One Markup to Rule Them All: Taxation by Liquor Pricing Regulation *

Eugenio J. Miravete† Katja Seim‡ Jeff Thurk§

July 16, 2017

Abstract

Government often chooses simple rules to regulate industry even when firms and consumers are heterogenous. We evaluate the implications of this practice in the context of alcohol pricing where the regulator uses a single-markup rule which does not vary across products. We estimate an equilibrium model of wholesale pricing and retail demand for horizontally differentiated spirits which allows for heterogeneity in consumer preferences across observable demographics. On aggregate, the single-markup rule decreases consumer welfare by $22.12 million, or 3.6% of the average drinking-age resident's liquor expenditure. It also benefits small distilleries and acts as a progressive tax that overprices the spirits favored by non-minority, older, educated, and wealthy consumers. We show beneficiaries are aligned politically so simple policy could potentially be used to curry favor.

Keywords: Taxation by regulation, Ramsey pricing, uniform rates, price discrimination, regulatory capture, externalities.

JEL Codes: D42, D63, L43, L66

---

* We thank Thomas Krantz at the Pennsylvania Liquor Control Board as well as Jerome Janicki and Mike Ehtesham at the National Alcohol Beverage Control Association for providing us with access to the data. We are grateful for comments and suggestions received at several seminar and conference presentations, and in particular to Jeff Campbell, Kenneth Hendricks, Louis Kaplow, and Joel Waldfogel. This research was supported in part by the Notre Dame Center for Research Computing. We are solely responsible for any remaining errors.

† The University of Texas at Austin, Department of Economics, 2225 Speedway Stop 3100, Austin, Texas 78712-0301; Centre for Competition Policy/UEA; and CEPR, London, UK. Phone: 512-232-1718. Fax: 512-471-3510. E–mail: *miravete@eco.utexas.edu*; http://www.eugeniomiravete.com

‡ Wharton School, University of Pennsylvania, Philadelphia, PA 19104-6372; and NBER. E–mail: *kseim@wharton.upenn.edu*; https://bepp.wharton.upenn.edu/profile/712/

§ University of Notre Dame, Department of Economics, Notre Dame, IN 46556. E–mail: *jthurk@nd.edu*; http://www.nd.edu/jthurk/

"The paramount role traditionally assigned by economists to government regulation was to correct the failures of the private market (...), but in fact the premier role of modern regulation is to redistribute income."

George J. Stigler: Preface to *Chicago Studies in Political Economy*

1 Introduction

Policymaking when agents have heterogeneous preferences over outcomes has been widely studied in the context of theoretical agency models applied to regulatory design, e.g., Laffont and Tirole (1993). Often however, practical policy interventions fail to follow the intricate nonlinear optimal contract design needed to account for moral hazard and adverse selection and, instead, simple policy rules prevail. For instance, in the classic work on regulation, Kahn (1970, §7) enumerates several technological and administrative limitations that in practice impede the implementation of efficient public utility pricing in many industries. But Kahn recognizes that political objectives are also at play in the choice of pricing rules, being rationalized on distributional grounds, and frequently justified on the basis of some induced externalities from which society benefits as a whole.

We study the use of simple policy in the regulation of alcohol in Pennsylvania where the Pennsylvania Liquor Control Board (*PLCB*) operates all retail stores and is legally-mandated to apply the same markup formula to all products regardless of differences in consumer demand or upstream market power. Our analysis combines sales data of 312 spirit products sold in 454 markets operated by the *PLCB* in 2003 and 2004 with local market demographics to estimate a random coefficient discrete choice model of demand for horizontally differentiated spirits based on Berry, Levinsohn and Pakes (1995), *BLP* hereafter, where we allow for, but do not impose, market power among upstream firms.[1] Our setting is unique in that the pricing rule is fixed so we need not assume an objective for the *PLCB* when estimating demand. The regulation also eases concerns over price endogeneity resulting from the pricing behavior of the upstream firms.

[1] The *PLCB* sells both wine and spirits but we focus on the latter as spirits represent the most significant category both in terms of tax revenue and ethanol content. U.S. sales of spirits have also been growing fast at 13.3% between 2007 and 2012, compared to 9% for wine and −4.3% for beer, e.g., see *2012 Beverage Information Group Handbook Advance* available at `http://beverage-handbook-store.myshopify.com/`.

A further advantage of our data is that we effectively observe an entire industry. This provides an opportunity to explore not only how simple regulation impacts welfare among heterogenous consumers but also how it impacts multi-product upstream firms which operate diverse product portfolios. Given our estimates of downstream consumer demand, we estimate the upstream marginal cost of each product assuming a non-cooperative, horizontally differentiated Bertrand-Nash equilibrium among upstream distillers.

We measure the implications of the single pricing rule by comparing the observed equilibrium to alternative Stackelberg equilibria in which the *PLCB* chooses a markup policy given the profit-maximizing behavior of upstream firms and utility-maximizing responses of downstream consumers. Since imperfect competition in the upstream market enables these firms to impact the equilibrium outcome in the event of a policy change, our counterfactual analysis allows upstream distillers to re-optimize their wholesale pricing decisions following any change to the *PLCB*'s markup policy. Similarly, the regulator is assumed to design its markup policy correctly anticipating the optimal reaction of upstream firms. In other words, we account for both, the *mechanical effect* and *behavioral response* to a change in policy (Saez, 2001) although considering a non-competitive environment that is commonly overlooked in the optimal taxation literature.[2]

We first evaluate whether current policy is effective at generating tax revenue for the state's general fund. We show that the current 30% markup rule captures 99.6% of potential tax revenues attainable with a single-markup policy. As the *PLCB* was initially created in 1933 after the 21st Amendment repealed Prohibition to, in the words of then Governor Gifford Pinchot, *"discourage the purchase of alcoholic beverages by making it as inconvenient and expensive as possible"*, this result is remarkable in that it provides evidence that, conditional on employing a single markup, current policy leaves little money on the table.

In a famous paper, Posner (1971) referred to the use of *uniform rates* to highlight the so-called *taxation by regulation* effect. In our context, the taxation by regulation effect of a single-markup rule is its induced income redistribution through cross-subsidization of spirit prices. The *PLCB*'s 30% pricing rule could therefore maximize tax revenue collection only in the unlikely event that demand elasticities of the hundreds of products it sells were

[2] The computational re-optimization of distillers wholesale pricing following a change in markup policy amounts to evaluating the pass-through effect of a tax in non-competitive model of horizontally differentiated products, an empirical extension of the work of Weyl and Fabinger (2013).

identical across all local Pennsylvania markets at the current retail prices. We show that this uniformity does not exist in our data and document the existence of important preference heterogeneity across demographic traits as well as large differences in market power among upstream firms.[3]

We compare the Stackelberg equilibria generated by the single markup to one in which the *PLCB* chooses 312 product-specific statewide markups which maximize tax revenue. Our results indicate that current pricing policy achieves 91.2% of the potential tax revenue ($255.7 out of $280.4 million). As this alternative policy generates prices that are the solution to the optimal multi-product monopoly problem reflecting the estimated own and cross price elasticities of consumers as well as the upstream responses of firms, our results indicate that ignoring this heterogeneity not only leaves significant tax revenue on the table but also decreases consumer surplus $9.47 million – equivalent to 1.5% (or $1.10) of liquor expenditure for the average drinking-age resident. In comparison to the *subsidy-free Ramsey policy* – the vector of 312 product markups which maximize aggregate consumer surplus subject to the externality-adjusted government balanced budget constraint – the effect on consumers is more severe as the average consumer's surplus falls $11.07, or 15.44% of her liquor expenditure.[4]

Finally, we measure the implicit redistribution of the single-markup policy – Posner's *taxation-by-regulation*. The impact on upstream distillers varies depending on their product portfolio, market power, and the demand elasticities of the spirits they sell. We find that the current single-markup policy transfers profits from large to small firms. This is a remarkable result because the largest beneficiary is Jacquin, a small firm based in Philadelphia. This evidence fits the narrative of Jordan's *Producer Protection* argument for regulation.[5] For consumers the current single-markup policy amounts to a progressive tax that overprices the spirits favored by non-minority, older, educated, and higher income consumers who are also less sensitive to changes in price. Although only 16% of Pennsylvania residents benefit

[3] The *PLCB*'s single-markup rule amounts to a uniform ad valorem tax across all alcoholic beverages. Atkinson and Stiglitz (1972) first showed that the same level of income redistribution could be achieved by some labor income taxation or by a carefully designed set of commodity tax rates. Dasgupta and Stiglitz (1971, 4.3) make explicit the conditions on preferences, demand elasticities, and labor supply that ensure a single-markup rule to characterize the optimal pricing solution. Our paper can thus also be viewed as a first empirical analysis of the redistributive effects of uniform commodity taxation.

[4] Our *subsidy-free Ramsey* policy is a modification of Ramsey (1927) to account for the existence of health externalities related to alcohol consumption.

[5] See Jordan (1972). Along the same line of reasoning, Pashigian (1984) illustrates how compliance with environmental standards harm smaller generating plants more than large ones.

from the current policy, we show these beneficiaries live in rural areas, highly dense urban neighborhoods and areas with a high concentration of democratic voters. Thus, it could be that the persistence of the single-markup rule since the *PLCB*'s inception in 1933 is due to the fact that these consumers constitute an important interest group which is both geographically and politically aligned. If true, the *PLCB*'s single-markup rule would be best described as a useful tool for legislators to galvanize political support.[6]

Posner's *taxation-by-regulation* has been acknowledged in the theoretical literature for decades though there exist few empirical studies. To the best of our knowledge, ours is the first to measure *taxation-by-regulation* using an equilibrium model which not only addresses the best responses of consumers to changes in government policy but also incorporates optimal responses of suppliers.[7] Moreover, we identify common traits among winners and losers of this regulation and find that current markup regulation generates significant distortions which favor particular constituencies: a small local distiller and certain consumer groups.[8] Whether or not these groups were explicitly targeted by state legislature in designing the single-markup is difficult to say. Our point is that regardless of whether it was the intent of the state government or not, these groups benefited from the retail price distortions generated by the single-markup policy.

The paper is organized as follows. Section 2 presents our data, documents heterogeneous consumption patterns across demographic groups, and discusses the rules currently governing *PLCB*'s pricing and its interaction with the upstream market firms, the distillers. Section 3 presents an equilibrium discrete choice model of demand of horizontally differentiated spirits that incorporates the features of the current pricing regulations while accounting for competition in the upstream distillery market. Section 4 reports our estimates

---

[6] See Stigler (1971) and Peltzman (1976, §1). Laffont and Tirole (1993, §11.7) present a formal analysis of a political economy model of cross-subsidization as the optimal response to the goals of interest groups representing the heterogeneous preferences of different consumers.

[7] For instance, Linneman (1980, §5) provides with back of the envelope estimates of profit redistribution (in favor of large manufacturers) and uneven price increases (hurting low income families) after the 1973 Mattress Flammability Standard. Finkelstein, Poterba and Rothschild (2009) make use of numerical simulations to evaluate the allocation efficiencies and redistribution effects of not allowing for gender pricing (different mortality risk) among participants of the U.K. annuity market. In another related paper, Hausman (1998) does not address redistribution effects and focuses only on the allocation inefficiency of taxing interstate telephone service to subsidize internet access for schools and libraries. Similarly, we are not aware of empirical studies that address the redistribution effects induced by the use of uniform commodity taxes.

[8] Seim and Waldfogel (2013, §1.C) also show that the unionized store clerks which operate the state-run network of liquor stores are overpaid (both in wages and benefits) relative to private retailing.

and documents significant heterogeneity of preferences for spirits, drawing into question the effectiveness of a single-markup as a tool to maximize *PLCB*'s tax revenues. In Section 5 we show the current 30% markup rule acts as a progressive tax but also forfeits significant tax revenue well in excess of health cost reductions associated to the induced consumption reduction. We further show that winners have common interests that could align them into an effective interest group capable of capturing their legislators. We summarize our results and conclude in Section 6. Additional information on data construction, detailed descriptive statistics, estimation algorithm, robustness, and detailed results are included in the Appendices.

2 The Pennsylvania Market for Spirits

In this section, we first briefly summarize Pennsylvania's current regulation of alcoholic beverages that informs our theoretical modeling and econometric identification. We then describe the data we obtained from the *PLCB* and other sources on sales, prices, and characteristics of products sold by the *PLCB* as well as the upstream distillery market. Finally, we document the heterogeneity of consumer preferences for different types of spirits and quantity of alcohol consumed that is behind the differentiated incidence of the current 30% taxation rule.[9]

2.1 The Mechanics of the Pricing Regulation

Pennsylvania adheres to the common three-tier distribution system adopted by most states after the repeal of Prohibition: distillers sell their products to wholesale distributors who then sell to retailers, and only retailers may sell to consumers. Unlike most states, the *PLCB* vertically integrates and monopolizes wholesale and retail distribution of wine and spirits.[10]

The Pennsylvania State Legislature provides guidance on the prices the *PLCB* charges both across products and across stores, e.g., Pennsylvania Liquor Code (47 P.S. §1-101 *et seq.*) and the Pennsylvania Code Title 40. Since its inception in 1933, the *PLCB* has

[9] Miravete, Seim and Thurk (2017) provide additional detail on the market environment, in particular pertaining to interaction along the supply chain.

[10] This is certainly true since 1933 to 2016 when Pennsylvania Act 39 allowed for the controlled entry of private retailers into wine sales, although the *PLCB* continues to serve as their supplier. Pennsylvania also has a private system for the sale of beer, allowing the controlled entry of private retailers.

regulated alcohol, particularly spirits and wines, using a simple pricing rule that transforms upstream prices to retail prices. This rule has been modified only a couple times. From 1937 until 1980 the *PLCB* implemented a uniform markup rule which amounted to a markup (i.e., an ad valorem tax) over wholesale cost of 55% for all gins and whiskeys and 60% for other products. In 1980, the Pennsylvania legislature introduced a per-unit handling fee, the *Logistics, Transportation, and Merchandise Factor* (*LTMF*) and reduced the markup to 25% for all products. In 1993, the markup increased to 30% and the handling fee began varying by bottle size, resulting in a per-unit charge of \$1.05, \$1.20, and \$1.55 for 375 ml, 750 ml, and 1.75 L bottles, respectively.[11] Finally, consumers also pay an 18% ad valorem tax on all liquor purchases – the so-called "Johnstown Flood Tax" that was instituted as a temporary emergency relief measure in 1936, but never repealed.[12] Summarizing these elements, the uniform pricing rule employed by the *PLCB* during our 2003-2004 sample period is

$$p = [p^w \times 1.30 + LTMF] \times 1.18\,, \tag{1}$$

where p is the retail price of a given product with wholesale price, p^w. Given the simple structure of the pricing regulation and the vertical integration of wholesale and retail segments in Pennsylvania, the pricing rule is simply a combination of ad valorem and unit taxes. Our focus in this paper is the 30% uniform markup and take at face value that the fixed fees simply represent the storage and transportation costs of bottles of different sizes.

Due to the legislated pricing formula, the wholesale pricing decisions of the *PLCB*'s suppliers, e.g., distillers, are largely responsible for inducing retail price changes; any change in their prices is immediately passed on to retail prices.[13] For the mature products we consider, the *PLCB* places certain restrictions on the number and frequency of wholesale prices over the course of the year. Temporary wholesale price changes, typically price reductions or sales, amount to 89.7% of price changes in the sample and last for four or

[11] In 2016 the Pennsylvania state legislature relaxed the requirement that the 30% tax be applied categorically to all products by allowing the *PLCB* to depart from uniform pricing on the top 150 wine and top 150 spirits products. At the time of this writing, the agency has chosen to exercise this option for only 17 of the 300 eligible products, focusing on wines and spirits outside the top 100 and lowering the price below the one prescribed by the uniform pricing rule.

[12] The *PLCB* collects an additional 6% Pennsylvania sales tax on the posted price to generate the final price paid by the consumer.

[13] Near the state's borders, the *PLCB* runs seven outlet stores close to the state's that sell products, such as multi-packs, not available in regular stores to reduce the so-called 'border bleed' of consumers' shopping in lower-priced neighboring states. The addition of these stores to the sample has little qualitative or quantitative effects on the results. See Appendix E

five weeks from the last Monday of each month. A product can be put on sale up to four times a year, or once per quarter. A product can thus go on sale for one month, but not for two in a row. Permanent price changes take effect at the beginning of one of the *PLCB*'s four-week long reporting periods for accounting purposes, a slightly different periodicity from the sale periods. See Appendix A for further details. The periodicity we employ in the analysis below relies on sales periods, resulting in 22 periods for our sample.[14] Finally, distillers need to inform the *PLCB* of any proposed temporary price changes at least five months ahead of the desired sale period. Because they need to decide far ahead of time when to run temporarily sales, the distillers' ability to respond to unexpected demand swings is limited, facilitating a cleaner identification of demand responses to price changes.

2.2 Data: Quantities Sold, Prices, and Characteristics of Spirits

Our data, obtained under the Pennsylvania Right-to-Know Law, contain daily information on quantities sold and gross receipts at the UPC and store level for all spirits carried by the *PLCB* during 2003-2004. The *PLCB* also provided the wholesale cost of each product, which is constant across stores, but varies over time reflecting the temporary or permanent price changes discussed above. We geocode the 624 stores' street addresses to link their geographic location to data on population and demographic characteristics for nearby consumers based on the 2000 Census.

Each store carries a vast variety of products among which we focus on popular 375 ml, 750 ml, and 1.75 L spirits products, representing 64.1% of total spirit sales measured in bottles and 70.1% of total spirit sales by revenue.[15] The resulting sample contains 312 products across the two-year sample.

We classify products into six categories: brandy, cordials, gin, rum, vodka, and whiskey. For each product, the *PLCB* provided its alcohol content measured as proof (100 proof corresponds to 50% alcohol content by volume) and whether or not the product is imported or contains flavorings. Table 1 summarizes these product characteristics across spirit types and bottle size. Vodkas and whiskeys have significantly larger market shares

[14]We drop periods that overlap with January due to a significant reduction in sales during this month.

[15]Many products are available to consumers but are seldom purchased. The 375 ml, 750 ml, and 1.75 L bottle sizes account for 80.9% of total spirit sales by volume and 91.6% of total spirit sales by revenue. Within these bottle sizes we further focus on popular products which we define as those products which account for 80% of bottle sales in each spirit type-bottle size pair. We also dropped tequilas as there were few products. In total, these restrictions allow us to drop a total of 1,313 products from our sample.

Table 1: Product Characteristics by Spirit Type

	Products	Price	Share	% Flavored	% Imported	Proof
By Spirit Type:						
BRANDY	26	13.90	7.26	30.77	26.92	76.15
CORDIALS	62	15.10	13.59	32.26	51.61	55.82
GIN	28	15.59	6.72	3.57	28.57	83.42
RUM	40	14.32	16.31	10.00	17.50	74.03
VODKA	66	13.76	32.10	21.21	40.91	81.60
WHISKEY	90	16.74	24.03	0.00	58.89	80.98
By Price:						
CHEAP	162	10.50	47.00	17.90	22.84	72.46
EXPENSIVE	150	19.91	53.00	12.00	64.67	77.82
By Bottle Size:						
375 ml	48	7.15	15.21	8.33	47.92	75.10
750 ml	170	14.49	50.29	21.76	44.71	72.95
1.75 L	94	18.83	34.50	6.38	37.23	78.77
ALL PRODUCTS	312	14.87	100.00	16.30	37.40	75.33

Notes: "Price" is the average price weighted by quantity sold (bottles). "Share" is based on number of bottles sold. "Cheap" ("Expensive") products are those products whose mean price is below (above) the mean price of all spirits of the same spirit type and bottle size.

