The Price of Liquor is Too Damn High: Alcohol Taxation and Market Structure

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Abstract

We study the relative benefits of taxation versus market structure regulations for distilled spirits. One popular regulation, called post and hold, helps wholesalers set collusive prices as the competitive equilibrium of a single period game. Assembling new datasets of wholesale and retail prices, and sales, we show PH leads to average wholesale markups of 30-40%, with higher markups on expensive products. Taxes distort relative prices less than PH. We show Connecticut could increase tax revenue by 350% and improve consumer welfare while holding alcohol consumption fixed. However, we also show our counterfactual policy may be slightly regressive compared to PH.

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The manufacture, distribution, and selling of alcoholic beverages are big business in the United States, with sales exceeding $100 billion in 2012. Alcohol markets are also subject to an unusual degree of government intervention. Federal, state, and even local governments levy excise taxes on alcohol, raising more than $15.5B annually.[1] In addition to being subject to industry-specific taxation, the sale and distribution of alcohol are tightly regulated. In this paper we study the implications of a particular but popular regulatory framework on the pricing of alcoholic beverages and examine how counterfactual government tax policies to restrict alcohol consumption could be potentially welfare-enhancing. Understanding these policies is particularly relevant now, given the evolving legal standing of these regulations and the growing interest among state governments in modifying alcohol regulations and increasing alcohol taxes.

States retain unusually broad powers to regulate the alcohol industry.[2] Nearly every state has instituted a *three-tier* system of distribution, in which the manufacture, distribution, and sales of alcoholic beverages are vertically separated.[3] Some states, known as *control* states, operate part or all of the distribution and retail tiers. Alcohol is effectively sold by a state-run monopolist. Control states—also called Alcohol Beverage Control (ABC) states—have been the subject of recent empirical work examining the impact of state-run monopolies on entry patterns (Seim and Waldfogel 2013) and the effect of uniform markup rules as compared to third-degree price discrimination (Miravete, Seim, and Thurk 2014). States in which private businesses own and operate the distribution and retail tiers are known as *license* states. License states often have ownership restrictions that govern not only cross-tier ownership, but also concentration within a tier. The welfare effects of exclusivity arrangements in the beer industry in these states have been studied by Asker (2005), Sass (2005) and Sass and Saurman (1993). Other work has examined the stickiness of retail pricing using beer prices as an example (Goldberg and Hellerstein 2013).

[1] Many states also levy sales taxes on alcohol and both state and federal governments subject producers, distributors and retailers to income taxes.

[2] The 21st Amendment ended Prohibition by turning the power to regulate the import, distribution and transportation of alcoholic beverages within their borders over to the states, largely exempting their regulations from scrutiny under the Commerce and the Import-Export Clauses of the U.S. Constitution. Since then numerous Supreme Court cases have questioned whether the amendment gave the states absolute control of alcohol policy notwithstanding those powers reserved for the federal government. The net effect of these cases has generally been the eroding of state control over alcohol policy, as the Court has held that state control of alcohol is subject to federal power under the Commerce Clause, the First Amendment and the Supremacy Clause, among others.

[3] The three-tier system dates back to the end of Prohibition, when it was easier for the tax authority to monitor and collect taxes from a smaller number of wholesalers rather than every bar and restaurant, especially when bootlegging was a major concern.

We examine the impact of a particular regulation called *post and hold* (PH), which governs pricing at the wholesale tier in 12 license states, on the structure of alcohol markets and the implications for alcohol tax policy. The only other paper to directly examine PH policies is Cooper and Wright (2012), who use state panel regressions to measure the impact of PH on per-capita ethanol consumption and motor vehicle accidents.)

PH requires wholesalers to submit a uniform price schedule to the state regulator, and commit to that schedule for 30 days. One way to understand this regulation is as a strong interpretation of the Robinson-Patman Act of 1936, which prevents wholesalers from price discriminating across competing retailers. Indeed, most proponents of the system cite the protection of small retail businesses as the principal benefit of PH. We show that the downside of PH is that it softens competition, and facilitates non-competitive pricing in the wholesale market. In fact, we show that the unique iterated weak dominant Nash equilibria of the PH pricing game leads to prices at least high as a single product monopolist would charge.[4] For consumers, PH leads to unambiguously higher prices, especially for more inelastically demanded (higher quality) products.

