Welfare Consequences of Nominal Excise Taxation ⋆

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Abstract

Alcohol consumption accounts for a large and growing share of worldwide premature death and disease, especially in low- and middle-income countries. Governments routinely utilize unit taxes to regulate alcoholic beverages but such taxes are rarely indexed to inflation. We use detailed data to estimate a model of alcohol demand and supply that ties consumers' demographic characteristics to heterogeneous preferences for spirits while placing no restrictions on the strategic price response of firms to changes in taxation. We find that nominal taxes kept retail prices low, benefited firms, and increased alcohol consumption significantly. Using recent epidemiological research, we show that increased consumption due to nominal taxation also increased the prevalence of alcohol-attributable diseases such as cancer, cirrhosis, and heart disease, especially among low income, minority, and rural residents – consumers which alcohol policies are often intended to target. Our results highlight that failing to index unit taxes has dramatic welfare consequences even in countries with modest rates of inflation.

Keywords: Optimal Taxation, Excise Taxes, Vertical Markets, Market Power, Equity.

JEL Codes: H21, H23, L43, L66

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"...taxing 'bads' like tobacco and sugar over 'goods' like savings and income is as close to a free lunch as you can get in economics."

Lawrence H. Summers
To Improve Global Health, Tax the Things That Are Killing Us.
Financial Times: January 18, 2018.

1 Introduction

Unhealthy lifestyles and their role in the spread of noncommunicable diseases, such as cardiovascular, cancer, respiratory disease, and diabetes, are an increasing focus of public health efforts worldwide, including in low- and middle-income countries, where noncommunicable diseases account for a significant share of premature death and disease and impose growing economic costs. The World Health Organization (2018) highlights as contributing causes the rising consumption of unhealthy products that frequently accompanies economic development: tobacco use or exposure, alcohol consumption, and obesity and diabetes associated with the spread of processed foods with added sugar. These products accounted for 13, 5, and 10 percent of annual deaths worldwide, respectively, in 2018 (Stanaway et al. 2018).

Excise taxation is a long-standing policy intervention geared at curbing the consumption of addictive and unhealthy products. Studies of alcohol and cigarette taxes and initial assessments of sugary beverage taxes suggest that they are effective at reducing consumption. They are also simple to implement as a small number of firms manufacture most products. Furthermore, the products' wide-spread consumption, combined with the limited number of available substitutes, results in significant tax revenue for government. Consequently, both the World Health Organization (2017) and the Task Force on Fiscal Policy for Health (2019), chaired by Michael Bloomberg and Lawrence Summers, cite increased reliance on taxation of unhealthy products as a key intervention for noncommunicable disease prevention not only in developed countries but also, and perhaps specifically, in the developing world. One of the primary conclusions of the Task Force on Fiscal Policy for Health is that:

> Countries should design their health taxes to be easy to administer, hard to manipulate, and difficult to game. This generally means applying **simple uniform specific taxes**, which have many advantages over ad valorem excises and over complex and multi-tiered taxes. **These taxes should be regularly adjusted for inflation and income growth to make sure that products become less affordable over time.** [emphasis added]

In practice, governments rarely index specific excise taxes to inflation, relying instead on what we refer to as nominal taxation.[1] For example, in the case of U.S. alcohol excise taxes, the focus of this paper, the federal tax on alcohol, a specific tax of $13.50 per proof gallon, has been in effect since 1991 and is not indexed to inflation.[2] In this paper, we evaluate both the efficiency and distributional consequences of indexing specific excise taxes to inflation.

We rely on detailed scanner data and study the consumer and producer responses to inflation-driven increases in excise taxes in a single alcohol market, thereby complementing the aggregate, cross-country or cross-state approach taken by many existing empirical studies of health taxes. Using a panel of product-level sales of all spirits products sold in each state-run liquor store in Pennsylvania, we estimate a model of demand and oligopolistic pricing that allows us to recover consumer preferences for spirits products and firms' marginal cost of producing them. We employ the estimated demand and supply model to perform a counterfactual analysis of the implications for aggregate consumption, firm profit, and tax revenue of indexing both the federal and the state-level unit tax components of Pennsylvania's alcohol tax structure to inflation. We find that nominal federal alcohol taxation significantly depresses retail prices of spirits products, leading to increases in bottles of spirits products sold of 31.9% and in consumption of liters of ethanol of 47.3%.

Our results highlight how quickly inflation erodes the effectiveness of excise tax policy over time. While changes in prices year-over-year may appear inconsequential – they amount to an average 2.36% in our sample – the cumulative effect of even moderate rates of inflation is significant. For example, had the federal government chosen in 1991 to index the excise tax on alcohol to the consumer price index, the tax would have risen by 38.7% by 2004, the end of our sample period. In areas of the world (e.g., Latin America) where inflation exceeds the low levels commonly experienced in the developed world, the impact of inflation is even more pronounced, ultimately making excise taxation irrelevant in a short period of time.

Our analysis combines sales data of 312 distilled spirit products sold in 454 local markets across Pennsylvania, representing all stores in 2003 and 2004. We rely on a modeling approach from an earlier companion paper (Miravete, Seim and Thurk, 2019), where we match these data 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).[3] As our data cover the entire Pennsylvania spirit industry, we evaluate the implications of nominal federal and

[1] A wide range of tax structures exists across countries: 38% of countries levy typically fixed specific excise taxes, while ad valorem excises and a combination of ad valorem and specific taxes are in place in 27% and 35% of countries, respectively (Chaloupka and Powell, 2019).

[2] A "proof gallon" is a liquid gallon of spirits comprised of 50% ethanol at 60 degrees Fahrenheit. By taxing according to this unit of measurement, the federal tax is increasing in proof and bottle size.

[3] Pennsylvania liquor stores sell both wine and spirits. We focus on the latter as spirits represent the most significant category in terms of both tax revenue and ethanol content. US 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/`.

state taxation in aggregate and in distribution not only on consumers, but also on multi-product distillers.

Our setting has several features that allow clean identification of consumer demand and thus reliable estimates of individual and spirit category price elasticities. First, as a state-run monopoly, the Pennsylvania Liquor Control Board ($PLCB$) controls the distribution and retail of alcohol sales and retail pricing obeys a publicly known, legislatively mandated pricing rule that requires uniform pricing across all stores at a particularly point in time. Statewide pricing enables reliable estimation of demographic variation in preferences. Second, and as a result, the $PLCB$ cannot adjust prices to changes in preferences over time, eliminating price endogeneity concerns in its setting of retail price. All retail price variation originates from pass-through of wholesale price changes by upstream producers, as their marginal cost or derived demand change. Third, these upstream producers face constraints imposed by the $PLCB$ on the frequency and advance notice of planned wholesale price changes, limiting their ability to respond to near-term, unexpected changes in consumer demand and easing common concerns over price endogeneity.

The robust demand estimates from Miravete et al. (2019) that we rely on here indicate large variation in consumer preferences for spirit types and characteristics. For example, older, lower-educated, and minority consumers prefer products with higher alcohol content. There is also significant heterogeneity in product-level demand elasticities that correlates with consumer demographics. The results highlight the value of disaggregate, product-level and market-level data: We show that aggregating prices and quantities across markets and products, as is frequently the case in studies in the large public health literature on alcohol taxation, leads to biased estimates of alcohol demand elasticities. These biases result in underestimation of the responsiveness of consumer demand to changes in price and, in turn, overestimation of the ability of excise taxation to generate tax revenue and the degree of taxation required to curb alcohol consumption by a given amount.

We pair the estimated model of consumer demand with a model of static oligopoly competition among the 34 producers of distilled spirits to estimate each product's marginal cost of production, under the assumption that firms' wholesale prices represent a non-cooperative, horizontally differentiated Bertrand-Nash equilibrium. At the estimated marginal cost, the average firm generates 36 cents in income for every dollar in revenue, despite the large number of products in this industry. Product differentiation thus enables distillers to position their products to maintain significant market power. As a result, firms have both incentive and ability to respond strategically to changes in federal and state tax policy, which we allow for in our analyses of inflation-indexed excise taxation. The retail price pass-through of such counterfactual tax structures is thus a function of the estimated demand curvature and elasticities, which drive the optimal pricing response of distillers.

In the Pennsylvania spirits market, there are both federal and state taxes. Manufacturers remit the federal specific tax on alcohol, which varies with the product's alcohol content and bottle size. In contrast, the state's bottle-size-specific tax is statutorily borne by consumers. For example, a 750 ml bottle of Smirnoff 80 proof vodka (average price \$11.82 in our data) is subject to a \$1.20 state tax and a \$2.14 federal tax. Since the latter is paid by the distiller, here Diageo PLC, the degree to which federal tax policy impacts the end consumer depends on the degree of demand pass-through (Weyl and Fabinger, 2013). An advantage of our demand model is that it allows for flexible product-level pass-through; i.e., 'undershifting', complete pass-through, and 'overshifting' can all arise. This stands in contrast to simpler models such as multinomial logit and nested logit where pass-through is 'undershifted' by assumption. Indeed, we estimate more than complete pass-through ('overshifting') of the excise tax for 96% of our products, consistent with earlier event studies of alcohol taxation (e.g., Kenkel, 2005).

We use the estimated model to measure the implications of nominal taxation by comparing our estimated equilibrium to counterfactual inflation-indexed equilibria. For the larger federal tax, inflation indexing impacts firm wholesale pricing through not only demand-side pass-through, but also the contribution of the federal tax to each product's total marginal cost. We find that for the median product, the nominal federal excise tax accounts for 42.09% of the estimated marginal cost. For large firms like Diageo and Bacardi, the federal tax contributes less to overall marginal cost (35.36% and 35.79%, respectively), however, due to the prevalence of relatively expensive products in their product portfolios. In contrast, smaller producers of less expensive products like Jacquin (88.94%) and Sazerac (80.33%) are more exposed to changes in federal tax policy.

The combination of more than complete pass-through and firms' significant exposure to federal taxation provides the mechanism by which an increase in the federal tax rate due to inflation indexation ultimately transmits down the supply chain to retail prices. We find that under full inflation indexing of the 1991 federal tax to the period of our sample, distillers' average tax-inclusive costs increase by 17.6%, or \$1.05, and their wholesale prices rise by 11.2%, or \$1.10, on average. After an additional markup by the downstream $PLCB$, the average retail price paid by the consumer increases \$1.69 (10.2%). While it is not surprising that the nominal federal tax maintains low wholesale and retail prices, we show that the implications for government tax revenue, firm profits, and consumer welfare are substantial.

We find that the nominal federal excise tax leads to an increase in both US (7.6%) and Pennsylvania (24.8%) tax revenue, raising combined receipts by \$59.13 million. Since retail prices are lower under the observed nominal federal tax, the state tax revenue increase results simply from the elastic demand for spirits. In contrast, we illustrate that given the significant state tax burden, even the current nominal federal tax exceeds the federal tax-revenue maximizing level, so indexing the tax to inflation only depresses federal tax revenue further. The nominal federal policy also enabled a substantial increase in firm profits \$26.34 million, or 30.4% from the estimated equilibrium. Since pass-through is more than complete, the majority of this change is due to market expansion resulting from low retail prices. While all firms benefit from the lower tax, we find above-average profit gains for smaller firms with lower-cost product portfolios, such as Sazerac (36.34%), compared to large producers like Diageo (27.65% increase).

The vast majority of consumers benefit from nominal taxation: aggregate consumer welfare increases \$57.75 million, or 9.37% of consumer expenditure on spirits. The lower tax-inclusive retail prices under nominal taxation elicit, under our estimated elastic demand, a large consumption response by Pennsylvania residents in terms of both bottles sold (31.9% increase) and ethanol consumed (6.4% increase). The relative changes in bottles sold and ethanol reflect substitution towards larger products and products with higher alcohol content. If alcohol presented no externalities, nominal taxation would thus – not surprisingly – be unambiguously welfare improving.

One key motivation for the taxation of alcohol, of course, is its negative externalities that grow with the significant consumption response. We find the additional social costs brought about by increased ethanol consumption more than offset the welfare gains from increased federal and state tax revenue, firm profits, and internalized utility from consumption. Using recent epidemiology research which connects alcohol consumption to disease, we document that nominal taxation increased deaths from alcohol-attributable diseases such as cancer, cirrhosis, and heart disease. Moreover, we demonstrate that death rates increased most among disadvantaged demographic groups such as lower income, minority, and rural residents. This suggests that nominal excise taxation may not only lead to large aggregate adverse health effects, but also implicitly promote consumption and associated external costs among particular consumer groups, including consumers such policy may intend to target. Our study amounts to the first welfare analysis of excise tax indexation, or lack thereof, and therefore provides detailed quantitative evidence of the conclusions put forth by the WHO and Task Force on Fiscal Policy for Health.

The aggregate effects of Pennsylvania's nominal excise tax are similar qualitatively to, but less pronounced than, those of the federal nominal excise tax. The difference in responses is driven by the different stages in the supply chain where the two taxes are levied. Upstream producers pass some of the expense of a higher federal specific tax on to the downstream retail market, where imperfect competition – here in its extreme form of public monopoly – leads to an additional markup. In contrast, state taxation occurs here at the downstream level; increases in unit taxes are marked up only once. Thus, double marginalization of the federal excise tax compounds the final effect on retail prices, resulting in the larger aggregate equilibrium effects we find – a simple but novel insight that we believe we are the first to identify and measure.

In summary, we use detailed scanner data and an equilibrium model of consumer demand plus oligopoly price-setting to estimate reasonable and robust estimates of demand and upstream firm marginal costs. We then use the estimated model to make three contributions. First, we directly evaluate the importance of indexing excise taxes to inflation, both in affecting equilibrium responses by consumers and firms, and in reducing alcohol related external costs. Our results demonstrate that failing to index excise taxes decreases aggregate welfare due to increased ethanol consumption and the associated external costs. Second, we evaluate distributional implications of increases in specific taxes and show that indexation, or equivalently changes in the specific tax, implicitly target particular consumers and firms. Third, we consider the role of imperfect competition and double marginalization along the supply chain in impacting the final retail price response of an increase in specific taxes, allowing a nuanced analysis of how the design of the excise tax structure interacts with inflation indexing. We demonstrate that tax policy which targets manufacturing firms compounds along the supply chain so a seemingly small error may generate significant adverse equilibrium effects, potentially undoing the policy's objective. Taken together, these contributions highlight the importance of simple policy improvements such as inflation indexing – a feature common in the provision of social security in the United States – towards achieving long term policy objectives like reducing deaths from noncommunicable diseases in not only rich countries like the United States but also in middle- and low-income countries where inflation is higher.

We begin the remainder of this paper with a simple theoretical model which illustrates how changes in in a specific excise tax – be it levied at the manufacturer or at the consumer – impacts firm pricing and ultimately retail prices. In Section 3 we provide a brief history of federal alcohol taxation in the United States with an emphasis on spirits – our object of interest. We then discuss taxation of spirits in the state of Pennsylvania in Section 4; outlining key features of the data which enable clean identification of consumer demand and firm costs. In Section 5 we present an equilibrium discrete choice model of demand for horizontally differentiated spirits that incorporates the features of the current pricing regulations while accounting for oligopoly competition in the distiller market. Section 6 reports our estimates and documents significant heterogeneity of preferences for spirits and market power by producers. We demonstrate our methodology provides robust estimates of upstream marginal costs and that federal alcohol excise taxes amount to a significant expense for firms. In Section 7 we compare the estimated equilibrium to counterfactual equilibria where we index federal and State excise taxes. We summarize our results and offer concluding remarks in Section 8. The Appendices contain additional information on data construction, descriptive statistics, estimation algorithm, robustness, and results.

2 A Simple Theoretical Framework of Excise Taxation

We begin by presenting a simple model of monopoly taxation. Our goal is to illustrate whether a unit tax is levied on the firm or consumer affects the firm's pricing response. When the tax is levied on the firm, a change in the tax (which we model here as a change in marginal cost) elicits a pricing response which determines how much the change in cost is passed through to consumers. When the tax is levied on the consumer, however, the firm's pricing response may mitigate or amplify the tax. Ultimately, the firm response will impact the equilibrium effects of nominal taxation on tax revenues, firm profits, and consumption.

Consider the case of a single-product monopolist with constant marginal cost c which faces twice-continuously differentiable consumer direct demand $q(p)$. Define $\eta(p) \equiv -pq_p(p)/q(p)$ as the price elasticity of demand, $\alpha(p) \equiv -p \times q_{pp}(p)/q_p(p)$ as the curvature of the direct demand, and (after applying the inverse function theorem) $\sigma(q) \equiv -q \times p_{qq}(q)/p_q(q) = q(p) \times q_{pp}(p)/[q_p(p)]^2$ as the curvature of the inverse demand. While the importance of the price elasticity of demand (η) in determining equilibrium price in imperfect markets is well-understood, the curvature of the inverse demand (σ) is less so and will play a crucial role in determining the equilibrium effects of taxation. As $\eta = \alpha/\sigma$ we further point out that while these statistics are related, they are not generally equivalent.

The monopolist chooses its price p to solve

$$\max_p \underbrace{(p - c) \times q(p; \tau)}_{\pi(p;\tau)}, \tag{1}$$

where final retail price is subject to a per unit ad valorem tax τ such that $p = p + \tau$. Profit-maximization requires the following first-order necessary condition to hold:

$$q(p; \tau) + (p - c) \times q_p(p; \tau) = 0. \tag{2}$$

Totally differentiating the first order condition (2) with respect to p, c and τ yields

$$\frac{dp}{dc} = \left[\frac{q_p}{2q_p + (p - c) \times q_{pp}}\right] \text{ and}$$
$$\frac{dp}{d\tau} = -\left[\frac{q_p + (p - c) \times q_{pp}}{2q_p + (p - c) \times q_{pp}}\right].$$

If we then impose downstream profit-maximization (i.e., $p-c = -q/q_p$), we find that the monopolist's equilibrium price response to a change in marginal cost is

$$\frac{dp}{dc} = \frac{q_p}{2q_p - q \times q_{pp}/q_p}$$
$$\Rightarrow \frac{dp}{dc} = \frac{1}{2 - \sigma(q)} > 0\,. \tag{3}$$

From (3) we observe that the (inverse) demand curvature (σ) determines how much of a change in firm cost is passed onto consumers. We say that cost pass-through is "incomplete" in the event $\frac{dp}{dc} < 1$, "complete" in the event $\frac{dp}{dc} = 1$, and "more than complete" in the event $\frac{dp}{dc} > 1$. Thus, pass-through is incomplete (or more than complete) if, and only if, the curvature of demand σ is less (greater) than unity.

Similarly, imposing downstream profit-maximization to the equilibrium price response given a change in the consumer per-unit tax yields

$$\frac{dp}{d\tau} = \frac{q_p}{2q_p - q \times q_{pp}/q_p}$$
$$\Rightarrow \frac{dp}{d\tau} = \frac{\sigma(q) - 1}{2 - \sigma(q)} \lesseqqgtr 0\,. \tag{4}$$

From (4) we observe that the demand curvature also affects the monopolist's price response to a change levied on consumers directly. In contrast to (3), however, the direction of the price response is not guaranteed and can be either amplifying (i.e., $\frac{dp}{d\tau} > 0$), mitigating (i.e., $\frac{dp}{d\tau} < 0$), or null (i.e., $\frac{dp}{d\tau} = 0$). Which case we are in, depends upon the curvature of demand; i.e.,

$$\frac{dp}{d\tau} = \begin{cases} < 0\,, & \text{if } \sigma(q) < 1 : \quad \text{“Mitigating”}, \\ 0\,, & \text{if } \sigma(q) = 1 : \quad \text{“Null”}, \\ > 1\,, & \text{if } \sigma(q) > 1 : \quad \text{“Amplifying”}. \end{cases}$$

Thus, whether the firm's price and the consumer tax are strategic substitutes or strategic complements depends fundamentally on the demand curvature σ. More generally, this indeterminacy reflects the fact that the firm's demand $q(p;\tau)$ may be either log-supermodular or log-submodular in p and τ.[4] While knowledge of the role of demand curvature in firm determining pass-through dates back to Cournot (1838) and has been addressed more recently in Bulow and Pfleiderer (1983) and Weyl and Fabinger (2013), the importance of demand curvature in determining not only the magnitude but also the direction of the firm response with respect to taxation is new.

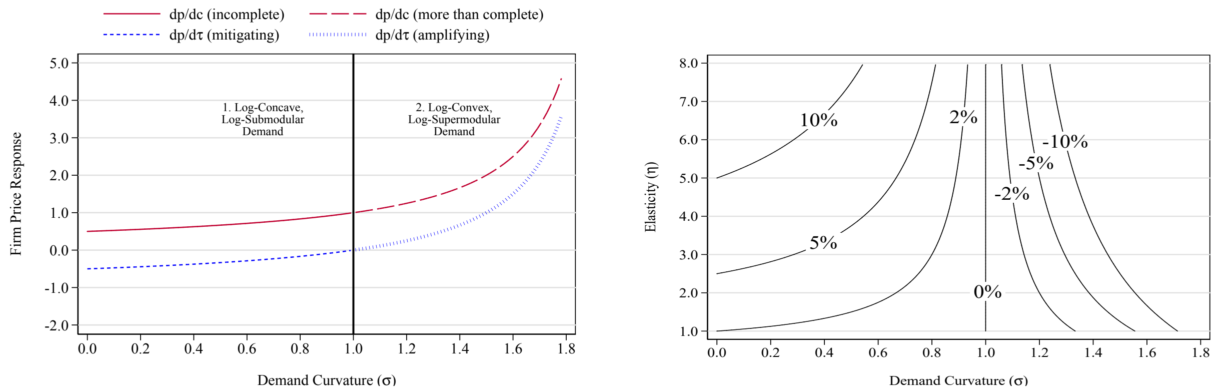
In terms of the relative impacts of changes in c and τ on firm price, we observe the following relationship:

$$\frac{dp}{dc} = \frac{1}{2 - \sigma(q)} > \left|\frac{\sigma(q) - 1}{2 - \sigma(q)}\right| = \left|\frac{dp}{d\tau}\right|. \tag{5}$$

The strict inequality follows due to our assumption that the profit function is strictly concave in price which is ensured if $\sigma < 2$. Thus, from (5) we observe that the firm's pricing response due to a change in its costs is strictly greater than its pricing response due to a change in a tax levied directly upon consumers. We summarize these results in panel (a) of Figure 1.