(32.10% and 24.03%, respectively), than rum (16.31%), cordials (13.59%), or brandy (7.26%), even though cordials in particular is one of the top categories in terms of number of products. Flavored spirits, which represent 16.3% of products, are primarily cordials and brandies and, to a lesser extent, rums and vodkas. Imported products account for more than 50% of whiskey and cordials sales, but significantly less in the other spirit categories. There is significant variation in proof across product categories; while the average across all products is 75.33, it ranges from 55.82 for cordials to 83.42 for gins.[16]

We characterize spirits as expensive when their simple averaged price exceeds the mean price of all spirits of the same type and bottle size. Table 1 shows that expensive spirits are purchased nearly as often as cheaper varieties, but are less likely to be flavored or domestically produced and have higher proof. The 750 ml bottle is the most popular size of product in terms of unit sales and product variety, accounting for 50.29% of unit sales and 54.5% of available spirits products, followed by the 1.75 L bottle with a share of 34.50%

[16]In addition to these characteristics, the empirical analysis also includes a measure of product quality obtained from `Proof66.com`, a spirits ratings aggregator. We do not include it in Table 1 because the product score is primarily informative within, but not across, spirit categories.

of unit sales and 30.1% of products. The smallest bottles we consider, those in the 375 ml format, account for the remaining 15.21% of units sold and 15.4% of products.[17]

Table 2: Frequency of Sales

	Holiday	Year	Times
By Spirit Type:			
BRANDY	34.62	61.54	2.47
CORDIALS	41.94	64.52	2.70
GIN	39.29	71.43	2.62
RUM	40.00	72.50	2.46
VODKA	48.48	78.79	2.44
WHISKEY	47.78	77.78	2.74
By Price:			
CHEAP	53.33	83.33	2.47
EXPENSIVE	35.19	62.96	1.36
By Bottle Size:			
375 ml	4.17	50.00	3.08
750 ml	49.41	78.24	2.53
1.75 L	54.26	74.47	2.68
ALL PRODUCTS	43.91	72.76	2.60

Notes: The "Holiday" season is defined as the two pricing periods that encompass Thanksgiving through the end of the year. Statistics reflect the percent of products with a temporary price reduction during the corresponding period except for "Times," which denotes the average number of times that spirits in each category are on sale during a year.

While Table 1 summarized mean price differences between products of different spirit types, Table 2 summarizes price changes over time. As discussed above, these largely originate from distillers temporarily adjusting their products' wholesale price resulting in monthly retail sales. Distillers temporarily change a product's price three times a year on average, and most products, 73%, go on sale at least once a year. Distillers place vodkas, whiskeys, and cheap varieties on sale more frequently than the rest while 375 ml products are less likely to go on sale. On the contrary, 44% of spirits go on sale at some point during the holidays, which we define as pricing periods that overlap with Thanksgiving through the end of the year, though this is a rare event for 375 ml bottles, just about 4%. While over 63% of expensive products go on sale at some point in the year, the average product is placed on sale only 1.36 times, far less than other product categories. Just the opposite is true of 375 ml products which, conditional on experiencing a price change, are place on

[17] Table 1 and Table B.1 in Appendix B show that average bottle prices increase with bottle size, both in total and within spirit category although it decreases by per ounce. This explains why the revenue share of 1.75 L bottles, 43.65%, exceeds the share of bottles sold, 34.5%.

sale 3 times per year on average. The monthly sales activity, together with variation in the amount of price reduction, are our primary source of price variation to identify consumers' price responsiveness.

2.3 The Upstream Distillers

Recall that our objective in this paper is to assess the different incidence of the uniform markup policy on equilibrium behavior on different groups of agents so as to uncover Posner's *taxation by regulation*. As the pricing formula in equation (1) highlights, how any alternative markup policy affects retail prices and consumer behavior depends on how wholesale prices respond to the markup policy. Weyl and Fabinger (2013, §4) show that pass-through of a tax may depend on how the market conduct affects the responses of upstream firms. In our framework upstream firms charge positive markups depending on the positioning of their product portfolios. This section provides a brief summary of characteristics and competitiveness of the upstream distillery market.

During our sample period, the upstream distillery market was composed of 34 firms with broad arrays of product portfolios summarized in Tables 3 and 4. The market leader, Diageo, accounted for 22% of total unit sales and 25% of revenue, while a large set of small fringe producers accounted for 42% and 46% of total quantity sold and revenue, respectively. Nineteen of these firms operated product portfolios of less than five products and seven were single product firms.

Table 3: The Upstream Market

		Share of Spirit Market	
Firm	Products	By Quantity	By Revenue
Diageo	63	22.10	25.02
Bacardi	22	8.89	9.72
Beam	32	9.69	8.84
Jacquin	27	9.52	5.97
Sazerac	18	7.95	4.69
Other Firms (29)	150	41.85	45.76

Notes: Sample of distilleries with national brands. Firms ordered according to market share based on revenue.

In Table 4 we show that large firms such as Diageo and Bacardi operated extensive product portfolios although there was also substantial heterogeneity across firms in their product offerings. For example, Diageo had a relatively balanced portfolio where rums, vodkas, and whiskeys generated approximately 21%, 31%, and 25% of its total revenue, respectively. In contrast, Bacardi operated a much more concentrated portfolio as 71% of its revenue came from its rum products compared to 19% from whiskey products. Meanwhile, Jacquin generated about 22% of its revenue from brandy products and faced competition from seven fringe firms, the largest of which was Allied Domecq which accounted for 5% of total bottles sold during the sample period.

Table 4: Upstream Product Portfolios

	BRANDY	CORDIALS	GIN	RUM	VODKA	WHISKEY	TOTAL
Diageo	0.00	11.22	11.67	21.27	30.99	24.85	100.00
Bacardi	0.00	1.98	8.26	70.89	0.00	18.88	100.00
Beam	0.00	16.22	5.14	4.06	10.40	64.18	100.00
Jacquin	21.57	9.77	1.77	22.12	43.26	1.52	100.00
Sazerac	0.00	13.29	3.62	0.00	63.90	19.18	100.00
Firms	8	18	10	10	14	20	34

Notes: Table presents share of total revenues for each firm by spirit type. "Firms" is the total number of firms with a product for the given spirit type. Firms ordered according to revenue market share.

Fringe firms may turn the market conduct of upstream distillers more competitive. However, despite this important competitive fringe, the upstream distiller market is best characterized as oligopolistic, with Herfindahl indices ranging from 1,023 for cordials to 3,087 for rums (951 overall). We therefore assume that distillers set wholesale prices non-cooperatively as in a Bertrand-Nash oligopoly with horizontally differentiated products, which allows us to recover the distillers' marginal costs and predict their optimal behavior under alternative *PLCB* pricing strategies.

2.4 Heterogeneity of Preferences for Quantity and Varieties of Spirits

Pennsylvania is a demographically diverse state, which allows us to trace consumer preferences across a wide range of demographic profiles. We combine Pennsylvania's Census block groups into markets, assigning each to the operating store that is closest to them in any time period. We further consolidate stores in the same ZIP code resulting in 454 total local markets.[18] Table 5 summarizes these demographic characteristics where about 38% of households in Pennsylvania make more than $50,000 a year, but the income distribution

[18] Because stores open and close during the year, the characteristics of stores' ambient consumers also change exogenously over time, which greatly helps identify the effect of demographic interactions. See Appendix A for further details on store openings and closings, ambient demographics, and widespread availability of most spirits in every store.

differs significantly across markets, with rich households comprising anywhere between 10% to 76% of the population across markets. Similarly, the share of minority households in a market ranges from virtually zero to 99%, with minorities comprising 13% of citizens in the average market. We see similar diversity in educational attainment where the 44% of residents in the average market report at least some college education but this varies from 13% to 87% across the state. Finally, we see less disparity in age where the average age in the average market is 40 while the youngest market has an average age of 31 and the oldest market has an age of 43.

Table 5: Demographic Attributes of Pennsylvania Markets

		Percentage of Population			
	POPULATION	AGE	EDUCATION	INCOME	MINORITY
Mean	26,241	40.07	44.06	38.81	13.07
Std. Dev.	16,386	1.45	14.41	14.33	18.83
Min	1,469	31.34	12.56	9.90	0.44
Max	112,065	43.06	87.01	75.92	98.95

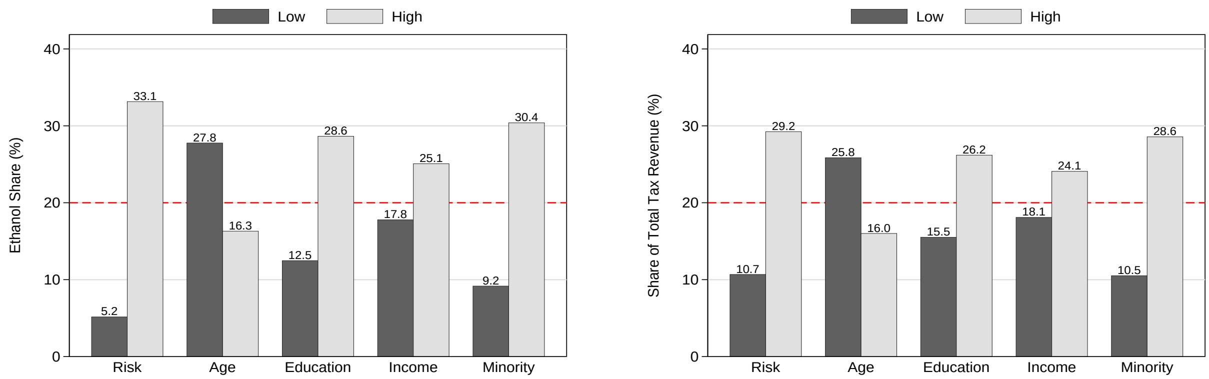
Source: 2000 Census of Population. AGE reports the average age in the market. EDUCATION reports the share of population with some college education. MINORITY defined as share of non-white population. INCOME is the share of households with income greater than $50,000. Figure B.1 in Appendix B we present the spatial distribution of demographics.

Do these wide differences in the demographics of local markets translate into heterogeneity in terms of ethanol consumed and tax revenue generated, both measures linked to the *PLCB*'s objectives? We answer this question by assigning the store markets into quantiles based on each of the four demographic traits – the share of households with incomes above $50,000, the share of non-white or minority households, the share of residents with some college education, and the average age. As markets differ in their consumption of ethanol, we also split the markets according to per capita ethanol consumption where a market in the top (bottom) quantile is designated as a high (low) "risk" market.

In Figure 1 we present the shares of total tax revenue and total ethanol consumption for markets in the top and bottom quintiles for each trait, relative to a 20% benchmark (the dashed line) if market attributes did not correlate with consumption and expenditures.[19]

[19] The finding that per capita ethanol consumption and income are positively correlated is nothing new though the exact mechanism is unclear (see Cerda, Johnson-Lawrence and Galea, 2011). Researchers often cite greater availability, social norms, or even social networking as causes.

Figure 1: Demographics and the *PLCB*'s Objectives



(a) Ethanol Consumption (b) Tax Revenue

Notes: Graphs compare shares of total ethanol consumption and tax revenue garnered by the bottom and top 20% of markets according to the demographic trait considered. We denote the difference between the retail price and the wholesale cost as the single amount of tax revenue per bottle, not differentiating between the ad valorem tax (markup), the handling fee, and the liquor tax. Total tax revenue is then tax revenue per bottle times number of bottles purchased. Since tax revenue per bottle is near proportional to the final retail price of equation (1), variation in total tax revenue across markets also maps into differences in consumer spending.

We observe high consumption and spending in markets with high concentrations of wealthy, well-educated, young, and non-white consumers. Interestingly, the difference in the consumption shares of the top and bottom markets in the distribution is always smaller than the difference in the share of taxes paid or expenditures. High risk markets (i.e., the top 20% of markets by per capita consumption) consume 33% of the total ethanol in the state and generate 29% of total tax revenue. As ethanol consumption in these markets exceeds the threshold number of weekly alcohol units deemed safe, 14, alcohol consumption in these markets also likely generates adverse health effects.[20] In contrast, ethanol consumption in low risk markets accounts for only 5% of total ethanol sales, generates 11% of total tax revenue, and poses little risk to the consumers' long run health. This evidence is suggestive that the current pricing rule fails to curb heavy drinking for a subset of neighborhoods with characteristics commonly deemed more prone to suffer from alcohol abuse (cf. (Teh, 2015) again).

[20] Maximum recommended limits vary slightly by country, gender, and age of the individuals. The U.K. health authorities recommend a maximum of 14 weekly units as the limit for moderate drinking. This is roughly equivalent to 350 ml of 40% ABV whiskey, 1 L of 13% ABV red wine, or 3.5 L of 4% ABV beer. See the publication of the House of Commons: *"Alcohol guidelines, Eleventh Report of Session 201012"* available at `http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/1536/1536.pdf`. The U.S. Centers for Disease Control and Prevention are less precise in defining moderate drinking behavior, but instead provide examples of numbers of "drinks" that nearly match the standard used in the text. See *"Fact Sheets - Moderate Drinking"* available at `http://www.cdc.gov/alcohol/fact-sheets/moderate-drinking.htm`.

Table 6: Connecting Consumer Preferences and Demographics

	RISK		AGE		MINORITY		EDUCATION		INCOME	
	Low	High	Low	High	Low	High	Low	High	Low	High
By Spirit Type:										
BRANDY	6.6	7.3	9.8	4.6	5.2	12.3	11.4	5.4	11.9	4.2
CORDIALS	14.7	12.9	13.2	13.4	15.3	12.4	14.7	12.2	13.0	12.9
GIN	5.3	8.0	8.1	6.4	4.7	9.1	7.8	7.6	8.4	6.9
RUM	18.4	15.4	17.5	14.2	16.6	16.8	18.2	14.2	17.5	13.7
VODKA	27.7	34.5	32.5	34.1	27.4	31.8	26.9	36.9	29.6	37.3
WHISKEY	27.3	21.9	18.8	27.4	30.9	17.6	21.0	23.6	19.7	25.0
By Price:										
CHEAP	56.1	50.7	55.0	49.1	54.8	56.6	57.5	47.7	59.0	46.6
EXPENSIVE	43.9	49.3	45.0	50.9	45.2	43.4	42.5	52.3	41.0	53.4
By Bottle Size:										
375 ml	15.1	15.7	20.1	10.6	10.5	22.8	19.3	13.6	22.5	11.6
750 ml	49.9	50.6	51.1	49.1	49.3	50.8	51.0	50.6	49.9	49.7
1.75 L	35.0	33.7	28.8	40.3	40.2	26.4	29.6	35.7	27.5	38.6

Notes: Statistics represent market shares (based on bottles sold) by product characteristic. Demographic categories are defined in Table 5 or, in the case of "Risk," in the text.

In Table 6 we complete our analysis by documenting the heterogeneity of preferences for different types of spirits across consumers with different demographics characteristics and alcohol consumption habits. Minorities strongly favor brandy, gin, and 375 ml products, but not whiskey or 1.75 L products. In markets with high income and highly educated population vodka is far more popular than rum and brandy. In these markets, the *PLCB* also sells a larger share of expensive spirits. Markets dominated by young, poorly educated, and low income populations show a clear preference for cheap products. The popular 750 ml bottle amounts to almost exactly half of all bottle sales across demographic traits, but between the 375 ml and 1.75 L sizes, higher-income markets clearly favor 1.75 L products. Finally, heavy drinkers, i.e., consumers in high risk markets, prefer expensive and vodka products but are unlikely to purchase 375 ml bottles; preferences which reflect the positive correlation between risk, i.e., per capita ethanol consumption, and income.

3 Model

In this section we describe a static model of oligopoly price competition with differentiated goods. We envision a two-stage Stackelberg game where the regulator first commits to a markup policy. Upstream distillers observe the policy and then simultaneous choose wholesale prices p^w to maximize profits each period. The chosen wholesale prices translate into specific retail prices based on the regulator's chosen markup policy. Finally, consumers in each market choose the product that maximizes their utility given the retail prices and characteristics of all products.

The purpose of the model is twofold. First, the model lays out how consumers respond to the chosen retail prices. We rely on a flexible utility specification to estimate consumer preferences from observed consumer choices over time and across markets. The estimated preferences facilitate predicting consumer responses to counterfactual pricing policies. Second, the model highlights that the retail prices the consumer is exposed to are driven to a significant degree by the strategic wholesale price choices in the upstream market. If the *PLCB* were to alter its pricing rule, upstream distillers would choose different wholesale prices leading to different retail prices and consumer purchase decisions. We thus need to incorporate upstream behavior in the model in order to appropriately conduct our counterfactual analysis. We begin with a description of the consumer's choice problem and then continue with distillers' pricing problem.

3.1 A Discrete Choice Model of Demand for Spirits

We follow the large literature on discrete-choice demand system estimation using aggregate market share data, (cf. Berry (1994), Berry et al. (1995), and Nevo (2001)), to model demand for spirits as a function of product characteristics and prices. By mapping the distribution of consumer demographics into preferences, the model enables us to estimate realistic substitution patterns between products while accounting for the heterogeneity in preferences exhibited in Table 6. We assume that consumer i in market l in period t obtains the following indirect utility from consuming a bottle of spirit $j \in J_{lt}$[21]

$$\begin{aligned} u_{ijlt} &= x_j\beta_i^* + \alpha_i^* p_{jt}^r + H_t\gamma + \xi_{jlt} + \epsilon_{ijlt}\,, \\ \text{where}\ \ i &= 1,\ldots,M_{lt};\quad j = 1,\ldots,J_{lt};\quad l = 1,\ldots,L;\quad t = 1,\ldots,T\,. \end{aligned} \tag{2}$$

The $n \times 1$ vector of observed product characteristics x_j is identical in all markets l where product j is available and fixed over time, though the availability of different spirits

[21] In the absence of individual purchase information we opt to treat bottles of different sizes of the same spirit as different products with identical observable characteristics other than size and focus on horizontal differentiation between products.

changes over time due to product introductions or removals. The $T \times 2$ matrix $H_t = [q3_t \quad m12_t]$ includes a summer dummy for periods in July, August, and September and a holiday dummy for periods t coinciding with the holiday season from Thanksgiving to the end of the year. The price of product j at time t is denoted p^r_{jt} and is the same across all markets l. We further allow utility to vary across products, markets, and time via the time and location-specific product valuations ξ_{jlt}, which are common knowledge to consumers, upstream firms, and the *PLCB* but unobserved by the econometrician. Lastly, ϵ_{ijlt} denotes the idiosyncratic unobserved preferences by consumer i for product j in market l and period t, which we assume to be distributed Type-I extreme value across all available products J_{lt}.

We characterize consumer i in market l by a d-vector of observed demographic attributes, D_{il} including age, education, income, and race. To allow for individual heterogeneity in purchase behavior, we model the distribution of consumer preferences over characteristics and prices as multivariate normal with a mean ν_{il} that shifts with these consumer attributes

$$\begin{pmatrix} \alpha_i^* \\ \beta_i^* \end{pmatrix} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + \Pi D_{il} + \Sigma \nu_{il}\,, \quad \nu_{il} \sim N(0, I_{n+1})\,, \tag{3}$$

where Π is a $(n+1) \times d$ matrix of coefficients that measures the effect of observable individual attributes on the consumer valuation of spirit characteristics including price, while Σ measures the covariance in unobserved preferences across characteristics. We restrict $\Sigma_{jk} = 0 \ \forall k \neq j$, and estimate only the variance in unobserved preferences for characteristics.[22] Similarly, the contribution of demographic and product characteristic interactions (Π) allows cross-price elasticities to vary differentially in markets with observed differences in demographics. Exogenous store openings/closings alter the demographic composition of demand for surrounding stores and help us identify these demographic interactions.

We make the common assumption that during a particular time period, each consumer selects either one bottle of the J_{lt} spirits available in her market, or opts to purchase beer or wine for off-premise consumption, i.e., not consumed in a restaurant or bar.[23] We denote

[22] Introducing unobserved preferences for a given characteristic j allows cross-price elasticities among products with similar characteristics (e.g., proof) to be higher than in a simple Logit model, thereby relaxing the restrictive substitution patterns generated by the Independence of Irrelevant Alternatives (IIA) property of the multinomial logit model.

[23] Nevo (2000, p.401) discusses limitations of the present discrete choice approach when instead, individuals purchase several products or multiple bottles of the same product at the same time. If such consumer behavior were important, Hendel (1999) and Hendel and Nevo (2006) show that assuming single-unit purchases could understate price elasticities in the case of assortment decisions, but overstate own-price

this outside option, denominated in 750 ml bottle-equivalents, by $j = 0$ with zero mean utility.