Non-competitive pricing due to PH restricts quantity, but when there are negative externalities associated with alcohol consumption, welfare effects are ambiguous. Our intuition from homogenous products implies that whether quantity is restricted via taxation or market structure is largely irrelevant from a total welfare perspective. We show that the PH system is a costly way to reduce ethanol consumption, because it also distorts relative prices and thus product choices. A specific tax would apply only to the ethanol content of distilled spirits, while a market structure restriction such as PH allows firms to extract revenue from inframarginal consumers based on other product characteristics such as product quality. While the state may have an interest in limiting ethanol consumption due to associated negative public health externalities, the state does not have an interest in otherwise distorting product choice. The state could achieve the same public health goal while reducing product choice distortions (and raise new revenue) by repealing laws that dampen wholesale competition and increasing specific or ad valorem taxes such that aggregate ethanol consumption was unchanged. Under such counterfactual taxes, consumers would substitute away from low-priced value brands and towards premium products, leaving most substantially better off.

We study the effects of PH and the potential for welfare-enhancing counterfactual policies

[4]Thus even the effects on small retailers may be ambiguous, as they trade off a potentially more competitive retail market against a less competitive wholesale market characterized by a cartel.

in the state of Connecticut, a license state. Liquor regulation in the state has come under increased scrutiny in recent years due to a growing awareness that prices in Connecticut are substantially higher than prices in surrounding states – despite the fact that alcohol taxes are not appreciably higher. Our work makes two contributions. First, we show theoretically and with our empirical estimates that PH significantly softens competition and diverts surplus from retailers and consumers to wholesalers. Second, we provide comparisons from a social welfare perspective of sales taxes, specific taxes, and market regulations in a world with imperfect competition and product differentiation. Previous investigations of the impact of alcohol taxes and regulations have focused on the consumption of ethanol, wherein each product's ethanol content was treated identically. We show that taking distortions of product choice into account substantively affects the assessment of policies toward alcohol markets.

Court decisions have recently affected the legal standing of PH. In a Supreme Court case, *California Retail Liquor Dealers Ass'n v. Midcal Aluminum, Inc* (1980), the court ruled that the wholesale pricing system in California at the time was in violation of the Sherman Act. The California system at the time resembled PH, but with the additional restriction that retail prices were effectively set via a resale price maintenance agreement by wholesale distributors.[5] The court's ruling established a two-part test for determining when state actions were immune to antitrust scrutiny: 1. a law must *clearly articulate* a valid state interest (such as temperance) 2. the policy must be *actively supervised* by the state. Later, the PH system was directly challenged in *Battipaglia v. New York State Liquor Authority (1984)*. In this case, Judge Friendly wrote for the Second Circuit:

> New York wholesalers can fulfill all of their obligations under the statute without either conspiring to fix prices or engaging in "conscious parallel" pricing. So, even more clearly, the New York law does not place "irresistible pressure on a private party to violate the antitrust laws in order to comply" with it. It requires only that, having announced a price independently chosen by him, the wholesaler should stay with it for a month.

A more recent challenge in the state of Washington found essentially the opposite. In *Costco v Maleng (2008)*, the Ninth Circuit's appellate decision affirmed that "the post-and-hold scheme is a hybrid restraint of trade that is not saved by the state immunity doctrine of the Twenty-first Amendment." These decisions are important as a motivation for empirical work. Several of the 12 states that currently have PH laws (see Table 2) have considered

[5] It is worth pointing out that prior to the *Leegin* decision in 2007, resale price maintenance was a *per se* violation in the United States.

modifying their laws. Understanding both theoretically and empirically the extent to which PH facilitates collusive practices and affects the level and distribution of surplus among the various tiers of the system, taxing authorities, and the general public will help inform the decisions and actions of state regulators and lawmakers.

In Section 1, we describe how alcoholic beverages are regulated and taxed. In Section 2, we present a theoretical model of the PH pricing game, and show the monopoly price emerges as the unique iterated weak dominant Nash equilibrium of a single (non-repeated) game. We then derive results for the case for multi-product wholesalers selling overlapping goods where we find that even when several firms sell identical products, the price remains at least as high as the single-product monopoly price. We then show how monopoly pricing would differ from the Pigouvian tax because monopoly pricing leads to higher prices on inelastically demanded products, rather than higher prices on products with a higher alcohol content.