[4] See Topkis (1998, §2.6.4) for a formal definition. Applications of log-supermodularity include auction theory (Milgrom and Weber, 1982); international trade (Costinot, 2009); monotone comparative statics (Milgrom and Shannon, 1994); its preservation under uncertainty (Jewitt, 1987); and in multivariate environments (Athey, 2002).

Figure 1: Taxation and Firm Pricing



(a) Firm Response (b) Quantity Effect

Notes: Panel (a) depicts $\frac{dp}{dc}$ and $\frac{dp}{d\tau}$ as functions of demand curvature as defined in the text (see equations 3 and 4, respectively). Region 1 corresponds to demand systems which are log-concave and log-submodular (the latter with respect to p and τ). Region 2 corresponds to demand systems which are log-convex and log-supermodular (the latter with respect to p and τ). Panel (b) presents the net quantity effect of the price response as a function of demand curvature and elasticity.

In panel (b) we addresses the importance of accounting for the firm's pricing response. Consider a "naïve" researcher or government official who mistakenly assumes the firm is perfectly competitive and therefore passes any change in its costs onto consumers one-to-one (i.e., complete pass-through) and cannot respond to any change in the downstream tax (i.e., a "null" pricing response). In such a setting, the net effect of a tax requires interacting the demand elasticity and the percent change in the tax: i.e., $\%\Delta Q = \eta \times \%\Delta\tau$. A more sophisticated researcher or government official recognizes that the firm may respond to a change in the tax, and that such a response may either amplify or mitigate the ultimate effect of the tax on quantity demanded (as well as firm profits and government tax revenue). We define the net effect of the pricing response is then as the percent change in quantity demanded under "naïve" pricing minus the percent change in quantity demanded in the "sophisticated" pricing response; i.e.,

$$\begin{aligned} \%\Delta Q\big|_{\frac{dp^w}{dc}=0} - \%\Delta Q\big|_{\frac{dp^w}{dc}\neq 0} &= \eta \times \frac{dp^w}{dc} \times \frac{c}{p} \\ &= \eta \times \left(\frac{1}{2-\sigma}\right) \times \frac{c}{p} \end{aligned} \tag{6}$$

$$\begin{aligned} \%\Delta Q\big|_{\frac{dp^w}{d\tau}=0} - \%\Delta Q\big|_{\frac{dp^w}{d\tau}\neq 0} &= \eta \times \left(1 - \frac{dp^w}{d\tau}\right) \times \frac{\tau}{p} \\ &= \eta \times \left(\frac{1}{2-\sigma}\right) \times \frac{\tau}{p} \end{aligned} \tag{7}$$

where positive values indicate that the naïve researcher would have over-estimated the effect of the tax on quantity demanded. Here, we observe that the net effect depends upon both the demand elasticity (η) and the demand curvature (σ); or equivalently upon the "demand manifold" introduced by Mrázova and Neary (2017). From Equations (6) and (7) we see that regardless of whether the tax is levied on the firm directly or on consumers, the net effect on quantity demanded is the same. Further, the net effect depends upon the interaction of the consumer demand elasticity (i.e., the behavioral response of consumers as in Saez (2001)), the pricing response of the firm, and the size of the tax relative to retail price. Only in the event $\sigma = 1$ – a knife-edge case – would assuming the firm cannot strategically respond be innocuous.

Discussion. The curvature condition of $\sigma(q) < 1$ (i.e., incomplete pass-through, log-submodular demand in p and τ) describes the class of log-concave demand functions, including both concave and somewhat convex demand functions.[5] An important empirical point is that many demand systems utilized by researchers are log-concave by construction (e.g., multinomial and nested logit). The curvature condition of $\sigma(q) = 1$ holds in the case of log-linear direct demands as shown by Mrázova and Neary (2017, p. 3841). Isoelastic Dixit-Stiglitz CES preferences demand – a common feature of consumer demand models in the macroeconomic literature – corresponds to a special case where the assumed or calibrated demand elasticity directly implies demand curvature via the relationship $\sigma = (\eta + 1)/\eta$ thus $\sigma > 1$.[6] In all of these cases, much, if not all, of the strategic behavior of the firm is pre-determined by the researcher via the empirical framework.

A defining feature our study is that, contrary to these other popular demand systems, our framework (mixed logit) does not impose demand curvature ex ante (Quint, 2014, §4.3). Instead, in the event consumer demand is homogenous across different consumer types, our demand system collapses into multinomial logit and yields incomplete pass-through and strategic substitutes between firm price and the consumer tax. If instead demand (preferences) is heterogenous across consumers, particularly related to price-sensitivity, ou demand system may yield demand curvatures greater than unity and therefore more than complete pass-through and strategic complementarity between firm price and the consumer tax. Griffith, Nesheim and O'Connell (2018) point out that including income effects can deliver estimates of demand curvature greater than one. Such a modeling choice may make sense in settings where consumers are choosing whether to buy an expensive product such as automobile (e.g., Berry et al. (1995)).

In categories where the consumer's expenditure on the product(s) amounts to small share of their budget – as in the case of distilled spirits – incorporating such wealth effects is inappropriate. A contribution of our empirical study then is to demonstrate how the presence of random coefficients and demographic interactions in a mixed-logit model with quasi-linear utility is capable of delivering pass-through rates greater than one as well. A further advantage of our approach is that we place no restrictions on whether high income consumers are more or less price sensitive than low income consumers where as the functional form assumptions often used to include wealth effects impose that high income consumers are less price sensitive.

[5] If $\sigma(q) < 1$, it follows from the definition of curvature that $q_{pp}(p) \times q(p) - [q_p(p)]^2 < 0$, which is the condition for demand to be log-concave.

[6] As Cobb-Douglas amounts to a special case of CES preferences where $\eta = 1$, curvature in this very special case is equal to two.

We could extend this analysis to various homogeneous good oligopoly models along the lines of the framework for analyzing tax incidence put forth in Weyl and Fabinger (2013). Unfortunately, theoretical results do not exist for the differentiated products we study in our empirical application (Fabinger and Weyl, 2016, Appendix E). The main challenge of developing theoretical results is the fact that change in the tax rate leads to substitution not only to the outside option, but also to other taxed products; the resulting overall change in tax revenue, firm profits, and consumption – all important variables affected by nominal taxation – therefore reflects varying changes in product sales due to heterogeneity in products' costs and characteristics as well as the curvature of demand. Further, firms and consumers respond differently to a tax rate change based on variation in market power and preferences, respectively. In the equilibrium, all of these forces interact so theoretical analysis becomes difficult without the aid of a computer. Moreover, results depend fundamentally upon both demand elasticities (η) and demand curvatures (σ) which may vary by setting. We therefore choose to evaluate these effects through the lens of an empirical equilibrium model which captures all of these interactions in an important, policy-relevant setting – alcohol taxation.

3 A Brief History of Alcohol Taxation in the United States

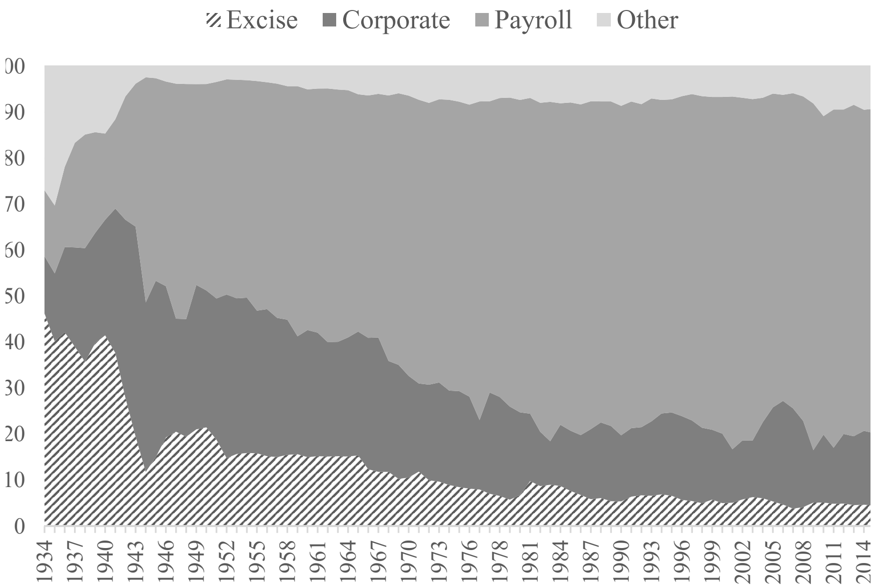
Federal alcohol excise taxes are levied at the manufacturing and importing firm based on the per unit production or importation of the corresponding beer, wine, or distilled spirit. While proponents of alcohol taxation often cite public health rationales, these taxes have a long history which dates to the founding of the country and, at least for the federal government, have almost entirely been introduced as a means of generating government revenue. Treasury Secretary Alexander Hamilton first introduced alcohol excise taxes in 1791 as a means to fund the early republic though the Congress was loathe to tax the population after having just fought a war over taxation. These taxes were generally reviled by the public and eventually repealed.[7]

Passage of the 21st Amendment on December 5, 1933 ended the nation's 14 year experiment of prohibiting alcohol production and sales. For the federal government, the re-introduction of alcohol as a legal market provided an new revenue source to replace lower payroll and corporate tax revenues due to the Great Depression (1929-1939). Congress took advantage of the opportunity and in 1934 passed a comprehensive alcohol tax bill. The consequence of this legislation was that tax revenue from alcohol came to account for roughly 40% of total federal income during the remainder of the 1930s and was a key component to financing the second World War as well as the Korean War (Figure 2).

Taxation of distilled spirits, the object of our interest, changed little from 1951 until 1985. On the heals of the 1981-1982 recession, Congress passed *The Deficit Reduction Act of 1984* (P.L. 98-369) on July 18, 1984 which increased the unit tax on distilled spirits in October 1985 from

[7] At the time western farmers converted grain to whiskey as a source of revenue since transporting grain over land via railroads and steam boats was expensive. The whiskey tax was therefore incredibly unpopular and eventually led to the Whiskey Rebellion (1791-1794). The tax was eventually repealed by Thomas Jefferson in 1802.

Figure 2: Federal Tax Revenue by Source



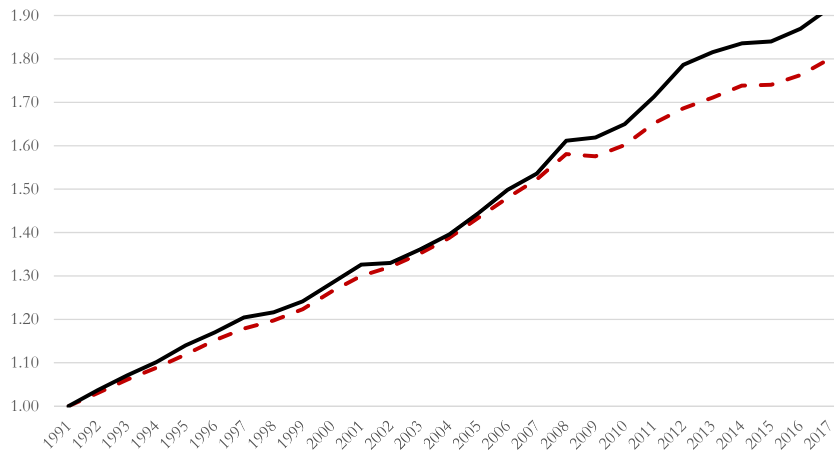
Notes: Figure presents federal income by source over time (1934-2014). "Payroll" refers to personal income taxes. "Corporate" refers to corporate income taxes. "Excise" refers to excise federal taxes on alcohol, fuel, and tobacco. "Other" corresponds to tax revenues collected for estate and gifts, customs duties (tariffs) and fees, Federal Reserve deposits.

$10.50 to $12.50 per "proof-gallon" defined as one liquid gallon of spirits of 50% ethanol at 60 degrees Fahrenheit. In 1990, passage of the *Omnibus Budget Reconciliation Act of 1990* (OBRA90; P.L. 101-508) increased the per unit tax to $13.50 per proof-gallon. The law became effective in January 1991 and again was intended to finance the federal budget to compensate for lower personal and corporate income taxes after the 1990-1991 recession. This federal unit tax is still in effect today.[8]

The key features of alcohol taxation which motivate this study are that taxes on distilled spirits, and alcohol generally, are (1) levied on a per unit basis, (2) have been adjusted by Congress on only a handful of occasions, and (3) are not indexed by inflation. These features are not unique to the Federal government either – a point we address when we discuss taxation of spirits in the state of Pennsylvania in Section 4.1. The consequence of applying a static per unit excise tax is that inflation erodes the effectiveness of such policy over time. While changes in prices year-over-year may appear inconsequential in the United States where inflation is low (on average 2.36% since the early 1990s), Figure 3 demonstrates the cumulative effects of even low rates of inflation. For example, had the Federal government chosen to index the distilled spirit excise rate to the consumer price index present in the figure, the tax in 2003 and 2004 (i.e., the period addressed in this study)

[8] The federal rate was not adjusted again until 2017 when the *Tax Cuts and Jobs Act* (P.L. 115-97) temporarily lowered the federal excise tax to $2.50 per proof-gallon on the first 100,000 proof-gallons produced or imported in order to promote small distillers. The 1991 rate of $13.50 per proof-gallon is then applied for production or imports greater than 100,000. Consequently, the reform had no effect on large distillers apart from any competitive pressures due to increased competition with small, local distillers. Unless Congress passes legislation to make the adjustment permanent, the federal rate will return to $13.50 in fiscal year 2020.

Figure 3: Rates of Inflation (1991–2017)



Notes: Figure presents U.S. consumer price index ("All Urban Consumers"). Source: Federal Reserve Economic Data (FRED). Pennsylvania consumer price index ("All Urban Consumers - Pittsburgh Area"). Source: Bureau of Labor Statistics. Both series are adjusted such that the base year is 1991.

would have been 35.1% and 38.7% higher. When we extend the time frame to current day, we observe, not surprisingly, that the compounding effects become substantial. In areas of the world (e.g., Latin America) where inflation is larger than the low per annum rate in commonly experienced in the developed world, the impact of inflation is even more pronounced; ultimately making such taxation irrelevant in a short period of time.

4 The Pennsylvania Market for Spirits

We begin by summarizing the regulation of alcoholic beverages in Pennsylvania. We then describe the data on sales, prices, characteristics of products sold by the *PLCB* and the distillery market. Finally, we document the heterogeneity of consumer preferences for different types of spirits. We use this variation to develop robust estimates of heterogenous consumer demand, firms costs, and demand curvature – attributes which interact in our market to determine the equilibrium effects of nominal taxation.[9]

4.1 The Mechanics of the Pricing Regulation

Pennsylvania adheres to the common three-tier alcoholic beverage distribution system: distillers sell their products to wholesale distributors who then sell to retailers, and only retailers may sell to consumers. The *PLCB* also vertically integrates and operates both the wholesale and retail distribution of wine (36% of *PLCB* revenue) and spirits (63% of *PLCB* revenue).[10] Until 2016,

[9] Miravete, Seim and Thurk (2018) provide additional detail on the market environment.

[10] Pennsylvania also has a private system for the sale of beer, allowing the controlled entry of private retailers. During our sample, beer license revenue accounted for less that one percent of *PLCB* revenue.

as well as during the period covered by our data, 2003-2004, it did so as a monopolist; today, the state allows for the controlled retail of wine, but not spirits, by private firms, although the *PLCB* continues to serve as their supplier.[11] We focus on the spirits category as it represents the majority of *PLCB* sales. Spirits further constitute a well-defined and mature product category with a small number of easily measurable product characteristics, including the type of spirit, the alcohol content, the possible addition of fruit or other flavors, and the product's country of origin.[12]

The *PLCB* has traditionally relied on a simple pricing rule that transforms distillers' wholesale prices into retail prices (Pennsylvania Liquor Code 47 P.S. §1-101 *et seq.* and Pennsylvania Code Title 40). From 1937 until 1980, it consisted of a uniform percent markup, an ad valorem tax, over wholesale cost of 55% for all gins and whiskeys and 60% for other products. In 1980, the 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%. Simultaneously, 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.[13] Consumers also pay an 18% ad valorem tax on all liquor purchases – the so-called "Johnstown Flood Tax," a temporary emergency relief measure adopted in 1936 that has never been repealed.[14] Summarizing these elements, the uniform pricing rule employed by the *PLCB* during the 2003-2004 sample period is

$$p^r = [p^w \times 1.30 + LTMF] \times 1.18\,, \tag{8}$$

where p^r 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.

At the state level our focus is the per unit *LTMF* bottle fees which account for 22.7% of the *PLCB* markup over wholesale prices though this share is decreasing in the wholesale price for a given product; i.e., unit fees account for 29.10% of the downstream markup for 375 ml products (average wholesale price \$5.03) versus 20.43% of the downstream markup for 1.75 L products (average wholesale price \$12.28). As in the case of federal taxes, these state-level unit fees were established in the early 1990s (1993) but were not indexed to inflation.[15]

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[11] Our data do not include on-premise sales (in bars and restaurants) accounting for approximately 20% of total spirit sales by volume and revenue.

[12] In contrast, wines have hard-to-measure quality determinants and a large number of products with limited life cycles leading to tiny, highly volatile market shares. For example, within the popular 750 ml bottle category, the top-100 selling wines (out of 4,675) constitute only 45% of total 750 ml wine revenue.

[13] In 2016 the 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 only a limited number of times.

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

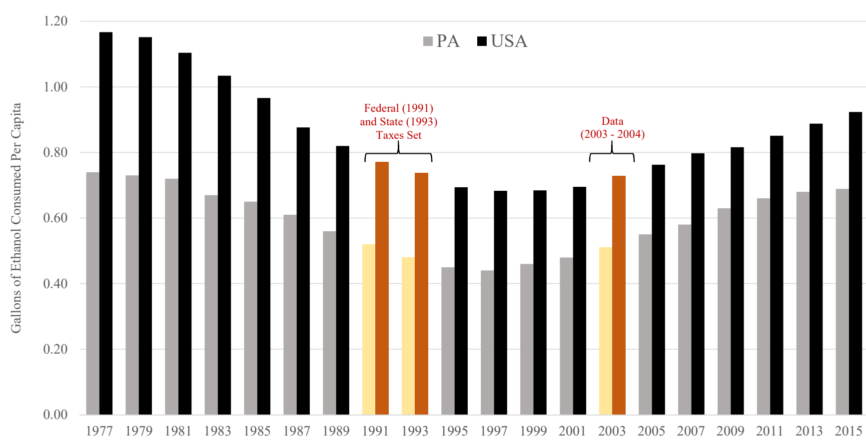
[15] Equation (8) suggests that the *PLCB* lacks any bargaining power in setting wholesale prices and that distillers effectively determine retail pricing through this pricing formula. This is indeed how interactions between distillers and the *PLCB* were organized until recently, when the passage of Act 39 in 2016 allowed for limited negotiation with distillers on the most popular products. The Tribune summarized the lack

4.2 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 and 2004. We aggregate the daily data to the monthly sales pricing periods, resulting in 22 periods for our sample. 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.

In Figure 4 we present annual per capita ethanol consumption (in gallons) in the United States and Pennsylvania. While Pennsylvania per capita consumption lies below average consumption for residents elsewhere – perhaps due to differences in preferences or state-level taxation – in both case we observe decreasing consumption until the early 1990s and increasing consumption thereafter. Importantly, a comparison of Figures (3) and (4) suggests that the decrease in the real price of spirits due to nominal taxation played a part in the increase in consumption. The quantitative importance of this connection in terms of tax revenue, firm profits, consumer welfare, and health is modulated by our estimates of demand curvature and is the empirical focus of this study.

Figure 4: Ethanol Consumption Over Time



Notes: Figure presents average per capita ethanol consumption from distilled spirits in both the U.S. and Pennsylvania. Source: Haughwout, Lavallee and Castle (2015) and NABCA.

Each store in our data 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.[16] The resulting sample contains 312 products

of bargaining power by the *PLCB* on 7/26/2017 `https://triblive.com/local/westmoreland/12551088-74/pennsylvania-set-to-raise-prices-on-some-liquor-wine-brands`. Similarly, the *PLCB* purchases at constant unit wholesale prices and does not benefit from any quantity discounts. See testimony by *PLCB* Board Member Mike Negra at `https://www.youtube.com/watch?v=wB4L4qjyx_8`.

[16] 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

across the two-year sample. We see little variation in the product set across stores indicating that consumers have equal access to the products we consider in the sample.[17]

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. Vodkas and whiskeys have significantly larger market shares (32.1% and 24%, respectively) than rum (16.3%), cordials (13.6%), or brandy (7.3%), even though cordials 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. Most whiskeys and cordials are imported while other spirits are predominantly domestically produced. There is significant variation in proof across product categories: the average across all products is 75.33, but it ranges from 55.82 for cordials to 83.42 for gins. We also obtained a product score rating products in each spirit category as a measure of within-category product quality from `Proof66.com`, a spirits ratings aggregator.

To report results and evaluate the diverse demand across demographic groups we characterize spirits as expensive when their simple averaged price exceeds the mean price of all spirits of the same type and bottle size. Expensive products are less likely to be flavored or domestically produced and have higher proof, but consumers purchase them nearly as frequently as cheaper ones. The 750 ml bottle is the most popular size in terms of unit sales and product variety, accounting for 50.3% of unit sales and 54.5% of available spirits products, followed by the 1.75 L bottle with a share of 34.5% of unit sales and 30.1% of products. The smallest bottles we consider, those in the 375 ml format, account for the remaining 15.2% of units sold and 15.4% of products.

These patterns in market shares reflect in part the product sets offered by distillers as not all brands are available in all bottle sizes. For instance, our final sample consists of 198 brands (e.g., *Captain Morgan*). Of these, 88 are available only in the 750 ml bottle size and one and 31 only in the 375 ml and 1.75 L sizes, respectively. The *PLCB* carries at least two bottle sizes for the remaining 78 brands (e.g., Diageo sold Captain Morgan in 375 ml, 750 ml, and 1.75 L sizes).