The annual potential market for location l is the number of drinking-age residents scaled by per-capita off-premise consumption. Hence, a consumer opting for the outside option is choosing to consume a 750 ml "bottle" of beer (i.e., two 375 ml bottles) or a 750 ml bottle of wine.[24] The average drinking-age Pennsylvanian consumed 96.2 liters of alcoholic beverages through off-premise channels in 2003, or 128.2 standard 750 ml bottle equivalents according to Haughwout, Lavallee and Castle (2015). The 2003 potential market for location l is then the number of drinking-age residents scaled by 128.2, which we allocate evenly across pricing periods according to the periods' lengths to give us the potential market per period, M_{lt}. To put this figure in perspective, beer accounts for approximately 90% of total consumption by volume so the average drinking-age Pennsylvanian consumed approximately five 375 ml bottles of beer per week versus annual consumption of four 750 ml bottles of both wine and liquor. We follow a similar approach in constructing the potential market for 2004.

Consumer utility-maximization connects the set of individual-specific attributes and the set of product characteristics as follows

$$A_{jt}\left(x_{\cdot}, p^r_{\cdot t}, \xi_{\cdot t}; \theta\right) = \left\{\left(D_{il}, \nu_{il}, \epsilon_{i \cdot lt}\right) | u_{ijlt} \geq u_{iklt} \quad \forall k = 0, 1, \ldots, J_{lt}\right\}\,, \tag{4}$$

where we summarize all model parameters by θ. We follow the literature in decomposing the deterministic portion of the consumer's indirect utility into a common part shared across consumers, δ_{jlt}, and an idiosyncratic component, μ_{ijlt}, given by

$$\delta_{jlt} = x_j \beta + \alpha p^r_{jt} + H_t \gamma + \xi_{jlt}\,, \tag{5a}$$

$$\mu_{ijlt} = \begin{pmatrix} x_j & p^r_{jt} \end{pmatrix} \left(\Pi D_{il} + \Sigma \nu_{il}\right)\,. \tag{5b}$$

elasticities in the case of stockpiling. In Miravete et al. (2017) we test for stockpiling using a similar dataset and find no evidence. Similarly, Seim and Waldfogel (2013) present suggestive evidence that the *PLCB*'s demand does not respond to price declines more strongly than average in areas with higher travel costs to the store where customers have a higher incentive to buy larger quantities or assortments.

[24] Note that this definition accounts for the total volume of alcoholic beverages but not for the different ethanol contents of beer (4.5% on average), wine (12.9% on average), and spirits (37.9% on average in our sample).

In estimating the model, we integrate over the distribution of $\epsilon_{i \cdot lt}$ analytically. The probability that consumer i purchases product j in market l in period t is then

$$s_{ijlt} = \frac{\exp\left(\delta_{jlt} + \mu_{ijlt}\right)}{1 + \sum_{k \in J_{lt}} \exp(\delta_{klt} + \mu_{iklt})} \,. \tag{6}$$

Deriving product j's aggregate market share in each location requires integrating over the distributions of observable and unobservable consumer attributes D_{il} and ν_{il}, denoted by $P_D(D_i)$ and $P_\nu(\nu_i)$, respectively. The market share for product j in market l at time t is:

$$s_{jlt} = \int_{\nu_l} \int_{D_l} s_{ijlt} dP_D(D_i) dP_\nu(\nu_i) \,. \tag{7}$$

The integration in equation (7) is done via simulation. We discuss this, the reduced concerns regarding price endogeneity due to the *PLCB*'s regulation of sales, and other elements of the estimation in greater detail in Appendix C.

3.1.1 Consumer Welfare

An advantage of a structural model is that it enables the researcher to assess equilibrium changes in welfare. The added advantage in this study is that we can ask: Who benefits from the single-markup policy? We identify beneficiaries of the single-markup policy by evaluating changes in consumer welfare via compensating variation, i.e., the amount of income necessary to keep individuals in a given market indifferent between the counterfactual set of prices p' and the current ones p under the single-markup rule,

$$CV_{ilt}(p, p') = \frac{1}{\alpha_i^\star} \ln \left[\frac{\sum_{j \in J_{lt}} \exp\left[V_{ijlt}(p'_t)\right]}{\sum_{j \in J_{lt}} \exp\left[V_{ijlt}(p_t)\right]} \right] \,, \tag{8}$$

where $V_{ijlt}(\cdot)$ is given by (2). The mean compensating variation for agents living in location l is

$$CV_l(p, p') = \sum_t M_{lt} \int_{\nu_l} \int_{D_l} CV_{ilt}(p, p') dP_D(D_i) dP_\nu(\nu_i) \,. \tag{9}$$

As defined, residents in location l are on average better off under the current policy when the mean compensating variation is greater than zero (i.e., $CV_l(p) > 0$) so they would be willing to pay the government to not adopt the policy which generates retail prices p'.[25]

3.2 An Oligopoly Model for Distillers

Given optimal consumer choices, we now consider competition between upstream distillers. A total of F firms compete in the upstream market where each firm $f \in F$ produces a subset J_t^f of the $j = 1, \ldots, J_t$ products. In each period t the upstream firms simultaneously choose the vector of wholesale prices $\{p_{jt}^w\}_{j \in J_t^f}$ to maximize period t profit

$$\max_{p_{jt}^w} \sum_{j \in J^f} \left[(p_{jt}^w - c_{jt}) \times \sum_{l=1}^{L} M_{lt} s_{jlt}\Big(p^r(p^w), x, \xi; \theta\Big) \right] , \tag{10}$$

where c_{jt} denotes the marginal cost of producing product j in period t. To simplify the notation of this static problem, we omit the period t subscripts going forward.[26] Define as $s_j(p^r, x, \xi; \theta) = \sum_{l=1}^{L} M_l s_{jl}(p^r, x, \xi; \theta)$ the state-wide demand for product j. Profit maximization in the upstream market implies that distiller f chooses prices $p_j^w \; \forall j \in J^f$ to solve the following set of first-order conditions,

$$s_j\Big(p^r(p^w), x, \xi; \theta\Big) + \sum_{m \in J^f} \Big(p_m^w - c_m\Big) \times s_m\Big(p^r(p^w), x, \xi; \theta\Big) \times \frac{\partial s_m}{\partial p_j^w} = 0 \,. \tag{11}$$

The final term $\frac{\partial s_m}{\partial p_j^w}$ is the change in quantity sold for product m in response to a change in the wholesale price and, through the pricing rule, the retail price, of product j. Assuming a pure-strategy Bertrand–Nash equilibrium in wholesale prices, the vector of profit-maximizing wholesale prices solves

$$p^w = c + \underbrace{[O^w * \Delta^w]^{-1} \times s\Big(p^r(p^w), x, \xi; \theta\Big)}_{\text{vector of markups}} , \tag{12}$$

[25] Implicitly we are assuming that change in *PLCB* policy has no effect on the utility of consumption for beer and wine (the outside good).

[26] We ignore any dynamic considerations to distillers' pricing decisions based on regulatory restrictions on their pricing. While the *PLCB* limits the number of times distillers can temporarily change a product's price to four, this regulation does not constrain upstream pricing for the majority of products. In the data, 73.5% of products go on sale three times or less.

where O_t^w denotes the ownership matrix for the upstream firms with element (j,m) equal to one if goods j and m are in J^f and upstream firm f chooses these prices jointly. We define Δ^w as a matrix that captures changes in demand due to changes in wholesale price,

$$\Delta^w = \begin{bmatrix} \frac{\partial s_1}{\partial p_1^r} & \cdots & \frac{\partial s_1}{\partial p_J^r} \\ \vdots & \ddots & \vdots \\ \frac{\partial s_J}{\partial p_1^r} & \cdots & \frac{\partial s_J}{\partial p_J^r} \end{bmatrix} \times \begin{bmatrix} \frac{dp_1^r}{dp_1^w} & \cdots & \frac{dp_1^r}{dp_J^w} \\ \vdots & \ddots & \vdots \\ \frac{dp_J^r}{dp_1^w} & \cdots & \frac{dp_J^r}{dp_J^w} \end{bmatrix}' = \Delta^d \Delta^{p\prime}, \tag{13}$$

where Δ^d is the matrix of changes in quantity sold in period t due to changes in retail price with element (k,m) equal to $\frac{\partial s_k}{\partial p_m^r}$ and Δ^p is the matrix of changes in retail price due to changes in wholesale price with element (m,j) equal to $\frac{dp_m^r}{dp_j^w}$.

In vertical retail pricing markets Δ^p can be a complicated object (see Villas-Boas, 2007). In our context, however, the state's regulation of alcohol sales simplifies this matrix significantly by committing downstream stores to a uniform pricing policy and by eliminating off-diagonal terms. For example, under the current pricing rule, $\frac{dp_j^r}{dp_j^w}$ is simply $1.30 \times 1.18 = 1.534$, reflecting the 30% uniform tax and the 18% liquor tax that translate a change in the wholesale price for product j to a change in the product's retail price. Further, the retail price for product m does not respond to a change in the wholesale price for product j since $\frac{dp_m^r}{dp_j^w} = 0 \; \forall m \neq j$. The uniform tax rule from equation (1) thus limits the *PLCB*'s ability to respond to changes in wholesale prices chosen by the upstream firms, resulting in a diagonal price response matrix Δ^p so that the demand response matrix Δ^w of equation (13) is

$$\Delta^w = \begin{bmatrix} \frac{\partial s_1}{\partial p_1^r} & \cdots & \frac{\partial s_1}{\partial p_J^r} \\ \vdots & \ddots & \vdots \\ \frac{\partial s_J}{\partial p_1^r} & \cdots & \frac{\partial s_J}{\partial p_J^r} \end{bmatrix} \times \begin{bmatrix} 1.534 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1.534 \end{bmatrix}. \tag{14}$$

Given estimates of consumer demand, data on retail prices, and the observed *PLCB* policy; we use this model of upstream behavior to recover product-level marginal costs via equation(12). This facilitates the evaluation of alternative pricing regulations we use to recover the aggregate and distributional consequences of the simple uniform policy employed by the *PLCB*. Modifications to the pricing rule also require adjustment of Δ^p as more flexible, product-based policies enable the *PLCB* to set markups which vary by product.

4 Estimation Results

We adapt the estimation approach of Nevo (2000) to the institutional features surrounding the price regulation of spirits in Pennsylvania. As in Miravete et al. (2017), we follow a three-step estimation procedure that takes advantage of the fact that the *PLCB* charges the same retail price for a given product in all local markets. This allows us to separately identify the contribution to demand of demographic taste heterogeneity across the state at a point-in-time and the contribution of time varying shifters of demand that are common across demographic groups, including price. In the first-stage, we estimate by *GMM* the deviations from a product's mean utility represented by interactions between product attributes and both observed and unobserved demographic characteristics of markets, controlling for market and product by pricing period fixed effects that absorb the mean effects of price, product characteristics, and seasonality. In the second stage, we use *IV* techniques to project the estimated product by pricing period fixed effects onto price, seasonality, and product *FE*, using contemporaneous prices in distant control states and input prices as instruments. Last, we project the estimated product *FE* from the second stage onto time-invariant product characteristics.

Identification of random coefficients Σ comes from correlation between a product's market share and its characteristics relative to other more or less similar products – see Berry and Haile (2014). We construct two instruments similar to those used in Bresnahan, Stern and Trajtenberg (1997). First, we employ the number of products in the market that share product j's characteristic. For example, to identify a random coefficient on brandies, we use the total number of competing brandies of the same bottle size in location l in period t as the instrument for a given brandy. Second, we use spirit product scores from `Proof66.com` as a measure of product quality and compute the average distance, measured in squared deviations, of product j to other products that share its characteristic. Thus, for the above brandy, this would be the average distance in product score space from other brandies available in l and t. This instrument provides additional identifying power since it allows for differential effects of offering a high-quality brandy in a market with other high quality brandies versus a market populated by largely low quality brandies.

Similarly, identification of demographic interactions Π is based on correlation between the market shares of products with particular characteristics in a given store market and the demographics of the population served by each store. We interact the above two instruments with the prevalence of a given demographic attribute in each market. For example, we would identify the differential taste of young households for the above brandy by interacting our earlier two instruments with the share of young consumers in each market. In the case of the interaction of income with price, we construct similar instruments based on the number of products sharing a given product's price category (cheap vs. expensive) and interact this count measure with the share of households in the market with income above $50,000. Berry and Haile (2010) point out that these "Waldfogel" instruments (Waldfogel, 2003) are valid provided there exist no demand spillovers from consumers in other similar markets.

Variation in prices over time identifies the price coefficient α, exploiting the fact that distillers do not change the wholesale prices p^w for all products at the same time. We identify seasonality and mean preferences β for time-invariant product characteristics such as proof and spirit type from systematic variation in market shares of spirits by time period or characteristic.

We present the estimation algorithm in detail in Appendix C where we also discuss potential sources of price endogeneity stemming from responses by distillers to unobserved demand shocks (via ξ), and the use of retail prices in other control states plus input costs as valid instruments.

4.1 Parameter Estimates

Table 7 presents the demand estimates of our preferred specification of the mixed logit model.[27] Given the size of our sample, parameters are very precisely estimated. We allow for rich variation across demographics by interacting consumer age plus indicator for minority and education indicators with spirit type, bottle size, an indicator for import status, and proof. The estimates of Π reveal significant differences in tastes for spirits across demographic groups. For example, while minority consumers favor brandy, cordials and rum over gin, the reference category, older and college-educated consumers prefer gin to cordials and rum, all else equal. We also find that older consumers, and to a lesser extent college educated consumers, are also more likely to purchase 1.75 L than 750 ml bottles, our reference category, while minority households are more likely to purchase 375 ml bottles. Older and particularly minority consumers also favor spirits with higher proof. This characterization of demand for

[27] In Appendix E we show that our estimation results are robust to arbitrage on the state border (i.e., the "border bleed"), other samples, and alternative instrumentation approaches.

Table 7: Mixed-Logit Demand

	Mean Utility	Random Coeff.	Demographic Interactions (Π)			
	(β)	(Σ)	AGE	EDUCATION	INCOME	MINORITY
PRICE	-0.2763 (0.0046)				0.0787 (0.0026)	
CONSTANT	-34.8299 (0.8218)	0.1759 (0.3653)	6.2002 (0.5176)	5.7245 (0.3197)		-7.3124 (0.6198)
375 ml	4.8700 (0.2451)	2.1181 (0.5896)	0.3947 (0.1487)	-0.7853 (0.1320)		0.8109 (0.1283)
1.75 L	9.0752 (0.2330)	0.0204 (1.1874)	3.2208 (0.7540)	0.9151 (0.1621)		-0.9581 (0.0530)
BRANDY	-60.4569 (0.3636)	10.0606 (0.5963)	13.6819 (1.1016)	-2.5638 (0.1221)		3.4660 (0.1696)
CORDIALS	20.7050 (0.3343)	0.7215 (0.3827)	-6.6553 (0.5039)	-3.5539 (0.1362)		4.4148 (0.3320)
RUM	24.8060 (0.3506)		-7.3399 (0.4846)	-2.4288 (0.0972)		1.9946 (0.1501)
VODKA	24.5847 (0.2760)	0.0819 (0.4193)	-7.2702 (0.4868)	0.6748 (0.1683)		-0.2070 (0.0481)
WHISKEY	-0.9444 (0.3187)	0.3425 (0.3474)	0.8279 (0.1885)	-1.2156 (0.0770)		-1.2939 (0.0435)
FLAVORED	-0.6278 (0.2130)		-0.1211 (0.0482)	-0.1971 (0.0709)		0.6804 (0.0745)
IMPORTED	-0.6931 (0.1960)	0.4807 (0.3356)	0.1772 (0.0810)	1.6193 (0.1162)		0.1681 (0.0417)
PROOF	-14.6819 (0.7327)	0.2244 (0.4845)	1.3367 (0.1999)	-3.9805 (0.3061)		15.9646 (0.7387)
QUALITY	4.0281 (1.2690)					
HOLIDAY	0.4483 (0.0075)					
SUMMER	0.0820 (0.0065)					

Notes: Robust standard errors are reported in parentheses. Estimates for random coefficients (Σ) and demographic interactions (Π) based on *GMM* estimation using 2,237,937 observations in 8,470 store-periods and 1,000 simulated agents in each market. AGE is log(age – 20), EDUCATION is an indicator variable equal to one if the agent has some level of college education, INCOME is log(income), and MINORITY is an indicator equal to one if the agent is non-white. Details regarding demographics are located in Appendix . Mean utility contributions of price, holiday, and summer are based on a product *FE* regression of the product-period *FE* from the *GMM* estimation after controlling for price endogeneity. Estimates of the contribution of time-invariant product characteristics to mean utility result from a the projection of the estimated product *FE* onto these observable characteristics. We document robustness of our results in Appendix E.

spirits mirrors well-documented patterns of spirit consumption across demographic groups and is broadly consistent with the descriptive analysis of Table 6 that compares the top and bottom quintiles of the unconditional distribution of tastes across demographic traits. In addition, we find that demand for wealthier consumers is steeper, consistent with their increased consumption of expensive spirits by “high income” consumers reported in Table 6. Our estimates also indicate that demand increases during the summer and the holiday season and that, on average, consumers prefer products of higher quality and lower proof and favor cordials, rums, and vodkas over gins and brandy.

We allow for unobserved variation in preferences for a number of the product characteristics, including bottle sizes, product categories, whether or not a product is imported and its proof. The estimated random coefficients are large, in particular for brandies and for the 375 ml size, indicating that after controlling for the large degree of observed demographic differences in tastes, there still exist unexplained characteristics among products within these categories that influence their substitution patterns.[28]

4.2 Elasticities

Next, we translate the parameter estimates into own-price elasticities which we summarize in Table 8. At the product-level, we estimate an average own-price elasticity of -3.75, which is within the range of median elasticities of Conlon and Rao (2015, Table 8) for spirits (from -2.61 for whiskeys to -3.80 for vodkas), and somewhat more elastic than the -2.41 own-price elasticity of wine estimate of Aguirregabiria, Ershov and Suzuki (2016). Our model estimates imply an estimated price elasticity of off-premise spirit demand of -2.48 overall, more elastic than the -1.5 estimate of Leung and Phelps (1993) in their review of the literature on demand estimation for alcoholic beverages. We attribute this difference to our exclusion (due to lack of data) of the on-premise consumption in bars and restaurants, which is likely less price sensitive than off-premise consumption. Second and perhaps more important, most earlier studies use aggregate consumption data whereas we have detailed local data on consumption choices.[29]

Most relevant to our research question is that own price elasticity estimates also exhibit substantial heterogeneity across spirit types and bottle sizes, thus questioning the optimality of a single-markup across products. The empirical distribution of estimated price

[28] To provide support for our flexible model specification we follow Gandhi and Houde (2016) to test the validity of the simplest alternative: a multinomial logit model with demographic interactions. We regress the log of the ratio of each product's market share and the outside share on product-period and store FE, product-demographic interactions, and our GMM instruments. If the multinomial logit were sufficient, the GMM instruments should have no explanatory power, which we reject using a simple F-test (F-statistic of $F = 2,676$ for all instruments; $F = 1,151$ and $F = 1,734$ for the subsets related to the random coefficients and demographics, respectively).

[29] To corroborate this hypothesis, Appendix E shows that aggregation in our data set drives the price coefficient (and consequently the estimated elasticity for spirits) toward zero. Appendix E also evaluates the sensitivity of our estimates to alternative samples and instrumentation strategies.

Table 8: Own Price Elasticities by Spirit Type, Price, and Size

	Price	Price Elasticity	
		Average	SD
By Spirit Type:			
BRANDY	14.41	-3.64	1.80
CORDIALS	14.08	-3.46	1.35
GIN	15.15	-3.90	1.82
RUM	13.72	-3.38	1.15
VODKA	16.82	-3.95	1.60
WHISKEY	16.77	-3.98	1.63
By Price:			
EXPENSIVE	20.43	-4.74	1.54
CHEAP	10.96	-2.81	0.84
By Bottle Size:			
375 ml	8.94	-2.36	0.89
750 ml	14.53	-3.58	1.32
1.75 L	20.65	-4.74	1.61
ALL PRODUCTS	15.16	-3.75	1.57

"Price" denotes the average price in the relevant category measured in dollars.

elasticities is most spread for brandy and gin and least for rums. A uniform increase in the *PLCB*'s markup will thus trigger a non-uniform response of demand across spirit varieties. The bottom of Table 8 corroborates that demand responses to a uniform increase of retail prices vary more widely across bottle sizes and price segments. The demand for 375 ml bottles is less elastic than for 1.75 L bottles, with the medium-sized 750 ml bottles in-between. Similarly, we also find that demand for expensive products is more elastic than the nearly half as expensive cheap spirits.