In Section 2.2, we describe the data we draw on from government and private sources, which show monthly case shipments from manufacturers and Connecticut PH wholesale prices and quantities at the brand-bottle size level. We also provide two pieces of descriptive evidence in Section 2.3 , which point to the effects of PH on consumption patterns. First, we present panel regressions exploiting changes in PH policy that show PH laws are associated with lower per capita alcohol consumption and greater prevalence of small retailers. The estimates provide descriptive evidence that PH may reduce consumption of spirits by between 4% and 10%, and have no positive impact on retail employment among alcohol retailers. We plot the timing and pattern of price changes by the various wholesalers selling four popular products. The plots show a remarkable level of co-movement of prices posted by different wholesalers, and very little price dispersion at the wholesale level. We also provide evidence that consumers in Connecticut consume relatively more value brands and relatively fewer premium products when compared to neighboring states.

Section 3 describes our demand model and reports parameter estimates. Our brand-bottle size level data allows us to estimate the full matrix of cross-price demand elasticities for each spirits product category. By making use of additional panelist data from Nielsen, we are able to link consumers' incomes to the heterogeneity in their willingness to pay and tastes for alcohol content. This allows us to make distributional statements regarding welfare. We use these estimated demand elasticities to assess how different regulatory and tax policies would affect the size and distribution of social surplus. Estimates suggest that, holding aggregate ethanol consumption fixed, the specific tax could be increased by $19.68 per proof gallon ($2.72 for a 750mL bottle of vodka), which would roughly double the overall tax burden and increase the revenue to the state of Connecticut by 364%. For context, this additional revenue would have covered more than a third of the state's recent debt issue for transportation.[6] Holding ethanol consumption fixed, consumers would substitute away from larger, more alcoholic products and towards smaller bottles or flavored products, for which the additional tax burden is lower than the relative wholesale markups under PH. Alternatively, without affecting total ethanol consumption, the state could levy additional an ad valorem tax of 35.1% (roughly in line with the flat 35% markup employed by Pennsylvania, a government monopoly state). Under both alternate scenarios, consumers are on average better off. For the same level of consumption, consumers are able to purchase higher-quality products, lower-proof flavored products, or smaller package sizes under the new tax scheme than they did under PH. The tax alternatives are somewhat more regressive than the PH regulation, and more of the benefits accrue to higher-income households, Section 4 concludes.

1 The Regulation and Taxation of Alcoholic Beverages

1.1 Alcoholic Beverage Regulation

States strongly regulate alcohol markets. The alcoholic beverage industry is one of few industries that is vertically separated by law.[7] Some states, known as *control* states, operate part or all of the distribution and retail tiers; alcohol is effectively sold by a state-run monopoly. We focus on states in which private businesses own and operate the distribution and retail tiers. These are known as *license* states.[8] License states often have ownership restrictions that govern not only cross-tier ownership, but also concentration within a tier.

We focus on a regulation used by approximately one-third of license states. The post and hold (PH) system is designed to encourage uniform wholesale pricing.[9] Under PH, quantity discounts are prohibited, and wholesalers are required to offer the same uniform price schedule to all retailers. This is implemented by requiring wholesalers to provide the

[6]For details on transportation debt issue see `http://www.ctnewsjunkie.com/archives/entry/bond_commission_approves_725m/`.

[7]Automobiles are another example, where many states require single-state entities to act as dealerships and preclude dealerships owned by the manufacturer.

[8]In many states these private businesses are subject to a number of retail regulations sometimes referred to as *blue laws*. These regulations govern everything from what kinds of stores can sell alcoholic beverages (specialty package stores, supermarkets, convenience stores), to what times of day and days of the week alcoholic beverages can be sold, to whether or not coupons or promotions are allowed.

[9]This is similar to a strong interpretation of the Robinson-Patman Act of 1936. However, Robinson-Patman does not apply to sales of alcohol when wholesalers only operate within a single state. Moreover, courts have interpreted Robinson-Patman as requiring wholesalers to produce (to courts) a formula (including quantity discounts) which could justify observed pricing behavior.

regulator with a list of prices at which they will sell to retailers in the following period (usually a month). Wholesalers are generally not allowed to amend these prices until the next period. However, some PH states, including Connecticut, also allow a *lookback* period, which allows wholesalers to amend prices downwards only, but not below the lowest price for the same item from the initial round. In Connecticut, this period lasts for four days after prices are posted – but well in advance of selling. Many states, including Connecticut, have a formula that maps posted wholesale prices into minimum retail prices. This prohibits retailers from pricing below cost (even to clear excess inventory).

