = D(beer, wine, F, Q, B) \text{ .... } (4.5)$$

$$S = S(beer, wine, F, Q, B) \text{ .... } (4.6)$$

$$I = I(beer, wine, F, Q, B) \text{ .... } (4.7)$$

The three commodities are each a function of alcohol consumption but also depend on how alcohol is consumed as captured by F, Q, and B. For example, "dining" may require regular drinking in small amounts, "social" may require less regular dinking in slightly higher amounts, and "intoxication" may require infrequent consumption of very high amounts. Differential demand for these commodities motivates different consumption behaviors.

Utility maximization (subject to budget constraints) yields the demand for each drinking behavior as a function of the prices of beer (P_B) and wine (P_W) and consumer characteristics (X):

$$F = F(P_B, P_W, X) \text{............} (4.8)$$

$$Q = Q(P_B, P_W, X) \text{............} (4.9)$$

$$B = B(P_B, P_W, X) \text{............} (4.10)$$

The price effects in these implied demand equations reflect two aspects of consumer choice. The first is the choice of which of the utility driving commodities to consume and so reflects parameters of the utility function. The second aspect is the production of the commodity and so reflects parameters from the household production functions. Thus, price elasticities from these demand equations will reflect a mixture of "utility" tradeoffs and "production" tradeoffs. Absent strong assumptions about the utility and production functions, these two aspects cannot be definitively separated.

4b. Method

Based on the demand equations derived in the previous section, we can write consumption as a function of prices and consumer characteristics:

$$D_{kit} = \alpha + \delta_1 T_{Bit} + \delta_2 T_{Wit} + \gamma_1 P_{Bit} + \gamma_2 P_{Wit} + X_{it}\beta + \epsilon_{it} \text{..................} (4.11)$$

In this model, D_{kit} represents drinking outcome k (frequency, quantity, or bingeing) for individual i at time (week) t, T_{Bit} and T_{Wit} represent the excise tax rates of beer and wine, P_{Bit} and P_{Wit} represent the price of beer and wine, and X_{it} is a vector of demographic characteristics. The parameters of interest are δ_1, δ_2, γ_1, and γ_2, which represent the effect of beer tax, wine tax, beer price, and wine price, respectively, on a given drinking behavior.

Because about half of the BRFSS sample did not consume alcohol in the past month, each of the drinking behavior variables have a large proportion of zeros. Furthermore, each behavior is a count, either of drinking occasions or of drinks. As a result, we use hurdle models (Cameron and Trivedi, 2009) in which we first model the likelihood of consuming any alcohol then model frequency, quantity, and bingeing conditional on consuming alcohol. A key identification assumption for this model is exogeneity. Alcohol tax and price may be endogenous if there exists county-level unobserved heterogeneity. To better identify the effect of price changes in the BRFSS data, which are repeated cross-sections rather than true longitudinal data, we include county-level fixed effects in all models. Given these fixed effects, our models identify the price elastic parameters using variation in prices over time within a county rather than using variation across counties.

We use Poisson Pseudo Maximum Likelihood (PPML) to estimate our primary models (Silva & Tenreyro, 2006; Correia et al., 2020). Poisson models are increasingly being used to model any non-negative outcome, including dichotomous outcomes (Talbot et al., 2023), because the only assumption required for consistency is the correct specification of the conditional mean of the outcome (Gourieroux, Monfort, and Trognon 1984). We use Stata version 17 to estimate PPML models with high dimensional fixed effects using the ppmlhdfe command (Correia et al., 2020). We do not use the log of price variables because we do not want to impose a constant elasticity assumption, although we find that results are qualitatively similar in constant elasticity models. We use the Stata margins command to obtain elasticities and their standard errors. All models use robust standard errors clustered at within year BRFSS survey strata to account for the multistage sampling design of the BRFSS, but results do not use BRFSS sampling weights since the weights vary primarily with geographic strata captured by the county fixed effects.

4c. Results

We present results from single-price models that enter each price separately and from multi-price models that include all four prices simultaneously. Because the single-price models include only one price at a time, they do not fully capture substitution across types of beer or wine in producing the utility driving commodities. Thus, they primarily capture utility considerations and so yield limited information on the production tradeoffs between types of alcoholic beverages in forming the underlying commodities. In contrast, the multi-price models allow for substitution across alcohol beverage types and so yield more information on the production elasticities. Neither type of model, however, completely isolates either utility or production elasticities. Nonetheless, the contrast across the two model specifications yields important insights. Because the decision to consume a commodity is equivalent to the decision to produce a commodity, our models of the decision to consume alcohol (i.e., the hurdle) primarily capture utility considerations rather than production considerations.

Single-Price Models

Table 4 presents estimated elasticities from models that enter each price separately, thus each cell in the table represents results from a different PPML model. All models include county fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey. We do not control for alcohol taxes or state alcohol control status because these variables are collinear with the county fixed effects. Column 1 presents models of total consumption (including zero consumption), column 2 presents drinker participation models, and columns 3 through 4 present models of frequency, quantity, and bingeing, respectively. Given the relatively small standard deviation of prices seen in table 2, we suspect that the inclusion of county fixed effects will result in a substantial loss of statistical power and so report significance at $p < .1$, $p < .05$, and $p < .01$.

Most elasticities are positive and insignificant, except for the price elasticities for regular beer which are positive and significant for most drinking outcomes. The estimated price elasticity of total consumption for regular beer is 0.272 and significant at $p <.01$. The participation elasticity is also positive, but not significant. Conditional on being a drinker, regular beer elasticates for frequency, quantity, and bingeing are also positive and significant at $p<.1$ or better. The elasticity of quantity with respect to the price of regular beer is nearly .1 and significant at $p<.05$, and the elasticity of bingeing with respect to the price of regular beer is nearly .2, although only marginally significant at $p<.1$. The results suggest that the increase in total consumption is driven primarily by increase in the quantity consumed and in binge drinking among drinkers.

These results clearly contradict the majority of alcohol price elasticity studies, but it is important to note that we are not modeling the sales of a specific good with respect to the price of that good. Rather, our results relate self-reported drinking behaviors to the average price of broad categories of alcohol beverages. As such, our results should not be interpreted as suggesting that regular beer drinkers increase their consumption when the price of beer increases. Rather, they suggest that the average drinker in a county – be they a light beer, regular beer, or wine drinker – increases their consumption when the price of beer increase in that county, without controlling for the price of other alcoholic beverages. Given the high degree of complementarity across, it is likely that we are capturing changes in drinking behaviors that results from substitution away from regular beer. In particular, our results suggest that the reason people consume alcohol (i.e., the commodity being produced) changes when the price of regular beer increases in such a way as to increase overall consumption of alcohol, presumably of cheaper alcohol products.