In Table 9 we further document the existence of heterogeneity in consumer preferences through differences in estimated product elasticities across consumer types, thereby providing evidence supporting Posner's claim that a one-size-fits-all policy leads to income redistribution in the presence of a heterogenous population. Notice that high-income, college-educated, and to a lesser extent, high-risk consumers are significantly less price responsive than low-income, uneducated, and moderate drinkers. At an aggregate level, demand elasticity is quite similar across racial groups but differences arise once we distinguish by types of spirits. In markets with larger shares of minorities, demands for their favorite varieties of cordials, gins, and rums, are slightly less elastic, while for the rest demands are slightly more elastic

Table 9: Estimated Product Elasticities Across Demographics

	RISK		AGE		EDUC.		INCOME		MINORITY	
	Low	High	Low	High	Low	High	Low	High	Low	High
By Spirit Type:										
BRANDY	-3.65	-3.57	-3.42	-3.87	-3.76	-3.44	-3.93	-3.33	-3.52	-3.91
CORDIALS	-3.61	-3.34	-3.27	-3.55	-3.74	-3.15	-3.77	-3.08	-3.67	-3.56
GIN	-4.08	-3.78	-3.75	-3.97	-4.15	-3.62	-4.17	-3.57	-4.09	-3.89
RUM	-3.52	-3.27	-3.20	-3.47	-3.65	-3.08	-3.68	-3.02	-3.56	-3.47
VODKA	-4.02	-3.87	-3.75	-4.08	-4.13	-3.66	-4.21	-3.60	-3.99	-4.09
WHISKEY	-4.06	-3.93	-3.78	-4.17	-4.20	-3.73	-4.28	-3.66	-4.01	-4.22
By Price:										
EXPENSIVE	-4.93	-4.63	-4.50	-4.89	-5.05	-4.37	-5.12	-4.30	-4.89	-4.92
CHEAP	-2.89	-2.74	-2.65	-2.92	-3.01	-2.57	-3.06	-2.51	-2.90	-2.92
By Bottle Size:										
375 ml	-2.39	-2.32	-2.45	-2.27	-2.51	-2.19	-2.55	-2.13	-2.42	-2.45
750 ml	-3.71	-3.49	-3.72	-3.43	-3.82	-3.30	-3.89	-3.22	-3.68	-3.74
1.75 L	-4.87	-4.67	-4.96	-4.52	-5.00	-4.42	-5.11	-4.33	-4.75	-5.03
ALL PRODUCTS	-3.85	-3.67	-3.57	-3.89	-3.98	-3.48	-4.04	-3.42	-3.85	-3.90

Notes: Statistics are average product elasticity in the relevant category-demographic pair. "High" refers to markets in the top 20% while "Low" refers to markets in the bottom 20% for the corresponding demographic trait. Demographic categories defined in Section 2.4.

than average. Overall, the large degree of variation in estimated elasticities across spirit types and demographics corroborates the existence of substantial preference heterogeneity.

The inclusion of random coefficients (Σ) and demographic interactions (Π) allows for flexible substitution patterns across observable characteristics, particularly bottle size and select spirit types. Our estimates indicate that the cross-price elasticity for two products in the same bottle size category is, on average, 1.79 times greater than across bottle sizes, e.g., see Table F.1. We also observe cross-price elasticities for two products of the same spirit type to be 8.9 times greater than across spirit types. Brandies appear to be particularly homogenous as the large estimated random coefficient in this category implies implies cross-price elasticities between two brandies is 39.21 times greater on average than between a brandy and a product of a different spirit type. Cordials, on the other hand, are quite heterogenous as reflected by a cross-price elasticity within spirit type only 1.3 times greater than across spirit types.

4.3 Implied Upstream Marginal Cost

The theoretical model from Section 3 laid out how consumers and upstream distillers respond to any chosen retail pricing policy by the *PLCB*. To consider the response in upstream behavior to *but-for* retail pricing policy alternatives, we require an estimate of the upstream firms' marginal costs. Beginning with our robust demand estimates, we assume Bertrand–Nash pricing behavior by upstream firms to recover the marginal cost that renders the observed wholesale prices optimal under the current pricing policy and ownership structure according to the first-order conditions in equation (12). We rely on these marginal cost estimates in conducting our counterfactual analysis below.

We find the marginal costs of expensive products are on average 2.7 times higher than of inexpensive products (see Table F.2 in Appendix F). If brandies and whiskeys are aged more than four years, their marginal costs are approximately 1.5 times higher than of non-aged products. Imported products are 1.8 times more costly than non-imported products on average, reflecting increased transportation costs and import tariffs where the latter is paid by the upstream firms.

Table 10: Estimates of Upstream Market Power (Select Firms)

	All	Diageo	Bacardi	Beam	Jacquin	Sazerac
By Spirit Type:						
BRANDY	45.25	-	-	-	50.73	-
CORDIALS	35.79	30.87	17.19	47.63	57.55	38.69
GIN	37.07	32.52	20.37	39.87	37.80	54.03
RUM	37.36	32.25	38.06	40.81	48.30	-
VODKA	35.82	38.58	-	37.33	38.81	43.01
WHISKEY	34.30	32.01	18.86	36.55	36.17	39.47
By Price:						
CHEAP	45.70	46.45	44.46	45.53	46.48	44.26
EXPENSIVE	27.12	28.92	24.48	27.57	-	26.52
By Bottle Size:						
375 ml	59.18	59.57	65.96	72.07	91.76	47.71
750 ml	36.99	34.16	33.78	44.45	56.80	54.25
1.75 L	29.16	23.19	21.43	29.07	35.21	37.12
ALL PRODUCTS	36.49	34.25	34.99	39.43	46.48	42.33

Notes: Numbers reflect average Lerner indices weighted by quantity sold. Lerner index defined as $100 \times \frac{p^w - \hat{c}}{p^w}$.

Our cost estimates further indicate that upstream firms have significant market power (Table 10) as they, on average, enjoy a Lerner index of 36.5 percent – that is for every dollar in revenue the average product yields 36 cents in income. Products manufactured by larger firms like Diageo and Bacardi tend to have lower Lerner indices (roughly 34%) while smaller manufacturers such as Jacquin and Sazerac operate more niche product portfolios and earn 46.5% and 42.3% for each dollar in revenue, respectively. Across products, CHEAP and 375 ml products tend to be more profitable for all manufacturers while EXPENSIVE and 1.75 L products tend to have lower Lerner indices.

The presence of upstream market power then does two things for our analysis. First, it indicates that current policy may implicitly redistribute rents within these firms or even enable these firms to extract additional rents from consumers and/or the *PLCB*. Second, upstream firms possess the ability to respond to changes in policy – a factor which we must account for in solving for the equilibrium of any alternative policy.

5 What Does the Single-Markup Rule Achieve?

In this section we use the estimates of consumer demand and upstream firm marginal costs to understand why the use of single-markup rules, or equivalently uniform taxation, is so widespread among alcoholic beverage regulators.[30] In particular, we are interested in assessing whether such policies implicitly serve as a redistribution mechanism.

We conduct this analysis in the context of a two-stage Stackelberg game in which the regulator chooses its pricing policy anticipating the distillers' optimal price responses to the change in pricing policy, i.e., we allow upstream distillers to re-optimize their wholesale pricing decisions by solving repeatedly the model until finding the mutual best response of markups that maximize tax revenues and wholesale prices that maximize distillers' profits. We thus account not only for the direct effect of changing the pricing rule, the *mechanical effect*, but also the adjustment following the optimal response of suppliers or *behavioral response* to the markup policy (Saez, 2001).

All alternative pricing strategies assume the period t price of product j is the same across Pennsylvania. Common pricing across areas, but not across products, is also standard in private retailing industries as it avoids arbitrage concerns across stores. Throughout the analysis we also hold unit fees fixed at current levels, which allows us to generalize our results

[30] Orbach and Einav (2007) study the efficiency loss of a different scenario where firms sell all products, despite apparent differences in attributes and quality, at a uniform price. Note that the current *PLCB* policy does not apply the same price, but instead the same percent markup, to all products.

beyond Pennsylvania since nearly all states in the US (liquor control or otherwise) employ simple ad valorem taxes to regulate alcohol. We also hold fixed the product ownership structure observed in the data and employ the estimated marginal costs and preferences from Section 4. We thus assume the value of the outside option does not change, implicitly fixing retail beer and wine prices. This is a reasonable simplification in our context since the beer industry is competitive and retail wine prices are controlled by the *PLCB*.[31]

We begin in Section 5.1 where we show the single-markup policy leaves money on the table. We then move to assess the welfare implications of the policy in Section 5.2 where we show that the policy negatively impacts consumers in aggregate. In Section 5.3 we assess the distributional effects *within* the upstream firm and downstream consumer segments. Here, we show that the single-markup policy acts as a progressive tax which benefits particular firms and consumer types.

5.1 Is the Single-Markup Policy an Effective Tool to Generate Tax Revenue?

In this section we evaluate single markup policy's ability to generate tax revenue (Table 11). We use the first alternative pricing policy ("Single") to evaluate how far the current single markup rule is from the single-markup policy that maximizes tax revenues. This enables us to take a revealed preference approach in evaluating the degree to which the *PLCB* is used to generate tax revenue for the state versus manage ethanol consumption. We find that current policy achieves 99.6% of the potential tax revenue afforded by a single markup rule. Interestingly, this small increase in tax revenue requires a modest decrease in the single-markup from 30% to 23.73% as the regulator anticipates distillers would respond by increasing their wholesale prices from an average price of \$9.14 to \$9.26 per bottle. The upstream distiller response leads to a modest decline in average retail price from \$15.53 to \$15.03 per bottle, or 3.2%. This decrease in retail price in turn leads to a 8.09% increase in consumption in terms of bottles and a 9.72% increase in liters of ethanol. While we cannot reject the null hypothesis that the *PLCB*'s pricing rule is designed to reduce ethanol

[31] See Miller and Weinberg (2015). We do not capture effects of alternative spirit pricing policies on tax revenue from wine sales or beer distributor and restaurant license fees. Relative to spirits, wine purchases account for only 40% of the tax revenue generated by state liquor stores. Substitution to off-premise beer or consumption of alcohol in restaurants is likely limited, due to increasing product dissimilarity and different points of sale. Meng, Brennan, Purshouse, Hill-McManus, Angus, Holmes and Meier (2014) find very small elasticities of substitution between the on- and off-premise markets (suggesting that optimal license fees remain largely unaffected by changes in spirit pricing). They also find small cross-price elasticities between beer and spirits (0.113) and wine and spirits (0.163).

consumption, our results do indicate that the state places significant weight on generating tax revenue.[32]

Table 11: Aggregate Effects of the Single-Markup

	UNIT	CURRENT	SINGLE	PRODUCT
PLCB Markup	Percent	30.00	23.73	55.51
Prices:				
Wholesale	Dollars	8.69	8.82	8.40
Retail	Dollars	14.87	14.41	15.01
Alcohol Consumption:				
Bottles	Bottles, millions	41.34	44.69	42.23
Ethanol	Liters, millions	16.54	18.14	18.06
Profits:				
Tax Revenue	Dollars, millions	255.70	256.60	280.38
Distillers	Dollars, millions	113.13	128.38	112.11
Industry	Dollars, millions	368.83	384.98	392.49
PLCB Share	Percent	69.33	66.65	71.44

Notes: "Current " denotes the current scenario with the 30% markup rule. "Single" corresponds to the Stackelberg equilibrium which maximizes tax revenue with one markup. "Product" corresponds to the Stackelberg equilibrium with 312 product-specific markups. The markup we display for "PLCB Markup" does not include the 18% Johnstown Flood Tax. "Industry" denotes the sum of *PLCB* and distiller profits, in millions of dollars. "Tax Revenue" is total *PLCB* tax revenue (profits), in millions of dollars.

Thus far we have argued that a uniform policy can only maximize tax revenue in the unlikely event of homogeneity among the diverse set of products, consumers, and firms in our industry – a fact we disprove in Section 4. In the right-most column of Table 11, we present the "Product" Stackelberg equilibrium when the *PLCB* chooses the vector of 312 product-specific (e.g., Bacardi Dry, 750 ml) state-wide markups which maximize aggregate tax revenue.[33] As these markups reflect the own and cross-price elasticities of demand

[32]In terms of statistical significance, bootstrapped standard errors for this counterfactual lead us to reject the null hypothesis that current policy maximizes tax revenue at the 99% confidence level. To make this statement precise, we construct a bootstrapped sample of revenue-maximizing tax rates using the sampling based on the standard errors from the demand estimation. The procedure is as follows. We draw a set of demand parameters using the point coefficients and corresponding standard errors. Given this demand, we recover upstream marginal costs using the firms' first-order conditions and solve for the tax revenue-maximizing single-markup. We repeat this procedure 100 times and confirm that 23.73% lies outside the 99/1 confidence interval of the bootstrapped sample.

[33]Griffith, O'Connell and Smith (2017) also compute product-specific markups that take into account elasticity differences across products and a Pigouvian tax on alcohol content that is aimed to minimize a generic (and difficult to identify) externality function. However, they do not observe wholesale prices and cannot control for distillers' optimal response to changes in the markup policy. We also explored a product-specific, tax revenue maximizing markup policy defined by an optimal single tax on ethanol content of each product. Results, which do not differ much from the counterfactual reported in this section, are available upon request.

among the products while accounting for the response of the upstream firms, it enables us to evaluate how much money current policy leaves on the table by ignoring heterogeneity among products, consumers, and firms.

From Table 11 we see this level of flexibility enables the *PLCB* to raise the average markup from 30% to 52%, a sharp increase driven by high average markups for the least elastic categories, e.g., 90.5% for 375 ml bottles and 85.31% for brandies (on average), while markups for the most elastic categories such as the 32.05% for expensive products and 29.75% for 1.75 L bottles change very little. In Table 12 we see that upstream distillers respond by reducing their wholesale prices from \$8.69 to \$8.40, or about 3.42% on average. The largest price reductions occur in the 375 ml bottle (−23.87%), cheap (−9.88%), and brandy (−10.08%) segments.

Total distiller profits change little between the current policy and the more flexible "Product" markup policy as the distillers adjust their wholesale prices to counteract movements in product-level markups by the *PLCB*. When the *PLCB* is constrained to a single-markup however, the modest movement in the single-markup rate elicits small but effective responses from distillers (Table 12) leading to a large change in total distiller profits from \$113.13 to \$128.30 million, a 13.4% increase.

For consumers, average retail price increases only 1% from \$14.87 to \$15.01 reflecting the countervailing forces of falling wholesale price and increasing *PLCB* markups. The increased flexibility in the markup policy enables the *PLCB* to increase tax revenues \$24.68 million or 9.66% of current revenues – a significant improvement. This increase in collected alcohol taxes results from capturing a larger share of rents from both consumers and upstream firms: the integrated industry profits increase 6.4% but total upstream profits decrease about 1% and the *PLCB*'s share of industry profits to increase 2.1%. Put differently, the current uniform markup policy forfeits \$25 million in foregone tax revenue, or about 8.80% of potential profits, some of which is captured by the upstream firms.

Product-specific prices also generate an increase in aggregate consumption both in terms of bottles purchased, 2.2%, and more importantly as measured by the amount of ethanol consumed, 9.3%. This occurs despite robust estimates of downward-sloping demand for all consumers as reported in Table 7. The answer to this puzzle lies in the substantial heterogeneity of our demand estimates that induce optimal price increases together with price reductions to take advantage of cross-price substitution effects in order to maximize

Table 12: Retail and Wholesale Prices by Product Category

		Wholesale			Retail		
	Elast.	Current	Single	Product	Current	Single	Product
By Spirit Type:							
brandy	-3.64	8.12	8.25	7.31	13.90	13.48	15.68
cordials	-3.46	8.93	9.05	8.78	15.10	14.62	15.03
gin	-3.90	9.13	9.26	8.82	15.59	15.09	16.10
rum	-3.38	8.34	8.46	8.14	14.32	13.88	14.46
vodka	-3.95	7.95	8.07	7.58	13.76	13.35	13.73
whiskey	-3.98	9.89	10.01	9.70	16.74	16.19	16.62
By Price:							
cheap	-2.81	5.85	5.97	5.27	10.50	10.24	11.41
expensive	-4.74	11.97	12.10	12.00	19.91	19.21	19.15
By Bottle Size:							
375 ml	-2.36	3.85	3.97	2.93	7.15	7.04	7.72
750 ml	-3.58	8.52	8.64	8.23	14.49	14.04	15.01
1.75 L	-4.74	11.08	11.21	11.06	18.83	18.19	18.23
all products	-3.75	8.69	8.82	8.40	14.87	14.41	15.01

Notes: "Elast." corresponds to the average estimated demand elasticities from Table 8. Other reported statistics are average wholesale and retail price ($). "Cheap" ("Expensive") products are those products whose mean price is below (above) the mean price of other spirits in the same spirit type and bottle size. "Single" indicates the counterfactual where the *PLCB* chooses a revenue-maximizing tax, given unit fees. "Product" employs 312 product-specific taxes. All statistics are weighted by quantity sold (bottles) under the current *PLCB* policy.

tax revenues. Thus, while the average retail price for less elastic brandies and 375 ml products increase, 12.8% and 8.0%, respectively, the average retail price for more elastic products all decrease, such as in the case of vodkas −0.3%, expensive products −3.8%, and 1.75 L bottles −3.2%. On net, the effects of the latter price reductions dominate as consumption shifts towards these products and increasing overall consumption.

5.2 What is the Welfare Impact of the Single-Markup?

In this section we extend the analysis to look beyond the effectiveness of *PLCB* towards generating tax revenue and evaluate the implications of the single markup policy on consumers. We begin by discussing the welfare implications of ignoring heterogeneity among consumers and firms by comparing the Stackelberg equilibria generated under the current and "Product" policies. This amounts to a commentary on the welfare effects of price discrimination in the regulation of alcohol where our results indicate that current policy not only leaves money on the table but is also bad for consumers. As the "Product" markup policy assumes tax revenue and not utility maximization, we also solve for the *subsidy-free Ramsey* policy which we define below.

Table 13: Pricing Rules and Welfare

	Unit	Product	Ramsey
Tax Revenue	Dollars, millions	-24.68	-18.32
Consumers Better Off	Percent	16.68	0.42
Consumer Surplus	Dollars, millions	-9.47	-22.12
Distiller Profits	Dollars, millions	1.02	-9.48
Total Welfare	Dollars, millions	-8.45	-31.60

Notes: All numbers reflect the impact of the 30% single-markup relative to product-specific pricing. Change in consumer surplus is the aggregate compensating variation $CV = \sum_l CV_l$ of Section 3.1.1. "Consumers Better Off" is the percent of Pennsylvania drinking-age residents who benefit from the current policy, i.e., have compensating variation greater than zero. Welfare defined as total distiller profits plus total consumer surplus.

In the "Product" column in Table 13 we show that current policy not only forfeits significant tax revenue but also is sub-optimal for consumers as consumer surplus falls $9.47 million and only 16.68% of Pennsylvania consumers prefer the current single markup policy to product-level markups. Put differently, the majority of Pennsylvania residents would benefit from product-level markups. If we define total welfare as the sum of upstream distiller profits and consumer surplus, the current policy decreases total welfare by $8.45 million as the net benefit to distillers (profits increase $1.02 million, or 0.9%) offsets some of the negative impact to consumers. For the average drinking-age resident this shift in policy decreases their surplus $1.10, or 1.5% of his or her liquor expenditure.

What is remarkable in this result is that the "Product" policy assumes the *PLCB* sets markups to maximize tax revenue but ignores the implications to consumer surplus. The mechanism underlying this result lies in the consumption response under the alternative policy (Table 11). Theoretically, the consumption response to the alternative product-specific markup policy is ambiguous ex ante. As in the case of third degree price discrimination relative to uniform pricing, e.g., Schmalensee (1981), the sign of the aggregate consumption response depends on the different elasticities of demand, how close substitutes these products are among themselves, and the distribution of consumer preferences across all spirits. Given our parameter estimates it appears that consumers substitute away from overpriced spirits in favor of less expensive ones with the overall effect of increasing the consumption of liquors as product-specific pricing implies higher markups for less elastic products and lower markups for more elastic ones. Ultimately, this increase in consumption leads to an increase in consumer surplus (Varian, 1985).