The monthly sales activity, including variation in the magnitudes of the price reductions, are our primary source of price variation to identify consumers' price responsiveness. Due to the legislated pricing formula, the wholesale pricing decisions of the *PLCB*'s suppliers – the distillers – are largely responsible for inducing retail price changes. Temporary wholesale price changes, typically price reductions or sales, amount to 89.7% of price changes in the sample and last for four or five weeks from the last Monday of each month. A mature product (as those we consider) can go on sale up to four times a year, or once per quarter. Permanent price changes take effect at the

sizes, we further focus on popular products that account for 80% of bottle sales in each spirit type-bottle size combination. We also drop tequilas, as there were few products and these products amounted to only 1.6% of total liquor bottle sales. In total, these restrictions allow us to drop a total of 1,313 products from our sample.

[17] The median store carries 98% of the top 100 and 82% of the top 1,000 products. Stores in high-income neighborhoods are more likely to carry more expensive niche products, but consumers can order any product in the catalog in any store at no charge. See Appendix A.

beginning of one of the *PLCB*'s four-week-long accounting reporting periods, a slightly different periodicity from the sale pricing periods. Distillers temporarily change a product's price 2.6 times per year on average, and most products (73%) go on sale at least once a year, with vodkas, whiskeys, cheaper products, and products in larger bottle sizes (750 ml or 1.75 L) on sale more frequently than average. A significant share of all spirits products (44%) 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. While over 63% of cheap products go on sale at some point in the year, the average such product goes on sale only 1.36 times, far less than other product categories. In contrast, the average 375 ml product goes on sale less frequently, but those 375 ml products with at least one sale see three temporary price reductions per year on average. See Appendix A for further detail. Finally, distillers need to inform the *PLCB* of any 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 temporary sales, the distillers' ability to respond to unexpected demand swings is limited, facilitating a cleaner identification of demand responses to price changes.

4.3 The Upstream Distillers

During our sample period, 34 firms compete in the spirits market. The market leader, Diageo, accounts for 22% of total unit sales and 25% of revenue, while a large set of small fringe producers (29) account for 42% and 46% of total quantity sold and revenue, respectively. Nineteen of these firms operate product portfolios of less than five products, and seven are single product firms. Table 1 documents that while large firms such as Diageo and Bacardi operate extensive product portfolios, there is substantial heterogeneity across firms in their product offerings. For example, Diageo has a relatively balanced portfolio where rums, vodkas, and whiskeys generate approximately 21%, 31%, and 25% of revenue, respectively. In contrast, Bacardi operates a more concentrated portfolio as 71% of its revenue comes from its rum products compared to 19% from its whiskey products. Among the larger competitors, only the Pennsylvania-based firm Jacquin sells brandies, where it faces only seven small competitors and generates 22% of its revenue. With a presence in all bottle sizes and spirit types, the company's portfolio focuses exclusively on cheap products. Table 1 furthermore documents that a significant number of competitors are present in all product categories. The variation in product portfolios translates into variation in concentration across categories, with Herfindahl-Hirschman indices ranging from 1,023 for cordials to 3,087 for rums (951 for spirits in total). This, combined with the observed degree of product differentiation, motivates our characterization of the distillery market as oligopolistic.

4.4 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 geocode the 624 stores' street addresses to link their geographic location to data on population and demographic characteristics for nearby consumers

Table 1: Upstream Product Portfolios

	Diageo	Bacardi	Beam	Jacquin	Sazerac	Firms
By Spirit Type:						
BRANDY	0.00	0.00	0.00	21.57	0.00	8
CORDIALS	11.22	1.98	16.22	9.77	13.29	18
GIN	11.67	8.26	5.14	1.77	3.62	10
RUM	21.27	70.89	4.06	22.12	0.00	10
VODKA	30.99	0.00	10.4	43.26	63.9	14
WHISKEY	24.85	18.88	64.18	1.52	19.18	20
By Price:						
CHEAP	19.60	34.20	52.61	100.00	85.30	25
EXPENSIVE	80.40	65.80	47.39	0.00	14.70	25
By Bottle Size:						
375 ml	5.82	5.90	2.93	10.24	15.07	18
750 ml	54.67	50.59	38.13	27.05	20.53	31
1.75 L	39.51	43.51	58.95	62.71	64.59	25
ALL PRODUCTS	100.00	100.00	100.00	100.00	100.00	34

Notes: Table displays firms' revenue share by spirit type, price, and bottle size. "Firms" is the total number of firms with at least one product in the given category.

from the 2000 Census. We combine Pennsylvania's Census block groups into markets, assigning each to the operating store that is closest to them in any period. We further consolidate stores in the same ZIP code resulting in 454 total local markets.[18] Table 2 summarizes these demographic characteristics. About 39% of households in Pennsylvania earn more than $50,000 a year, but the income distribution 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 residents in the average market. We see similar diversity in educational attainment with 44% of residents in the average market reporting at least some college education but this varies from 13% to 87% across the state. Finally, the average age in the average market is 40 years, ranging from 31 to 43 years across markets.

Table 2: Demographic Attributes of Pennsylvania Markets

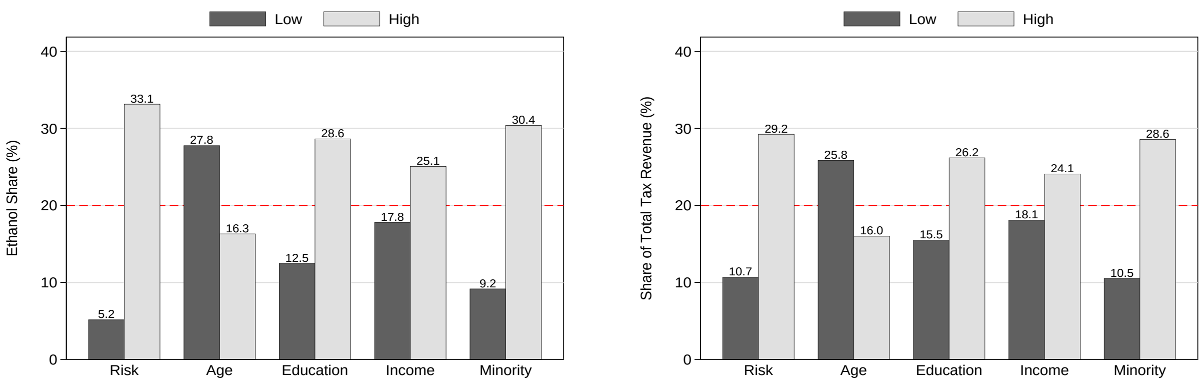
		Percentage of Population			
	POPULATION	AGE	EDUCATION	INCOME	MINORITY
Mean	26,241	40.07	44.06	38.81	13.07
Std. Dev.	16,386	1.45	14.41	14.33	18.83
Min	1,469	31.34	12.56	9.90	0.44
Max	112,065	43.06	87.01	75.92	98.95

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

[18] As stores open and close during the year, the characteristics of stores' ambient consumers also change over time, which helps identify the effect of demographic interactions. See Appendix A for detail.

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 dividing the store markets into quintiles based on each of the four demographic attributes – 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. We also account for differences in per capita consumption of ethanol in each market.

Figure 5: Demographics and the PLCB's Objectives



(a) Ethanol Consumption (b) Tax Revenue

Notes: Figures compare shares of total ethanol consumption and tax revenue attributable to markets in the bottom ("Low") and top ("High") quintiles of each demographic attribute.

In Figure 5 we present the shares of total tax revenue and total ethanol consumption for markets in the top and bottom quintiles for each attribute, relative to a 20% benchmark (the dashed line) corresponding to the case where market attributes do not correlate with consumption and expenditures. We observe high ethanol consumption and spending in markets with high concentrations of wealthy, well-educated, young, and non-white consumers.[19] Interestingly, the difference in the consumption shares of the top and bottom markets in the distribution is always greater than the difference in the share of taxes paid. 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. In contrast, ethanol consumption in low-risk markets accounts for only 5% of total ethanol sales and generates 11% of total tax revenue.

We complete this descriptive analysis by documenting the heterogeneity of preferences for spirit types and product characteristics across demographic attributes and alcohol consumption habits. We compare unit-sales market shares for various product categories across demographic market groupings. For instance, the top quintile of markets by income garner a 38.6% share of 1.75 L bottles. Table 3 highlights important market share differences across demographics (columns) for different product categories (rows). These purely reflect differences in preferences

[19] The finding that per capita ethanol consumption and income are positively correlated has been demonstrated in earlier work though the exact mechanism is unclear, e.g., see Cerda, Johnson-Lawrence and Galea, 2011. Researchers often cite social norms or even social networking as causes.

Table 3: 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: Table displays market shares based on bottles sold by product characteristic for markets in the bottom ("Low") and top ("High") quintiles of each demographic attribute. RISK denotes per capita ethanol consumption. See notes to Table 2 for remaining attribute definitions.

since retail prices at a point in time are identical across the state and stores have similar product offerings (see Appendix A).

The data indicate that minorities strongly favor brandy, gin, and 375 ml products, but not whiskey or 1.75 L products. In markets with high income and a highly educated population, vodka is far more popular than rum and brandy while consumers also buy spirits that are more expensive. Markets dominated by young, less educated, and lower 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 attributes, 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, reflecting a positive correlation between per capita ethanol consumption and income.

Important Data Features. To summarize, the data are useful in investigating indexation of alcohol taxes for three reasons. First, the *PLCB*'s markup formula is the same regardless of aggregate demand differences or by local markets. Second, the product set is heterogeneous, but varies little across retail stores, and the products' characteristics correlate systematically with consumer purchases. Combined, these features provide for clean identification of preferences driven by demographic differences between local markets. This enables us to reliably identify changes in consumption by different demographic groups in a world in which US and Pennsylvania officials had crafted legislation such that alcohol specific taxes are indexed to inflation; this clean identification enables us to better identify the distributional effects of nominal taxation among consumers.

Third, we observe all spirit sales in the state during the sample period. This enables us to evaluate the effects of nominal excise taxation not only on a diverse set of consumers, but also on the manufacturers of the taxed spirits. Unlike the majority of studies of commodity taxation, we do not assume that the taxed industry is competitive but rather allow for market power using the estimated model. Moreover, our methodology further enables us to take a "hands off" approach to estimating the influence of federal and state taxation on equilibrium outcomes (e.g., federal and state tax revenue, firms profits, consumer welfare) and particularly the behavior of upstream firms. To highlight the role of firm behavior, we now turn to an equilibrium model of demand and firms' oligopolistic pricing in an environment with federal and state taxation.

5 Model

We specify a static model of oligopoly price competition with differentiated goods. We envision a two-stage Stackelberg game where the federal and state governments chooses and commits to their tax policy. Distillers observe this choice 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 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 preference specification which does not restrict elasticities of demand for individual products or their demand curvatures ex-ante. This rules out, for example, the CES preferences used in international trade or macroeconomic models that yield identical demand elasticities across products.[20] Instead, we make use of the flexible approach of Berry et al. (1995) to estimate consumer preferences from observed consumer choices over time and across markets. The estimated preferences facilitate predicting consumer responses to changes in retail prices due to an increase in federal and/or state unit taxes.

Second, the model highlights that the strategic wholesale price choices in the upstream market significantly affect the retail prices the consumer pays. As we demonstrate in the simple theoretical framework of Section 2, increasing the federal and/or state tax by indexing these policies to inflation would (likely) lead to distillers choosing different wholesale prices and consequently different retail prices and consumer purchase decisions. Accounting for such upstream responses is thus important in the counterfactual analyses that follow. Moreover, the flexibility of our consumer demand model places little restrictions on this response.

5.1 A Discrete Choice Model of Demand for Spirits

We follow the large literature on discrete-choice demand system estimation using aggregate market share data (Berry, 1994; Berry et al., 1995; Nevo, 2001) to model demand for spirits as a function

[20] Stiglitz (2015) singles out the field of macroeconomics for unnecessarily limiting the number of policy instruments to favor uniform taxation under the misguided belief of its "neutrality" in not affecting agents labor supply and consumption behavior.

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 3. 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]

$$
\begin{aligned}
&u_{ijlt} = V_{ijlt} + \epsilon_{ijlt} = x_j \beta_i^* + \alpha_i^* p_{jt}^r + H_t \gamma + \xi_{jlt} + \epsilon_{ijlt}\,, \\
&\text{where} \;\; i = 1, \ldots, M_{lt}; \quad j = 1, \ldots, J_{lt}; \quad l = 1, \ldots, L; \quad t = 1, \ldots, T\,.
\end{aligned}
\tag{9}
$$

The $n \times 1$ vector of observed time-invariant product characteristics x_j is identical in all markets l, though the availability of different spirits 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. We denote the price of product j at time t by p_{jt}^r; it 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, firms, and the *PLCB* but unobserved by the econometrician. Lastly, ϵ_{ijlt} denotes 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 and relax the restrictive substitution patterns inherent in the multinomial Logit, we model the distribution of consumer preferences over characteristics and prices as multivariate normal:

$$
\begin{pmatrix} \alpha_i^* \\ \beta_i^* \end{pmatrix} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} + \Pi D_{il} + \Sigma \nu_{il}\,, \quad \nu_{il} \sim N(0, I_{n+1})\,, \tag{10}
$$

where ν_{il} captures mean-zero, unobserved preference shifters with a diagonal variance-covariance matrix Σ (i.e., $\Sigma_{jk} = 0 \; \forall k \neq j$). Π is a $(n+1) \times d$ matrix of coefficients that measures the effect of observable individual attributes on the consumer valuation for spirit characteristics including price, allowing cross-price elasticities to vary differentially in markets with observed differences in demographics.

[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. It is likely that firms use bottle size as a quantity discount and therefore they set product prices jointly, solving a second degree price discrimination problem as consumers self-select into different bottle sizes depending on their willingness to pay. Modeling such second degree price discrimination formally requires accounting for informational asymmetries between distillers and consumers. Given the reasonable substitution patterns in the estimated model (see Section 6.2), we believe our approach is a good first approximation to the complex pricing problem of second degree price discrimination among multi-product firms in oligopoly competition, especially given that, to our knowledge, there does not exist a tractable theoretical model of nonlinear multi-product oligopoly pricing.

We make the common assumption that during period t, each consumer either selects one of the J_{lt} spirits available in her market or chooses the outside option.[22] We define the potential market, M_{lt}, to be the consumption of all alcoholic beverages off the premise of the seller, i.e., not in a restaurant or bar ("off-premise consumption"), during pricing period t. We calculate M_{lt} as the number of drinking-age residents scaled by per-capita off-premise consumption, where we allocate the available annual per-capita consumption evenly across pricing periods according to the periods' lengths. The outside option thus consists of closed-container beer or wine purchases denominated in 750 ml bottle-equivalents.[23] We denote it by $j = 0$ with zero mean utility.[24]

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

$$A_{jt}\left(x_{\cdot}, p^r_{\cdot t}, \xi_{\cdot t}; \theta\right) = \left\{\left(D_{il}, \nu_{il}, \epsilon_{i \cdot lt}\right) | u_{ijlt} \geq u_{iklt} \quad \forall k = 0, 1, \ldots, J_{lt}\right\}, \tag{11}$$

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

$$\delta_{jlt} = x_j \beta + \alpha p^r_{jt} + H_t \gamma + \xi_{jlt}, \tag{12a}$$

$$\mu_{ijlt} = \begin{pmatrix} x_j & p^r_{jt} \end{pmatrix} \left(\Pi D_{il} + \Sigma \nu_{il}\right). \tag{12b}$$

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

$$s_{ijlt} = \frac{\exp\left(\delta_{jlt} + \mu_{ijlt}\right)}{1 + \sum\limits_{k \in J_{lt}} \exp(\delta_{klt} + \mu_{iklt})}. \tag{13}$$

[22] Nevo (2000) discusses limitations of the present discrete choice approach when 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 elasticities in the case of stockpiling. In Miravete et al. (2018), we test for stockpiling using a similar dataset and find no evidence. Seim and Waldfogel (2013) present suggestive evidence that the *PLCB*'s demand does not respond disproportionately to price declines in areas where consumers have higher travel costs to the store and thus a higher incentive to buy larger quantities or assortments.

[23] This definition of the potential market accounts for the total volume of alcoholic beverages but not for the different average ethanol contents of beer (4.5%), wine (12.9%), and spirits (37.7%) in our sample.

[24] For example, according to Haughwout et al. (2015), the average drinking-age Pennsylvanian consumed 96.2 liters of alcoholic beverages through off-premise channels in 2003, or 128.2 750 ml bottle equivalents. The 2003 potential market for location l is then the number of drinking-age residents scaled by 128.2. To put this figure in perspective, beer accounts for approximately 90% of total consumption by volume so the average drinking-age Pennsylvanian consumed slightly less than five 375 ml bottles of beer per week, but only approximately thirteen 750 ml bottles of both wine and spirits annually. We follow a similar approach in constructing the potential market for 2004.

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:

$$s_{jlt} = \int_{\nu_l} \int_{D_l} s_{ijlt} dP_D(D_i) dP_\nu(\nu_i)\,, \tag{14}$$

which we evaluate using simulating techniques. See Appendix C for detail.

Consumer Welfare. An advantage of a structural model is that it enables the researcher to assess equilibrium changes in welfare. At retail prices p^r, the (expected) consumer surplus of consumer i in location l at period t is

$$\text{CS}_{ilt}(p^r) = \frac{1}{\alpha_i^\star} \times \sum_{j \in J_{lt}} \exp\left[V_{ijlt}(p_t^r) \right] + C, \tag{15}$$

where C is an unknown constant on integration reflecting the fact that the absolute level of consumer utility cannot be measured. We identify beneficiaries of nominal taxation 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 any counterfactual set of prices $p^{r\prime}$ and the current ones p^r. Since consumer utility is quasi-linear, changes in retail prices generate no income effects so the Marshallian demand is equivalent to Hicksian demand. As a result, therefore changes in consumer surplus (CS) are equivalent to compensating variation:

$$\text{CV}_{ilt}(p^r, p^{r\prime}) = \frac{1}{\alpha_i^\star} \ln \left[\frac{\sum\limits_{j \in J_{lt}} \exp\left[V_{ijlt}(p_t^{r\prime})\right]}{\sum\limits_{j \in J_{lt}} \exp\left[V_{ijlt}(p_t^r)\right]} \right]\,, \tag{16}$$

where $V_{ijlt}(\cdot)$ is given by (9). The mean compensating variation for agents living in location l is

$$\text{CV}_l(p^r, p^{r\prime}) = \sum_t M_{lt} \int_{\nu_l} \int_{D_l} CV_{ilt}(p^r, p^{r\prime}) dP_D(D_i) dP_\nu(\nu_i)\,. \tag{17}$$

Residents in location l are thus on average better off under the current policy when $CV_l(p) > 0$, indicating that they require positive compensation to be unaffected by the new policy with retail prices p'.

5.2 An Oligopoly Model for Distillers

Given optimal consumer choices, we now consider competition between 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. We assume that in each period t, distillers set wholesale prices vector of wholesale prices

$\{p^w_{jt}\}_{j\in J^f_t}$ non-cooperatively as in a Bertrand-Nash differentiated products oligopoly to maximize period t profit

$$\max_{p^w_{jt}} \sum_{j\in J^f}\left[(p^w_{jt}-c_{jt})\times\sum_{l=1}^{L} M_{lt}s_{jlt}\Big(p^r(p^w),x,\xi;\theta\Big)\right], \tag{18}$$

where c_{jt} denotes the marginal cost of product j in period t. To simplify the notation of this static problem, we omit the period t subscripts going forward.[25] Define as $s_j(p^r,x,\xi;\theta)$ the statewide demand for product j, $\sum_{l=1}^{L} M_l s_{jl}(p^r,x,\xi;\theta)$. Profit maximization in the upstream market implies the following first-order condition for distiller f's product j, $\forall j\in J^f$:

$$s_j\Big(p^r(p^w),x,\xi;\theta\Big)+\sum_{m\in J^f}\Big(p^w_m-c_m\Big)\times\frac{\partial s_m}{\partial p^w_j}=0\,. \tag{19}$$

The final term $\frac{\partial s_m}{\partial p^w_j}$ is the response in product m's quantity sold to a change in the wholesale price and, through the pricing rule, the retail price of product j. Assuming a pure-strategy equilibrium in wholesale prices, the vector of profit-maximizing wholesale prices is

$$p^w=c+\underbrace{[O^w*\Delta^{w\prime}]^{-1}\times s\Big(p^r(p^w),x,\xi;\theta\Big)}_{\text{vector of \$ markups}}, \tag{20}$$

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

$$\Delta^w=-\begin{bmatrix}\frac{\partial s_1}{\partial p^r_1}&\cdots&\frac{\partial s_1}{\partial p^r_J}\\ \vdots&\ddots&\vdots\\ \frac{\partial s_J}{\partial p^r_1}&\cdots&\frac{\partial s_J}{\partial p^r_J}\end{bmatrix}\times\begin{bmatrix}\frac{dp^r_1}{dp^w_1}&\cdots&\frac{dp^r_1}{dp^w_J}\\ \vdots&\ddots&\vdots\\ \frac{dp^r_J}{dp^w_1}&\cdots&\frac{dp^r_J}{dp^w_J}\end{bmatrix}=-\begin{bmatrix}\frac{\partial s_1}{\partial p^r_1}&\cdots&\frac{\partial s_1}{\partial p^r_J}\\ \vdots&\ddots&\vdots\\ \frac{\partial s_J}{\partial p^r_1}&\cdots&\frac{\partial s_J}{\partial p^r_J}\end{bmatrix}\times\begin{bmatrix}1.534&\dots&0\\ \vdots&\ddots&\vdots\\ 0&\dots&1.534\end{bmatrix}, \tag{21}$$

where Δ^d is the matrix of changes in quantity sold due to changes in retail price with element (k,m) equal to $\frac{\partial s_k}{\partial p^r_m}$ and Δ^p is the matrix of changes in retail price due to changes in wholesale price with element (m,j) equal to $\frac{dp^r_m}{dp^w_j}$. In our context, the state's regulation of alcohol sales simplifies this matrix significantly by eliminating off-diagonal terms so that $\frac{dp^r_j}{dp^w_j}$ is simply $1.30\times1.18=1.534$ for all stores, reflecting the 30% uniform markup and the 18% liquor tax.