Table 4: Unweighted price elasticities from single price models

	(1)	(2)	(3)	(4)	(5)
	Total consumption	Drinker	Frequency	Quantity	Binge
Price per 6-pack	0.081	-0.049	0.047	0.053	0.028
of light beer	(0.080)	(0.031)	(0.042)	(0.040)	(0.124)
Price per 6-pack	0.272***	0.030	0.076*	0.094**	0.193*
of regular beer	(0.080)	(0.029)	(0.039)	(0.037)	(0.114)
Price per bottle	0.029	-0.007	0.027*	-0.001	0.047
of dry domestic wine	(0.036)	(0.012)	(0.014)	(0.014)	(0.047)
Price per bottle	0.019	0.008	-0.009	-0.006	-0.028
of dry imported wine	(0.048)	(0.016)	(0.022)	(0.021)	(0.070)
N	1,510,869	1,510,869	798,825	798,825	798,794

Standard errors in parentheses. All models include county fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey. * $p < .1$, ** $p < .05$, *** $p < .01$

Each model includes prices for only the main (single) alcoholic product type.

Multi-Price Models

To better understand substitution across beverage types, Table 5 presents results from models that include all prices. Thus, each column in Table 4 represents a single model that includes all prices simultaneously. As before, all models include county fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey.

The estimates in Table 5 support our conjecture that the positive price elasticities shown in Table 4 were attributable to substitution across beverage types. We find a negative and significant light beer price elasticity of total consumption of -0.222 when holding other prices constant. Although we find negative price elasticities for all drinking behaviors, the total consumption elasticity appears to be driven by the participation elasticity which is -0.140 and highly significant. The light beer price elasticity of frequency is near zero, suggesting that any reduction in total consumption among those that continue to drink is not driven by changes in the frequency of drinking. Although not significant, the price elasticity for bingeing is relatively large at -0.207, suggesting that reductions in consumption among drinkers is driven by a reduction in binge drinking episodes.

In contrast to the light beer price results, the price elasticities for regular beer remain positive in Table 5 and are more statistically significant compared to the results in Table 4. The regular beer price elasticity of total consumption is 0.421 ($p<.01$). As with light beer, this effect appears to be driven by an increase in participation (elasticity = 0.128; $p<.01$) and an increase in the quantity consumed (elasticity = 0.120; $p<.05$) and bingeing (elasticity = 0.329; $p<.05$).

When taken together, the results for light beer and regular beer suggest that people substitute among these alternatives when the relative price changes. Moreover, because these results are more influenced by production substitutions, they suggest that when the price of regular beer increase relative to the price of regular beer, people change the inputs to production of the desired commodities in such a way as to increase their total consumption. For example, our results are consistent with binge drinkers shifting away from regular beer and into light beer to produce intoxication when the relative price of regular beer increases. Because light beer has a lower alcohol content, this shift in inputs to the production of intoxication requires greater overall consumption.

Table 5: Unweighted price elasticities from multi price models

	(1) Total consumption	(2) Drinker	(3) Frequency	(4) Quantity	(5) Binge
Price per 6-pack	-0.222**	-0.140***	-0.006	-0.030	-0.207
of light beer	(0.110)	(0.041)	(0.055)	(0.055)	(0.163)
Price per 6-pack	0.421***	0.128***	0.076	0.120**	0.329**
of regular beer	(0.113)	(0.039)	(0.053)	(0.051)	(0.152)
Price per bottle	0.009	-0.015	0.030*	-0.005	0.047
of dry domestic wine	(0.039)	(0.012)	(0.016)	(0.014)	(0.051)
Price per bottle	-0.015	0.012	-0.034	-0.013	-0.072
of dry imported wine	(0.053)	(0.018)	(0.024)	(0.023)	(0.077)
N	1,510,869	1,510,869	798,825	798,825	798,794

Standard errors in parentheses. All models include county fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey. * $p < .1$, ** $p < .05$, *** $p < .01$

Each model includes prices for all the main (multi) alcoholic product type.

Sensitivity Test

A potential threat to the validity of our results is unobserved heterogeneity at the county level. If each county is a separate market, then higher demand counties will have higher prices. We see some evidence that this may be the case in Chapter Three (see Table 2) in that drinkers face a higher average price than nondrinkers across all alcohol beverages. Because all our models include county-level fixed effects, our results are identified by within county variation in price over time, which partially mitigates this concern. Nonetheless, time varying unobserved heterogeneity within county could bias our results. To further explore this concern, we estimate models that also include month fixed effects (in addition to county fixed effects) to capture possible seasonality in prices and consumption, and models that interact county and month to allow for county-specific seasonality.

Table 6 presents price elasticities from models that include month fixed effects as seasonality controls. The most obvious difference from the results in Table 5 is an overall loss of statistical significance, which is to be expected. Another difference is a slight attenuation of all elasticities, although not so much so that the results are qualitatively different. We see a similar pattern in Table 7, which included county-specific seasonality controls. One interpretation of these results is that our main results are sensitive to unobserved, time varying heterogeneity at the county level, and to some extent this is almost certainly true. But our sensitivity analyses also suggest that our primary finding of substitutions across beverage types and drinking behaviors is robust and that using fixed effects to control for unobserved heterogeneity likely absorbs much of the meaningful variation in prices that can be used to precisely identify such effects.

Table 6: Unweighted price elasticities from multi price models with seasonality controls

	(1) Total consumption	(2) Drinker	(3) Frequency	(4) Quantity	(5) Binge
Price per 6-pack	-0.120	-0.047	-0.004	-0.022	-0.141
of light beer	(0.110)	(0.043)	(0.056)	(0.056)	(0.162)
Price per 6-pack	0.255**	0.067*	0.007	0.099*	0.154
of regular beer	(0.114)	(0.040)	(0.053)	(0.051)	(0.157)
Price per bottle	0.012	-0.013	0.028*	-0.005	0.036
of dry domestic wine	(0.039)	(0.013)	(0.017)	(0.015)	(0.051)
Price per bottle	-0.046	-0.012	-0.039	-0.015	-0.095
of dry imported wine	(0.054)	(0.018)	(0.024)	(0.023)	(0.078)
N	1,510,869	1,510,869	798,825	798,825	798,794

Standard errors in parentheses. All models include county and month fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey. * $p < .1$, ** $p < .05$, *** $p < .01$

Each model includes prices for all the main (multi) alcoholic product type.