Our analysis thus far excludes any negative externalities from ethanol consumption so it could be true that the current single markup policy foregos $24.68 million in tax revenue in order to reduce ethanol consumption by 1.53 million liters – a shadow value of $16.24 per liter of ethanol or $4.62 per 750 ml, 80 proof bottle. Laffont and Tirole (1993, §3.9) note that the cross-subsidization of certain population groups by others, for instance via a single-markup rule, can be optimal if the regulator intentionally distorts prices to favor a targeted class of consumers. Thus, an alternative hypothesis to justify the use of simple pricing rules is that the policy of the regulator was designed to protect certain consumer groups. Both of these hypotheses are rejected by the data, however (Appendix, Section D).

Of course, a product-specific markup policy which maximizes tax revenue is not likely to also maximize consumer surplus. To address the potential welfare impacts of the single markup, we solve for Stackelberg equilibrium under what we call the *subsidy-free Ramsey* markup policy which we define as the vector of 312 product markups that maximize aggregate consumer surplus subject to a government balanced budget constraint. Here, we modify Ramsey (1927) and assume that current policy generates sufficient revenue to cover any expenses incurred by the state related to ethanol consumption.[34] We further assume this expense scales linearly with ethanol consumption so the marginal social expense of ethanol consumption incurred by the state is $\frac{\$255.70 \textbf{ million}}{16.54 \textbf{ million liters of ethanol}} = \$15.46$ dollars per liter of ethanol. We view both of these assumptions as extreme so the results underlying our "Ramsey" equilibrium are conservative.[35] In comparison to the Ramsey markup policy the current single markup policy reduces consumer surplus $22.12 million and nearly all residents benefit from the alternative policy. In per capita terms, the average drinking-age consumer is worse off by $2.57 or 3.59% of her expenditure on liquor.

[34]This policy is "subsidy-free" as all upstream firms remain profitable in the Stackelberg equilibrium and would therefore each firm is willing to sell its product(s) in the state-run store.

[35]For instance, assuming the *PLCB* chooses markups to maximize consumer surplus while meeting only the level of tax revenues observed today (i.e., Ramsey, 1927) generates similar qualitative results to our "subsidy-free Ramsey" solution though the impact to consumer surplus is larger. Decreasing the social cost factor serves to modulate the impact to consumption.

5.3 Measuring Redistribution Effects from Uniform Pricing

In this section we use our robust estimates from the structural model to measure the implicit redistribution generated by the single markup, i.e., Posner's *taxation-by-regulation*. This enables us to identify identify common traits among winners and losers of this regulation.

The idea that regulation can serve a select few is of course not new. Stigler (1971) first articulated the hypothesis that regulation mostly served the interests of the firms in the regulated industry. Peltzman (1976) built on this view to consider consumers and other interest groups that may influence the design of regulatory rules and eventually the redistribution of rents among constituencies through the political process.[36] A novel aspect of our study is that we use a structural equilibrium model to identify winners and losers among both the regulated firms and consumers.

5.3.1 Upstream Performance Under Different Policies.

Our analysis begins in the upstream distillery market where we evaluate the induced redistribution of profits *within* upstream distillers. As these firms operate different product portfolios of Table 4 with the heterogeneous range of elasticities documented in Table 8, we hypothesize that *PLCB* policy impacts these firms differently – a point we confirm in Table 14. For simplicity, we focus our analysis of the upstream market to a comparison of the current equilibrium and the "Product" policy in which the *PLCB* selects 312 product-specific markups to maximize revenue. We show in Table E.4 (Appendix E) that, at least qualitatively, our conclusions are robust across a wide spectrum of alternative policies.

The implementation of product-specific prices leads to an average reduction in wholesale prices of 3.42%. Much of this decline is driven by smaller firms like Jacquin and Sazerac who lower their prices by 13.15% and 13.97%, respectively. In contrast, the reduction in wholesale price for large multi-product distillers like Diageo, Beam, and Bacardi is much smaller, 1.77%, 4.08%, and 1.32%, respectively, reflecting the diverse product sets offered by these firms. Moving to product-specific prices also increases the quantity sold for the firms in our sample.

[36] These theories of regulation build upon the influential work by Olson (1965) on collective action and politics. Noll (1989) summarizes the political economy aspects of regulatory capture and Laffont and Tirole (1993, §11) elegantly formalize it within a principal-agent model of regulation.

Table 14: Upstream Performance under Alternative Policies

	Wholesale Price ($)		Bottles Sold (M)		Margins (%)		Profits ($M)	
FIRM	CURRENT	PRODUCT	CURRENT	PRODUCT	CURRENT	PRODUCT	CURRENT	PRODUCT
Diageo	9.95	9.77	9.14	9.49	34.33	32.15	26.59	28.31
Beam	7.89	7.56	4.01	3.56	39.37	35.81	10.87	9.02
Jacquin	5.21	4.53	3.94	3.44	46.28	40.75	10.11	6.24
Bacardi	9.57	9.45	3.68	4.19	35.11	33.06	9.98	11.97
Sazerac	4.86	4.18	3.29	3.21	42.30	38.02	8.29	5.61
All Firms	8.69	8.40	41.34	42.23	36.54	33.59	113.13	112.11

Notes: "Current" corresponds to the current equilibrium. "Product" corresponds to the Stackelberg equilibrium with 312 product-specific markups. Upstream firms ordered according to total profits observed in the data. "Wholesale Price" is the average wholesale price (p^w) weighted by current bottles sold. "Margin" is defined as the average Lerner index (i.e., $100 \times \frac{p-c}{p}$) for each firm, weighted by current bottles sold.

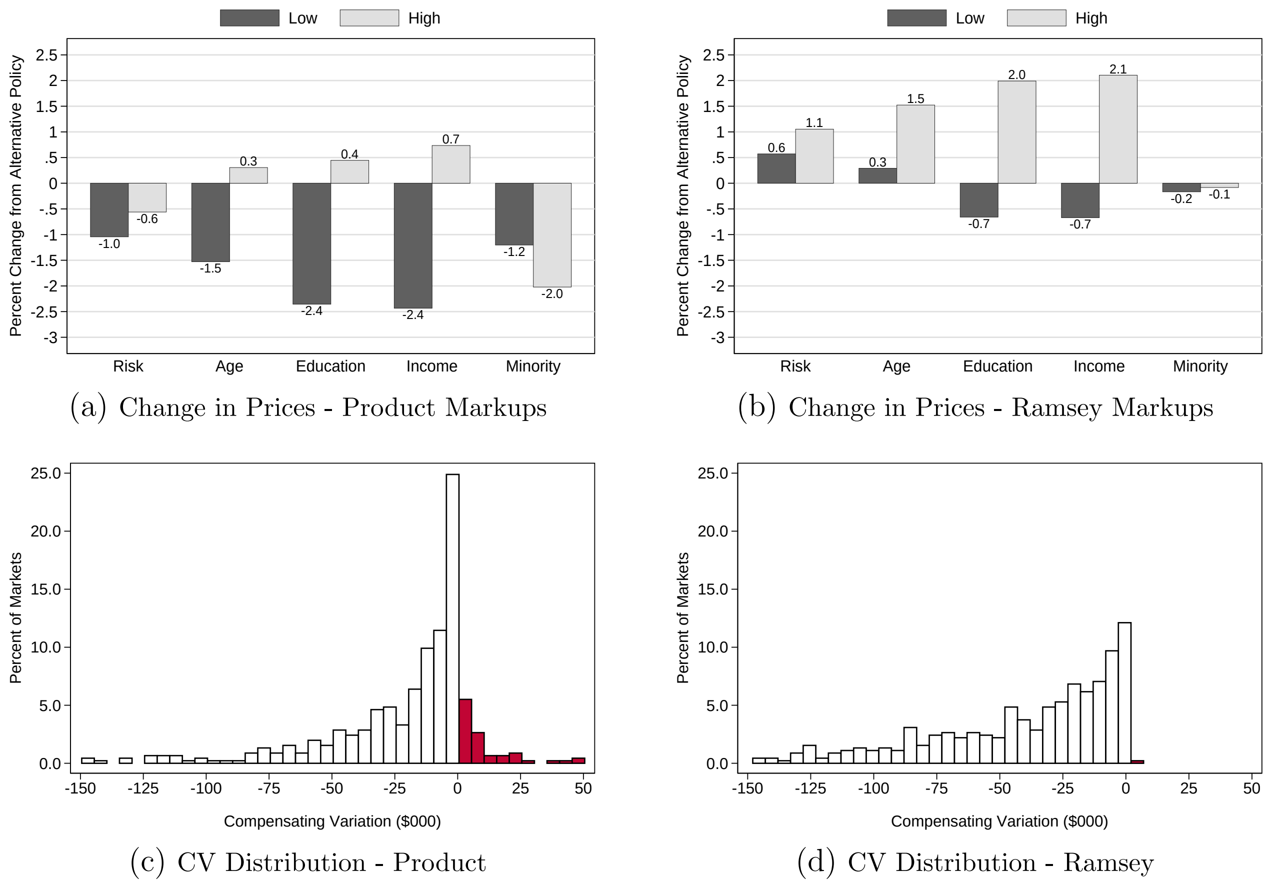
Moving to product prices ultimately shrinks the Lerner margins for all firms, reflecting the *PLCB*'s ability to flex its first-mover and monopoly power in the Stackelberg game. Not all firms are worse off, however, as large companies like Diageo and Bacardi are able to increase their aggregate profits by 6.44% ($1.71 million) and 19.99% ($1.99 million), respectively. This growth comes at the expense of smaller, more specialized firms like Jacquin and Sazerac as well as Beam who operates a product portfolio concentrated in the relatively elastic whiskey category, e.g., see Table 8.

We conclude that product-specific prices enable the regulator to extract market power from each of the firms while changes in product-level quantity demanded enables some firms to increase their profits at the expense of others. Put differently, the *PLCB*'s current single-markup increases market power in the upstream market while transferring profits from large firms like Diageo and Bacardi to small firms like Jacquin – a Philadelphia distillery.

5.3.2 Taxation by Regulation Among Consumers.

We turn now to the downstream segment to measure redistribution among different consumer types due to the single-markup rule. In Figure 2 we evaluate the change in equilibrium retail prices in the current policy relative to the Stackelberg equilibria under product-specific pricing (Panel a) and Ramsey markups (Panel b). To reflect differences in preferences across consumer types, we first calculate average retail price in each market under each policy using quantity sold under the current single markup rule as weights. Thus, a positive number indicates consumers pay a higher price under the current 30% markup for the products they favor than under the alternative policy considered.

Figure 2: Taxation by Single-Markup Regulation Among Consumers



(a) Change in Prices - Product Markups

(b) Change in Prices - Ramsey Markups

(c) CV Distribution - Product

(d) CV Distribution - Ramsey

Notes: Statistics represent percent change from the Stackelberg equilibria under the alternative markup policy to the one observed under the current 30% markup rule. Percent change in retail price is weighted by market shares in the data to capture differences in demand across demographic groups. Average of markets with top and bottom 20% of AGE, MINORITY, EDUCATION, and INCOME(as defined in Table 5. "Risk" is defined in Section 2.4. In panels (c) and (d) we present the distribution of compensating variation $\{CV_l\}_{l=1}^{454}$ under each policy, denominated in thousands of dollars.

Panel (a) indicates that by ignoring the heterogenous preferences documented in Tables 6 and 8, the current 30% single-markup rule induces substantial price distortions across demographic traits. For instance, the current regulation results in underpricing of spirits by 2.4% in the least affluent markets while overpricing them by 0.7% in wealthy neighborhoods – a 3.1 percentage point difference across consumers of different income levels. A similar result arises when we classify markets by the share of population with some college education, which is highly correlated with income. To our knowledge, this redistribution effect of alcohol taxation regulation has not been documented before.

In panel (b) we see that the bars shift up relative to panel (a) reflecting the general decrease in retail prices under the Ramsey markup policy where the state government maximizes consumer welfare subject to their externality-adjusted budget constraint. Again, low income and poorly-educated consumers pay lower retail prices under the current system – confirming our initial finding that the current system acts as a progressive tax. Interestingly, when we differentiate the markets by minority share, markets with both high and low minority shares pay prices under the single markup which are nearly identical to the Ramsey solution.

How do these price changes translate to differences in welfare? In panels (c) and (d) we present the distribution of consumer compensating variation under each alternative policy. In both figures we see that consumers are generally worse-off under the current policy (i.e., compensating variation less than zero) though some consumers benefit, particularly when the *PLCB* sets policy to maximize tax revenue (i.e., "Product"). The distribution of compensating variation under "Product" pricing (panel a) is also more concentrated around zero than under Ramsey pricing. In Table 15 we project these distributions onto observable market characteristics to identify the relative impacts to different consumer types thereby measuring Posner's *taxation-by-regulation* among consumers.

In regressions (i) and (iv) we see that among the characteristics that summarize the consumers used in our estimation, the consumers who are less-educated, have less income, and are minorities tend to be impacted less by the current policy. When compared to the Ramsey policy, we see similar results with the exception of minority share which is insignificant indicating that the share of a market which identifies as non-white provides little information as to whether consumers in the market would benefit Ramsey policy.

In the remaining regressions we evaluate Stigler's hypothesis by investigating whether political views are aligned with the relative winners and losers. Our results indicate the share of a market which is registered democrat increases compensating variation under both alternatives, even after controlling for population density as a proxy for downtown urban areas. At the same time, consumers who live outside the Philadelphia and Pittsburgh areas, i.e., living in "rural" areas, also benefit under the current policy as do consumers who live in areas with a large number of churches per capita. In stark contrast, the prevalence of liquor-related crimes (e.g., domestic violence) is not a strong predictor.

It is important to recall that most consumers are worse-off under the current policy so the results in Table 15 largely reflect differences in the willingness to pay of consumers to not live under the current policy. If we constrain the analysis to just the Product alternative policy where roughly 17% of residents actually prefer the current single markup policy –

Table 15: Measuring Taxation by Regulation Across Different Consumers

	Product			Ramsey		
	(i)	*(ii)*	*(iii)*	*(iv)*	*(v)*	*(vi)*
Age	−3.7956**			0.2724		
	(1.7853)			(2.4097)		
Education	−7.5975***			−8.4576***		
	(0.6468)			(0.8933)		
Income	−3.7976***			−4.0895***		
	(0.6915)			(0.738)		
Minority	1.7433***			−0.7192		
	(0.3382)			(0.5286)		
Registered Democrat		5.3282***	5.3021***		3.8962***	4.1787***
		(0.6298)	(0.7009)		(0.5774)	(0.6699)
population density		0.3899***	0.3844***		0.0812	−0.0236
		(0.1067)	(0.1272)		(0.1035)	(0.125)
churches per capita		1.6554***	1.5812***		1.9161***	1.8031***
		(0.1936)	(0.2134)		(0.2041)	(0.2335)
rural		2.7962***	2.7097***		2.3551***	2.0484***
		(0.5013)	(0.5741)		(0.478)	(0.5208)
liquor related crimes			0.0026			0.0020
			(0.0033)			(0.0037)
R^2	0.6616	0.3861	0.3896	0.6123	0.3754	0.3754
N	454	454	355	454	454	355

Notes: Dependent variable mean market l compensating variation (Section 3.1.1) divided by total market l liquor expenditure. Robust standard errors reported in between parentheses with p-values denoted by * $p < 0.10$, ** $p < 0.05$, and **** $p < 0.01$. All regressions include a constant (not reported). age is log(average age) in the location. education, income, and minority are defined in Table 5. Registered Democrat is the share of the population registered as democrats as of 2009 according to the Pennsylvania Department of State, `https://www.pavoterservices.state.pa.us`. churches per capita denotes the number of establishments located in the market's census blocks with a primary NAICS code of 8131 (source: Reference USA) divided by the market population. rural is equal to one if the MSA is outside Philadelphia or Pittsburgh. liquor related crimes is logged per-capita number of reported incidences of domestic violence, drunk driving, drunkenness, vandalism over 2002-2003. Data on this variable is limited to 355 locations. The R^2 statistic in the probit model is the pseudo-R^2.

implicitly assuming the state uses the *PLCB* solely as a source of tax revenue – our results become stronger. In Table 16 we identify characteristics of consumers who are better off under the single-markup rule via a probit regression where the left-hand variable is equal to one when the mean compensating variation of market l is greater than zero (i.e., the average resident is better off under the current policy). Again, we see that consumers who live in rural areas, consumers who live in areas with large shares of registered democrats, or consumers who live in areas with a large number of churches per capita tend to benefit from the current policy.

Stigler argued that interest groups can capture a regulator in order to generate preferential policy. The fact we find that urban areas benefit from the single-markup pricing rule

Table 16: Who Benefits from the Current Uniform Rule?

	(*i*)	(*ii*)	(*iii*)
Age	0.9726**		
	(0.4931)		
Education	−0.4083**		
	(0.1886)		
Income	−0.8294***		
	(0.1951)		
Minority	0.4048***		
	(0.1000)		
Registered Democrat		0.7430***	0.8819***
		(0.1326)	(0.1603)
population density		0.0131	0.0170
		(0.0203)	(0.0267)
churches per capita		0.2665***	0.2588***
		(0.0446)	(0.0518)
rural		0.1713*	0.2532**
		(0.1010)	(0.1263)
liquor related crimes			−0.0002
			(0.0007)
R^2	0.2901	0.2464	0.3186
N	454	454	355

Notes: Results reflect a probit regression of "$\mathbf{CV}_l > 0$" onto observable characteristics where the alternative pricing model is product-specific markups which maximize tax revenue (i.e., "Product" in the text). Dependent variable is equal to one when a market has mean compensating variation less than zero (i.e., the average drinking-age resident is better off under the current policy). Marginal effects reported. Robust standard errors reported in between parentheses with p-values denoted by * $p < 0.10$, ** $p < 0.05$, and **** $p < 0.01$. All regressions include a constant (not reported). age is log(average age) in the location. education, income, and minority are defined in Table 5. Registered Democrat, population density, churches per capita, rural, and liquor related crimes are described in Table 15. The R^2 statistic is the pseudo-R^2.

supports another component of Stigler's argument that successful lobbying efforts are more likely to arise in populated urban areas that are more conducive to political coordination and where they may deliver a larger share of votes. Whereas Stigler focused on explicit lobbying efforts, our results indicate that differences in tastes that vary systematically with location could allow agents to implicitly coordinate via the legislative process.[37] Citizens in rural areas therefore may benefit from the current policy simply because they prefer cheap products and they vote for state representatives who guarantee not to change this policy.

[37] Since the analysis of occupational licensing by Stigler (1971), many early applications of the Chicago School have tried to characterize the political groups benefiting from regulation. See for instance the works of Linneman (1980) and Pashigian (1985).

6 Concluding Remarks

We study the redistributive effects of simple policy when agents have heterogeneous preferences over outcomes. We focus on the regulation of spirits where we observe the pricing decisions of all upstream firms as well as the final retail prices faced by heterogenous consumers. In our setting, the regulator is legally-mandated to charge a uniform 30% markup on all horizontally-differentiated products it sells in state-run stores. We show there exists significant heterogeneity in the consumption patterns of different consumer types as well as heterogeneity in the size and product portfolios offered by the upstream suppliers; hence, a uniform policy likely generates winners and losers among both firms and consumers.

We show that the *PLCB*'s single-markup policy is sub-optimal as it achieves 91.2% of potential revenue and decreases consumer welfare. Few consumers benefit from the single-markup policy but those who do benefit tend to be low income, poorly-educated, young, and/or minority consumers. Since these beneficiaries also live in areas with large shares of registered democrats, in rural areas, or in areas with a high concentrations of churches; our results suggest that the persistence of the single-markup policy *PLCB* could be the result of "Legislative Capture" as state representatives garner the favor of these constituent groups. The fact that we also find that Jacquin, an upstream firm with local roots in Pennsylvania, benefits substantially from the current policy is corroborating evidence. If we add to the documented evidence that unionized store clerks employed in the state-run stores capture most of the profits of the *PLCB* through wages that double those prevailing in the private retailing sector, e.g., Seim and Waldfogel (2013, §1.C), it seems likely that the *PLCB* is an effective rent-seeking mechanism for very specific interest groups.

References

Aguirregabiria, V., D. Ershov, and J. Suzuki (2016) "Estimating the Effect of Deregulation in the Ontario Wine Retail Market," Mimeo, University of Toronto.