Given estimates of consumer demand, data on retail and wholesale prices, and the observed *PLCB* policy, we use this model of upstream behavior to recover product-level marginal costs via (20). These marginal cost estimates are a combination of production costs and federal unit

[25] 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 annually, 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 per year.

taxes on alcohol where the latter is a function of alcohol content. As we discuss in more detail in Section 6.4,the relative important of these federal taxes are pinned down via these estimated marginal costs. When marginal cost estimates are large, this necessarily means the equilibrium impact of the nominal federal taxes is minor. Of course, just the opposite is true in the event the marginal cost estimates are small (i.e., federal taxes play a prominent role in determining equilibrium wholesale and retail prices). Since marginal cost estimates are pinned down by the combination of quantity sold and demand elasticities (Equation 20) and the former is simply data, the importance of federal alcohol taxation (and also whether or not these taxes are indexed to inflation) depend upon attaining reasonable demand estimates and product demand elasticities – an issue which we discuss below.

6 Estimation Results

We adapt the estimation approach of Nevo (2000) to the institutional features surrounding the price regulation of spirits in Pennsylvania. 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 identify separately 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 use generalized method of moments techniques to estimate the determinants of deviations from a product's mean utility μ_{ijlt}, 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 employ instrumental variables techniques to project the estimated product by pricing period fixed effects onto price, seasonality, and product fixed effects, using contemporaneous prices in distant control states and input prices as instruments. Last, we project the estimated product fixed effects from the second stage onto time-invariant product characteristics. We refer the interested reader to our Appendix C and to our companion piece, Miravete et al. (2018), which provides details of the estimation procedure for a more parsimonious version of the demand model that we estimate here.

Before discussing the estimation results, we turn to the variation in the data that allows identification of two key aspects of the demand model: heterogeneity in consumer preferences and consumer price sensitivity. We identify unobserved heterogeneity in consumer preferences – the random coefficients Σ in equation (10) – 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 taste variation for 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 the root mean square distance in spirit product scores, as a measure of product quality, of product j

and other products that share its characteristics. Thus, for the above brandy, this would be the average product score distance from other brandies available in market l at time t. This instrument provides additional identifying power since it captures the differential effect on the market share of a high-quality brandy, say, as the product quality of the brandies that it competes against changes, e.g., over time.

Variation in consumer preferences due to demographic variation across markets – the demographic interactions Π in equation (10) – reflects 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. A key feature aiding identification of Π is the uniform retail price for each product across markets, facilitating the linking of purchases to demographic variation in preferences alone. Following Waldfogel (2003), 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 its product score distance to and the count of other brandies with the share of young consumers in each market. To identify a differential effect of price by income, we construct similar instruments based on the set of products sharing a given product's price category (cheap vs. expensive) interacted with the share of high-income households in the market.

The mean response across locations to variation in retail 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 rely on input costs and retail prices in other control states as instruments to address possible confounding effects of unobserved demand shocks ξ that distillers respond to in setting wholesale price. Appendix D shows that our results are robust to alternative sets of price instruments, as well as sample construction and arbitrage on the state border. 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 period or characteristic.

6.1 Parameter Estimates

Table 4 presents the demand estimates of our preferred specification of the mixed-logit model. The parameters estimates are precise, and the estimated demand specification captures the patterns of spirit consumption across demographic groups documented in Table 3.

We allow for rich variation across demographics by interacting consumer age and indicators for minority and high educational attainment with proof and indicators for spirit type, bottle size, and import status. The estimates of Π reveal significant differences in tastes for spirits across demographic groups. While minority consumers favor brandy, cordials and rum over gin, the reference category, older and college-educated consumers prefer gin to cordials and rum. We also find that older consumers and, to a lesser extent, college-educated consumers are 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. The estimated demand for wealthier consumers is steeper, which is

Table 4: Mixed-Logit Demand

	Mean Utility (β)	Random Coeff. (Σ)	Demographic Interactions (Π)			
			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 ln(age−20), EDUCATION is an indicator variable equal to one if the agent has some level of college education, INCOME is ln(income), and MINORITY is an indicator equal to one if the agent is non-white. Mean utility contributions of price, holiday, and summer are based on a product fixed effects regression of the product-period fixed effects from the *GMM* estimation, controlling for price endogeneity. Remaining coefficients result from a projection of the estimated product fixed effects onto time-invariant product characteristics.

consistent with the increased consumption of expensive spirits by high-income consumers reported in Table 3. Older and minority consumers favor spirits with higher proof.

We allow for unobserved variation in preferences for a number of the product characteristics, including proof and certain bottle sizes, product categories, and import status. The estimated random coefficients are large, in particular for brandies and for the 375 ml size, indicating that even after controlling for the significant degree of observed differences in tastes on average and by demographic groups, there still exist further similarities between products in these categories that influence their substitution patterns. Lastly, we find 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.

Table 5: **Price Elasticities by Spirit Type, Price, and Size**

	Products	Price	Price Elasticity (ε_{jj}) Avg.	SD	Cross-Price Elast. (ε_{ji}) Ratio	Best Subst.
By Spirit Type:						
BRANDY	26	14.41	−3.64	1.80	39.21	100.00
CORDIALS	62	14.08	−3.46	1.35	1.30	72.58
GIN	28	15.15	−3.90	1.82	2.09	100.00
RUM	40	13.72	−3.38	1.15	1.97	17.50
VODKA	66	16.82	−3.95	1.60	2.07	64.64
WHISKEY	90	16.77	−3.98	1.63	1.88	35.56
By Price:						
EXPENSIVE	150	20.43	−4.74	1.54	1.20	92.67
CHEAP	162	10.96	−2.81	0.84	0.98	25.93
By Bottle Size:						
375 ml	48	8.94	−2.36	0.89	1.88	100.00
750 ml	170	14.53	−3.58	1.32	0.89	89.41
1.75 L	94	20.65	−4.74	1.61	2.69	76.60
ALL PRODUCTS	312	15.16	−3.75	1.57	N/A	N/A

Notes: In columns 2-5 we present the number of products, the average retail price, plus the average and standard deviation of the estimated own-price elasticity across spirit type, price-point, and bottle size. Figure G.1 in Appendix G presents the distribution of own-price elasticity across these liquor groups. In the remaining columns we present descriptive statistics for the cross-price elasticities. "Ratio" is the average cross-price elasticity among products of a characteristic (e.g., spirit type) relative to the average cross-price elasticity among products which do not have that characteristic. Values greater than one indicate that consumers are more likely to substitute towards a product which shares the characteristic in question (e.g., same liquor type). "Best Subst." is the percent of products which share a characteristic (e.g., same liquor type) where the best substitute (i.e., the product with the largest cross-price elasticity) also shares that characteristic (e.g., is of the same liquor type). See Table G.3 for examples of best substitutes for a selection of popular products.

6.2 Elasticities

The objective of this paper is to measure the effects of nominal alcohol taxation on tax revenue collected, firm profits earned, and consumer welfare. To do so we use the estimated elasticities from our demand side model alongside the model of upstream oligopoly competition (Section 5.2) to infer upstream production costs net of the federal excise tax as well as use the estimated model as a laboratory to evaluate the effects of nominal taxation. Our estimated elasticities are therefore crucial to accurately measuring these effects. We summarize the empirical distribution of own-price elasticities in Table 5.

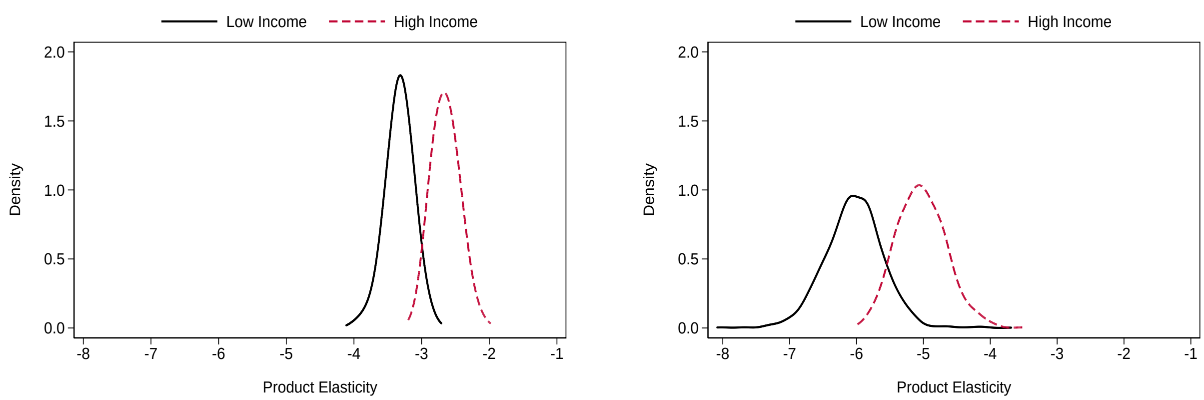
At the product level, we estimate an average own-price elasticity of −3.75, which is within the range of median elasticities of Conlon and Rao (2015, Table 8) for spirits (from −2.61 for whiskeys to −3.80 for vodkas), and somewhat more elastic than the −2.41 own-price elasticity of wine estimate of Aguirregabiria, 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.[26] We address this discrepancy in detail below.

The estimated own-price elasticity exhibits substantial heterogeneity within and across spirit types and bottle sizes. Within spirit types, its distribution has the largest spread for brandies and gins and the lowest for rums. The bottom of Table 5 shows that demand responsiveness varies more widely across bottle sizes and price segments than across spirit types. The demand for 375 ml bottles is less elastic than for 1.75 L bottles, with the 750 ml bottles in-between. This ordering of elasticities mirrors unreported results from descriptive OLS regressions of log bottles sold on log price. Similarly, we find that demand for expensive products is more elastic than the nearly half as costly cheap spirits.

Table 5 demonstrates that the estimated elasticities vary across the products in our sample. Table 3 and, in a multivariate environment, Table 4 indicate further that consumer preferences are correlated with demographics. Putting these two facts together, we find that demand in low-income areas is more price sensitive: the same product has more elastic demand the lower the income of the population served. At the same time, low-income consumers prefer less expensive products. Across products, these have relatively inelastic demand, on average.

Figure 6: Demand Elasticities and Income



(a) Smirnoff Vodka, 750 ml ($11.82) (b) Grey Goose Vodka, 750 ml ($24.75)

Notes: Figures compare kernel densities of the own-price demand elasticity for two sample products. We denote the distributions for markets in the bottom ("Low") and top ("High") quintiles of the income distribution by solid and dashed lines, respectively.

In Figure 6 we provide an example by presenting the distribution of estimated price elasticities across our 454 local markets for two popular 750 ml bottles of vodka: *Grey Goose* and *Smirnoff*. We define *Grey Goose* as an "expensive" product as the average retail price of $24.75 lies above the median average price of 750 ml vodkas. In contrast, *Smirnoff* sells for an average retail price of $11.82, a "cheap" product under our definition. We observe that the empirical distribution of *Smirnoff*'s estimated price elasticities (panel a) is shifted to the right of *Grey Goose* (panel b).

[26] The estimated price elasticity of off-premise spirit demand under a comparable multinomial logit specification is −3.39. Thus, including the flexibility of random coefficients and demographic interactions decreases consumers' willingness to substitute to the outside option – a similar finding to Berry et al. (1995).

Thus, the demand for the "cheap" *Smirnoff* is typically less elastic than the "expensive" *Grey Goose* – a finding consistent with Table 5. We also observe that for both products the empirical distribution of price elasticities shifts to the left, i.e., estimated demand is more elastic, as we move from high-income (dashed line) to low-income (solid line) markets, where the average consumer is more price sensitive. Since low-income consumers prefer the inexpensive *Smirnoff* to the expensive *Grey Goose*, their consumption decisions and welfare are more sensitive to retail price changes of the relatively inelastic *Smirnoff*, however.

Turning to cross-price elasticities, we evaluate the substitution patterns in the estimated model through two statistics. In the "Ratio" column, we present cross-price elasticities for products within a group to products (e.g., brandies) outside the group (e.g., other spirit types). That is, for product j we compute

$$\text{Ratio}_j^d = \frac{\frac{1}{|\mathcal{G}_j^d|}\sum_{i\neq j, i\in\mathcal{G}_j^d}\varepsilon_{ji}}{\frac{1}{|\mathcal{G}_j^{-d}|}\sum_{i\neq j, i\in\mathcal{G}_j^{-d}}\varepsilon_{ji}}$$

where ε_{ji} is the average cross-price elasticity between products i and j in the sample and $\mathcal{G}_j$ is the products which share characteristic d with product j. For example, if product j is a RUM, $\mathcal{G}_j^{d=\text{RUM}}$ is the set of all RUM products and $|\mathcal{G}_j^{d=\text{RUM}}|$ is the total number of RUM products. Ratio_j^d then is the ratio of the average cross-price elasticity among products which share the same characteristic d with product j to the average cross-price elasticity among products which do not share characteristic d with product j (i.e., are in $\mathcal{G}_j^{-d}$). "Ratio" in Table 5 is then the average across the product set for a given characteristic d where values greater than one indicate that consumers are more likely to substitute towards another product within the group. In right-most column we present the likelihood that the "best substitute" for a product (i.e., the competing product with the greatest cross-price elasticity) shares characteristic d with product j.[27] This statistic is bounded between zero and one hundred where higher values indicate that a higher percentage of products which share characteristic d have a best substitute which also has characteristic d.

From Table 5 we observe that the random coefficients (Σ) and demographic interactions (Π) in the estimated model generate reasonable substitution patterns as consumers substitute towards products of similar characteristics (i.e., "Ratio" is greater than one and "Best Substitute" greater than 50 for most characteristics). This is particularly true for BRANDY products and to a lesser extent GIN, VODKA, EXPENSIVE, 375 ml, and 1.75 L products. We also find that an increase in the price of a CHEAP product leads consumers to substitute away from other CHEAP products (i.e., "Ratio" less than one and "Best Substitute" close to zero). Recall that a product is "CHEAP" when its average price is below the median value among products of the same spirit type and bottle size. Thus, substitution away from our definition of "CHEAP" product reflects consumers switching to "EXPENSIVE" products in a different spirit type but same bottle size, different bottle size but same spirit type, or both a different spirit type and bottle size. Given the fact that consumers appear to not switch very often across bottle size (i.e., "Best Substitute" close to 100 across all bottle size

[27] See Table G.3 in Appendix G for a list of specific "best substitutes" for a select number of popular products.

characteristics), much of this switching is across liquor type. For example, the best substitute for a 750 ml bottle of *Bacardi Light*, a CHEAP RUM, is a 750 ml bottle of *Fire Water Hot Cinnamon Schnapps*, an EXPENSIVE CORDIAL.

6.3 Elasticity Measurements Compared to Other Studies

As noted earlier, the validity of our demand estimates, and particularly the corresponding demand elasticities, are crucial to estimating upstream marginal costs (via 20), capturing accurate consumer responses to changes in retail prices do to changes in taxation, and ultimately towards developing reliable estimates as to the consequences of nominal taxation. Moreover, studies on alcohol routinely find own-price demand elasticities between -0.5 and -1.0 for beer, wine, and spirits; though there is considerable disagreement across studies due to differences in data quality (i.e., survey vs. purchase), level of aggregation, and modeling approach.

The product-level own-price elasticity in our demand model is -3.75. Thus, product demands are elastic, consistent with profit-maximization by upstream firms. It is possible to simultaneously generate elastic product-level demands while spirits as a category remains inelastic – recall a key feature of mixed logit models is that consumers are less likely to consume the outside good – we find the estimated price elasticity of off-premise spirit demand is -2.48 which is more elastic than the values found in the literature, including Leung and Phelps (1993) who present an estimate of -1.5 for spirits as a category.

Why the difference? One possibility is that our analysis focuses on off-premise purchases and excludes on-premise consumption in bars and restaurants, which is likely less price sensitive than off-premise consumption. Recall, however, that off-premise purchases account for roughly 80% of sales by volume (Section 4) so it seems unlikely that the exclusion of off-premise alone is sufficient to explain the discrepancy.

A second possibility is that our study differs in the quality of data used to estimate demand. A key differentiating feature of our setting is that we have detailed data at the store level and features of the data enable us to identify exactly when prices change. Moreover, these price changes occur at the same point in time for all stores so we are not forced to aggregate price changes across a period of time; e.g., average price in June, 2003. Ruhm, Jones, McGeary, Kerr, Terza, Greenfield and Pandian (2012) demonstrates that price data the American Chamber of Commerce Researchers Association (ACCRA) cost of living index – a common data source for the vast literature which presents estimates of alcohol demand – are poor inputs to estimated demand because the price data are collected for only one brand of beer, wine, or spirit which exposes the estimates to significant measurement error in the event the chosen brand is not representative for the given population.[28] In Appendix D we further demonstrate that aggregation in our data leads to estimated demand systems which are less sensitive to changes in price thereby delivering spirit elasticity estimates

[28] An additional problem which likely affects data quality is that collectors are not trained as data gatherers (Ruhm et al., 2012).

more in-line with the literature. Since the vast majority of research in this area uses aggregated data, our results suggest these estimates of alcohol demand price elasticities are biased towards zero because the data underlying the estimates combine the price and quantity responses among heterogenous goods and consumers.

A differentiating feature of our study – and an important contribution to both the literature and public policy – is that we incorporate detailed price-quantity information in a industry and regulatory setting which enables clean identification of demand-side parameters, particularly price. By combining these data within the context of an equilibrium model of consumer behavior – thereby accounting for consumer substitution among varieties due to changing retail prices – our methodology addresses many, if not all, of the shortcomings of previous studies while not imposing that the elasticity of spirits as a category fall in a particular region.[29] A limitation of our study, however, is that we hold aggregate alcohol consumption fixed since consumers decide between purchasing one of the 312 spirits or the outside option which amounts to a 750 ml bottle of beer or wine. Thus, our elasticity estimate for spirits as a category is best viewed as a cross-price elasticity

Discussion. Demand elasticities generated in the literature are commonly applied to policy as in the "naive" model of Section 2. Even in the event firms in an industry lack market power, policy recommendations based on inelastic demand estimates both overestimate the ability of taxation to generate tax revenue and underestimate the degree of taxation required to curb alcohol consumption to reduce externalities. A simple example of the former effect is contained in Task Force on Fiscal Policy for Health (2019) where the authors assume inelastic alcohol demand and conclude that the "additional [tax] revenue that can be obtained from such tax increases, while secondary to the health gains, are substantial." A researcher or policy-maker equipped with a demand elasticity which is less elastic than the true demand elasticity will incorrectly believe consumption to be less responsive to retail prices leading to predictions of tax windfalls.[30]

A similar argument holds for the implication of using an incorrect demand elasticity to inform policy intended to limit consumption. An increase in the alcohol tax unambiguously translates to higher retail prices and ultimately less alcohol consumption due to downward-sloping demand. A government intent on curbing consumption by a fixed amount which incorrectly perceives demand to be inelastic will necessarily choose a tax rate which is too high leading to excessive retail prices and reduced consumer welfare. Identifying the true demand elasticity is therefore fundamental for a benevolent government to craft optimal tax policy which balances the equilibrium trade-offs among tax revenue, consumer welfare, and societal externalities. Testing the extent to which our data and

[29] Recall that mixed-logit models not only generate more reasonable substitution patterns, they also tend to reduce the willingness of consumers to substitute to the outside good; i.e., they yield less elastic estimates of the "inside" good.

[30] A subtle point is that demand elasticity in much of the policy literature is an input to calculate the effects of changes in policy and is therefore fixed. This stands in stark contrast to structural equilibrium models of consumer behavior as in this study where the elasticity is simply a descriptive statistic of equilibrium prices and quantities.

methodology extend beyond spirits and applies to alcohol demand more generally is therefore an important policy-relevant avenue of future research.[31]

6.4 The Upstream Market

In this section we turn our attention to the upstream market. To consider the response in upstream behavior to alternative retail pricing policies, we first require an estimate of the firms' marginal costs. We combine our demand estimates with the above assumption of Bertrand–Nash pricing to recover the marginal costs that render the observed wholesale prices optimal under the current pricing policy (see the first-order conditions in Equation 20). We rely on these marginal cost estimates in conducting our counterfactual analysis.

Table 6: 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: Table displays average Lerner index, defined as $100 \times (p^w - \hat{c})/p^w$, weighted by bottles sold.

We find that the marginal costs of expensive products are on average 2.7 times higher than those of inexpensive products and that brandies and whiskey are the least and most costly products, respectively, to manufacture on average (see Table G.1 in Appendix G). For the subset of brandies and whiskeys with age information, we find that marginal costs are approximately 1.5 times higher for products that distillers age more than four years than for non-aged products. Imported products have 1.8 times the marginal cost of domestically produced products on average, reflecting increased transportation costs and import tariffs that the distillers pay.

Table 6 documents the significant market power implied by our cost estimates; on average, the firms earn 36.5 cents in profit per dollar in revenue. Products manufactured by larger firms, such as Diageo and Bacardi, have lower Lerner indices (roughly 34%) while smaller manufacturers

[31] An additional criticism may be that the outside good in the consumer model is beer and wine so aggregate volume of alcoholic beverages is fixed. Regressing logged quantity sold on logged retail price yields a similarly elastic estimate of spirit demand (−3.90) so this assumption appears to not be critical.

such as Jacquin and Sazerac operate niche product portfolios (see Table 1) on which they keep 46.5% and 42.3% of revenue in profit, respectively. Across manufacturers, CHEAP and 375 ml products are particularly profitable. The presence of upstream market power indicates that firms possess the ability to respond to both changes in either federal or state tax policy – a factor we account for in considering the implications of indexing federal and state tax policies.

Estimates of Demand Curvature. In Table 7 we present our estimates of demand curvature across product characteristics and firms. We observe that only 5.3% of product-level demands are log-concave and pass-through rates vary little across product characteristics or firm portfolios. These results indicate that pass-through rates are more than complete for the vast majority of products but there exists little heterogeneity across products or firms in terms of how firms pass-through changes in cost to consumers.