Table 7: Unweighted price elasticities from multi price models with county-specific seasonality controls

	(1)	(2)	(3)	(4)	(5)
	Total consumption	Drinker	Frequency	Quantity	Binge
Price per 6-pack	-0.081	-0.015	0.038	-0.029	-0.126
of light beer	(0.126)	(0.045)	(0.065)	(0.060)	(0.172)
Price per 6-pack	0.225*	0.030	-0.044	0.127**	0.125
of regular beer	(0.132)	(0.044)	(0.059)	(0.056)	(0.167)
Price per bottle	-0.010	-0.020	0.021	-0.004	0.026
of dry domestic wine	(0.039)	(0.013)	(0.017)	(0.014)	(0.050)
Price per bottle	-0.090	-0.022	-0.057**	-0.016	-0.127
of dry imported wine	(0.061)	(0.020)	(0.027)	(0.026)	(0.089)
N	1,509,377	1,509,377	798,071	798,071	791,388

Standard errors in parentheses. All models include county x month (interactive) fixed effects and control for age, sex, income, education, marital status, race, and year in which the respondent completed the survey.

* $p < .1$, ** $p < .05$, *** $p < .01$

Each model includes prices for all the main (multi) alcoholic product type

4d. Discussion

This chapter contributes to literature by making three important advances. First, we show that beverage-specific price elasticities differ among specific drinking behaviors. Our results are consistent with consumer substitution across beverage types to produce a specific drinking-related commodity such as social interaction or intoxication, but they also suggest that the price elasticity of demand for these underlying commodities also differs by beverage type. Our study is the first to conceptualize multiple drivers of the demand for alcoholic beverages in a way that lends itself to the estimation of differing price elasticities.

The second finding is that we validate alcohol pricing policies' effectiveness at directing people to consume alcohol within drinking guidelines. We find that the effects of prices on total alcohol consumption comes from decreases in the likelihood of drinking, the typical quantity consumed, and number of binge episodes. Specifically, the reduction on quantity has the potential to drive the alcohol intake down to CDC advised ranges, and the reduction on bingeing has economic benefits through mitigating costs associated with excessive alcohol consumption. Lastly, we find that prices can affect drinking behaviors through both drinking choice (extensive margin) and drinking intensity (intensive margin), setting the foundation for conditional estimation studies for future research.

Despite these contributions, there are several limitations to our work. The most evident practical limitation is the exclusion of liquor tax and prices. Distilled spirits are a special subject in alcohol consumption because its availability is much more restricted than beer or wine in many U.S. states. Therefore, we are not able to include the cost of liquor as a predicting factor without losing a substantial amount of observations. We face potential bias from unobserved liquor prices, as they should also be defined in the demand equations. Although we incorporate time fixed effects and county-time interactive terms (in sensitivity tests), these measures may not fully address this threat to validity. Nonetheless, we argue that our research still provides the most valuable and crucial information regarding the effect of alcohol price on bingeing, since over 70% of binge drinkers consume beer exclusively and predominantly (Naimi et al., 2007).

An econometric limitation of this research is that the cross-sectional data used is not suitable for us to observe individual heterogeneity. To account for people's long-term drinking habits, the study requires survey data that follows the same group of respondents over time. Future research on similar topics may consider longitudinal studies that collect panel data such as the National Longitudinal Survey of Youth (NLSY). Since we do not have the ability to differentiate between moderate drinkers and heavy drinkers for group-specific targeted research, the results are most applicable to non-exclusive policies that involve the general population, such as tax.

Additionally, there are two types of effects on extensive margins of bingeing, yet we have no feasible way to make the distinction. We cannot tell if a person's decision to not binge is because they do not consume alcohol in general or that their alcohol consumption does not involve binge behaviors. This may have undermined the results of the participation equation or the probability of a person making the choice to binge. If the majority of respondents choose to not binge because they are non-drinkers, then the true effect of price on binge drinking is greater than estimated and vice versa. While we could make inferences about individuals' past drinking habits from the frequency and quantity variables, we do not observe alcohol consumption beyond the past 30 days.

A less concerning but still noticeable drawback of this research is the use of BRFSS data. While using survey data renders our price elasticities more targeted (consumption instead of demand), it may raise questions about underreporting less socially desirable behaviors, or drinking in this case. We could expect some differences in magnitudes of price elasticities if this is believed to be true, but not in the directions of signs since we have no reason to suggest that respondents underreport their consumption at certain times more than at other times. It is more likely that random underreporting behaviors have little impact on the results.

Given these limitations, our specific point estimates results are clearly not sufficient to rely on for policy formation, but policy should never rely on the results of a single study. Our results clearly show, however, that there are complex interactions among beverage types and consumption behaviors that need to be considered when formulating alcohol pricing policies. For example, minimum unit pricing policies may not have desired effects if they change relative prices in such a way as to promote a substitution away from beverages that are used for less harmful drinking behaviors and into beverages that are more commonly used for excessive drinking.

Despite its limitations, this chapter provides new insights on the potentials of alcohol pricing policies to target excessive alcohol consumption behaviors. We advance the knowledge on alcohol price elasticities and cross-drink substitution effects and lay the foundation for future studies on non-aggregate drinking behaviors. We also accomplish the first step in identifying an effective strategy to target excessive drinking.

CHAPTER V: PASS-THROUGH RATE

The alcohol excise tax predominates other forms of alcohol taxation in the United States, which makes it critical that we understand its effect on alcohol consumption (Nelson et al., 2013). The previous chapter in this dissertation discusses the effect of alcohol pricing policies in terms of beverage-specific price elasticities for difference consumption behaviors. However, the price elasticity serves as the best informative tool on tax effects if the market is perfectly competitive. The impact of the excise tax is contingent on its being passed on to the prices of alcoholic products, subsequently affecting consumption. This calls for investigation of the pass-through rates of alcohol excise tax.