Atkinson, A. B. and J. S. Stiglitz (1972) "The Structure of Indirect Taxation and Economic Efficiency," *Journal of Public Economics*, Vol. 1, pp. 97–119.

Berry, S. (1994) "Estimating Discrete-Choice Models of Product Differentiation," *RAND Journal of Economics*, Vol. 25, pp. 242–262.

Berry, S., J. Levinsohn, and A. Pakes (1995) "Automobile Prices in Market Equilibrium," *Econometrica*, Vol. 63, pp. 841–890.

Berry, S. T. and P. A. Haile (2010) "Nonparametric Identification of Multinomial Choice Demand Models with Heterogeneous Consumers," Discussion Paper 1718, Cowles Foundation. Yale University.

——— (2014) "Identification in Differentiated Products Markets Using Market Level Data," *Econometrica*, Vol. 82, pp. 1749–1797.

Bouchery, E. E., H. J. Harwood, J. J. Sacks, C. J. Simon, and R. D. Brewer (2011) "Economic Costs of Excessive Alcohol Consumption in the U.S., 2006," *American Journal of Preventive Medicine*, Vol. 41, pp. 516–524.

Bresnahan, T. F., S. Stern, and M. Trajtenberg (1997) "Market segmentation and the sources of rents from innovation: Personal Computers in the Late 1980s," *RAND*, Vol. 28, pp. S17–S44.

Cerda, M., V. Johnson-Lawrence, and S. Galea (2011) "Lifetime income patterns and alcohol consumption: Investigating the association between long and short-term income trajectories and drinking,"Technical report, National Institute of Health.

Chintagunta, P., J.-P. Dubé, and V. Singh (2003) "Balancing Profitability and Customer Welfare in a Supermarket Chain," *Quantitative Marketing & Economics*, Vol. 1, pp. 111–147.

Conlon, C. T. and N. Rao (2015) "The Price of Liquor is Too Damn High: The Effects of Post and Hold Pricing," Mimeo, Columbia University.

Dasgupta, P. and J. E. Stiglitz (1971) "Differential Taxation, Public Goods, and Economic Efficiency," *Review of Economic Studies*, Vol. 38, pp. 151–174.

Dubé, J.-P., J. T. Fox, and C.-L. Su (2012) "Improving the Numerical Performance of Static and dynamic Aggregate Discrete Choice Random Coefficients Demand Estimation," *Econometrica*, Vol. 80, pp. 2231–2267.

Finkelstein, A., J. Poterba, and C. Rothschild (2009) "Redistribution by Insurance Market Regulation: Analyzing a Ban on Gender-Based Retirement Annuities," *Journal of Financial Economics*, Vol. 91, pp. 38–58.

Gandhi, A. and J.-F. Houde (2016) "Measuring Substitution Patterns in Differentiated Products Industries," Mimeo, University of Wisconsin-Madison.

Griffith, R., M. O'Connell, and K. Smith (2017) "Design of Optimal Corrective Taxes in the Alcohol Market," Mimeo, Institute for Fiscal Studies.

Haughwout, S. P., R. A. Lavallee, and I.-J. P. Castle (2015) "Apparent Per Capita Alcohol Consumption: National, State, And Regional Trends, 1977-2013,"Technical report, National Institute on Alcohol Abuse and Alcoholism.

Hausman, J. (1998) "Taxation by Telecommunications Regulation," *Tax Policy and the Economy*, Vol. 12, pp. 29–48.

Hendel, I. (1999) "Estimating Mulitple-Discrete Choice Models: An Application to Computerization Returns," *Review of Economic Studies*, Vol. 66, pp. 423–446.

Hendel, I. and A. Nevo (2006) "Measuring the Implications of Sales and consumer Inventory Behavior," *Econometrica*, Vol. 74, pp. 1637–1673.

Jordan, W. A. (1972) "Producer Protection, Prior Market Structure and the Effects of Government Regulation," *The Journal of Law and Economics*, Vol. 15, pp. 151–176.

Kahn, A. E. (1970) *The Economics of Regulation. Vol. I: Economic Principles*, New York, NY: John Wiley & Sons.

Laffont, J.-J. and J. Tirole (1993) *A Theory of Incentives in Procurement and Regulation*, Cambridge, MA: The MIT Press.

Leung, S. F. and C. E. Phelps (1993) "My Kingdom for a Drink?: A Review of the Price Sensitivity of Demand for Alcoholic Beverages," in M. Hilton and G. Bloss eds. *Economics and the Prevention of Alcohol-Related Problems*, Washington, DC: National Institute on Alcohol Abuse and Alcoholism, NIH Publication No. 93-3513.

Linneman, P. (1980) "The Effects of Consumer Safety Standards: The 1973 Mattress Flammability Standard," *The Journal of Law and Economics*, Vol. 23, pp. 461–479.

McDonald, J. B. (1984) "Some Generalized functions for the Size Distribution of Income," *Econometrica*, Vol. 52, pp. 647–663.

Meng, Y., A. Brennan, R. Purshouse, D. Hill-McManus, C. Angus, J. Holmes, and P. S. Meier (2014) "Estimation of own and cross price elasticities of alcohol demand in the UKA pseudo-panel approach using the Living Costs and Food Survey 20012009," *Journal of Health Economics*, Vol. 34, pp. 96–103.

Miller, N. H. and M. Weinberg (2015) "Mergers Facilitate Tacit Collusion: Empirical Evidence from the U.S. Brewing Industry," Mimeo, Georgetown University.

Miravete, E. J., K. Seim, and J. Thurk (2017) "Market Power and the Laffer Curve," Mimeo, University of Texas at Austin.

Nelson, J. P. and A. D. McNall (2016) "Alcohol Prices, Taxes, and Alcohol-related Harms: A Critical Review of Natural Experiments in Alcohol Policy for Nine Countries," *Health Policy*, Vol. 120, pp. 264–272.

Nevo, A. (2000) "Mergers with differentiated Products: The Case of the Ready-to-Eat Cereal Industry," *RAND Journal of Economics*, Vol. 31, pp. 395–421.

——— (2001) "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica*, Vol. 69, pp. 307–342.

Noll, R. G. (1989) "Economic Perspectives on the Politics of Regulation," in R. Schmalensee and R. Willig eds. *Handbook of Industrial Organization,* Vol. 2, New York, NY: North-Holland.

Olson, M. (1965) *The Logic of Collective Action*, Cambridge, MA: Harvard University Press.

Orbach, B. Y. and L. Einav (2007) "Uniform Prices for Differentiated Goods: The Case of the Movie-Theater Industry," *International Review of Law and Economics*, Vol. 27, pp. 129–153.

Pashigian, B. (1984) "The Effects of Environmental Regulations on Optimal Plant Size and Factor Shares," *Journal of Law and Economics*, Vol. 27, pp. 1–28.

——— (1985) "Environmental Regulation: Whose Self-Interests Are Being Protected?" *Economic Inquiry*, Vol. 23, pp. 551–584.

Peltzman, S. (1976) "Toward a More General Theory of Regulation," *Journal of Law and Economics*, Vol. 19, pp. 211–240.

Posner, R. A. (1971) "Taxation by Regulation," *BELL Journal of Economics and Management Science*, Vol. 2, pp. 22–50.

Ramsey, F. P. (1927) "A Contribution to the Theory of Taxation," *Economic Journal*, Vol. 37, pp. 47–61.

Sacks, J. J., K. R. Gonzales, E. E. Bouchery, L. E. Tomedi, and R. D. Brewer (2015) "2010 National and State Costs of Excessive Alcohol Consumption," *American Journal of Preventive Medicine*, Vol. 49.

Saez, E. (2001) "Using Elasticities to Derive Optimal Income Tax Rates," *Review of Economic Studies*, Vol. 68, pp. 205–229.

Schmalensee, R. (1981) "Output and Welfare Implications of Monopolistic Third-Degree Price Discrimination," *American Economic Review*, Vol. 71, pp. 242–247.

Seim, K. and J. Waldfogel (2013) "Public Monopoly and Economic Efficiency: Evidence from the Pennsylvania Liquor Control Boards Entry Decisions," *American Economic Review*, Vol. 103, pp. 831–862.

Somaini, P. and F. Wolak (2015) "An Algorithm to Estimate the Two-Way Fixed Effect Models," *Journal of Econometric Methods*, Vol. 4.

Stigler, G. J. (1971) "The Theory of Economic Regulation," *BELL Journal of Economics and Management Science*, Vol. 2, pp. 3–21.

Teh, B.-R. (2015) "Do Liquor Stores Increase Crime and Urban Decay? Evidence from Los Angeles," Mimeo, University of California-Berkeley.

Varian, H. R. (1985) "Price Discrimination and Social Welfare," *American Economic Review*, Vol. 75, pp. 870–875.

Villas-Boas, S. B. (2007) "Vertical Relationships between Manufacturers and Retailers: Inference with Limited Data," *Review of Economic Studies*, Vol. 74, pp. 625–652.

Waldfogel, J. (2003) " Preference Externalities: An Empirical Study of Who Benefits Whom in Differentiated-Product Markets," *RAND Journal of Economics*, Vol. 34, pp. 557–68.

Weyl, E. G. and M. Fabinger (2013) "Pass-through as an economic tool: Principles of incidence under imperfect competition," *Journal of Political Economy*, Vol. 121, pp. 528–583.

Appendix

A Data

In this section we discuss the data in more detail. We begin with a discussion of how we aggregate the initial daily, store-level *PLCB* data and how we define market areas served by each store. We also address the possibility of stock-outs and how we link the available demographic information to our geographic market definition.

To reduce the size of the estimation sample, we consider the periodicity with which we observe price changes in the data. *PLCB* regulation in place during our sample period allows price to change only for two reasons: permanent and temporary wholesale price changes. Both follow set timing requirements. Permanent price changes can take effect on the first day of one of the *PLCB*'s four-week long accounting reporting periods. Temporary sales, on the other hand, begin on the last Monday of each month and last for either four or five weeks until the day before the last Monday of the following month. Reporting periods and temporary sales periods thus align largely, but not perfectly. To recognize that temporary price reductions are more prevalent than permanent ones (89.7% of price changes in the sample are temporary in nature) and avoid having multiple very short periods, we use sales periods as our time interval. In case of permanent price changes that take effect at the beginning of a reporting period that bisects two sales periods, we assume that the price change takes effect in the sales period that most overlaps with the given reporting period. This results in 22 "pricing periods" during which prices remain constant. In aggregating our daily sales data to the level of sales during a pricing period, we treat a product as being available in a store if we observe a sale at least once during a given pricing period. The length of the pricing period alleviates concern about distinguishing product availability from lack of sales in the period.

Stores exhibit significant variation in the product composition of purchases. These differences reflect heterogeneity in consumer preferences more than differences in the availability of products across stores: Of the 100 best selling products statewide in 2003, the median store carried 98.0%, while a store at the fifth percentile carried 72.0% of the products. Similarly, of the 1000 best selling products statewide in 2003, the median store carried 82.03%, while a store at the fifth percentile carried 44.2% of the products. The product availability at designated "premium" stores is somewhat better than the average, with the median premium store carrying all of the top 100 products and 95.1% of the top 1000 products. In addition, a customer can request to have any regular product in the *PLCB*'s product catalog shipped to his local store for free, should that store not carry the product.

The fact that most stores carry most popular products and can provide access to all products in the catalog easily, together with the absence of price differences across stores, supports an assumptions underlying our demand model: Differences in product availability do not drive customers' store choices to a significant degree and as a result, consumers visit the store closest to them. In making this assumption, which allows us to focus on the consumer's choice between different liquor products available at the chosen store, we follow previous studies using scanner data such as Chintagunta, Dubé and Singh (2003).

To define the population served by each store, we calculate the straight-line distance to each store from each of Pennsylvania's 10,351 regular block groups and assign consumers to the closest open store for each pricing period. In instances where the *PLCB* operates more than one store within a ZIP code, we aggregate sales across stores to the ZIP code level; there are 114 such ZIP codes out of a total of 1,775. Note that these instances include both store relocations, where a store moved from one location in a ZIP code to another during 2003, but the data contain separate records for the store in the two locations, and instances where the *PLCB* operates two stores simultaneously within a ZIP code.[38] We consider the resulting block group zones as separate markets.

We derive consumer demographics for the stores' market areas by calculating the total population and population-weighted average demographics. We obtained detailed information on each block group's discrete income distribution by racial identity of the head of household, with household income divided into one of 16 categories. We aggregate across racial groups and across block groups in a store's market area to derive the discrete income distribution separately for white and non-white households. We construct two income measures. First, we calculate the share of high-income households by minority status, defined as households with incomes above $50,000. Second, we fit continuous market-specific distributions to the discrete distributions of income conditional on minority status. We employ generalized beta distributions of the second kind to fit the empirical income distributions. McDonald (1984) highlights that the beta distribution provides a good fit to empirical income data relative to other parametric distributions. Similarly, used a generalized beta distribution to estimate the continuous market-specific age distribution though due to data census limitations could not condition this on race or income.

We similarly obtained information on educational attainment by minority status and aggregated across several categories of educational attainment to derive the share of the population above the age of 25 with at least some college education, by minority status and market.

Our price instruments come from two sources. First, the data on retail prices in other liquor control states consists of monthly product-level shelf prices by liquor control state. We assign a month to our Pennsylvania pricing periods to facilitate a match between the two data sets. Second, we attained historical commodity prices for corn and sugar from Quandl, a data aggregator. The prices are the monthly price of a "continuous contract" for each

[38] We drop wholesale stores, administrative locations, and stores without valid address information, for a total of 13 stores.

commodity where a "continuous contract" is defined as a hypothetical chained composite of a variety of futures contracts and is intended to represent a the spot market price of the given commodity. We also attained prices for rice, sorghum, wheat, barley, oats, and glass (as a cost input for bottle size) but found these input costs provided little additional explanatory power.

B Additional Descriptive Statistics

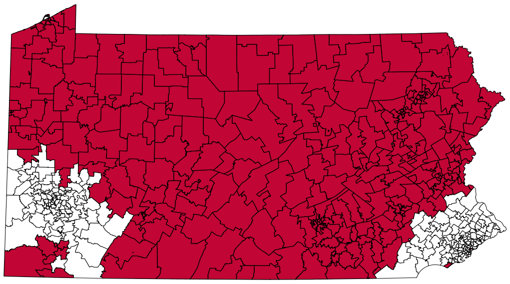
Table B.1 presents the distribution of bottle prices contained in our sample of 312 products. Average price is increasing across bottle sizes both within a category and for the whole sample. Vodkas tend to be the most expensive products, while rums are least expensive.

Table B.1: Average Price and Market Shares by Type and Size

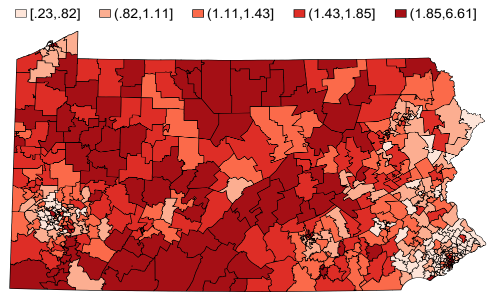
			Share of Market	
	Products	Avg. Price	By Quantity	By Revenue
BRANDY	26	14.41	7.26	6.75
375 ml	7	8.54	1.75	1.09
750 ml	13	15.56	4.28	4.13
1.75 L	6	18.76	1.22	1.52
CORDIALS	62	14.08	13.59	13.71
375 ml	13	10.76	2.11	1.49
750 ml	46	14.16	10.80	11.05
1.75 L	3	27.34	0.67	1.17
GIN	28	15.15	6.72	7.04
375 ml	4	7.80	0.62	0.33
750 ml	46	12.40	3.19	2.92
1.75 L	3	21.06	2.91	3.79
RUM	40	13.72	16.31	15.70
375 ml	5	6.59	1.65	0.73
750 ml	23	12.66	9.56	8.11
1.75 L	12	18.71	5.11	6.86
VODKA	66	16.82	32.10	29.80
375 ml	8	8.14	6.76	2.34
750 ml	33	15.54	10.85	11.08
1.75 L	25	21.29	14.50	16.37
WHISKEY	90	16.77	24.03	27.01
375 ml	11	9.12	2.33	1.37
750 ml	42	15.50	11.61	11.70
1.75 L	37	20.49	10.10	13.94
ALL PRODUCTS	312	16.35	100.00	100.00

Notes: "Quantity" market share is based on bottles while "Revenue" is based on dollar values.

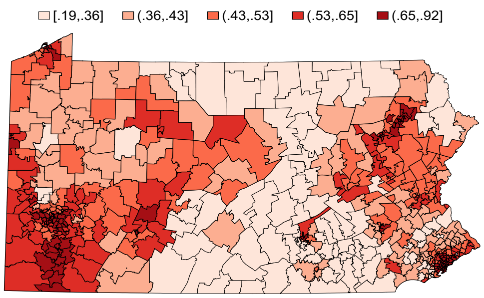
Figure B.1: Spatial Distribution of Consumer Characteristics



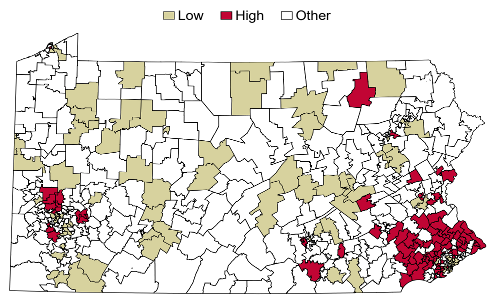
(a) Rural



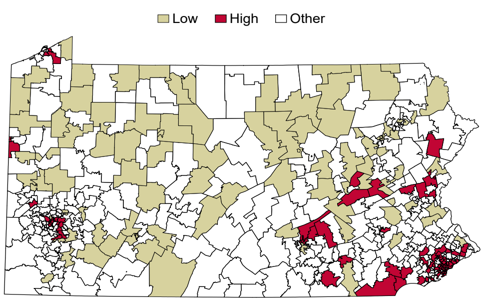
(b) Churches per Capita



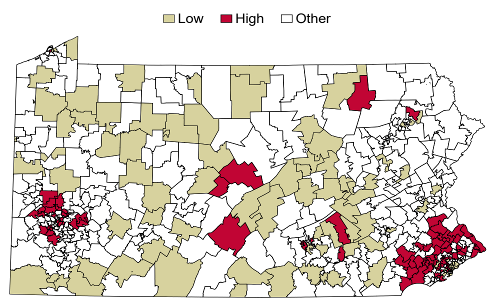
(c) Registered Democrat



(d) Income



(e) Minority



(f) Education

C Estimation Procedure

In this Appendix, we lay out the three-stage estimation procedure we adopt to estimate contributions to the consumer's mean utility from a given product, δ_{jlt}, and individual-specific contributions to utility, μ_{ijlt}. We discuss each stage in turn, highlighting the variation in the data that allows us to identify the relevant parameters in each stage.

C.1 Stage 1: Random Coefficients and Demographic Interactions

In the first of the three estimation stages, we estimate the contributions of unobserved (Σ) and observed (Π) demographic interactions to deviations from mean utility, μ_{ijlt}, controlling for location and product by time FE. We decompose the unobserved product valuations, ξ_{jlt}, as follows

$$\xi_{jlt} = \zeta_l^1 + \xi_{jt} + \Delta\xi_{jlt} \,. \tag{C.1}$$

In equation (C.1), ζ_l^1 is a market fixed effect that captures systematic variation across locations in the preference for spirits consumption, relative to beer and wine.[39] We control for systematic variation in preferences for a given product over time via ξ_{jt}, to reflect the fact that across the state, a product's mean demand varies over the course of the year. The remaining structural error $\Delta\xi_{jlt}$ represents deviations in unobserved product valuations within a store from these mean product-time valuations, controlling for the average taste for spirits in market l.

This decomposition of ξ_{jlt} simplifies the mean utility of product j, δ_{jlt} in equation (5a), to

$$\delta_{jlt} = \zeta_l^1 + \zeta_{jt}^2 + \Delta\xi_{jlt} \,, \tag{C.2}$$

where the product and time specific fixed effect ζ_{jt}^2 comprises the effect of product characteristics ($x_j\beta$), seasonal buying ($H_t\gamma$), price (αp_{jt}^r), and ξ_{jt} on a product's mean utility.