Table 7: Estimates of Demand Curvature (Select Firms)

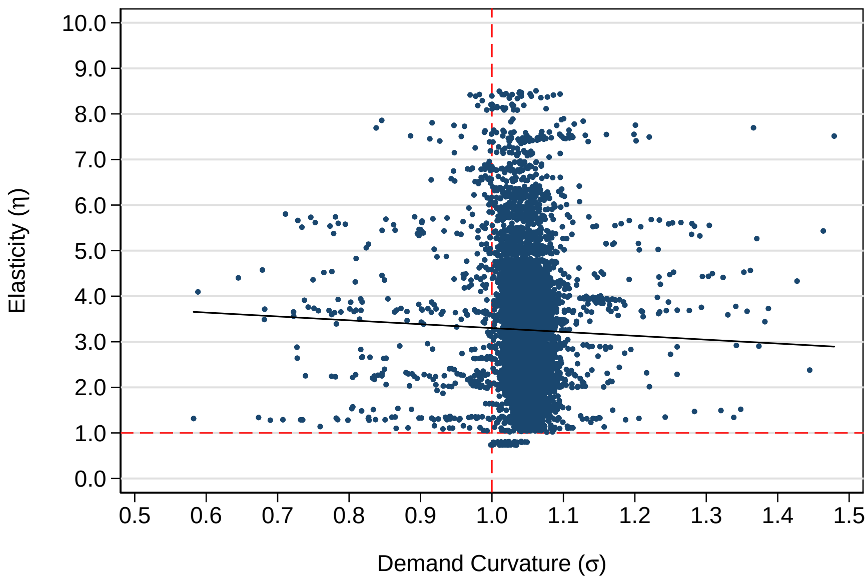
	ALL	DIAGEO	BACARDI	BEAM	JACQUIN	SAZERAC
By Spirit Type:						
BRANDY	1.00	-	-	-	1.02	-
CORDIALS	1.05	1.05	1.03	1.05	1.06	1.05
GIN	1.05	1.05	1.07	1.06	1.05	1.05
RUM	1.05	1.04	1.05	1.05	1.05	-
VODKA	1.04	1.04	-	1.05	1.02	1.03
WHISKEY	1.05	1.04	1.04	1.04	1.04	1.05
By Price and Size:						
CHEAP	1.04	1.05	1.05	1.05	1.03	1.04
EXPENSIVE	1.04	1.04	1.05	1.04	-	1.05
375 ml	1.03	1.05	1.05	1.05	1.03	1.02
750 ml	1.04	1.05	1.05	1.05	1.05	1.05
1.75 L	1.04	1.03	1.04	1.04	1.02	1.04
ALL PRODUCTS	1.04	1.05	1.05	1.05	1.03	1.04

Notes: Table displays average (inverse) demand curvature defined as $D_{jt}(p)D''_{jt}(p)/[D'_{jt}(p)]^2$ by product characteristic and firm. $D_{jt}(p)$ is state-wide demand for product j in period t defined as $D_{jt}(p) = \sum_{l=1}^{L} D_{jlt}(p)$. Statistics are weighted by bottles sold in the data.

In Figure 7 we present our empirical estimates of the demand manifold of Mrázova and Neary (2017). As we discuss in Section 2, our results depend on the strategic behavior of firms – including both the ability of firms to pass-through changes in federal taxation and their willingness to respond to changes in downstream state-level taxation – and such behavior depends upon $\hat{\sigma}$. In our setting, the flexible demand system we estimate places no restrictions upon demand curvature and therefore the strategic behavior firms while also not restricting the relationship between product demand curvature and demand elasticity. Indeed, we find there exists little connection between the two.

Decomposing Firm Costs. One of the objectives of this paper is to assess the equilibrium effects of the 1991 $13.50 per proof-gallon federal alcohol tax which is paid by distillers but has become less important over time due to inflation. As this tax is per unit and paid by distillers, its effect

Figure 7: The Estimated Demand Manifold



Notes: Figure presents estimated statewide product demand elasticities and demand curvature where the latter is defined as $D_{jt}(p)D''_{jt}(p)/[D'_{jt}(p)]^2$ and $D_{jt}(p) = \sum_{l=1}^{L} D_{jlt}(p)$ is state-wide demand for product j in period t.

is embedded in our estimates of upstream marginal costs $\hat{c}_{jt}$. Formally, we decompose estimated marginal costs $\hat{c}_{jt}$ into production-related expenses $\widehat{mc}_{jt}$ and federal taxes τ_j as follows:

$$\hat{c}_{jt} = \widehat{mc}_{jt} + \tau_j$$

where τ_j is the per unit federal tax which varies slightly across products due to variation in bottle size and alcohol proof. While we observe τ_j directly, we use our demand estimates and the oligopoly model of upstream firm price competition (i.e., Equation 20) to infer marginal costs ($\hat{c}_{jt}$).

Table 8: Decomposing the Upstream Market

	Number of Products	Production Cost ($\widehat{mc}$)	Federal Tax (τ)	Marginal Cost ($\hat{c}$)	Wholesale Price (p^w)
Diageo	63	4.72	2.58	7.31	10.21
Bacardi	22	5.02	2.80	7.82	10.58
Beam	32	2.13	2.67	4.80	7.48
Jacquin	27	0.32	2.58	2.90	5.51
Sazerac	18	0.76	3.11	3.88	6.46
All Firms	312	$ 3.73	$ 2.71	$ 6.44	$ 9.19

Notes: With the exception of "Products", statistics correspond to the median value. "Production Cost" is defined as $\widehat{mc}_{jt} = \hat{c}_{jt} - \tau_j$ where $\hat{c}_{jt}$ is the estimated marginal cost of product j (e.g., Bacardi 750 ml) in period t (e.g., June 2003) and τ_j is the federal specific tax applied to product j implied by Equation 20 at the estimated demand parameters ($\hat{\theta}$). "Wholesale Price" is the observed wholesale price charged by upstream firms in the data. Firms listed in descending order according to market share.

In the event these estimated marginal costs are very high because demand is very elastic, the federal tax would comprise a minor share of a firm marginal costs so an increase in the tax would elicit a small pricing response and ultimately have little impact on retail prices and consumption.

Of course, just the opposite is true in the event that federal tax accounts for a significant share of estimated marginal costs. Ultimately, the quantitative importance of nominal taxation at the federal level depends on the federal tax share of firm marginal costs; i.e., $\tau_j/\hat{c}_{jt}$. It is important to note that we place no restrictions on $\tau_j/\hat{c}_{jt}$ ex ante so these tax shares may be either big or small.

In Table 8 we observe that the federal alcohol tax accounted for 42.09% of the total median product's marginal cost in our data – a large share of total marginal cost. Not all firms are equally exposed to the tax, however, and . For example, the federal tax share is the lowest for Diageo and Bacardi (35.36% and 35.79%, respectively) due to these firms' focusing a greater share of their product portfolio on relatively expensive products (Table 1). In contrast, federal taxes account for the bulk of the marginal cost for Jacquin (88.94%) and Sazerac (80.33%) reflecting these firms focus on selling relatively inexpensive products, particularly 1.75 L products where the federal tax is greatest (Table 9).

Summary of Results. We conclude from these results that firms possess market power and will indeed respond to changes in the federal and state tax policies. Our estimates of demand curvature (Table 7) suggest that changes in the federal tax will be more than passed-on to the downstream market while changes in the state-level tax will be amplified by the upstream firms (i.e., the state-level tax and the upstream firm prices are strategic complements) though our curvature estimates of close to unity suggest such amplification will be small (Section 2). As the federal tax amounts to a significant share of firm marginal costs further indicates that changing the federal tax rate will elicit a significant change in wholesale prices and large equilibrium effects to tax revenue, profits, and consumer welfare.

7 Welfare and Distributional Effects of Nominal Excise Taxes

In this section we use the estimated model to evaluate the equilibrium effects of nominal excise taxation of distilled spirits on federal and state tax revenue, firm profits, and consumer welfare. A novel feature of our analysis is that our equilibrium model incorporates both the optimal pricing behavior of heterogenous firms and the utility-maximizing behavior of heterogenous consumers which enables us to develop robust estimates of the aggregate (Section 7.1) and distributional (Section 7.2) consequences of nominal taxation.

Preliminaries. We identify the equilibrium effects of federal and state nominal taxation by comparing our estimated equilibrium to two counterfactual equilibria in which excise taxes are not fixed but are rather indexed to inflation. In the first, we consider an alternative world in which the US Congress establishes an addendum to the *Omnibus Budget Reconciliation Act of 1990* which indexes the \$13.50 per proof-gallon excise tax to the urban consumer price index published annually by US Bureau of Labor Statistics (BLS). We call this counter-factual experiment "Federal." In the second experiment, we similarly envision an environment where the Pennsylvania state legislature establishes the *LTMF* fees in 1993 and indexes these fees to the urban consumer price index published by the BLS for Pennsylvania (Pittsburgh). We call this counter-factual experiment "State." Both series are depicted in Figure 3.

In both of these counter-factual experiments we hold several aspects of the equilibrium model fixed: the product set as well as the firm portfolios, the estimated marginal (production) costs of firms and demand estimates $(\hat{\beta}, \hat{\Sigma}, \hat{\Pi})$ as well as the unobserved (to the econometrician) demand shocks $(\hat{\xi})$. As changes in federal or state taxation impact equilibrium firm and consumer behavior, one might expect many (perhaps all) of these elements of the model may change under alternative policies. Exploring how changes in these policies may have impacted either firm (e.g., introduction of new products) or consumer behavior (e.g., changes in preferences) along these dimensions are important areas for future research.

In Table 9 we compare the federal and state taxes across different product characteristics. We observe that although the federal tax is uniform and very simple, it nonetheless generates variation in taxation across product types due to heterogeneity in proof and bottle size. Similarly, variation in the State taxes across type and price-point (CHEAP vs. EXPENSIVE) reflects the prevalence of different bottle sizes in each characteristic. Our second observation is that indexation of both federal and State excise taxes leads to a significant (i.e., 27.1% to 38.7%) increase in these taxes. As federal taxes amount to approximately 40% of firm marginal costs (Section 6.4) and State taxes amount to approximately 20% of the downstream markup, such a change in these taxes are likely to have significant impact on equilibrium wholesale and retail prices. Moreover, heterogeneity among the number and characteristics embodied in firm product portfolios as well as heterogeneity among consumer preferences by demographics suggests that indexing these taxes will likely have significant distributional consequences.

Table 9: Nominal and Indexed Excise Taxes

	Products	Federal			State		
		Nominal	2003	2004	Nominal	2003	2004
By Spirit Type:							
BRANDY	26	2.25	3.05	3.12	1.22	1.55	1.59
CORDIALS	62	1.41	1.91	1.98	1.19	1.52	1.56
GIN	28	3.40	4.59	4.76	1.34	1.70	1.75
RUM	40	2.76	3.73	3.84	1.29	1.64	1.69
VODKA	66	3.23	4.36	4.47	1.33	1.69	1.73
WHISKEY	90	3.26	4.41	4.49	1.33	1.70	1.73
By Price:							
EXPENSIVE	150	2.93	3.95	4.04	1.31	1.66	1.70
CHEAP	162	2.78	3.76	3.89	1.29	1.64	1.68
By Bottle Size:							
375 ml	48	1.03	1.39	1.43	1.05	1.33	1.37
750 ml	170	1.97	2.66	2.74	1.20	1.52	1.56
1.75 L	94	4.94	6.68	6.85	1.55	1.97	2.02
ALL PRODUCTS	312	2.85	3.85	3.96	1.30	1.65	1.69

Notes: Table presents federal and Pennsylvania state excise taxes by product characteristic. "Federal" is based on $13.50 per proof-gallon (i.e., per liquid gallon equal to 50% ethanol at 60 degrees Fahrenheit) so variation across product types reflects differences in proof and bottle size. "State" corresponds to the *LTMF* unit fees based on bottle size. Variation across type and price-point therefore reflects the prevalence of different bottle sizes in each characteristic. "Nominal" refers to the current federal and Pennsylvania nominal (i.e., non-indexed) excise taxes, while "2003" and "2004" refer to these excise taxes indexed to inflation. Indexing of federal taxes in 2003 and 2004 reflects a 35.1% and 38.7% increase, respectively, assuming Congress had indexed these excise taxes to the national (urban) Consumer Price Index. Indexing of the Pennsylvania state *LTMF* in 2003 and 2004 reflects a 27.1% and 30.3% increase, respectively, assuming the state legislature had indexed these excise taxes to the local (urban) Consumer Price Index. See Figure 3. All statistics are weighted by quantity sold in the data to reflect consumer preferences.

7.1 Aggregate Effects

We begin our analysis with a discussion of the aggregate effects of nominal taxation (Table 10). On average, indexing the federal tax leads upstream firms to increase wholesale price $1.10 (12.6%) – a wholesale price change greater than the change in costs reflected in Table 9. Thus, the estimated model with multi-product oligopoly predicts pass-through which is more than complete consistent with the prediction Section 2 for demand curvatures greater than one.

Pass-through at the downstream market is more-than-complete by construction due to the *PLCB*'s markup formula which applies a 53.4% ad valorem markup to the wholesale price. Thus, the final impact on retail prices is an increase of $1.69 (11.3%). These results indicate that nominal taxation at the federal level therefore depresses retail price significantly. While it is unsurprising that nominal taxation reduces prices, the size of the difference in wholesale and retail prices depends upon the equilibrium pass-through rate implied by the estimated model where an important feature of mixed logit demand is that pass-through may either be less than complete, perfect, or more than complete. This stands in stark contrast to multinomial logit and nested logit where pass-through is incomplete by assumption (Quint, 2014).

Ultimately, lower retail prices due to nominal taxation increased consumption both in terms of both bottles (31.9%) and liters of ethanol (47.3%). This expanded the market for firms and enabled them to increase their profits $26.34 million (30.4%). While it may not be shocking that lower taxes enabled firms to increase profits, the estimated model demonstrates that because pass-through in this market is approximately complete, the majority of this growth is due to market expansion as lower retail prices increased the total number of spirit bottles demanded.

Table 10: Aggregate Effects of Nominal Taxation

		Indexed Excise Taxes	
	Nominal	Federal	State
Prices:			
– Wholesale	8.71	9.81 [9.80, 9.82]	8.72 [8.72, 8.72]
– Retail	14.89	16.58 [16.57, 16.59]	15.35 [15.35, 15.35]
Consumption:			
– Bottles	41.34	31.35 [31.07, 32.15]	38.12 [38.02, 38.4]
– Ethanol Per Capita	1.38	1.30 [1.29, 1.31]	1.36 [1.35, 1.37]
Profits:			
– Federal Tax Revenue	117.94	109.62 [108.3, 113.49]	108.17 [107.86, 109.09]
– PA Tax Revenue	255.69	204.88 [202.6, 210.67]	252.90 [252.18, 254.86]
– Firms	113.09	86.75 [82.92, 92.06]	104.76 [100.68, 109.38]
Consumers:			
– Compensating Variation	-	57.75 [57.09, 58.96]	18.18 [18.03, 18.32]
– CV as % of Expenditure	-	9.37 [9.26, 9.57]	2.95 [2.92, 2.97]

Notes: All numbers correspond to the entire sample, 2003-2004. "Bottles" corresponds to millions of bottles. "Ethanol" corresponds to annual gallons per capita. Federal and state tax revenue are denominated in millions of dollars. Firm profits are denominated in millions of dollars and are net of federal taxes. 95% confidence intervals located in brackets where appropriate. See Appendix F for details regarding the construction of these intervals.

Absent public health externalities, all consumers in our sample benefit from nominal taxation and the lower prices due to nominal taxation benefited Pennsylvania residents $57.75 million. To put this amount perspective, the average drinking-age person in Pennsylvania would have been willing to pay roughly $7, or roughly nine percent of their liquor expenditure, to ensure the federal government would not index its tax policy. If the goal of alcohol tax policy is to discourage consumption, failing to index the federal excise tax leads to an increase in consumption thereby undermining the effectiveness of the policy over time – a key point argued in Task Force on Fiscal Policy for Health (2019). The history of US federal tax policy, however, suggests that government is more concerned with alcohol taxes as a revenue source than as a deterrent. Here, we observe that failing to index the nominal federal tax rate enabled the US government to increase tax revenue 7.6%. This result reflects the fact that the current federal tax of \$13.50 per proof-gallon rate exceeds the revenue-maximizing rate of \$12.16 so any tax increase due to indexation will only push the industry further into the "prohibitive" region of the Laffer curve. Tax revenue in Pennsylvania also increased \$50.81 million (24.7%) due to the nominal federal policy. As *PLCB* revenue is not earmarked for specific government programs but rather accrues to the state's general fund, such an increase likely funded a variety of programs.

Public health externalities are, however, a key motivation for the taxation of alcohol and must be accounted for in the welfare analysis. Sacks et al. (2013) provide an estimate of the external costs of alcohol consumption borne during this period in the state of Pennsylvania equal to \$1.81 per US standard drink, or equivalently \$102.26 per liter of ethanol.[32] Using this figure, our results indicate that the federal nominal excise tax generated \$505 million in additional external costs from alcohol consumption during 2003–2004.[33] In order for nominal taxation to be welfare improving, we find that the social cost per standard drink would have to be less than 51 cents, or roughly less than one-quarter of the Sacks et al. (2013) estimate. The additional social costs brought about by increased ethanol consumption therefore more than offset the welfare gains from increased federal and state tax revenue, firm profits, and internalized utility from consumption. Our study amounts to the first welfare analysis of excise tax indexation, or lack thereof, and therefore provides detailed quantitative evidence of the conclusions put forth by the WHO and Task Force on Fiscal Policy for Health.

The effects of Pennsylvania's nominal excise policy generates similar qualitative results: lower retail prices, greater consumption, higher federal and state tax revenues, higher firm profits, and positive consumer welfare effects absent public health externalities. The magnitudes are generally smaller, though, than in the case of federal nominal taxation despite the fact that the inflation adjustments applied to the federal and Pennsylvania excise taxes are similar. Of particular interest is the large difference in the degree to which upstream firms re-optimize their prices across different tax regimes. Whereas an increase in the federal excise tax elicited a significant response by upstream firms to increase their wholesale prices (from \$8.71 to \$9.81), an increase in the downstream excise tax elicited only a very small (complementary) pricing response (from \$8.71 to \$8.72). Why? As we discussed in Section 2, the culprit is the nature of the excise tax – per unit versus ad valorem. In Miravete et al. (2018) we demonstrate that ad valorem taxes such as a sales taxes elicit large countermanding price responses from firms (i.e., the ad valorem tax and wholesale prices are strategic substitutes) but in the case of unit taxes in markets with demand curvature greater than one, there exists a strategic complementarity between the per unit tax

[32] A "standard drink" in the United States is 14 grams (17.7 milliliters) of pure ethanol. For distilled spirits a standard drink then is roughly one mixed drink.

[33] Sacks et al. (2013, Table 1) decompose the total expense of alcohol consumption into costs borne explicitly by state government (42.9%). If we use this measure of the externality, the estimated external cost falls to \$44.1 per liter of ethanol, limiting the aggregate increases in external cost to \$217 million and a more moderate total welfare reduction of \$74.47 million due to indexation.

and wholesale prices. The wholesale prices documented in Table 10 illustrate this effect. Because demand curvature is close to one, the wholesale pricing response is small and one could effectively ignore the upstream pricing response.

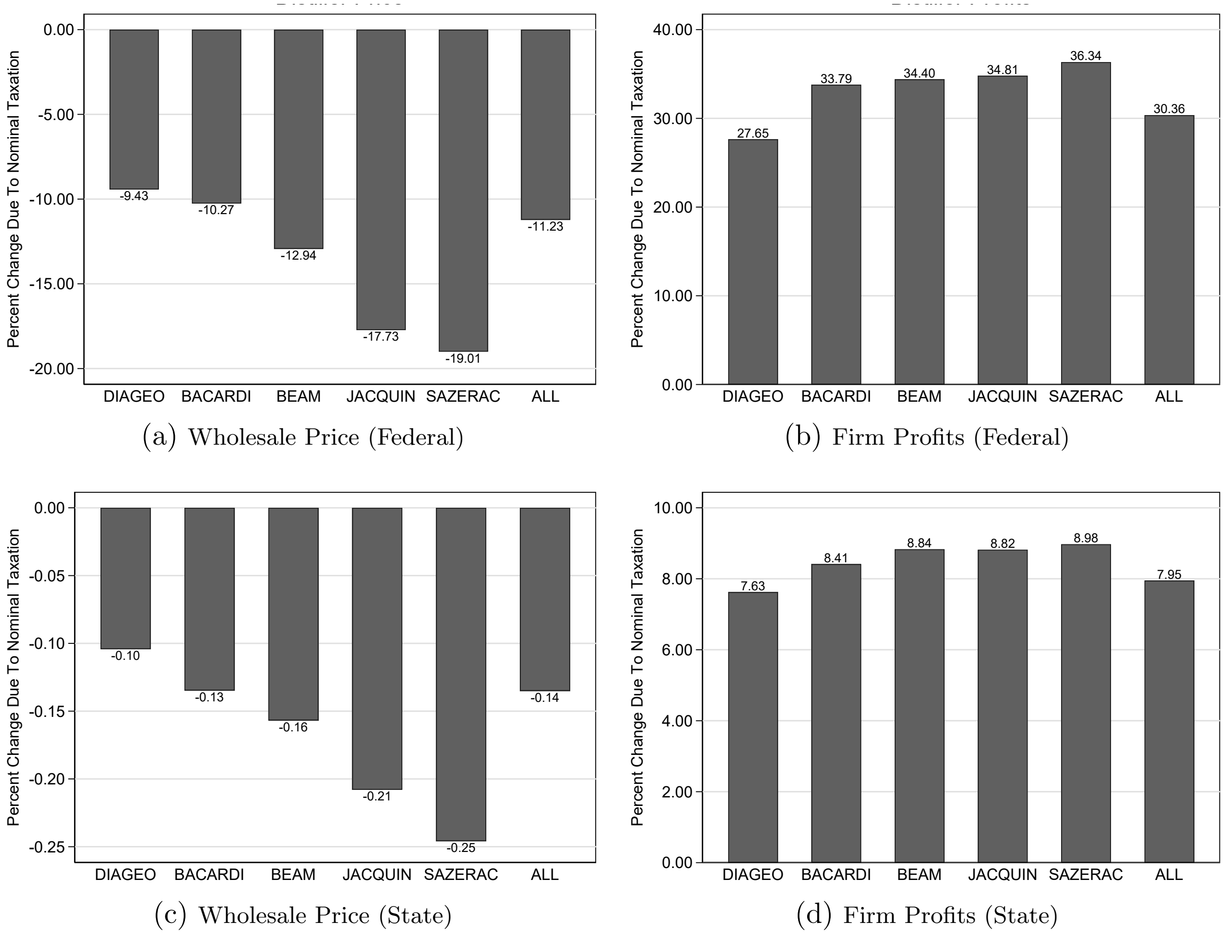
The most important factor driving the difference in results between the federal and state counterfactual exercises is double marginalization. When the US government modifies its federal tax policy, the change in the federal excise tax leads upstream firms to pass some of this expense on to the downstream market – here a public monopoly but more generally an oligopoly – where imperfect competition leads to an additional markup. Thus, double marginalization of the federal excise tax compounds the final effect on retail prices, and changes in federal taxation have much larger aggregate equilibrium effects than changes in local taxation when markets are vertical. Put differently, our results indicate that a seemingly minor oversight or error in federal policy can amplify down the supply chain leading to large unintended consequences. This is a simple but novel insight which we believe we are the first to identify as well as measure. More generally, as technology has enabled supply chains to become longer, more complex, and involve more firms; this insight highlights the importance of not only well-crafted initial policy but also the willingness of Congress to revisit and revise policy down the road.