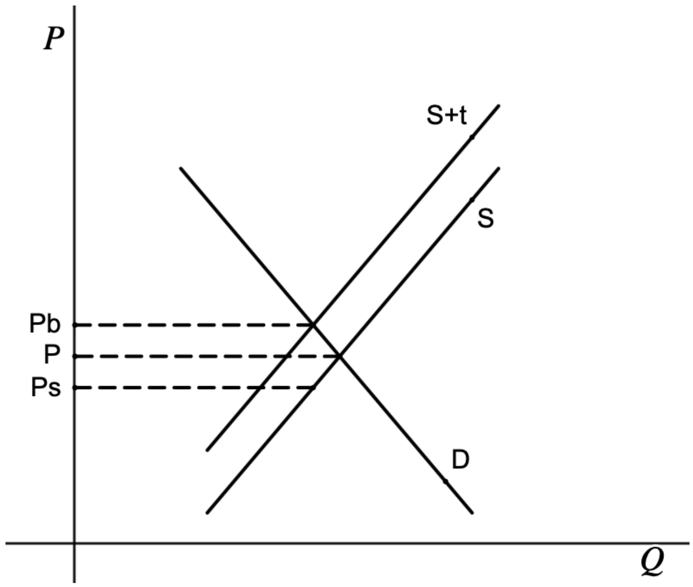
While previous literature has conducted some studies on the effect of alcohol taxation on price, the result of tax pass-through rate is inconclusive. There is a substantial range of pass-through rate estimations, with mixed conclusions of both undershift to overshift (Nelson & Moran, 2019). Additionally, there is insufficient knowledge about the tax pass-through rates for specific types of alcoholic beverages within the general categories. This chapter addresses the beer excise tax pass-through literature by separately examining the prices of regular beer ("beer") and light beer surrounding a tax hike occurred on September 1st, 2009, in Illinois. We use the synthetic control method to create a counterfactual Illinois as the control group. The synthetic-DiD results reveal overshifts from the tax hike for both beer and light beer products. The four-cent excise tax increase pass on to real beer prices at a pass-through rate of 5.64 and to real light beer prices at a pass-through rate of 2.08. Both rates are significantly higher than the median estimation from previous studies, with beer pass-through rate notably surpassing the highest estimation previously reported.

5a. Theory

In perfect competition, prices are determined by the supply and demand in the market. Firms are "price takers" and lack control over prices. The burden of an excise tax increase is shared by consumers and producers through price increases and revenue losses. Therefore, an excise tax hike that increases the cost of production or distribution will be passed onto market prices between 0% to 100% (as shown in Figure 1). In other words, the tax would be undershifted or one-to-one shifted. On the other hand, firms in an imperfect competition market (monopolist) have market power and an ability to influence prices. These firms face a downward-slopping demand curve and would not lose all customers if they increase their prices. Consequently, these firms may strategically adjust price more than the tax hike and still maintain profits on their products.

In the United States, the alcohol production and sales are extremely concentrated. For beer products, the top 2 companies make up more than 67% of the market share and the top 10 companies combined make up 88% of the market share (Jernigan & Ross, 2020). As a result, the alcohol industry is highly profitable, extensively marketed, and poses significant barriers for new firms to enter. The incredible market power derived from the oligopoly structure of the alcohol industry allows the firms to either absorb or amplify the effects of changes in production and distribution cost. The tax pass-through rate determines if a tax increase can be an effective intervention for excessive drinking (rate is > 0).

Figure 1: Tax in Perfect Competition



When tax t is imposed in the perfectly competitive market, the supply S is shifted upwards to S+t. Instead of the original equilibrium price P, the buyers now pay Pb to purchase the good and the sellers receive Ps from selling the good. The burden of tax (Pb-Ps, or t) is distributed between buyers and sellers, so the tax pass through rate is between 0 and 100%.

5b. Method

IL tax hike

The specific excise tax for 5% alcohol, commonly known as the beer excise tax, charges a fixed amount per alcohol volume without periodic inflation adjustments. Since the alcohol excise tax is imposed on manufacturers or importing distributors, we would observe increases in tax reflected on prices of alcoholic products. As mentioned in section 3c, three states experienced changes to excise tax in 2009 (five total during the study period, the other two are post-2009) according to APIS. In this dissertation, we chose to focus on the Illinois 2009 excise tax hike.

On September 1st, 2009, the beer excise tax increased to \$0.231 per gallon in the state of Illinois. Compared to a previous rate of \$0.185 per gallon, this is an increase of 4.6 cents per gallon (0.04 cents per ounce) or a 25% tax hike. For a 12-ounce beer, the new tax rate would drive the retail price up by 0.43 cents if the tax hike is 100% passed on. For a six-pack of beer (72 oz), the tax hike would translate to a 2.59 cents price increase assuming a 100% pass through rate. The average price for regular beer is $4.25 for a six-pack in August 2009, which means a 2.59-cent increase is roughly a 0.6% increase. The state of Illinois imposes general sales tax on alcoholic products but should not interact with excise tax. (235 Ill 2011; CDC, 2024; Wagenaar & Livingston, 2015)

The excise tax for 7% alcohol, increased to $1.39 per gallon on September 1st from a rate of $0.73 per gallon prior. The tax increase on wine products is 66 cents per gallon (0.7 cents per ounce), which is roughly a 90% increase. In terms of retail price, this tax increase would raise average wine price by 13 cents per 750 ml bottle.

The tax increase on September 1st, 2009 also involves a change for 40% alcohol, typically distilled spirits. A $4.05 per gallon (3 cents per ounce), or 90% tax hike increased the excise tax rate for liquor from $4.55 per gallon to $8.55 per gallon. According to the study by Wagenaar and Livingston (2015), this would raise a standard drink of distilled spirit's retail price by 4.8 cents.

The beer tax pass-through rate can theoretically be calculated without employing an analytical method. In a tax pass-through study focused on the Alaska market, Kenkel (2005) finds the real tax hike by calculating the difference between inflation-adjusted prices before and after an alcohol excise tax increase. Subsequently, he identifies the pass-through rate by dividing the real price hike by the amount of tax increase. A direct calculation of the pass-through rate using Kenkel's method shows the increase in price following the Illinois excise tax increase is equivalent to a pass-through rate of 2.65. However, a simple calculation does not distinguish between the effects of a price increase and effects of a tax increase. The price of alcoholic products may rise due to inflation or seasonal factors. Comparing the prices in Illinois with prices in a control unit surrounding a tax increase isolates the impact of tax increase from time-variant factors, allowing for a more accurate estimation of alcohol excise tax hike effects on alcohol prices.