Equation (C.2) highlights an advantage to our setting: since price does not vary across locations l, we are able to control for its mean contribution to utility via product by time FE, which we then use in a second stage estimation to isolate α.

Given a guess at $\theta_A = \{\Sigma, \Pi\}$, we solve for the structural error $\Delta\xi_{jlt}(\theta_A)$ using the following algorithm. We first find the mean-utility levels $\delta_{jlt}(S_{jlt};\theta_A)$ that set the predicted market share of each product, s_{jlt} in equation (7), equal to the market share observed in the data, S_{jlt}.[40]

[39] This accounts for the fact that the potential market is defined based on the average Pennsylvanian's consumption as disaggregated per-capita consumption of alcoholic beverages is not available.

[40] We make use of the contraction mapping procedure outlined in Appendix I of *BLP*, imposing a tolerance level for the contraction mapping of 1e-14 as advised by Dubé, Fox and Su (2012, §4.2) to ensure convergence to consistent stable estimates.

To evaluate the integral in equation (7) we simulate for each market l the purchase probabilities of $1,000$ randomly drawn heterogeneous consumers who vary in their demographics and income. We construct the sample of simulated consumers for each market by relying on the empirical distributions of the demographic attributes considered above – whether a consumer is young, non-white, college educated, and their income level – incorporating correlations between demographic attributes where possible. Conditional on a realization of a consumer's minority status, we take random draws from the corresponding income and educational attainment distributions and assign the consumer to an age bin based on the unconditional distribution of age above 21 years in the relevant location. See Appendix A for further details. Since the ambient population of stores changes with store openings and closings over the course of the year, the simulated set of agents changes in each pricing period. Lastly, we account for the unobserved preferences via Halton draws.

Given mean utility levels that equate predicted and actual market shares, we then follow Somaini and Wolak (2015) and use a within transformation of δ to remove the store and product-period *FE* ζ_l^1 and ζ_{jt}^2, leaving only $\Delta\xi_{jlt}$.

We follow the earlier literature in using a generalized method of moments (*GMM*) estimator that interacts $\Delta\xi$ with within-transformations of suitable instruments Z. Define Z^+ as the within transformation of the instruments matrix; e.g., for instrument k, $Z_{jlt}^{+,k} = Z_{jlt}^k - \overline{Z_{jt}^k} - \overline{Z_l^k}$. The *GMM* estimator exploits the fact that at the true value of parameters $\theta^\star = (\Sigma^\star, \Pi^\star)$, the instruments Z^+ are orthogonal to the structural errors $\Delta\xi(\theta^\star)$, i.e., $E\left[Z^{+'}\Delta\xi(\theta^\star)\right] = 0$, so that the *GMM* estimates solve

$$\hat{\theta}_A = \underset{\theta_A}{\operatorname{argmin}} \left\{\Delta\xi(\theta_A)' Z^+ W^+ Z^{+'} \Delta\xi(\theta_A)\right\}, \tag{C.3}$$

where W^+ is the weighting matrix, representing a consistent estimate of $E[Z^{+'}\Delta\xi\Delta\xi' Z^+]$.[41] To increase the likelihood of achieving a global minimum, we employed the Knitro Interior/Direct algorithm suggested by Dubé et al. (2012) starting from several different initial conditions.

C.2 Stage 2: Mean Utility – Price and Seasonality Coefficients

In the second of the three stages of the estimation procedure, we decompose the mean utility implied by the estimated first-stage coefficients $\hat{\theta}_A$, $\delta_{jlt}(\hat{\theta}_A)$, into the associated location and

[41] In constructing our optimal weighting matrix, we first assume homoscedastic errors and use $W^+ = [Z^{+'}Z^+]^{-1}$ to derive initial parameter estimates. Given these estimates, we solve for the structural error $\Delta\xi$ and construct $E[Z^{+'}\Delta\xi\Delta\xi' Z^+]^{-1}$ as a consistent estimate for W^+.

product by type *FE*, $\zeta_l^1(\hat{\theta}_A)$ and $\zeta_{jt}^2(\hat{\theta}_A)$. We then project ζ_{jt}^2 onto price and the seasonal indicators, controlling for product *FE* ζ_j,

$$\zeta_{jt}^2 = H_t\gamma + \alpha p_{jt} + \zeta_j + \xi_{jt}\,. \tag{C.4}$$

Equation (C.4) highlights the potential for price endogeneity, to the extent that price responds to time varying preference variation for a given product that is common across locations, in the form of, for example, category-specific seasonal variation in consumption. The *PLCB* pricing cannot respond to unobserved demand shocks. However, the predictable link between wholesale and retail prices opens the possibility to spirit prices being endogenous because of the pricing behavior of upstream distillers whose wholesale prices reflect, through their products' market shares, the unobserved common tastes for product characteristics of spirits, ξ_{jt}. Recall the pricing optimality conditions in equation (12).

In principle, such endogeneity concerns are mitigated by the fact that distillers need to request both temporary and permanent changes to their wholesale price a number of months before the new price takes effect. Prices thus only respond to predictable variation in a product's demand over time. At the same time, none of the available product characteristics vary across time, limiting our ability to flexibly represent such time varying preference heterogeneity at the level of the product. We therefore use instrumental variables techniques to estimate the parameters in equation (C.4) using the contemporaneous average price of a given product from liquor control states outside of the Northeast and Mid-Atlantic regions (Alabama, Iowa, Idaho, Michigan, Mississippi, North Carolina, Oregon, Utah, and Wyoming) as an instrument for price denoted as Z_B. Our identifying assumption is that cost shocks are national (since products are often produced in a single facility) but demand shocks are at most regional, perhaps due to differences in demographics or climate.[42] We add to this instrument changes in input prices, sugar and corn, interacted with spirit-type dummies to account for exogenous cost shifts across spirit types. For instance, a major input for rums is sugar while corn is an input to gins, vodkas, and whiskeys. We found that contemporaneous futures prices worked best while including price-type interactions for barley, glass, oats, rice, rye, sorghum, and wheat did not improve our estimates. Collapsing the second stage parameters into vector θ_B, this implies the following parameter estimates

$$\hat{\theta}_B = (\hat{X}_B'\hat{X}_B)^{-1}\hat{X}_B'\zeta^2\,, \tag{C.5}$$

[42] For example, whiskey consumption, more so than the consumption of other spirits, peaks during the colder fall and winter months. Whiskey consumption also varies significantly across demographic groups; for example, African American households consume larger amounts of whiskey than other racial groups relative to their baseline levels of spirit consumption.

where $\hat{X}_B = Z_B(Z_B' Z_B)^{-1} Z_B' X_B$, with $X_B = [H_t \quad p_{jt} \quad \zeta_j]$. The price coefficient is identified by variation in prices over time, benefiting from the fact that distillers do not change the wholesale prices p^w for all products at the same time.

C.3 Stage 3: Mean Utility – Product Characteristics Coefficients

In the third and final estimation stage, we recover product *FE* ζ_j from equation (C.5) and project them onto observable product characteristics x_j, resulting in

$$\hat{\theta}_C = (x'x)^{-1} x' \zeta \, . \tag{C.6}$$

where mean preferences for these product characteristics are identified by variation in market shares of spirits of differing characteristics, e.g., proof or spirit type.

D Does PLCB Policy Manage Alcohol Consumption?

The optimal markup policy in the presence of a consumption externality equates the value of the marginal reduction of alcohol consumed with the marginal foregone tax revenues. While our estimated model allows us to solve for the latter, computing the former requires an estimation of the adverse health externalities associated with alcohol consumption – a difficult task with even detailed individual health information. There exists a large literature attempting to fill this gap but their estimates require strong and often *ad hoc* assumptions connecting alcohol consumption to observable costs, e.g., Sacks, Gonzales, Bouchery, Tomedi and Brewer (2015). Moreover, it is not clear to what degree alcohol pricing can alleviate short (drunk driving) vs. long-term (cirrhosis) health consequences related to alcohol.

The benefits of alcohol taxation rely on the assumption that taxation modifies behavior, particularly among consumers who abuse alcohol. Nelson and McNall (2016) use 45 cross-country natural experiments involving tax changes to show "no strong pattern of [adverse health] outcomes within or across countries" in response to changes in alcohol taxes though they do find some evidence of decreased mortality due to liver disease in Finland and Russia when taxes are increased. This suggests that even if our estimated cost of reducing consumption was less than the benefit found in Bouchery, Harwood, Sacks, Simon and Brewer (2011), it would be doubtful that changes in taxation would actually translate to reductions in the health care expenses associated to excessive alcohol consumption. It seems likely then that the objective of regulation in this industry would be to generate enough tax revenue to support later alcohol-related expenses borne by the state government – a hypothesis which we test in this section.

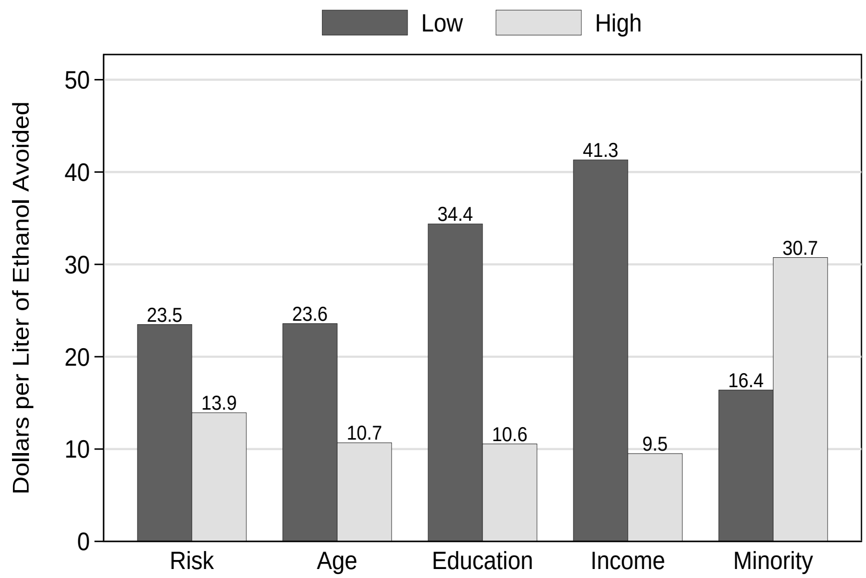
We have already established that the 30% single-markup forgoes 24.7 million in tax revenue but it also reduces alcohol consumption 2.1% in terms of bottles and 8.5% in terms of liters of ethanol. Thus, the 30% single-markup sets a shadow value of foregone alcohol consumption worth \$16.24 per liter of ethanol, or \$27.78 per 750 ml bottle equivalent not consumed. Are those foregone taxes worth it? Is the state compensated by reductions in health care costs associated with lower alcohol consumption levels? Might this be the reason why uniform pricing rules are so prevalent in the regulation of alcohol? Whether this is a reasonable position then hinges on estimates of the externality and whether government taxation can actually address it.

Bouchery et al. (2011) estimate the costs of alcohol consumption across US states. Using their data, we estimate the social cost of ethanol consumption in Pennsylvania is \$3.42 per ethanol liter, or \$1.03 per 750 ml bottle of an 80 proof spirit.[43] Thus, current *PLCB*

[43] Bouchery et al. (2011) estimate that each standard drink generates \$1.81 in social cost, the majority of which is borne by private citizens and stems from lost worker productivity. They estimate that 6% of this cost ($\approx$ 11 cents) is health care expense for which the state is responsible. We then multiply this figure expense by the number of standard drinks from a liter of ethanol (56.5) to get the social cost per liter of ethanol.

pricing rule appears to put an excessive weight on health externalities, at least in aggregate, at the expense of substantial tax revenue.

Figure D.1: Foregone Taxes across Demographics



Notes: Statistics represent percent change from alternative product-specific markup policy Stackelberg equilibrium to the one observed in the data with the current 30% taxation rule. Average of markets with top and bottom 20% of AGE, EDUCATION, INCOME, and MINORITY(as defined in Table 5. "Risk" is defined in Section 2.4.

Laffont and Tirole (1993, §3.9) note that the cross-subsidization of certain population groups by others, for instance via a single-markup rule, can be optimal if the regulator intentionally distorts prices to favor a targeted class of consumers. Thus, an alternative hypothesis to justify the use of simple pricing rules is that the policy of the regulator was designed to protect certain consumer groups. Figure D.1, however, suggests that the costs of such a policy would again far outweigh its benefits as current policy forgoes significant tax revenues across all demographic traits, from low risk drinkers ($23.5 per liter of ethanol) to poor ($41.3), as well as Caucasians ($30.7), uneducated ($34.4), and young consumers ($23.6). Thus, the *PLCB* appears to give up significant tax revenue in order to reduce consumption but the foregone revenues far exceed the associated reduction in health care cost so that in practice, the current regulation becomes a net transfer from the government to consumers where not all consumer demographics benefit equally.

E Robustness

In this Appendix, we present the results of several alternative demand specifications.

In Table E.1 we demonstrate the robustness of our demand results to alternative samples using a simple OLS multinomial logit demand system. For each model, we regress the logged ratio of product to outside share on product-period and store FE, including interactions between mean demographics and product characteristics (e.g., % minority-X-rum dummy). In Column (i) we presents results using the sample in the main text. This model generates product elasticities which are similar preferred mixed-logit model while the elasticity for spirits as a category is more elastic reflecting the IIA problem of logit demand systems (see *BLP*). In Columns (ii)-(iv) we vary the number of markets to show that including markets with premium (i.e., large stores) and border stores (i.e., stores located within five miles of the PA border) as well as the holiday period has little effect on our estimated price coefficient and elasticities. This indicates that restricting the sample has little effect on our results.

Table E.1: OLS Demand Estimates Based on Different Samples (Multinomial Logit Demand)

	(i)	(ii)	(iii)	(iv)
PRICE	−0.2396	−0.2469	−0.2238	−0.2341
	(0.0032)	(0.0033)	(0.0032)	(0.0028)
Product FEs	Y	Y	Y	Y
Premium Stores	Y	N	Y	Y
Border Stores	Y	Y	N	Y
Holiday Period	Y	Y	Y	N
Statistics:				
R^2	0.9584	0.9589	0.9564	0.9736
N	6,852	6,852	6,852	5,606
Elasticities:				
Average	−3.7454	−3.8610	−3.4916	−3.6618
% Inelastic	0.7353	0.3626	0.7477	0.7389
Spirits	−3.3936	−3.5374	−3.1225	−3.3134

Notes: The dependent variable for all models is the estimated product-period fixed effect from a first-stage regression of $\log(S_{jmt}) - \log(S_{0mt})$ onto product-period FE and demographic-product interactions. Robust standard errors in parentheses. "% Inelastic" is the percentage of products with inelastic demand. "Spirits" is the price elasticity of total *PLCB* off-premise (i.e., sold in a state-run store) spirit sales. "Premium Stores" are a *PLCB* designation. These stores typically carry greater number of products. "Border Stores" are stores located within five miles of the Pennsylvania border.

In Table E.2, we show that our estimation approach based on disaggregated data provides superior identification. In Model (i) we deviate from our multi-step approach and estimate the model in a single step, regressing the logged ratio of product share to outside share on price, brand FE, bottle size FE, pricing period FE, market FE, and mean demographic interactions, where brand refers to all bottle sizes of a particular "brand name", e.g., "Absolut Vodka". Demand becomes steeper relative to the Model (i) in Table E.1 when following this alternative approach leading to less elastic demand. We see even steeper effects when aggregating product demand across the state (Models iii and iv).

Interestingly, we see that not conducting the estimation via the steps outlined in the text leads to price elasticity estimates found by Leung and Phelps (1993) as well as other studies. Less elastic product demands increase estimated dollar markups for upstream firms, ultimately driving down estimated upstream marginal costs. Miravete et al., 2017 show using similar data that spirit category elasticities presented in the health literature (e.g., Leung and Phelps, 1993) imply negative marginal costs for these upstream firms. Table E.2 therefore suggests that such studies may suffer from an aggregation bias that leads to less elastic estimated demand.

Table E.2: OLS Demand Estimates Using Different Approaches (Multinomial Logit Demand)

	(i)	(ii)	(iii)	(iv)
PRICE	−0.1224	−0.0513	−0.0822	−0.0103
	(0.0004)	(0.0003)	(0.0022)	(0.0016)
Brand FEs	Y	N	Y	N
Statistics:				
R^2	0.5129	0.2420	0.8218	0.1441
N	2,237,937	2,237,937	6,852	6,852
Elasticities:				
Average	−1.9133	−0.8028	−1.2853	−0.1610
% Inelastic	12.9738	77.7657	39.1113	100.0000
Spirits	−1.7512	−0.7393	−1.1805	−0.1488

Notes: The dependent variable for models (i)-(ii) is $\log(S_{jmt})-\log(S_{0mt})$ while it is $\log(S_{jt})-\log(S_{0t})$ for models (iii)-(iv). Robust standard errors in parentheses. "% Inelastic" is the percentage of products with inelastic demand. "Spirits" is the price elasticity of total *PLCB* off-premise (i.e., sold in a state-run store) spirit sales.

In Model (ii) we replace the product *FE* with observable characteristics (e.g., dummies for spirit type, imported). Demand becomes even steeper and demand becomes much more inelastic due the coarseness of our observable characteristics. For example, two brands of imported rum could have different unobservable quality to consumers thereby leading different product shares and firms choosing to charge different prices but in this specification, the estimation wrongly correlates differences in price with the differences in shares (quantity sold). In Models (iii)-(iv) we aggregate consumption to the state-level requiring us to drop the demographic interactions but otherwise using the same controls as Models (ii)-(iii). Again, we see the inclusion of brand *FE*s is important to absorbing differences in unobservable (to the econometrician) characteristics across brands. We further see that aggregation drives the elasticity of off-premise spirits to become more inelastic, well within the set of estimates included in Leung and Phelps (1993).

As discussed in Section C.2, we use the contemporaneous average price in distant control states as an instrument for price in the second step. In Table E.3, we consider the sensitivity of our results to the particular instrumentation strategy. We compare the estimated price coefficient from alternative two-stage least squares regression models of the estimated first stage product-period FE underlying the estimates in Table 7 projected onto price, seasonal dummies, and product FE.

Relative to $IV1$, our preferred specification, the estimated price coefficients are stable across alternative instruments, and, as expected, entail larger price responses than an uninstrumented OLS specification. Each estimated price coefficient is significant at the 95% level and the sets of IVs generate significant F-statistics for all specifications. This suggests that, as expected, our time-invariant observable characteristics are unable to fully capture the variation in a product's preferences that distillers base their pricing decisions on.

Table E.3: Price Endogeneity

	OLS	*IV1*	*IV2*	*IV3*
PRICE	-0.2412	-0.2763	-0.2781	-0.2775
	(0.0038)	(0.0046)	(0.0046)	(0.0046)
Instruments:				
Input Prices		Y	Y	Y
Alabama		Y		Y
Iowa		Y	Y	
Idaho		Y	Y	Y
Michigan		Y		
Mississippi		Y	Y	
North Carolina		Y	Y	
Oregon		Y	Y	Y
Utah		Y	Y	
Wyoming		Y	Y	Y
F-Statistic		1,280.2	1,235.1	1,235.8
N	6,852	6,852	6,852	6,852

Notes: Specifications include the same covariates as in Table 7.