7.2 Distributional Effects

In this section we turn our attention to the distributional consequences of nominal taxation in order to evaluate whether such policy implicitly favors certain firms and consumers. In Figure 8 we present the impact of nominal taxation on the select number of firms we discussed in Section 4.3. In panel (a) we present the percent change in the firm-level wholesale observed in the data (p^w) from the counterfactual equilibrium wholesale prices ($p^{w\prime}$) when the federal government indexes the excise tax (i.e., $100\times(p^w/p^{w\prime}-1)$). Consistent with the aggregate results, we observe that all firms increase their wholesale prices under indexing, or equivalently that nominal taxation leads firms to reduce their wholesale prices 11.23%, on average. There is however, variation among the firms as price reductions among smaller firms like Jacquin (17.72%) and Sazerac (19.01%) are greater than Diageo (9.43% reduction), Bacardi (10.27%), or Beam (12.94%) reflecting differences in the firms' product portfolio and exposure to the federal tax (Table 8). The differences in pricing translate to variation in profits (panel b) as we find that the relatively aggressive pricing response of these small firms translates into larger impacts on profits. Specifically, we find that nominal taxation benefited Jacquin (30.34%) and Sazerac (36.34%) more than Diageo (27.65%). The impact of state-level nominal taxation on firm performance (i.e., panels c and d) is similar to that of the federal case, albeit the magnitudes are smaller as nominal taxes elicit small reductions in wholesale prices and moderate profit gains for all firms (7.95%), particularly Jacquin (8.82%) and Sazerac (8.98%).

These results demonstrate that while all firms benefited from the failure of federal and state governments to index their alcohol excise taxes (equivalently, the inability or unwillingness to periodically revise them), the benefits particularly accrued to smaller firms whose product portfolios

Figure 8: Nominal Taxes and Firm Performance

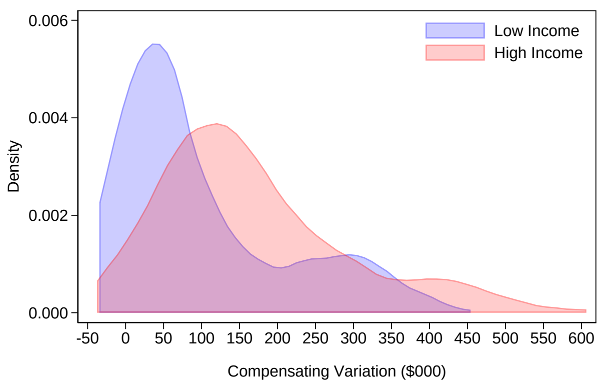


Notes: Panels (a) and (c) present the percent change in wholesale price (p^w) due to nominal taxation. Panels (b) and (d) present the percent change in estimated firm profits ($\hat{\pi}$) due to nominal taxation. Left columns correspond to the the counterfactual equilibrium where the federal government indexes the alcohol specific tax. The right column corresponds to the counterfactual equilibrium where the state of Pennsylvania indexes the *LTMF* bottle fees to inflation.

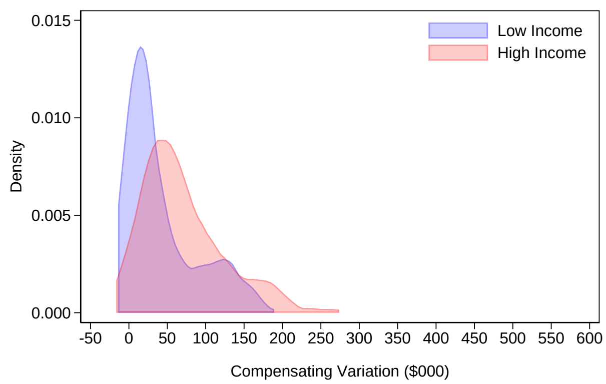
were uniquely positioned to take advantage of the oversight. A limitation of our analysis is that we have assumed the product set is exogenous and fixed. It could be that such nominal policies, particularly the federal tax, provided a profit incentive to develop less expensive products. When we look at product introductions from 2001 to 2017, we observe little evidence that firms strategically introduced such inexpensive products. We cannot rule out the possibility, however, that Jacquin and Sazerac's product portfolios are a response to nominal taxation.

Consumer Welfare. Our estimated model also accounts for variation in consumer preferences across demographic groups so it is likely that nominal taxation had differential welfare effects among Pennsylvania residents. In Figure 9 we compare the distribution of location-level mean compensating variation (i.e., $\text{CV}_l(p^r, p^{r\prime})$ from Equation 17). For simplicity, we focus on the effects of nominal taxation of the federal excise tax. We observe that high income consumers tend to benefit more from nominal taxation than low income households. This is because these consumers tend to have less elastic demand (Table 4) so they are less likely to substitute when prices increase as they do when the federal government indexes its alcohol excise tax to inflation. Thus, across equilibria wealthy consumers tend to consume the same products but pay a higher price under the counterfactual indexed federal tax policy.

Figure 9: Consumer Welfare Effects by Income Group When the Federal Excise Tax is Indexed



(a) Federal



(b) State

Notes: Figure presents the distribution of compensating variation (Equation 17) for markets in the bottom ("Low") and top ("High") quintiles of the state income distribution. Panel (a) corresponds to the case when the federal government indexes the alcohol specific tax, while panel (b) corresponds to the counterfactual equilibrium where the state of Pennsylvania indexes the *LTMF* bottle fees to inflation. See Figure G.2 in Appendix G for distributions of compensating variation across all demographic attributes.

Of course, consumers in our data vary by much more than just income so identifying the differential consumer welfare effects of nominal tax policy is more complicated than Figure 9. In the first column of Table 11 we project the distribution of compensating variation (divided by liquor expenditure to control for differences in market size) onto observable consumer characteristics. We find that the beneficiaries of nominal federal taxation tend to be older, well-educated, low-income, and white consumers which live in rural areas though there still exists significant variation outside of these dimensions ($R^2 = 0.234$).

Quantifying the welfare effect to consumers (and society) extends beyond just measuring compensating variation, however, since an extensive literature in public health has connected alcohol consumption to adverse health conditions such as cancer, cirrhosis, and heart disease. As our estimated model predicts changes in ethanol consumption due to changes in taxation, we use our results to evaluate the degree to which increased ethanol consumption due to nominal taxation contributed to deaths related to alcohol-attributable disease. We do so by levering recent epidemiological research (Griswold et al., 2018) which provides estimates of dose-response curves for the risk of developing 23 diseases associated with alcohol consumption (e.g., cirrhosis, mouth and esophageal cancer). We combine these dose-response curves with evidence on morbidity from the Center for Disease Control (CDC) "Multiple Cause of Death" database (Center for Disease Control, 2019) where we compute causes of death using the detailed *International Statistical Classification* *of Diseases and Related Health Problems, 10th Revision* (i.e., ICD-10) codes for 2001 to 2009. We then calculate the increased morbidity due to increased ethanol consumption from nominal taxation by location and disease. See Appendix E for a detailed discussion of our methodology. To assess systematic pattern across demographic groups, we project the vector of increased morbidity for each disease onto observable demographics. We present these results in Table 11.

Table 11: Consumer Welfare Effects From Nominal Taxation

		HEALTH CONSEQUENCES				
	$\text{CV}_l/\text{SPEND}_l$	ALL DISEASE	CANCER	CIRRHOSIS	HEART DISEASE	INJURY
AGE	1.984	161.857	9.110	1.319	18.354	1.510
	[1.845, 2.1]	[131.914, 172.044]	[6.59, 9.862]	[1.094, 1.39]	[15.475, 19.396]	[1.033, 1.619]
EDUCATION	0.204	154.358	12.400	1.286	14.559	1.608
	[0.174, 0.255]	[144.961, 156.334]	[11.59, 12.623]	[1.218, 1.309]	[13.66, 14.711]	[1.499, 1.633]
INCOME	-1.220	-198.737	-13.423	-1.565	-20.996	-1.617
	[-1.313, -1.187]	[-201.111, -179.63]	[-13.532, -11.945]	[-1.578, -1.434]	[-21.28, -19.017]	[-1.628, -1.411]
MINORITY	-0.796	16.016	3.024	0.326	-0.097	0.521
	[-0.831, -0.773]	[10.943, 21.362]	[2.385, 3.49]	[0.257, 0.371]	[-0.377, 0.378]	[0.403, 0.585]
URBAN	-0.151	-4.781	-0.287	-0.034	-0.471	-0.025
	[-0.166, -0.148]	[-7.607, -3.667]	[-0.564, -0.182]	[-0.06, -0.023]	[-0.693, -0.379]	[-0.061, -0.01]
N	454	454	454	454	454	454
R^2	0.234	0.096	0.086	0.124	0.104	0.085
	[0.227, 0.243]	[0.092, 0.106]	[0.082, 0.096]	[0.12, 0.134]	[0.1, 0.114]	[0.081, 0.095]
Unconditional	-	86.011	8.085	0.773	7.215	1.119
Deaths per 100k	-	342.942	58.597	15.329	212.481	47.988

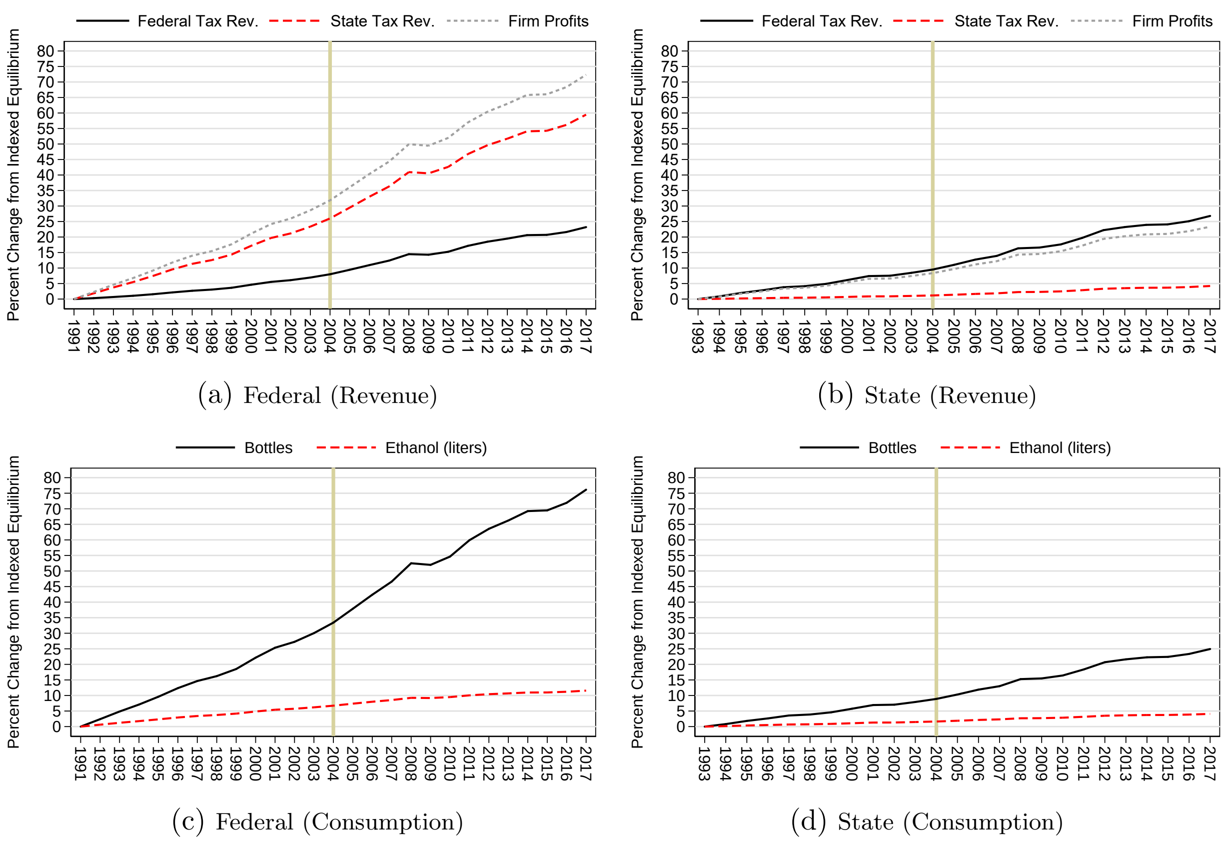
Notes: The dependent variable in the left column is market l compensating variation (Equation 17) divided by market l liquor expenditure observed in the data as we move from indexed to nominal federal taxation. The dependent variable in the remaining regressions is change in deaths per 100,000 as we move from indexed to nominal federal taxation (Equation E.1). URBAN is an indicator for a market in the Philadelphia and Pittsburgh Metropolitan Statistical Areas. Remaining demographic attributes are defined in Table 2. 95% confidence intervals located in brackets. See Appendix F for details regarding the construction of these intervals. Coefficients for the constant and number of drinkers (N^{Drinkers}) not reported. "Cancer" includes cancer of the breast, colon, esophagus, larynx, lip, liver, nasopharynx, oral cavity, pharynx, and rectum. "Cirrhosis" includes liver disease including fibrosis and alcoholic cirrhosis of liver, hepatic fibrosis with hepatic sclerosis, hepatitis, oesophageal varices with bleeding, and portal hypertension. "Heart Disease" includes deaths from atrial fibrillation and flutter, hemorrhagic stroke, hypertensive heart disease, and ischemic heart disease. "Injury" includes deaths from interpersonal violence, self harm, transportation, and unintentional accidents. All mappings between disease definitions and ICD-10 codes are consistent with Griswold et al. (2018). We describe construction of disease death rates in Appendix E.

We find that nominal taxation led to increased rates of cancer, cirrhosis, heart disease, and injury. The increased morbidity is particularly true older, well-educated, low-income, and minority residents. We also observe that nominal taxation increased morbidity from these diseases less among urban consumers (i.e., residents in Philadelphia and Pittsburgh) than rural consumers.

7.3 Robustness

We have thus far focused on the case where federal and state excise taxes are indexed to inflation for the years in our data (i.e., 2003 and 2004) and have found significant aggregate and distributional effects to tax revenue collected (both at the national and state level), firm profits, and consumer welfare. This analysis however focuses on a period roughly half-way from present day to when these policies were initiated so they necessarily neglect the impact of nominal taxation on more recent years. Similarly, this analysis ignores the effects of nominal policy on the 1990s. We address the potential short-term and long-term effects of nominal excise taxes, we extend our analysis in the following way: We take our estimated model for 2004 and recompute the equilibrium for each year since 1991 and 1993 (i.e., the dates on which the federal and state tax policies came into effect) using the CPI series from Figure 3 to modify the excise taxes. While this analysis employs the strong assumption that our estimated model, including the firm product portfolios, are constant from 1991 to 2017, it nonetheless is useful in understanding the cumulative effects of nominal taxation as inflation erodes the impact of the tax policies across time.

Figure 10: Cumulative Effects of Indexing on Tax Revenue, Firm Profits, and Consumption



(a) Federal (Revenue)

(b) State (Revenue)

(c) Federal (Consumption)

(d) State (Consumption)

Notes: Panels depict the effect of indexing over time. In each panel we use the estimated demand and supply model from 2004 and recompute the equilibrium when indexing federal (panels in left column) and State (panels in right column) unit fees in a given year. Each panel compares the percent change in the estimated equilibrium to the counterfactual equilibrium. Solid vertical line corresponds to the results from comparing the estimated equilibrium to indexing unit fees to 2004 inflation.

From panels (a) and (b) of Figure 10 we observe the compounding effects of nominal taxation are significant for both tax revenue and firm profits, particularly for federal tax policy. This reinforces the insight addressed earlier that policy mistakes made at the federal level tend to magnify in vertical markets withe imperfect competition due to double marginalization. We also observe that, conditional on the strong assumption that the estimated model for 2004 was still relevant in 2017, the aggregate results we presented in Section 7.1 greatly underestimate the more recent impact of nominal taxation. Similar conclusions hold for consumption in terms of bottles sold and ethanol, where the sharp increase in ethanol consumption suggests that failing to index the federal excise tax has resulted in a sharp increase in ethanol consumption. Figure 10 also demonstrates that the compounding effect of even moderate levels of inflation (e.g., 2%) like those common in the developed world are significant. It therefore provides a stark reminder that indexing unit taxes in areas of the world where inflation is larger is of the utmost importance in order to maintain the effectiveness of tax policy as a consumption deterrent.

8 Concluding Remarks

We study the relationship between inflation and per unit excise taxes in a non-competitive vertical industry – distilled spirits. Our motivation is to provide measurements on the equilibrium effects of failing to index federal and state per unit excise taxes to inflation. We do so by combining detailed scanner data from the state of Pennsylvania with and an equilibrium model of consumer demand plus oligopoly price-setting to estimate reasonable and robust estimates of demand and upstream firm marginal costs. While not an explicit goal of this study, we show that poor data quality commonly employed by other researchers leads to biased demand elasticity estimates and that this bias leads to overestimates of the ability of taxation to generate tax revenue and underestimates of the degree of taxation required to curb alcohol consumption to reduce externalities.

We then demonstrate that despite the low inflation environment in the United States and Pennsylvania, failure to index the specific tax to inflation generates lower wholesale and retail prices and ultimately greater ethanol consumption. The corresponding increase in external costs more than offsets any gains from tax revenue, firm profits, and internalized utility from consumption. Moreover, we highlight the distributional consequences of nominal taxation as ethanol consumption increases most by consumers which such policy may have been originally intended to target – low income and poorly-educated residents. Finally, we demonstrate that a small error in tax policy which targets manufacturers compounds along the supply chain leading to significant adverse equilibrium effects. As technology and globalization have enabled supply chains to become longer and involve more firms, such an insight applies to a wide variety of industries and government policies.

These contributions are important because they provide evidence that simple adjustments to tax policy such as indexing per unit excise taxes to inflation are fundamental towards curbing the consumption of addictive and unhealthy products and limiting the spread of noncommunicable diseases in both high income countries as well as in low- and middle-income countries, where noncommunicable diseases account for a significant share of premature death and disease. Our work therefore highlights the empirical relevance of recommendations by the World Health Organization and Task Force on Fiscal Policy for Health (2019), chaired by Michael Bloomberg and Lawrence Summers, since excise taxes are common government tools but are rarely indexed to inflation.

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Appendix

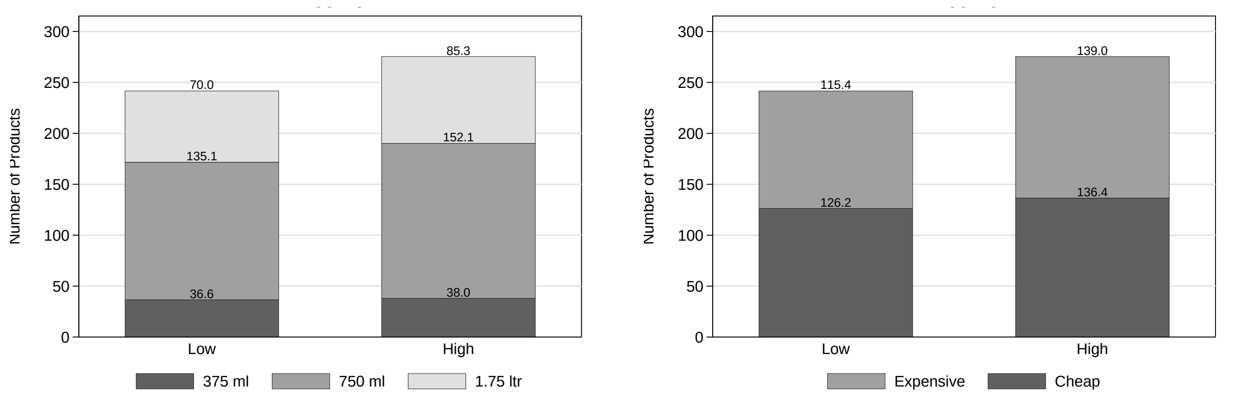
A Data

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.

Product Set Variation Across Stores. Stores exhibit significant variation in the product composition of purchases but little variation in their product offering. 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 these products. Similarly, of the 1000 best selling products statewide in 2003, the median store carried 82.0%, 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 consumer 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. In Figure A.1 we demonstrate the product set available to consumers in wealthier markets is greater for 1.75 L and EXPENSIVE products though the difference is small and consumers in poor neighborhoods clearly have access to a large set of these products. Further, the products purchased more often in high-income markets are all in the far right-tail of the sales distribution so it is reasonable to assume any bias they may introduce into our demand estimates are very small.