Model

To isolate the causal effect of the IL tax increase on beer prices, we use a difference-in-differences (DiD) approach. The theoretical and statistical background of DiD is well established. We estimate a standard DiD model using the following form:

$$Y_{)\&} = \beta_{*} + \beta_{'} post + \beta_{(} IL + \beta_{+}(post * IL) + \mu_{)} + \upsilon_{)\&} \quad \text{..................}(5.1)$$

where $Y_{)\&}$ is the real price of product j at month t, $post$ is a dummy variable indicating if this price is observed after tax increase on September 1st, 2009, IL is a dummy variable indicating whether this unit is in Illinois, μ is a vector of state fixed effects, and υ is the unobserved error term. By estimating the interaction term between $post$ and IL, or β_{+}, we are able to determine the effect of the IL alcohol excise tax hike excluding the pre-tax-hike baseline differences between groups and accounting for changes over time.

Standard DiD

DiD method is an econometric technique used to estimate causal effects without the need to control for unobserved factors directly. Thus, it is a common estimating tool for treatment effects, such as the Illinois tax hike. However, the DiD estimation relies on the key assumption that the treated and control group have similar trajectories during the pre-intervention period, commonly known as the parallel trends assumption. Moreover, although the DiD method has a well-constructed theoretical foundation, it has been pointed out that the estimation results and statistical significance can be heavily influenced by DiD specification (Ryan et al., 2014).

Without specifying state's characteristics, it is natural to use neighboring states that experience no intervention in the same time frame as the control group. In this context, Illinois is bordered by Wisconsin, Indiana, Kentucky, Missouri, and Iowa, all of which did not see changes to alcohol excise tax during the study period. However, while the DiD estimation may be the conventional approach for investigating the impact of Illinois excise tax hike, our graphical results indicate potential issues that challenge the validity of traditional DiD. This means the results may be consist of both the effects of actual policy and of the pre-treatment difference between Illinois and its control states. Therefore, it is advisable to explore alternative models.

The Synthetic Control Method, initially introduced by (Abadie & Gardeazabal, 2003) compares the treated group with a constructed "synthetic control group" in the event where natural control group is absent or lacks similarities. This method is subsequently (Abadie et al., 2010) extended to and gained popularities among comparative case studies. The Synthetic Control Method measures the treatment effect without requiring the treated group to have an accompanying control group, relaxing the parallel trends assumption.

Another reason our data is particularly suitable for the Synthetic Control Method is that only a few units are exposed to policy changes while the majority are not. The Synthetic Control Method constructs a weighted average of the available control units so that the treated unit is compared to the combination of the control group instead of any single unit (Abadie et al., 2010). In the case of Illinois tax hike, all other states but New York and North Carolina may serve in the "donor pool" and contribute to the data-driven counterfactual outcome for Illinois if it remains untreated (Kreif et al., 2015). While not all "donor states" are eventually utilized in constructing the “synthetic Illinois”, this method proves beneficial by eliminating the selection of most appropriate controls and uncertainty of the parallel trends.

Synthetic Control DiD

The parallel trend assumption is critical to ensure the validity of DiD. This assumption implies that the difference between treated group and control group remain the same over the period prior to the treatment. In other words, the trend of the two groups should be parallel in the absence of treatment. A standard method to preliminarily test for the parallel trend assumption is through visual assessment.

Without investigating the state specific characteristics, it is a common strategy to use neighboring states as control group to minimize the impact of geographical, cultural, and economic factors. Figure 2 to 6 show the baseline comparison between Illinois beer prices and its neighboring states’ beer prices. It is evident that the Iowa, Indiana, Kentucky, and Wisconsin all fail the parallel trend assumption on some level. Figure 7 to 11 show the comparison between Illinois and its neighboring states on light beer prices. Similarly, Iowa, Indiana, and Kentucky also fail the parallel trend assumption in this category. Conversely, Wisconsin’s baseline (figure 10) is visually parallel to Illinois’s before the tax hike, with a distinct difference afterward.

For both baseline comparisons, Missouri (figure 6 and 11) seems to be the only state among Illinois’s neighbors to pass the visual assessment of parallel trend assumption. However, the trends of prices remain relatively parallel even after the policy change. This could occur if the tax hike has no impact on prices, indicating the tax pass through rate is equal to zero. However, the consistent parallel trend could also be attributed to spillover effects, suggesting the control group, in this case, Missouri, may also be influenced by the tax hike in Illinois. The latter explanation is more plausible, as we demonstrate by employing a synthetic state or the state of Michigan as our control group.