Table E.4: Identifying Beneficiaries of the Current Uniform Pricing Rule

	Type		Product		Optimal		Alt Ramsey		Ramsey	
AGE	−6.0234		−3.7956		−6.7260		−1.6730		0.2724	
	(1.7155)		(1.7853)		(4.4153)		(3.071)		(2.4097)	
EDUCATION	−3.2326		−7.5975		−14.0334		−10.6214		−8.4576	
	(0.6302)		(0.6468)		(1.774)		(1.192)		(0.8933)	
INCOME	0.4230		−3.7976		−5.8918		−5.6282		−4.0895	
	(0.5688)		(0.6915)		(1.6426)		(1.0614)		(0.738)	
MINORITY	5.0919		1.7433		2.0507		0.0829		−0.7192	
	(0.3712)		(0.3382)		(1.1219)		(0.7467)		(0.5286)	
REGISTERED DEMOCRAT		2.9066		5.3021		9.1870		6.4471		4.1787
		(0.5532)		(0.7009)		(1.4445)		(0.9601)		(0.6699)
POPULATION DENSITY		0.7241		0.3844		0.4248		0.1211		−0.0236
		(0.0946)		(0.1272)		(0.2655)		(0.1762)		(0.125)
CHURCHES PER CAPITA		0.8038		1.5812		2.9799		2.3893		1.8031
		(0.2)		(0.2134)		(0.4504)		(0.3117)		(0.2335)
RURAL		1.8380		2.7097		4.2247		2.9754		2.0484
		(0.4212)		(0.5741)		(1.1478)		(0.7526)		(0.5208)
LIQUOR RELATED CRIMES		0.0007		0.0026		−0.0029		−0.0003		0.0020
		(0.0013)		(0.0033)		(0.0056)		(0.0045)		(0.0037)
R^2	0.5497	0.3522	0.6616	0.3861	0.4665	0.2935	0.5660	0.3577	0.6123	0.3754
N	454	355	454	355	454	355	454	355	454	355
Change in Tax Revenue	−3.44		−8.80		0.00		−5.35		−6.69	
Change in Ethanol Consumption	−14.02		−8.46		−33.61		−20.34		−6.69	
Shadow Value	2.17		16.14		0.00		3.42		15.46	
Change in Upstream Profits	−6.93		0.91		−36.91		−23.59		−7.73	
- Diageo	−6.20		−6.05		−44.42		−33.52		−17.04	
- Beam	−18.02		20.47		−28.08		−7.74		27.21	
- Jacquin	−0.35		61.89		10.78		45.26		81.74	
- Bacardi	−4.56		−16.66		−48.75		−35.80		−15.56	
- Sazerac	−3.33		47.80		5.58		34.68		58.77	
Change in Consumer Surplus ($M)	−15.34		−9.47		−95.08		−56.68		−22.12	
Percent of residents better off	6.17		16.68		0.00		0.00		0.42	
Change in Retail Price	1.20		−0.91		11.11		6.07		0.51	
- Low Income	−0.4		−2.4		9.3		4.8		−0.7	
- High Income	1.9		0.7		12.8		7.6		2.1	
Number of Markups	9		312		312		312		312	
Constrained?	N		N		N		Y		Y	

Notes: In the top panel we regress compensating variation divided by total liquor expenditure in market l on market characteristics. Robust standard errors reported in between parentheses. All regressions include a constant (not reported). AGE is log(average age) in the location. EDUCATION, INCOME, and MINORITY are defined in Table 5. REGISTERED DEMOCRAT is the share of the population registered as democrats as of 2009 according to the Pennsylvania Department of State, `https://www.pavoterservices.state.pa.us`. CHURCHES PER CAPITA denotes the number of establishments located in the market's census blocks with a primary NAICS code of 8131 (source: Reference USA) divided by the market population. RURAL is equal to one if the MSA is outside Philadelphia or Pittsburgh. LIQUOR RELATED CRIMES is logged per-capita number of reported incidences of domestic violence, drunk driving, drunkenness, vandalism over 2002-2003. Data on this variable is limited to 355 locations. In the bottom panel we compare current policy to each alternative policy. For example, retail prices are on average 0.91% lower in the current policy than when the *PLCB* uses product-specific markups (i.e., the "Product" column). "Number of Markups" refers to the number of markups chosen by the *PLCB*. A policy is "Constrained" when the *PLCB* chooses its markup policy subject to an aggregate budget constraint. "Product" and "Ramsey" policies are described in the text. "Type" corresponds to the equilibrium when the *PLCB* chooses markups for bottle size (3) and spirit type (6) to maximize tax revenue. "Optimal" corresponds to the equilibrium when the *PLCB* chooses product markups to maximize consumer surplus subject to generating at least as much tax revenue as under the single pricing rule. "Alt Ramsey' corresponds to the Ramsey equilibrium using $3.42 per liter of ethanol as the social cost.

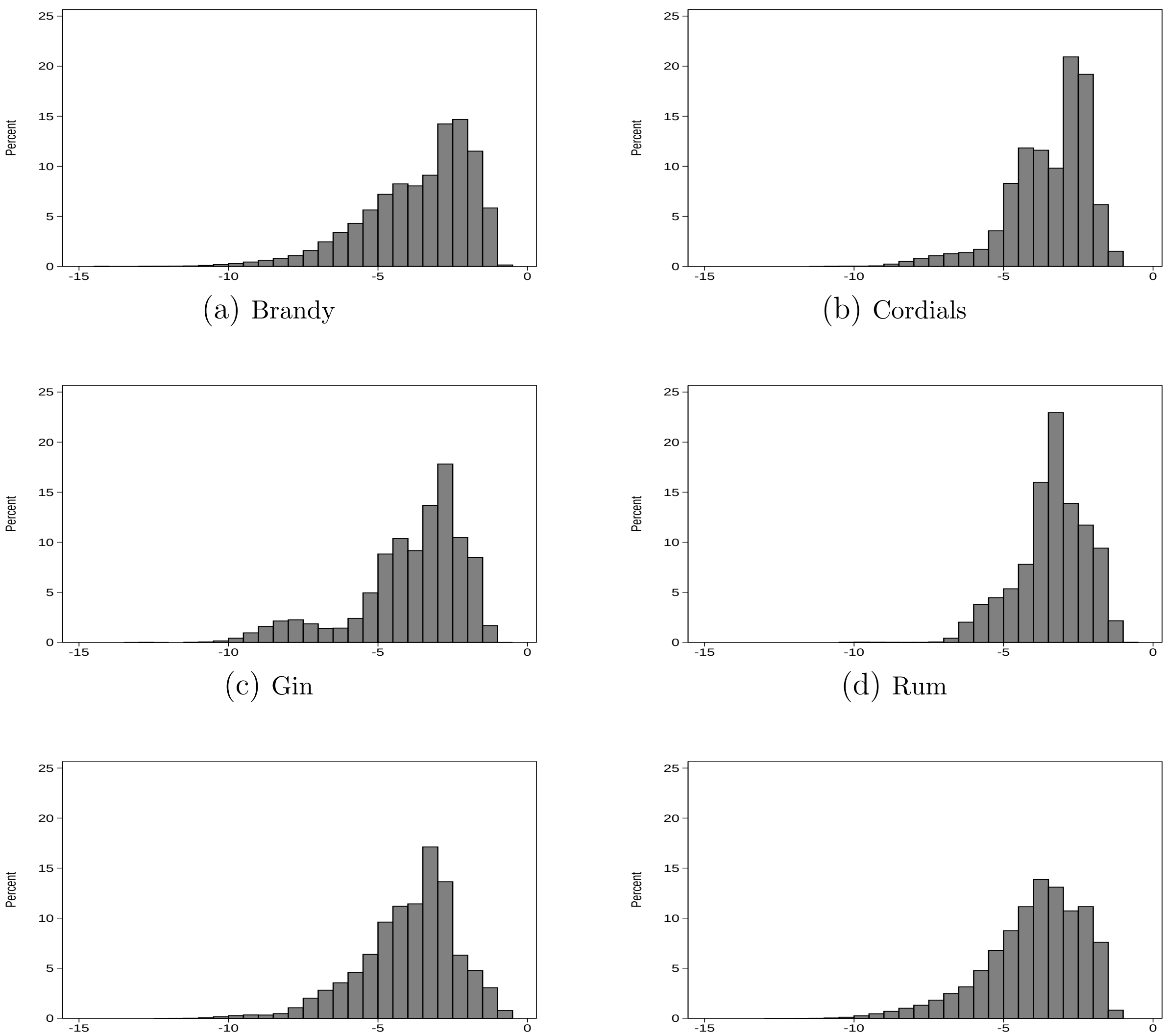
F Additional Results and Figures

Table F.1: Estimated Cross-Price Elasticities

	Ratio
By Type:	
BRANDY	39.21
CORDIALS	1.30
GIN	2.09
RUM	1.97
VODKA	2.07
WHISKEY	1.88
By Size:	
375 ml	1.88
750 ml	0.89
1.75 L	2.61
By Characteristic:	
Flavored	0.83
Not Flavored	2.43
Imported	1.05
Domestic	1.28

Notes: For each product we calculate the average cross-price elasticity for (1) products within the corresponding group and (2) products outside the group. "Ratio" is the average ratio of (1) to (2).

Figure F.1: Distribution of Demand Elasticities by Spirit Type



(a) Brandy

(b) Cordials

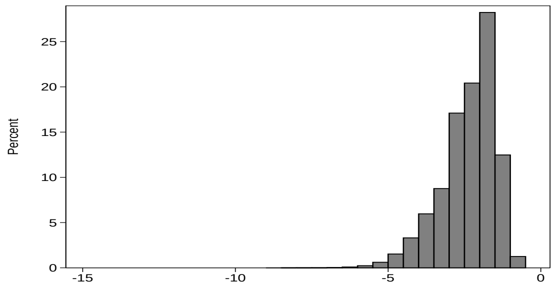
(c) Gin

(d) Rum

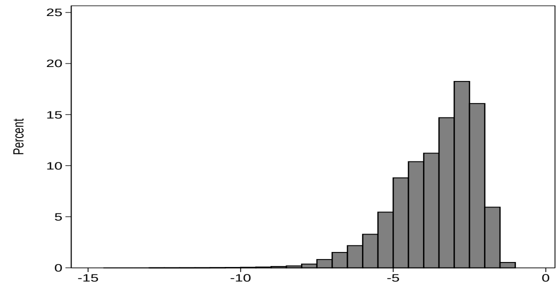
(e) Vodka

(f) Whiskey

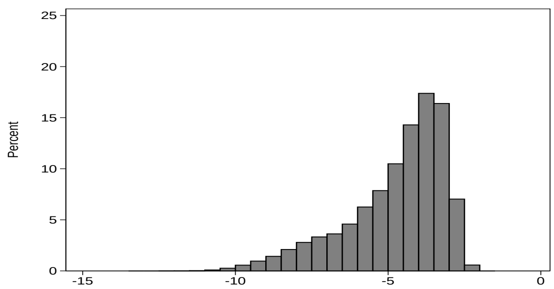
Figure F.2: Distribution of Demand Elasticities by Price and Bottle Size



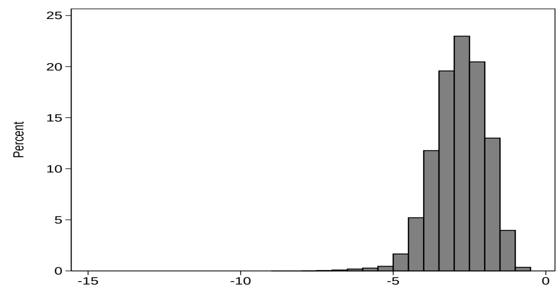
(a) 375 ml



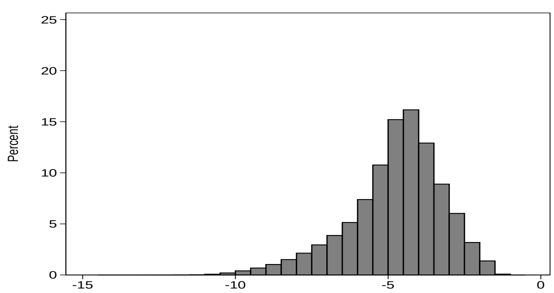
(b) 750 ml



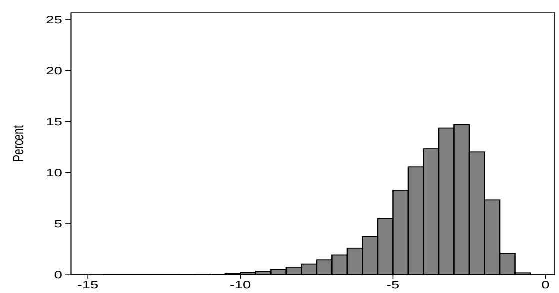
(c) 1.75 Ltr



(d) Cheap



(e) Expensive



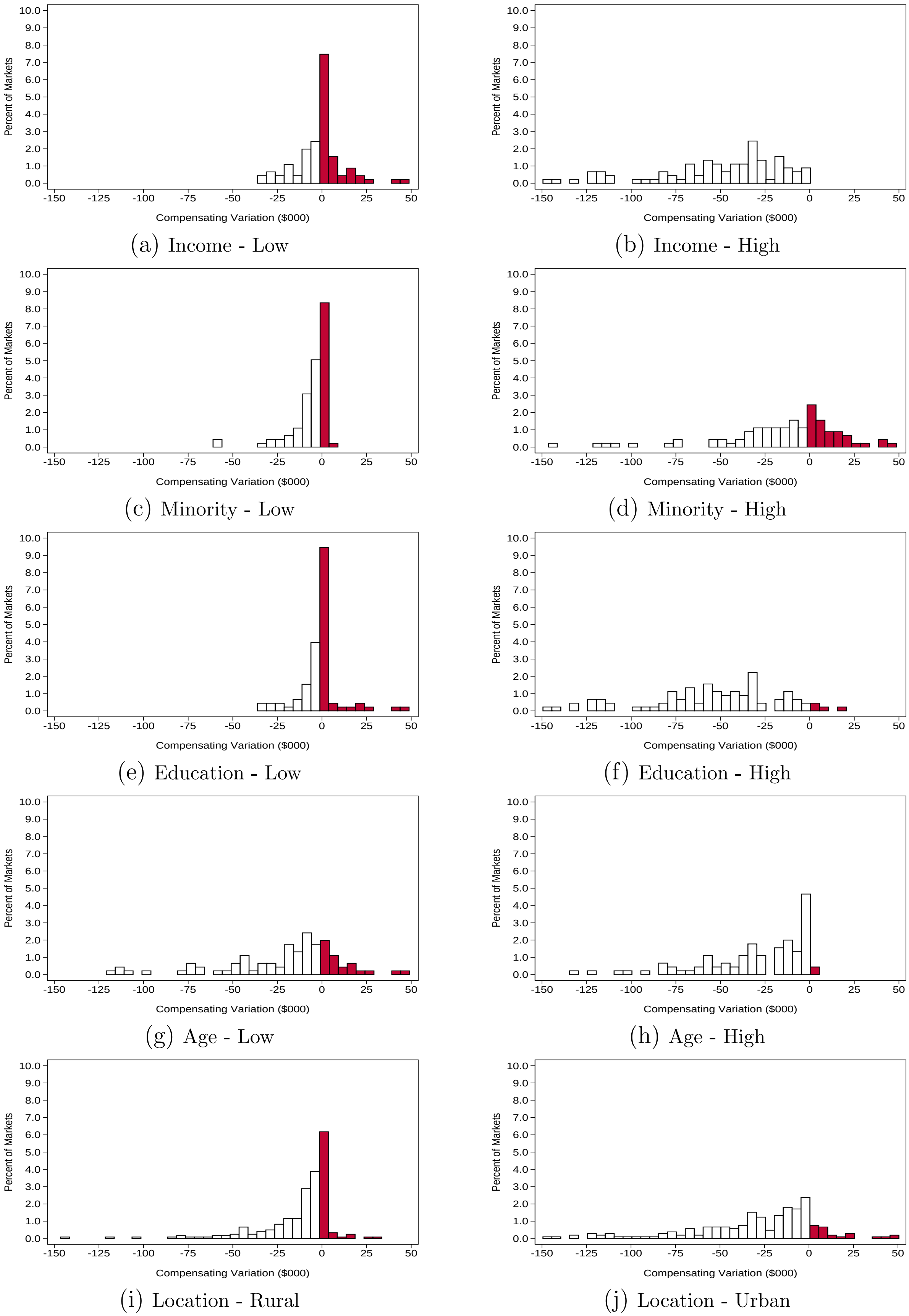
(f) All Products

Table F.2: Estimated Marginal Costs (Select Firms)

	All	Diageo	Bacardi	Beam	Jacquin	Sazerac
By Spirit Type:						
BRANDY	5.34	-	-	-	3.66	-
CORDIALS	6.16	7.18	15.00	3.21	1.98	5.08
GIN	6.43	7.72	12.51	4.90	4.29	2.67
RUM	5.66	7.05	5.48	4.47	3.45	-
VODKA	6.37	6.07	-	4.64	4.24	3.83
WHISKEY	7.11	8.17	14.82	6.05	4.67	4.88
By Price:						
CHEAP	3.67	3.66	3.67	3.62	3.59	3.70
EXPENSIVE	9.04	8.53	10.46	8.08	-	7.78
By Bottle Size:						
375 ml	2.39	2.13	1.45	1.02	0.23	2.89
750 ml	5.81	6.13	5.83	3.51	2.02	2.97
1.75 L	8.24	11.28	11.84	7.54	5.00	4.68
ALL PRODUCTS	6.33	6.33	6.89	5.14	3.59	4.14

Notes: Estimated upstream marginal costs weighted by sales.

Figure F.3: Compensating Variation by Consumer Demographics



(a) Income - Low

(b) Income - High

(c) Minority - Low

(d) Minority - High

(e) Education - Low

(f) Education - High

(g) Age - Low

(h) Age - High

(i) Location - Rural

(j) Location - Urban

Table F.3: Aggregate Effects of the Single-Markup

	Unit	Current	Single	Product	Ramsey
Prices:					
Wholesale Price ($)	Dollars	8.69	8.82	8.40	8.85
Retail Price ($)	Dollars	14.87	14.41	15.01	13.38
Markups:					
PLCB Markup Rule	Percent	30.00	23.73	55.51	30.66
Distiller Markup	Dollars	2.37	2.49	2.07	2.52
Alcohol Consumption:					
Bottles	Bottles, millions	41.34	44.69	42.23	56.44
Ethanol	Liters, millions	16.54	18.14	18.06	24.91
Profits:					
Tax Revenue	Dollars, millions	255.70	256.60	280.38	255.70
Distillers	Dollars, millions	113.13	128.38	112.11	179.31
Industry	Dollars, millions	368.83	384.98	392.49	392.49
PLCB Share	Percent	69.33	66.65	71.44	65.15

Notes: "Current " denotes the current scenario with the 30% markup rule. "Single" corresponds to the Stackelberg equilibrium which maximizes tax revenue with one markup. "Product" employs 312 product-specific taxes to maximize tax revenue. "Ramsey" corresponds to the 312 product-specific markups which maximize consumer surplus subject to generating at least as much tax revenue as the current policy. The markup we display for "PLCB Markup Rule" does not include the 18% Johnstown Flood Tax. "Industry" denotes the sum of *PLCB* and distiller profits, in millions of dollars. "Tax Revenue" is total *PLCB* tax revenue (profits), in millions of dollars.

Table F.4: Retail and Wholesale Prices by Product Category

		Wholesale				Retail			
	Elast.	Current	Single	Product	Ramsey	Current	Single	Product	Ramsey
By Spirit Type:									
BRANDY	-3.64	8.12	8.25	7.31	7.41	13.90	13.48	15.68	15.07
CORDIALS	-3.46	8.93	9.05	8.78	8.92	15.10	14.62	15.03	14.42
GIN	-3.90	9.13	9.26	8.82	8.86	15.59	15.09	16.10	15.89
RUM	-3.38	8.34	8.46	8.14	8.22	14.32	13.88	14.46	14.29
VODKA	-3.95	7.95	8.07	7.58	7.59	13.76	13.35	13.73	13.72
WHISKEY	-3.98	9.89	10.01	9.70	9.75	16.74	16.19	16.62	16.45
By Price:									
CHEAP	-2.81	5.85	5.97	5.27	5.27	10.50	10.24	11.41	11.41
EXPENSIVE	-4.74	11.97	12.10	12.00	12.12	19.91	19.21	19.15	18.70
By Bottle Size:									
375 ml	-2.36	3.85	3.97	2.93	2.97	7.15	7.04	7.72	7.60
750 ml	-3.58	8.52	8.64	8.23	8.40	14.49	14.04	15.01	14.29
1.75 L	-4.74	11.08	11.21	11.06	10.96	18.83	18.19	18.23	18.70
ALL PRODUCTS	-3.75	8.69	8.82	8.40	8.45	14.87	14.41	15.01	14.79

Notes: "Elast." corresponds to the average estimated demand elasticities from Table 8. Other reported statistics are average wholesale and retail price ($). "Cheap" ("Expensive") products are those products whose mean price is below (above) the mean price of other spirits in the same spirit type and bottle size. "Single" indicates the counterfactual where the *PLCB* chooses the revenue-maximizing markup. In "Product" the *PLCB* employs 312 product-specific markups to maximize tax revenue. In "Ramsey" the *PLCB* employs 312 product-specific markups to maximize aggregate consumer surplus subject to an externality-adjusted government balanced budget constraint.