Figure A.1: Product Availability and Income



(a) Bottle Size (b) Price

Notes: A product is considered in the product set of a geographic market if it is ever sold during 2003-2004. Numbers reflect the average number of products in each category (e.g., 1.75 L products) carried by stores in the relevant income group.

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 important assumption underlying our demand model: Differences in product availability do not drive consumers' 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).[34]

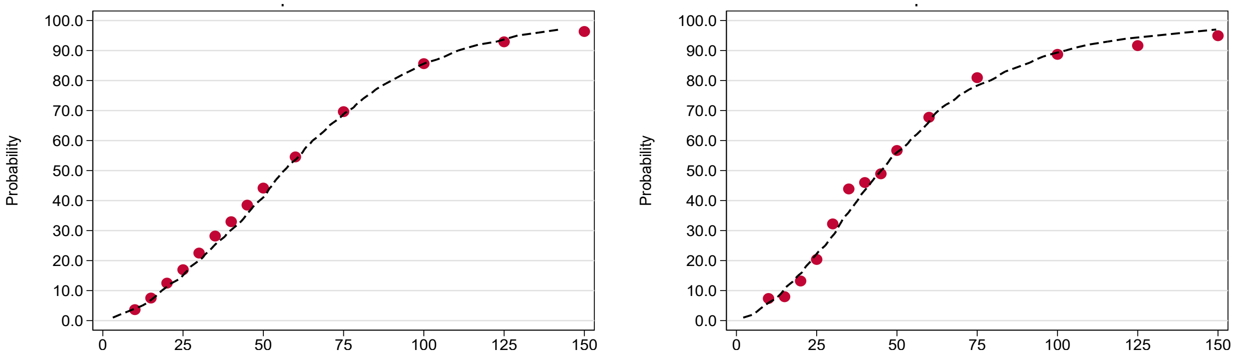
Simulating Consumers. To define the population served by each store, we calculate the straight-line distance to each store from each of Pennsylvania's 10,351 regular block groups and assign consumers to the closest open store for each pricing period. In instances where the *PLCB* operates more than one 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.[35] 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

[34] Near the state's borders, the *PLCB* runs seven outlet stores 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 D

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

Figure A.2: Income Distributions Conditional on Race



(a) White Consumers (92.2%)

(b) Minority Consumers (7.8%)

Notes: In each panel we compare estimated income distribution (dashed line) and the block group discrete income distribution (dots). Income distributions are organized by racial identity of the head of household where panel (a) corresponds to white consumers and panel (b) corresponds to non-white (minority) consumers. In parentheses we present the share of consumers each racial category represents in the market. Results correspond to a store located in Reading, Pennsylvania.

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. We use this measure in constructing the figures and descriptive statistics in the text. Second, we fit continuous market-specific distributions to the discrete distributions of income conditional on minority status. We use this measure in estimating the model and conducting counterfactual experiments. We employ generalized beta distributions of the second kind to fit the empirical income distribution for each market l. McDonald (1984) highlights that the beta distribution provides a good fit to empirical income data relative to other parametric distributions. In Figure A.2 we compare the estimated cumulative distribution functions for income conditional on minority status for a store located in Reading, PA. We observe that in this location the income distribution for white consumers first-order stochastically dominates the income distribution for minority consumer.

We also used a generalized beta distribution to estimate the continuous market-specific age distribution though due to data census limitations we could not condition this on race or income. We also 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. Any correlation between educational attainment and income is therefore captured through the correlation between education and minority status and then minority status 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. 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 (ν_{il}) via scrambled Halton draws. As demonstrated by Train (2009), using Halton draws enables us to more efficiently cover the space of unobserved preferences (ν_{il}).

To summarize:

1. We use census data to construct a joint distribution of demographics for each market l.
   - We use census data for each market l to estimate the joint income distribution conditional on racial status (minority, non-minority). This yields L-by-2 estimated generalized beta distributions.
   - We complement this with census data on educational attainment conditional on racial status (minority, non-minority) by market l.
   - We include consumer age using the unconditional age distribution for each market l.
2. We simulate market l agents by drawing from the corresponding market l joint distribution, adding unobserved preferences (ν_{il}) via scrambled Halton draws.
3. In order to ensure we adequately cover the space of consumer characteristics, we chose a large number of simulated agents (1,000).

Price Instruments. 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 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

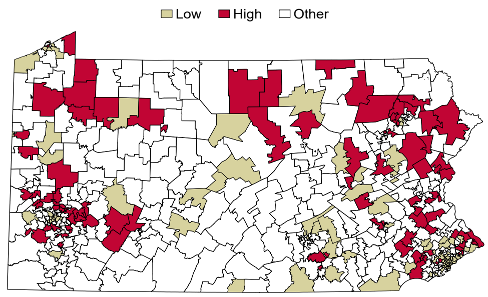
Table B.1 presents the distribution of bottle prices contained in our sample of 312 products. Average price is increasing across bottle sizes both within a category and for the whole sample. Vodkas are the most expensive products on average, while rums are least expensive. Figure B.1 documents the demographic diversity of Pennsylvania. Although correlated, the spatial distribution of demographics are not perfectly aligned.

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

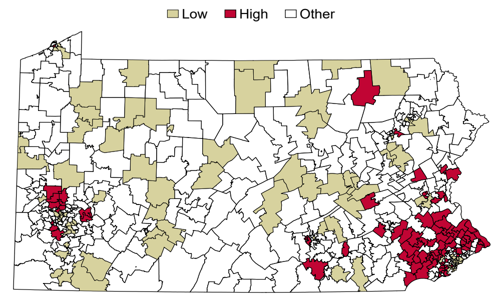
			Share of Market	
	Products	Avg. Price	By Quantity	By Revenue
BRANDY	26	14.41	7.26	6.75
375 ml	7	8.54	1.75	1.09
750 ml	13	15.56	4.28	4.13
1.75 L	6	18.76	1.22	1.52
CORDIALS	62	14.08	13.59	13.71
375 ml	13	10.76	2.11	1.49
750 ml	46	14.16	10.80	11.05
1.75 L	3	27.34	0.67	1.17
GIN	28	15.15	6.72	7.04
375 ml	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.

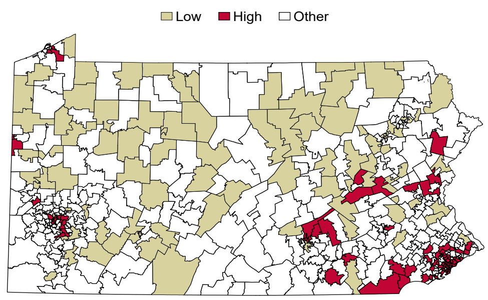
Figure B.1: Spatial Distribution of Consumer Characteristics



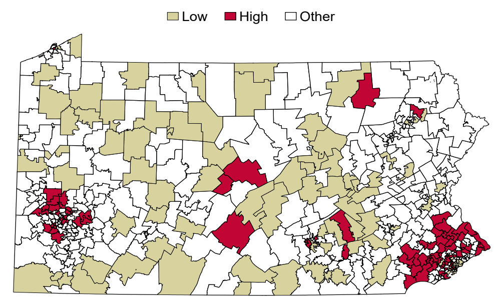
(a) Age



(b) Income



(c) Minority



(d) Education

Notes: Maps correspond to the spatial distribution of characteristics in Pennsylvania during the sample. Outlined polygons correspond to geographic markets (i.e., "stores" in the text). Dark shaded regions correspond to markets in the top quintile of the demographic attribute ("High" in the text). Lightly shaded regions correspond to markets in the bottom 20% for the corresponding demographic attribute ("Other" in the text). Remaining markets ("Other" in the figures) are not shaded.

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.

Stage 1: Random Coefficients and Demographic Interactions. In the first of the three 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 fixed effects. 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.[36] 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 (12a), 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 fixed effects, 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 (14), equal to the market share observed in the data, S_{jlt}.[37] To evaluate the integral in equation (14) we simulate for each market l the purchase probabilities of 1000 randomly drawn heterogeneous consumers who vary in their demographics.

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-

[36] 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.

[37] 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.

period fixed effects 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. We include in Z the following information: the number of products of the same type and price category, the root mean square distance in spirit product scores, plus interactions between these variables and demographics (see Section 6 for further detail). 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 $E[Z^{+'}\Delta\xi\Delta\xi' Z^+]$.[38] 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.

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 product by type fixed effects, $\zeta_l^1(\hat{\theta}_A)$ and $\zeta_{jt}^2(\hat{\theta}_A)$. We then project ζ_{jt}^2 onto price and the seasonal indicators, controlling for product fixed effects 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 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 (20).

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

[38] 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^+.

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.[39] 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 does not improve our estimates. Collapsing the second stage parameters into vector θ_B, this implies the following parameter estimates

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

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 simultaneously.

Stage 3: Mean Utility – Product Characteristics Coefficients. In the third and final estimation stage, we recover product fixed effects 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.

[39] 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.

D Robustness

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

In Table D.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 fixed effects, 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 that are similar to our 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 D.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 $\ln(S_{jmt})-\ln(S_{0mt})$ onto product-period fixed effects 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 D.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 fixed effects, bottle size fixed effects, pricing period fixed effects, market fixed effects, 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 D.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 distiller marginal costs. Miravete et al., 2018 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 firms. Table D.2 therefore suggests that such studies may suffer from an aggregation bias that leads to less elastic estimated demand.

Table D.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 $\ln(S_{jmt}) - \ln(S_{0mt})$ while it is $\ln(S_{jt}) - \ln(S_{0t})$ 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 fixed effects with observable characteristics (e.g., dummies for spirit type, imported). Demand becomes even steeper and demand becomes 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 fixed effects 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, we use the contemporaneous average price in distant control states as an instrument for price in the second step. In Table D.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 fixed effects underlying the estimates in Table 4 projected onto price, seasonal dummies, and product fixed effects.

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. Removing the average price in other states decreases the price coefficient but also decreases the F-Statistic.

Table D.3: Price Endogeneity

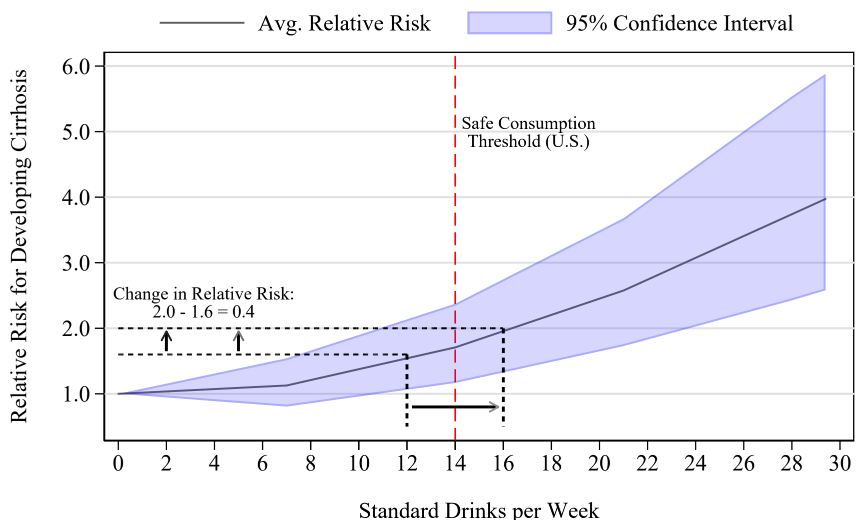
	OLS	$IV1$	$IV2$	$IV3$	$IV4$
PRICE	-0.2412	-0.2763	-0.2781	-0.2775	-0.3145
	(0.0038)	(0.0046)	(0.0046)	(0.0046)	(0.0051)
Instruments:					
Input Prices		Y	Y	Y	Y
Alabama		Y		Y	
Iowa		Y	Y		
Idaho		Y	Y	Y	
Michigan		Y			
Mississippi		Y	Y		
North Carolina		Y	Y		
Oregon		Y	Y	Y	
Utah		Y	Y		
Wyoming		Y	Y	Y	
F-Statistic		1,280.2	1,235.1	1,235.8	920.79
N	6,852	6,852	6,852	6,852	6,852

Notes: Specifications include the same covariates as in Table 4. "Input Prices" is the interaction of spirit type and commodity prices. This amounts to nine interactions: corn-x-gin, corn-x-vodka, corn-x-whiskey, sugar-x-brandy, sugar-x-cordials, sugar-x-gin, sugar-x-rum, sugar-x-whiskey, and sugar-x-vodka where "corn" and "sugar" corresponds to the futures price of corn and sugar during the period. In models 1-4 we also include contemporaneous average price in distant control states as an instrument for price but vary the states used to compute the average.

E Connecting Alcohol Consumption with Disease

We present an example of our methodology in Figure E.1 for cirrhosis.

Figure E.1: Connecting Changes in Ethanol to Disease Prevalence



Notes: Figure outlines our methodology for connecting changes in store-level ethanol consumption to the likelihood of developing cirrhosis using the estimated dose-response curve from Griswold et al. (2018). "Relative Risk" is the probability of developing the disease for a drinker relative to a non-drinker (i.e., relative risk is equal to one when standard drinks consumed per week is equal to zero). Safe drinking threshold corresponds to the U.S. recommendation for men of two drinks per day as designated in "Dietary Guidelines for Americans 2015-2020" published by the U.S. Department of Health. The recommendation for women is one drink per day.

The solid line in Figure E.1 corresponds to the estimated "relative risk" of developing cirrhosis for varying levels of alcohol consumption where the term "relative risk" is defined as the probability of developing the disease for a drinker relative to a non-drinker at different levels of ethanol exposure. In the case of cirrhosis, the epidemiological data indicate a monotonically-increasing risk of developing the disease. Thus, while a non-drinker still is at risk of developing cirrhosis, perhaps because they have fatty liver disease or hepatitis, a drinker increases their risk with each additional drink. A drinker who routinely drinks more than 10 "standard drinks" in a week, faces a statistically-significant higher risk than a non-drinker. As the U.S. Department of Health recommends that men (women) consume less than 14 (7) standard drinks per week, we observe that even dosages considered "safe" yield higher risk of developing cirrhosis. Moreover, Griswold et al. (2018) find that nearly all of the alcohol-attributable diseases they investigate follow this pattern leading the researchers to conclude that "the safest level of drinking is none" – a recommendation which they note is "in conflict with most health guidelines, which espouse health benefits associated with consuming up to two drinks per day."[40]

[40] The exception is ischaemic heart disease where Griswold et al. (2018) found statistically-significant evidence of a J-curve: decreasing relative risk for small levels of consumption and increasing relative risk thereafter. In the case of ischaemic stroke, the optimal amount of consumption was found to be 5.81 and 6.44 standard drinks per week for men and women, respectively.

To connect changes in alcohol consumption with disease risk, we first compute average ethanol consumption by store location in the estimated and counterfactual equilibria including consumption of beer and wine captured in the outside option. We convert these statistics into standard drinks using the World Health Organization definition of 10 grams of ethanol per standard drink. As we have shown that nominal taxation decreased retail prices and thereby increased consumption, in Figure E.1 this corresponds to the increase in ethanol consumption from 12 to 16.1 standard drinks per week in this location, or equivalently an increase from 1.6% to 2.0% (i.e., 40 percentage points) in the likelihood of developing cirrhosis relative to a non-drinker. This number alone, however, is not sufficient to understand the change in morbidity due to increased alcohol consumption since it does not account for the unconditional likelihood of developing cirrhosis for a drinker. We connect the changing disease probabilities from the estimated equilibrium model to deaths using data on morbidity from the Center for Disease Control (CDC) "Multiple Cause of Death" database (Center for Disease Control, 2019) where we compute causes of death using the detailed *International Statistical Classification of Diseases and Related Health Problems, 10th Revision* (i.e., ICD-10) codes for 2001 to 2009 at the county-level.[41] We then calculate the death rate for each disease category per 100,000 population and apply this as the baseline death rate for all locations in the corresponding county.

Since changes in the alcohol tax rate will only affect consumption among drinkers, we separately identify the probability of drinkers and non-drinkers of developing each disease by combining the death rates and estimated relative risks with information on the prevalence of non-drinkers by county (Dwyer-Lindgren, Flaxman, Ng, Hansen, Murray and Mokdad, 2015). Formally, the death rate in location l in the estimated model, denoted by the "b" superscript, is

$$\begin{aligned}\text{Death Rate}_l^b &= \overbrace{\text{Pr}_l^b[E>1]}^{\substack{\text{Prob. of Disease,}\\ \text{With Ethanol Cons.}}} \times N_l^{\text{Drinkers}} + \overbrace{\text{Pr}_l[E=0]}^{\substack{\text{Prob. of Disease,}\\ \text{No Ethanol Cons.}}} \times N_l^{\text{Non-Drinkers}} \\ &\equiv \text{Pr}_l[E=0] \times \left[\text{RR}_l^b \times N_l^{\text{Drinkers}} + N_l^{\text{Non-Drinkers}}\right]\end{aligned}$$

where the relative risk (RR) in the baseline estimated model is defined as

$$\text{RR}_l^b = \frac{\text{Pr}_l^b[E>0]}{\text{Pr}_l[E=0]}.$$

[41] To maintain consistency with the estimated relative risk curves from Griswold et al. (2018), we used the same ICD-10 mapping to broader, more recognizable, disease categories. For example, "Cirrhosis" includes not only code K70.3 "alcoholic cirrhosis of liver" but also code I85.0 "oesophageal varices with bleeding", among others. Note that this definition of cirrhosis is broader than Case and Deaton (2017) who restrict attention only to codes K70, K73, and K74. Case and Deaton (2017) therefore fail to account for a large set of deaths where the underlying cause was liver failure, potentially due to alcohol abuse.

Given information on drinking prevalence $\{N_l^{\text{Drinkers}}, N_l^{\text{Non-Drinkers}}\}$ from Dwyer-Lindgren et al. (2015) and the relative risk of each disease given our estimated model, we solve for the probability of a non-drinker getting each disease in each location l; i.e.,

$$\Pr_l[E=0] = \frac{\text{Death Rate}_l^b}{\text{RR}_l^b \times N_l^{\text{Drinkers}} + N_l^{\text{Non-Drinkers}}} \,.$$

Given $\Pr_l[E=0]$, the average location l drinker gets the disease at probability $\Pr_l^b[E>0]$ which follows directly from the definition of relative risk. In computing the change in disease from nominal taxation, we hold the number of non-drinkers which develop the disease fixed (i.e., $\Pr_l[E=0] \times N_l^{\text{Non-Drinkers}}$) and use the change in relative risk described above to identify the change in alcohol-attributable deaths due to nominal taxation; i.e.,

$$\Delta\text{Deaths}_l = \left(\Pr_l^b[E>0] - \Pr_l^{cf}[E>0]\right) \times N_l^{\text{Drinkers}} \tag{E.1}$$

where $\Pr_l^{cf}[E>0]$ follows directly from the relative risk implied in the counterfactual equilibrium (i.e., $\text{RR}^{cf} = \frac{\Pr^{cf}[E>0]}{\Pr_l[E=0]}$). To identify systematic patterns across demographics, we project this matrix of location-by-disease changes in deaths onto observable market-level characteristics.

F Confidence Intervals for Counterfactual Experiments

For each counterfactual exercise, we constructed 95% confidence intervals via bootstrap simulation based on the multivariate empirical distribution implied by the estimated demand parameters (Table 4). The confidence intervals are based on $n = 1, \ldots, 1000$ random samples of the demand parameters where we restricted the draws to be over the nonlinear parameters $\{\Sigma, \Pi\}$ and the linear price coefficient (α). This both increases tractability of the bootstrap procedure and focuses the analysis on the parameters, especially the mean price coefficient α and the income-price interaction (in Π), which drive the own and cross-price elasticities, estimates of upstream marginal costs, and ultimately the impact of nominal excise taxation.

A counterfactual simulation proceeds as follows. Define $\theta_n = \{\alpha_n, \Sigma_n, \Pi_n\}$ as the bootstrap parameters for sample n. We use $\{\Sigma_n, \Pi_n\}$ and the observed vector of product market shares s_j to recover the mean utility $\delta(\theta_n; s_j)$ following the solution method outlined in Section C of this Appendix. Estimates of firm-level marginal costs then follow using the observed product-ownership matrix and equation (20) as discussed in section 6.4. By using this procedure, we guarantee that each bootstrap simulation n generates predicted market shares which match the data and marginal costs estimates which are consistent with upstream Bertrand–Nash pricing. Thus, each counterfactual equilibrium generated from a bootstrap simulation generates the data under the 30% markup rule, or, equivalently, starts from the same place.

Define $\overline{\xi}_n = \delta(\theta; s_j) - \alpha_n p^r$ where p^r is the vector of observed retail prices in the data. We then use $\{\alpha_n, \Sigma_n, \Pi_n, c_n, \overline{\xi}_n\}$ to solve for each of the counterfactual equilibria in the main text (e.g., "Profit") where changes in the level of federal and state taxation lead to a new set of equilibrium upstream firm prices (p_n^w), retail prices (p_n^r), and consumer purchase decisions. The retail prices impact consumer mean utility since $\delta_n = \alpha_n p_n^r + \overline{\xi}_n$, and ultimately lead to changes in consumer demand via equation 13.

For each bootstrap simulation and counterfactual equilibrium, we compute the descriptive statistics presented in the text (e.g., aggregate tax revenue in Table 10). To compute compensating variation in each simulation, we compare consumer surplus (up to an additive constant) given observed prices and θ_n (i.e., consumer surplus in the observed equilibrium conditional on θ_n) to the consumer surplus generated in the counterfactual Stackelberg equilibrium.

Most of our analysis compares summary statistics from the current equilibrium to summary statistics from counterfactual Stackelberg equilibria using the point-estimates from our demand estimation ($\hat{\theta}$). Where possible, we also include the 95% confidence intervals from the bootstrap simulations in order to demonstrate the robustness of our conclusions. The 95% confidence intervals presented in the text correspond to the range of bootstrap simulation-counterfactual equilibria for the given statistic which fall between the 2.5% and 97.5% quartiles, i.e., the middle 95%.