Figure 2: Beer Price Baseline IL vs. IA

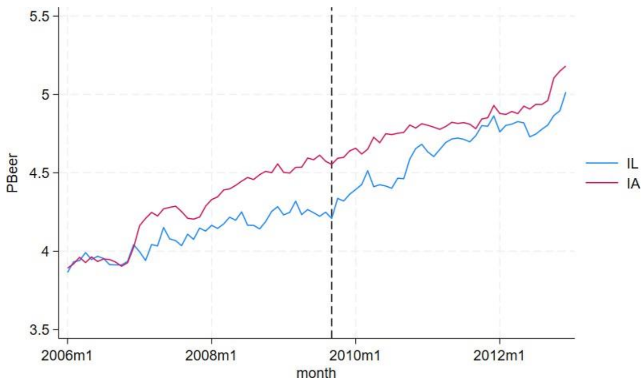


Figure 3: Beer Price Baseline IL vs. IN

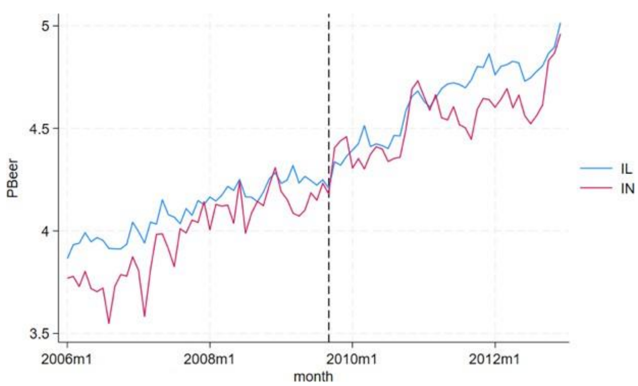


Figure 4: Beer Price Baseline IL vs. KY

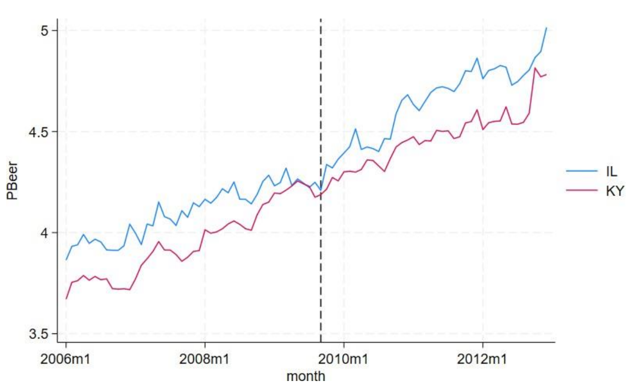


Figure 5: Beer Price Baseline IL vs. WI

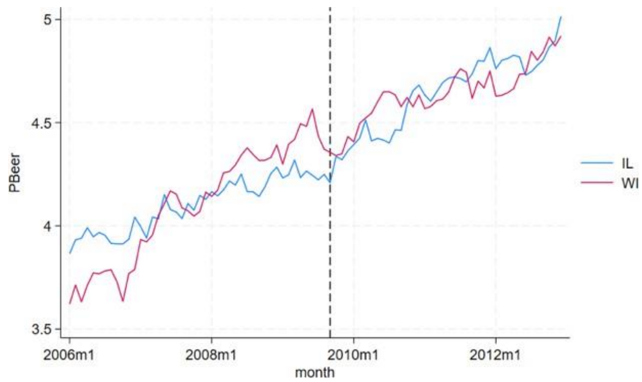


Figure 6: Beer Price Baseline IL vs. MO

Figure 7: Light Beer Price Baseline IL vs. IA

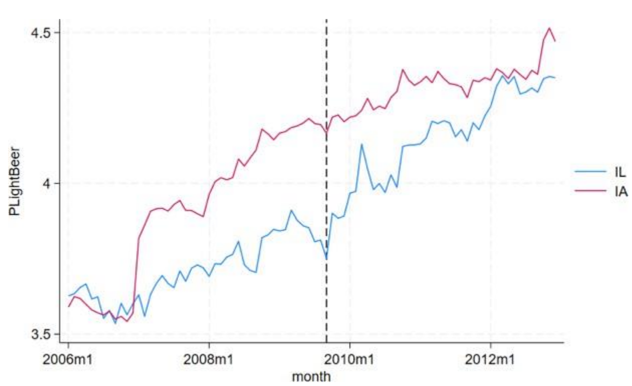


Figure 8: Light Beer Price Baseline IL vs. IN

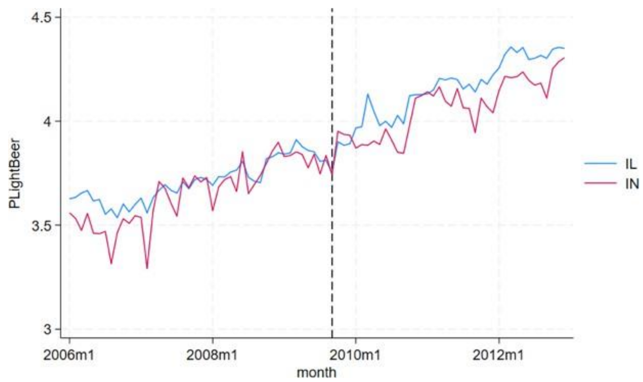


Figure 9: Light Beer Price Baseline IL vs. KY

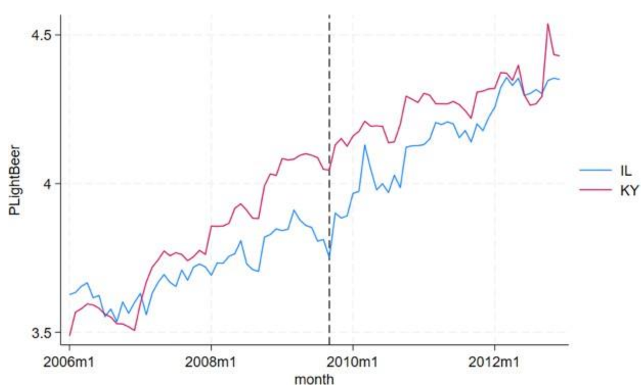


Figure 10: Light Beer Price Baseline IL vs. WI

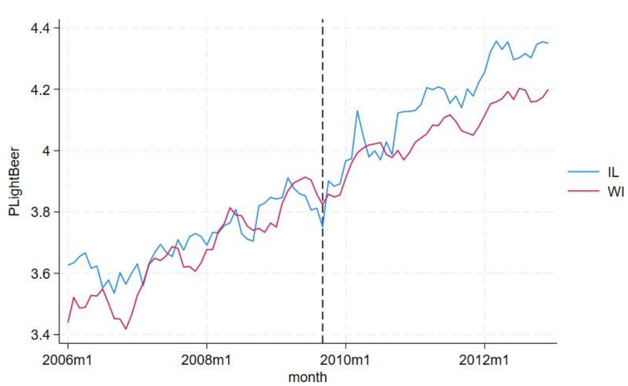
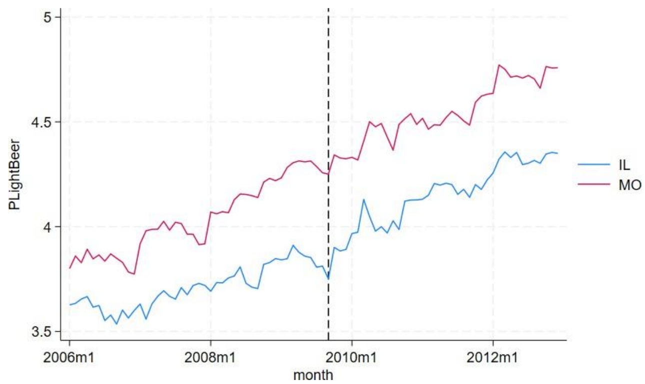


Figure 11: Light Beer Price Baseline IL vs. MO



The synthetic control method constructs a time-invariant weighted average of the donor group, where the weights are nonnegative and sum to one (Kreif et al., 2015; Doudchenko & Imbens, 2016). Using the Stata synth package, a synthetic Illinois is created from non-missing states with no changes in specific excise tax for beer during the study period (see appendix for synthetic Illinois composition). This synthetic unit demonstrates a counterfactual outcome for Illinois as if the policy change were absent. This construction relaxes the parallel trend (or rather, it creates the parallel trend between treated and control group) assumption for DiD analysis, as illustrated in figure 12 and 13. Additionally, the synthetic control method allows the omission of control selection, which mitigates the potential selection bias or interference from pre-treatment differences.