As Section 2 shows, PH provisions effectively facilitate non-competitive wholesale pricing. There is a large literature in industrial organization on collusion and cartel behavior related to the pricing behavior we see here. The bulk of the empirical collusion literature has examined explicit collusive agreements among competitors, rather than tacit collusion, ostensibly because the former is more likely to end up in court. Much of the theoretical literature has focused on when collusion can and cannot be sustained. For example, Green and Porter (1984) examine the role of dynamics in understanding when and how collusive agreements are sustained or break down. The role of monitoring in maintaining collusive agreements is further explored in Sannikov and Skrzypacz (2007), Skrzypacz and Harrington (2005), and Harrington and Skryzpacz (2011). In theoretical work, Harrington (2011) examined how price-posting mechanisms served to facilitate cartel behavior. In our case, the state provides the monitoring and punishment necessary to maintain the cartel.[10]

One rationale for regulations like PH is that they may protect small retailers from larger chain stores such as Costco or BevMo.[11] The PH system can be seen as a transparent way to ensure uniform pricing. Otherwise retailers might worry that prices "change" exactly when large customers place orders. The justification of the lookback period is less clear. It stems from fears that wholesalers may accidentally set a price that is too high and therefore risk losing sales for an entire month, since rapid price adjustments are no longer allowed. However, a consequence of these regulations is that the wholesale market becomes less competitive; retailers trade off facing discriminatory pricing and quantity discounts against a higher but

[10]Another part of the literature seeks to understand how to identify collusive practices from data. Much of this literature, as reviewed by Harrington (2008) and Porter (2005), focuses on detecting cartel behavior, often in procurement settings. Some well known public sector procurement examples include Porter and Zona (1993) Porter and Zona (1999) in the Ohio school milk cartel. Another non-procurement example is Porter (1983)'s seminal work on the Joint Executive Committee. More recent work has examined the distribution of rents and internal organization mechanisms within a cartel (Asker 2010).

[11]Prior to May of 2012, Connecticut liquor regulations explicitly prohibited retail chains with more than two locations, though it now allows as many as nine retail outlets per chain.

uniform wholesale price.

A second rationale relates to the impact of the higher wholesale prices that result from PH regulations on alcohol consumption. Alcohol consumption exerts a negative externality on public safety and public health. Studies employing tax changes to generate exogenous variation in alcohol consumption find that lower consumption is associated with lower rates of motor vehicle accident fatalities (Wagenaar, Livingston, and Staras 2015), better health outcomes (Cook and Tuachen 1982), (Cook, Ostermann, and Sloan 2005), and less crime (Cook and Durrance 2013). Regulations like PH grant wholesalers pricing power, effectively raising prices and thus limiting quantity—with the potential to restrict consumption enough to achieve the socially optimal quantity. As part of of our counterfactual simulations we examine how the allocation of surplus would differ if the state did not facilitate collusion through PH and instead increased taxes such that total ethanol consumption was unchanged.

1.2 Alcoholic Beverage Taxation

Taxes comprise a substantial portion of costs in the alcoholic beverages industry and have been an attractive source of new revenue for states in recent years.[12] Alcohol taxes come in two forms. *Specific* taxes are related to the quantity ethanol in the product but not the price, while *ad valorem* taxes like retail sales taxes are proportional to the price charged.[13] Both of these taxes are thought to serve two purposes: one, decrease consumption of alcoholic beverages in light of the negative externalities associated with alcohol; and two, provide a source of revenue to the government.

Specific taxes on alcohol are typically tailored to the alcohol content and type of beverage, with different tax schedules applying to beer, wine, and distilled spirits. If pure alcohol exerts an atmospheric negative externality, the specific tax on spirits at least partly addresses the externality directly. In distilled spirits, it is common to tax proof-gallons, which correspond to a gallon of spirits that is 50% alcohol at 50 °F.[14] Connecticut's specific tax on spirits was increased form \$4.50 to \$5.40 in July 2011. Connecticut, along with the majority of states in the region, includes alcohol in its general retail sales tax base.