G Additional Results and Figures

Table G.1: 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.

Table G.2: Retail and Wholesale Prices by Product Category

	Elast.	MC ($\hat{c}$)	Wholesale Price (p^w)			Retail Price (p^r)		
			Current	Federal	State	Current	Federal	State
By Spirit Type:								
brandy	-3.64	3.00 [3, 3]	8.09	8.94 [8.93, 8.94]	8.09 [8.09, 8.09]	13.85	15.15 [15.14, 15.16]	14.27 [14.27, 14.27]
cordials	-3.46	4.74 [4.74, 4.74]	8.88	9.43 [9.42, 9.43]	8.89 [8.89, 8.89]	15.03	15.87 [15.86, 15.88]	15.45 [15.45, 15.45]
gin	-3.90	3.01 [3.01, 3.01]	9.14	10.46 [10.45, 10.47]	9.15 [9.15, 9.16]	15.61	17.63 [17.61, 17.64]	16.08 [16.07, 16.08]
rum	-3.38	2.89 [2.89, 2.89]	8.35	9.42 [9.41, 9.43]	8.36 [8.36, 8.37]	14.34	15.98 [15.97, 15.99]	14.80 [14.79, 14.8]
vodka	-3.95	2.06 [2.06, 2.06]	7.99	9.24 [9.23, 9.25]	8.00 [8, 8]	13.82	15.74 [15.72, 15.75]	14.29 [14.29, 14.3]
whiskey	-3.98	3.85 [3.85, 3.85]	9.89	11.14 [11.13, 11.15]	9.90 [9.9, 9.9]	16.74	18.66 [18.65, 18.67]	17.21 [17.21, 17.21]
By Price:								
cheap	-2.81	0.46 [0.46, 0.46]	5.85	6.93 [6.92, 6.94]	5.86 [5.86, 5.86]	10.50	12.16 [12.14, 12.17]	10.95 [10.95, 10.96]
expensive	-4.74	6.12 [6.12, 6.12]	11.94	13.06 [13.05, 13.07]	11.95 [11.94, 11.95]	19.85	21.58 [21.56, 21.59]	20.31 [20.31, 20.31]
By Bottle Size:								
375 ml	-2.36	0.36 [0.36, 0.36]	3.89	4.28 [4.28, 4.29]	3.90 [3.89, 3.9]	7.20	7.81 [7.81, 7.82]	7.57 [7.57, 7.58]
750 ml	-3.58	3.83 [3.83, 3.83]	8.53	9.30 [9.29, 9.3]	8.55 [8.54, 8.55]	14.51	15.68 [15.67, 15.69]	14.93 [14.93, 14.94]
1.75 L	-4.74	3.30 [3.3, 3.3]	11.09	13.00 [12.98, 13.01]	11.10 [11.1, 11.1]	18.84	21.77 [21.74, 21.78]	19.39 [19.38, 19.39]
all products	-3.75	3.12 [3.12, 3.12]	8.71	9.81 [9.8, 9.82]	8.72 [8.72, 8.72]	14.89	16.58 [16.57, 16.59]	15.35 [15.35, 15.35]

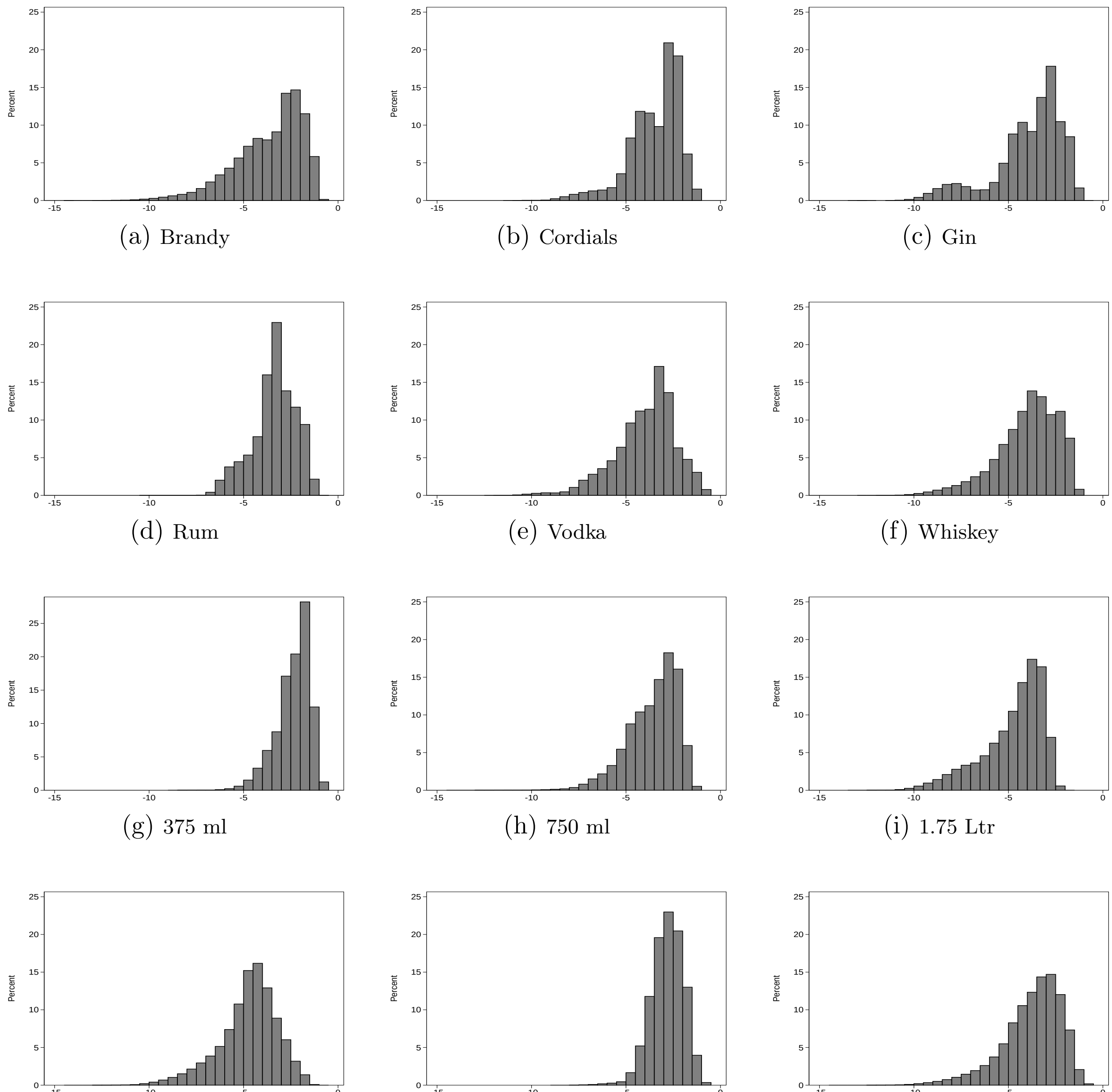
Notes: "Elast." corresponds to the average estimated demand elasticities from Table 5. "MC" corresponds the estimated upstream firm marginal costs including applicable federal excise tax. Other reported statistics are average wholesale and retail price ($). "Cheap" ("Expensive") products are those products whose mean price is below (above) the mean price of other spirits in the same spirit type and bottle size.

Table G.3: Best Substitutes

		Closest Substitute		
Product	Type	Product	Type	ϵ_{ji}
HENNESSY V. S. COGNAC - 375 ML	BRANDY	COURVOISIER V. S. COGNAC - 375 ML	BRANDY	0.2522
E & J CAL. BRANDY - 375 ML	BRANDY	E & J CAL. V.S.O.P. BRANDY - 375 ML	BRANDY	0.1005
THE CHRISTIAN BROS. CAL. BRANDY - 375 ML	BRANDY	E & J CAL. V.S.O.P. BRANDY - 375 ML	BRANDY	0.0547
E & J CAL. BRANDY - 750 ML	BRANDY	PAUL MASSON GRANDE AMBER BRANDY - 750 ML	BRANDY	0.1503
HENNESSY V. S. COGNAC - 750 ML	BRANDY	MARTELL V. S. COGNAC - 750 ML	BRANDY	0.3900
THE CHRISTIAN BROS. CAL. BRANDY - 750 ML	BRANDY	THE CHRISTIAN BROS. CAL. BRANDY - PET BOTTLE - 750 ML	BRANDY	0.1114
E & J CAL. BRANDY - 1.75 LTR	BRANDY	E & J CAL. V.S.O.P. BRANDY - 1.75 LTR	BRANDY	0.1216
THE CHRISTIAN BROS. CAL. BRANDY - 1.75 LTR	BRANDY	E & J CAL. BRANDY - 1.75 LTR	BRANDY	0.1118
JACQUIN'S BLACKBERRY FLAV. BRANDY - 1.75 LTR	BRANDY	JACQUIN'S APRICOT FLAV. BRANDY - 1.75 LTR	BRANDY	0.1261
BAILEYS ORIGINAL IRISH CREAM LIQUEUR - 375 ML	CORDIALS	GREY GOOSE IMP. VODKA - 375 ML	VODKA	0.0073
JAGERMEISTER IMP. HERB LIQUEUR - 375 ML	CORDIALS	YUKON JACK CANADIAN LIQUEUR - 375 ML	CORDIALS	0.0292
KAHLUA IMP. COFFEE LIQUEUR - 375 ML	CORDIALS	DI SARONNO AMARETTO IMP. LIQUEUR - 375 ML	CORDIALS	0.0095
KAHLUA IMP. COFFEE LIQUEUR - 750 ML	CORDIALS	ABSOLUT IMP. VODKA - 100 PROOF - 750 ML	VODKA	0.0147
SOUTHERN COMFORT - 76 PROOF - 750 ML	CORDIALS	FIRE WATER HOT CINNAMON SCHNAPPS - 750 ML	CORDIALS	0.0297
HPNOTIQ IMP. LIQUEUR - 750 ML	CORDIALS	BELVEDERE IMP. VODKA - 750 ML	VODKA	0.0112
SOUTHERN COMFORT - 76 PROOF - 1.75 LTR	CORDIALS	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 750 ML	WHISKEY	0.0272
DEKUYPER PEACHTREE SCHNAPPS - 1.75 LTR	CORDIALS	KAHLUA IMP. COFFEE LIQUEUR - 1.75 LTR	CORDIALS	0.0018
KAHLUA IMP. COFFEE LIQUEUR - 1.75 LTR	CORDIALS	GREY GOOSE IMP. FRENCH VODKA - 1.75 LTR	VODKA	0.0078
SEAGRAM'S EXTRA DRY GIN - 375 ML	GIN	BANKER'S CLUB DRY GIN - 375 ML	GIN	0.0164
TANQUERAY IMP. DRY GIN - 375 ML	GIN	BANKER'S CLUB DRY GIN - 375 ML	GIN	0.0141
GORDON'S DRY GIN - PET - 375 ML	GIN	BANKER'S CLUB DRY GIN - 375 ML	GIN	0.0083
TANQUERAY IMP. DRY GIN - 750 ML	GIN	BOMBAY IMP. SAPPHIRE GIN - 750 ML	GIN	0.0610
SEAGRAM'S EXTRA DRY GIN - 750 ML	GIN	FIVE O'CLOCK EXTRA DRY GIN - 750 ML	GIN	0.0136
GORDON'S DRY GIN - 750 ML	GIN	BEEFEATER IMP. DRY GIN - 750 ML	GIN	0.0078
GORDON'S DRY GIN - 1.75 LTR	GIN	BOMBAY IMP. SAPPHIRE GIN - 1.75 LTR	GIN	0.0319
BANKER'S CLUB DRY GIN - 1.75 LTR	GIN	BEEFEATER IMP. DRY GIN - 1.75 LTR	GIN	0.0136
SEAGRAM'S EXTRA DRY GIN - 1.75 LTR	GIN	TANQUERAY IMP. DRY GIN - 1.75 LTR	GIN	0.0174
BACARDI LIGHT-DRY P. R. RUM - 375 ML	RUM	SOUTHERN COMFORT - 100 PROOF - 375 ML	CORDIALS	0.0171
CAPTAIN MORGAN P. R. SPICED RUM - 375 ML	RUM	YUKON JACK CANADIAN LIQUEUR - 375 ML	CORDIALS	0.0130
BACARDI LIMON P. R. RUM - 375 ML	RUM	SOUTHERN COMFORT - 100 PROOF - 375 ML	CORDIALS	0.0051
CAPTAIN MORGAN P. R. SPICED RUM - 750 ML	RUM	CAPTAIN MORGAN PRIVATE STOCK P. R. SPICED RUM - 750 ML	RUM	0.0358
BACARDI LIGHT-DRY P. R. RUM - 750 ML	RUM	FIRE WATER HOT CINNAMON SCHNAPPS - 750 ML	CORDIALS	0.0207
CAPTAIN MORGAN P. R. SPICED RUM PET - 750 ML	RUM	CAPTAIN MORGAN PRIVATE STOCK P. R. SPICED RUM - 750 ML	RUM	0.0211
BACARDI LIGHT-DRY P. R. RUM - 1.75 LTR	RUM	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 750 ML	WHISKEY	0.0547
CAPTAIN MORGAN P. R. SPICED RUM - 1.75 LTR	RUM	SMIRNOFF VODKA - 100 PROOF - 1.75 LTR	VODKA	0.0512
JACQUIN'S WHITE RUM - 1.75 LTR	RUM	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 750 ML	WHISKEY	0.0204
NIKOLAI VODKA - 80 PROOF - 375 ML	VODKA	STOLICHNAYA IMP. VODKA - 80 PROOF - 375 ML	VODKA	0.0402
JACQUIN'S VODKA ROYALE - 80 PROOF - 375 ML	VODKA	NIKOLAI VODKA - 80 PROOF - 375 ML	VODKA	0.0287
SMIRNOFF VODKA - 80 PROOF - 375 ML	VODKA	STOLICHNAYA IMP. VODKA - 80 PROOF - 375 ML	VODKA	0.0199
ABSOLUT IMP. VODKA - 80 PROOF - 750 ML	VODKA	ABSOLUT IMP. VODKA - 100 PROOF - 750 ML	VODKA	0.0496
SMIRNOFF VODKA - 80 PF. PORTABLE - 750 ML	VODKA	ABSOLUT IMP. VODKA - 100 PROOF - 750 ML	VODKA	0.0220
SMIRNOFF VODKA - 80 PROOF - 750 ML	VODKA	ABSOLUT IMP. VODKA - 100 PROOF - 750 ML	VODKA	0.0154
JACQUIN'S VODKA ROYALE - 80 PROOF - 1.75 LTR	VODKA	BEEFEATER IMP. DRY GIN - 750 ML	GIN	0.0448
NIKOLAI VODKA - 80 PROOF - 1.75 LTR	VODKA	NIKOLAI VODKA - 100 PROOF - 1.75 LTR	VODKA	0.0375
VLADIMIR VODKA - 1.75 LTR	VODKA	BEEFEATER IMP. DRY GIN - 750 ML	GIN	0.0272
JACK DANIEL'S OLD NO. 7 BLACK LABEL WKY. - 375 ML	WHISKEY	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 375 ML	WHISKEY	0.0450
CROWN ROYAL CANADIAN WKY. - 375 ML	WHISKEY	TANQUERAY IMP. DRY GIN - 375 ML	GIN	0.0225
WINDSOR CANADIAN SUPREME WKY. - 375 ML	WHISKEY	TANQUERAY IMP. DRY GIN - 375 ML	GIN	0.0110
JACK DANIEL'S OLD NO. 7 BLACK LABEL WKY. - 750 ML	WHISKEY	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 750 ML	WHISKEY	0.0506
JIM BEAM STR. BOURBON WKY. - 750 ML	WHISKEY	WILD TURKEY STR. BOURBON WKY. - 101 PROOF - 750 ML	WHISKEY	0.0195
CROWN ROYAL CANADIAN WKY. - 750 ML	WHISKEY	TANQUERAY IMP. DRY GIN - 1.75 LTR	GIN	0.0348
WINDSOR CANADIAN SUPREME WKY. - 1.75 LTR	WHISKEY	BEEFEATER IMP. DRY GIN - 1.75 LTR	GIN	0.0462
JIM BEAM STR. BOURBON WKY. - 1.75 LTR	WHISKEY	CROWN ROYAL CANADIAN WKY. - 1.75 LTR	WHISKEY	0.0351
SEAGRAM'S 7 CROWN AMERICAN BLEND WKY. - 1.75 LTR	WHISKEY	BEEFEATER IMP. DRY GIN - 1.75 LTR	GIN	0.0233

Notes: Table presents the three best-selling products by number of bottles for each spirit type, bottle size pair, and the corresponding best substitute based on cross-price elasticity.

Figure G.1: Distribution of Demand Elasticities



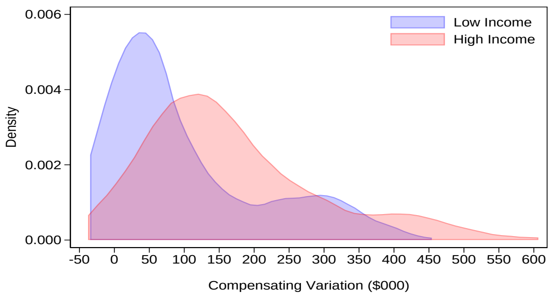
(a) Brandy (b) Cordials (c) Gin

(d) Rum (e) Vodka (f) Whiskey

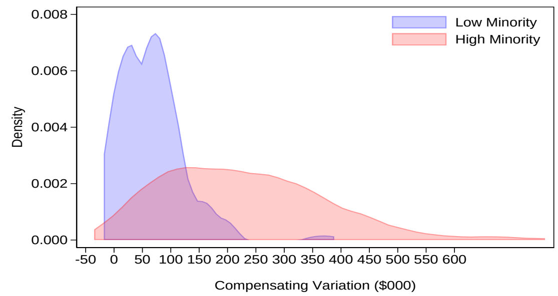
(g) 375 ml (h) 750 ml (i) 1.75 Ltr

(j) Expensive (k) Cheap (l) All Products

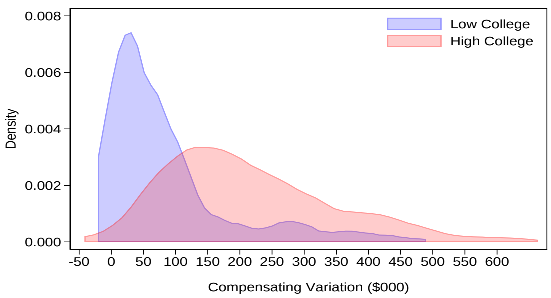
Figure G.2: Compensating Variation by Consumer Demographics



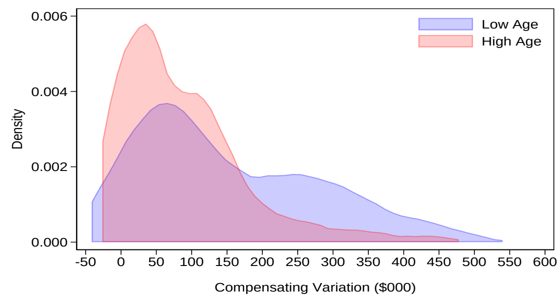
(a) Income (Federal)



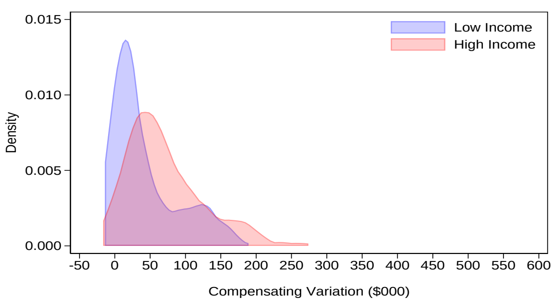
(b) Minority (Federal)



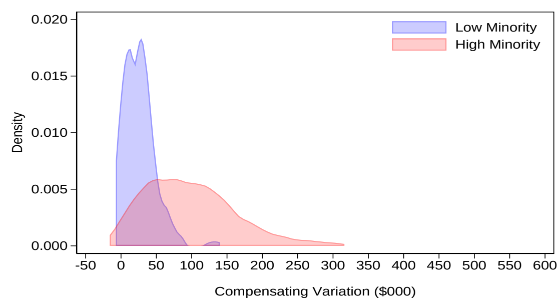
(c) Education (Federal)



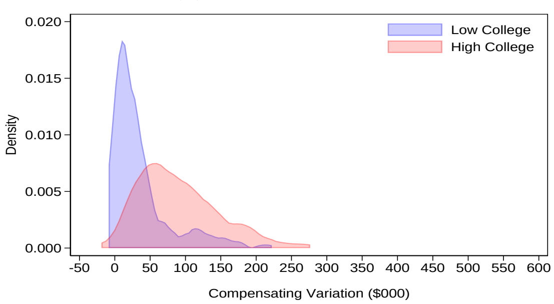
(d) Age (Federal)



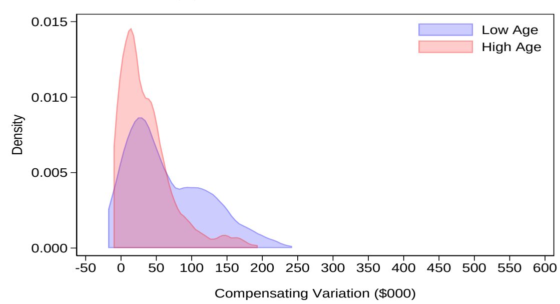
(e) Income (State)



(f) Minority (State)



(g) Education (State)



(h) Age (State)

Notes: We present the distribution of compensating variation $\{CV_l\}_{l=1}^{454}$, denominated in thousands of dollars, calculated as the mean compensating variation in each market l (Equation 17). "High" and "Low" defined respectively as markets in the top and bottom 20% of AGE, MINORITY, EDUCATION, and INCOME as defined in Table 2. Positive compensating variation indicates that consumers are worse-off in the counterfactual, or equivalently prefer excise taxes which are not indexed to inflation. As noted in the text, compensating variation does not include externalities.