Alternatively, the synthetic control method also provides insights on which donors states are most suitable as the control group in standard DiD. The construction of synthetic Illinois heavily relies on Michigan, which contributes nearly 60% (the Appendix presents the synthetic control weights for all states). Figure 14 and 15 presents the baseline prices in Illinois and Michigan. It is evident that Michigan satisfies the parallel trend assumption. This result may provide additional guidance for future studies in control group selections. Nevertheless, both synthetic Illinois and Michigan exhibit differences in trajectories in price trends compared to real Illinois, suggesting the tax hike is passed on to the prices to some extent. Therefore, we dismiss the use of Missouri as a control group due to suspicions of spillover effects.

While this dataset is fitting for the synthetic control procedure due to its large pool of suitable donors, the validity of the synthetic Illinois could be compromised if we fail to exclude inappropriate control units, specifically those that experience unobserved alcohol related policy changes (outside of specific excise tax). However, this possibility is not too worrisome considering the synthetic control Illinois closely match the actual Illinois in the pre-treatment period.

Figure 12: Beer Price actual IL vs. synthetic IL

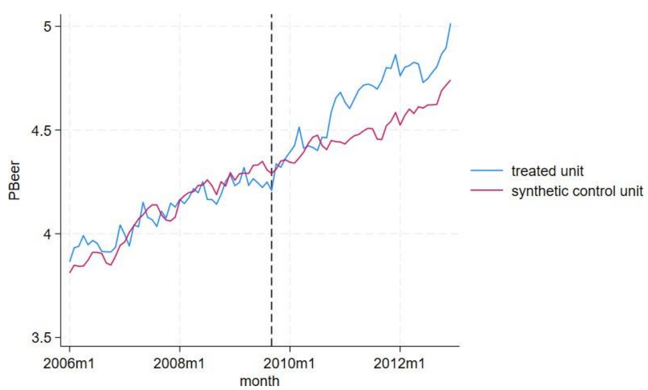


Figure 13: Light Beer Price actual IL vs. synthetic IL

Figure 14: Beer Price Baseline IL vs. MI

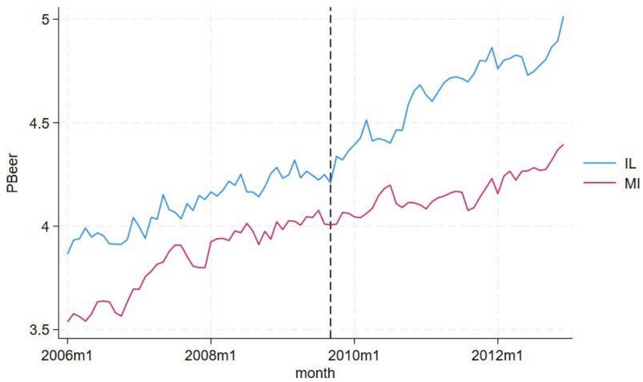
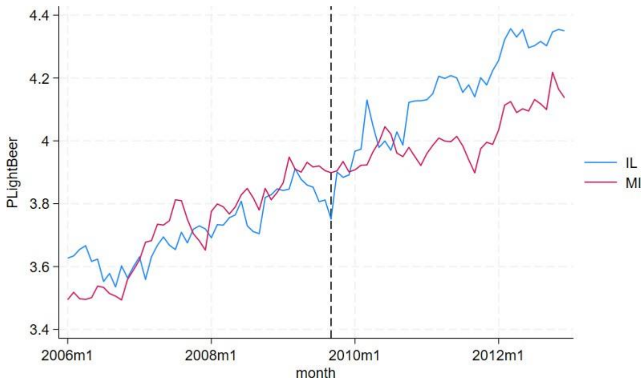


Figure 15: Light Beer Price Baseline IL vs. MI



5c. Results

The specific excise tax for 5% alcohol increased from $0.19 to $0.23 per gallon, which is equal to a four-cent ($0.04) increase per gallon, or a 2.25 cent ($0.0225) increase per six pack based on a standard beer drink (citation: standard drink). Table 8 presents the findings from DiD analysis using synthetic Illinois as the control group. This analysis yields a treatment effect of nearly 13 cents ($0.1268) on beer that is statistically significant. In other words, the tax hike causes the real price of beer to increase by 12.68 cents compared to the control group following the policy change. This result corresponds to a pass-through rate of 5.64, indicating a substantial overshift of tax. A treatment effect smaller in magnitude yet still statistically significant is also observed for light beer prices, as presented in Table 9. The results show a real price increase of 4.68 cents, corresponding to a pass-through rate of 2.08, is caused by the Illinois alcohol excise tax hike. In comparison to regular beer, light beer experiences a lesser impact from the tax hike. Nevertheless, the results still indicate an overshift at a relatively higher rate compared to past research. The results are not sensitive to controls for other alcoholic products.

Table 8: Beer Price Changes

	(1) Without control for other alcoholic products	(2) With control for other alcoholic products
IL	0.00138	0.00138
	(0.01310)	(0.01220)
post	-0.01522	-0.03279
	(0.02117)	(0.02195)
IL*post	0.12675***	0.12675***
	(0.01898)	(0.01767)
N	168	168

Standard errors in parentheses. All models include time fixed effect. * $p < .1$, ** $p < .05$, *** $p < .01$

Table 9: Light Beer Price Changes

	(3) Without control for other alcoholic products	(4) With control for other alcoholic products
IL	0.00429	0.00429

	(0.01322)	(0.01227)
post	0.06162***	0.03960*
	(0.02137)	(0.02206)
IL*post	0.04678**	0.04678***
	(0.01916)	(0.01778)
N	168	168

Standard errors in parentheses. All models include time fixed effect. * $p < .1$, ** $p < .05$, *** $p < .01$

5d. Discussion

A practical limitation of this chapter is the limited scope of the results since it is state specific. Additionally, a specific excise tax hike is a relatively uncommon event. As discussed in section 3c, there are only five tax hikes (no more than one per state) during the seven-year period examined. However, these limitations can be readily addressed. We can examine the other four (especially those occurring around the same time) tax hikes. By employing triple-difference studies, we can expand the scope of the results and enhance generalizability. We can also explore the difference between changes in prices and changes in affordability to better gauge the frequency and magnitude necessary for these tax hikes to effectively intervene in excessive drinking.

While controversy exists over the true impact of alcohol tax (Naimi et al., 2018; Kerr et al., 2013; Chaloupka, 2013), the primary objective of alcohol taxes remains focused on consumption intervention, whether through the discouragement of drinking or the support of alcohol control programs with tax-generated revenue (Chaloupka, 2013). However, alcohol tax is only an effective tool if a tax hike leads to price increases and subsequently results in decreases in consumption. This chapter contributes to the literature by validating excise tax hike as a tool for raising alcohol prices for beer products. In fact, our estimation indicates beer excise tax is substantially overshifted in the case of Illinois 2009 tax hike.

Previous literature suggests more than one-to-one pass-through rates are likely due to alcohol sellers' market power (Kenkel, 2005). This aligns with the varying outcomes observed within the beer category: the second contribution of this chapter is measuring the impact of the tax hike for different beverage types separately. Our results demonstrate a notable difference between the pass-through rates for regular beer and light beer, which corroborates similar findings in pass-through studies using more micro-level data. We also accomplish the second step in identifying an effective strategy to target excessive drinking.

Lastly, this chapter employs the synthetic control method that few studies have explored before in the field of tax pass-through research. This innovative approach lays the foundation for future work to further explore this topic when only suboptimal control units are available.

CHAPTER VI: CONCLUSION

Given the substantial costs associated with excessive drinking and taxation being the primary intervention method, there is a pressing need to understand the effectiveness of pricing (tax) policies in addressing excessive alcohol consumption. The goal of this dissertation is to provide empirical evidence and insights to bridge this critical gap in research.

Chapter 3 studies the price elasticities for non-aggregate level alcohol consumption behaviors using a PPML model. Holding all other prices constant, light beer has a negative effect (-0.222) on total consumption, driven by participation elasticity. The light beer price elasticity of frequency is near zero, and while not significant, the light beer price elasticity for bingeing is relatively large at -0.207. Regular beer has a positive and significant elasticity, driven by a positive participation elasticity (0.128), a positive quantity elasticity (0.120), and a positive bingeing elasticity (0.329).

Chapter 3 offers evidence that beverage-specific price elasticities vary across typical frequency, typical quantity, and number of binge episodes of alcohol consumption. The results also indicate that pricing policies are effective in steering individuals towards consuming alcohol within drinking guidelines. Furthermore, it lays the foundation for future research by demonstrating that price can impact both extensive and intensive margins of alcohol consumption.

There are two main limitations in this chapter: the exclusion of liquor prices and unobserved heterogeneity. While these are partially addressed by incorporating county and time fixed effects, exploring alternative approaches in the future research remains necessary.

Chapter 4 in this dissertation studies the extent an alcohol excise tax hike is pass on to the prices of beer products using a synthetic control DiD. The pass-through rate for regular beer products is 5.64 and the pass-through rate for light beer products is 2.08, both suggesting substantial overshift of tax.

This chapter provides evidence that beer excise tax is not only an effective tool at raising beer prices but may also be excessively efficient (and potentially causing market failure). The results also show the pass-thru rates differ across types of beer beverages, suggesting a role of market power. The primary limitation in this chapter is its informativeness, which calls for repeated examination of similar tax hikes and cross-comparison.

This dissertation makes significant contribution to the literature by offering fresh perspectives and employing innovative approaches to examine how pricing and tax policies can reduce excessive alcohol consumption. Building on the findings presented in this dissertation, we continue to advocate for pricing policies, particularly specific excise tax hikes, as the principal method for excessive alcohol consumption intervention, provided that changes across all alcoholic products are implemented concurrently.

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APPENDIX A: SYNTHETIC ILLINOIS COMPOSITION

State	Weight
ALABAMA	.013
ARIZONA	.009
ARKANSAS	.014
CALIFORNIA	.008
COLORADO	.005
CONNECTICUT	.005
DELAWARE	.012
DISTRICT OF COLUMBIA	.004
FLORIDA	.011
GEORGIA	.012
IDAHO	.012
INDIANA	.014
IOWA	.014
KENTUCKY	.015
LOUISIANA	.011
MAINE	.013
MARYLAND	.01
MASSACHUSETTS	.006
MICHIGAN	.586

MINNESOTA	.013
MISSISSIPPI	.008
MISSOURI	.013
MONTANA	.009
NEBRASKA	.013
NEVADA	.01
NEW HAMPSHIRE	.013
NEW JERSEY	.005
NEW MEXICO	.008
NORTH DAKOTA	.009
OHIO	.014
OREGON	.012
SOUTH CAROLINA	.014
SOUTH DAKOTA	.012
TEXAS	.007
VERMONT	.01
VIRGINIA	.014
WASHINGTON	.009
WEST VIRGINIA	.014
WISCONSIN	.014
WYOMING	.005

Synthetic Illinois (Light Beer) Composition:

ALABAMA	.01
ARIZONA	.007
ARKANSAS	.012
CALIFORNIA	.011
COLORADO	.004
CONNECTICUT	.004
DELAWARE	.684
DISTRICT OF COLUMBIA	.004
FLORIDA	.007
GEORGIA	.008
IDAHO	.012
INDIANA	0
IOWA	.012
KENTUCKY	.011
LOUISIANA	.007
MAINE	.01
MARYLAND	.009
MASSACHUSETTS	.005
MICHIGAN	.008
MINNESOTA	.012
MISSISSIPPI	.007
MISSOURI	.011

MONTANA	.007
NEBRASKA	.012
NEVADA	.009
NEW HAMPSHIRE	.011
NEW JERSEY	.005
NEW MEXICO	.005
NORTH DAKOTA	.004
OHIO	.011
OREGON	.01
SOUTH CAROLINA	.011
SOUTH DAKOTA	.01
TEXAS	.006
VERMONT	.007
VIRGINIA	.012
WASHINGTON	.008
WEST VIRGINIA	.011
WISCONSIN	.002
WYOMING	.003