As detailed by Bovenberg and Goulder (2002), direct regulation of ethanol consumption and taxes under certain assumptions can achieve the same policy objective, albeit with

[12] Connecticut, Kentucky, New Jersey, New York, North Carolina, Oregon have all increased their effective tax rates on alcohol while many other states considered similar increases in light of budget shortfalls.

[13] Auerbach and Hines (2003) show that in the presence of imperfect competition ad valorem taxes are generally welfare superior to specific taxes.

[14] See `http://www.ttb.treas.gov/forms_tutorials/f511040/faq_instructions.html` for a full description.

different efficiency impacts depending on the use of the tax revenues. Here, however, the state is not employing direct ethanol regulation but is instead granting wholesalers non-competitive pricing power, which curtails consumption. If alcoholic beverages are viewed as homogenous goods, then our intuition from Harberger (1954) suggests that any policy that reduces alcohol consumption and brings the quantity consumed closer to the socially optimal level reduces deadweight loss. Figure 1 illustrates the impact of PH on a market in which alcoholic beverages are viewed as homogenous goods and, for the sake of expositional clarity, wholesalers collectively behave like a monopolist and face constant marginal costs. The negative externality of alcohol consumption leads to a deadweight loss of $A+B$ if firms price competitively at P^C. Non-competitive pricing leads to a higher price, P^{PH}, and restricts quantity to Q^{PH}. While P^{PH} is not sufficiently high enough to fully reflect the marginal damage of alcohol consumption, it does reduce consumption and thus deadweight loss from $A+B$ to B. If alcoholic beverages are viewed as a homogeneous good then PH has the same welfare impact as a tax of $P^{PH} - P^C$ (though of course a Pigouvian tax would raise tax revenue rather than direct surplus to the wholesale tier).

Alcoholic beverages, however, are not homogenous goods. Products differ in terms of branding, flavoring, and packaging, in addition to ethanol content. PH grants wholesalers pricing power, which they use to price products relative to demand for the products, taking cross-price effects into account. In other words, though two products may have the same marginal costs and the same ethanol content (and would thus be sold at the same Pigouvian tax-inclusive price under a tax system designed to correct the externality in the competitive market), under PH wholesalers may choose to price them differently, taking consumer willingness to pay into account. The allocation of consumers to products that results from the distorted relative prices of PH can lead to welfare costs not suggested by a model that views alcoholic beverages as homogeneous goods.

2 Post and Hold, Non-Competitive Pricing, & Optimal Tax Alternatives

2.1 Theoretical Model of Post and Hold

Consider the following two stage (static) game with N (wholesale) firms. In the first period, each firm submits a constant linear pricing schedule to the regulator. Firms are not allowed to set non-linear prices, or negotiate individual contracts, or price discriminate in any way. Before the beginning of the second period, the regulator distributes a book of all available prices to the same N firms. During the second stage, firms are allowed to revise their prices with two caveats: a) prices can only be revised downwards from the first stage price, and b) prices cannot be revised below the lowest competitors' price for that item. Demand is realized after the second stage.

More formally, consider the case of a single homogenous product and index firms $i = 1, \ldots, N$. In the first stage firm i sets a price p_i^0, and then in the second stage sets prices p_i subject to the restrictions:

$$p_i \in [\underline{p}^0, p_i^0] \quad \forall i \qquad \text{where } \underline{p}^0 \equiv \min_j p_j^0$$

Suppose that consumer demand is described by $Q(P)$. Then firms charging p_i face:

$$D(p_i, p_{-i}) \;=\; \begin{cases} 0 & \text{if } p_i > \min_j p_j; \\ \frac{Q(p_i)}{\sum_k I[p_k = \min_j p_j]} & \text{if } p_i = \min_j p_j. \end{cases}$$

If each firm has constant marginal cost c_i, then in the second stage firms solve:

$$p_i^* = \arg \max_{p_i \in [\underline{p}^0, p_i^0]} \pi_i \;=\; (p_i - c_i) \cdot D(p_i, p_{-i})$$

which admits the dominant strategy:

$$p_i^* = \max\{c_i, \underline{p}^0\} \quad \forall i$$

Now consider the first stage game. Given the dominant strategy in the second stage, it turns out that an equilibrium choice for p_i^0 is:

$$p_i^0 \in [\max\{c_i, \min_{j \neq i} c_j\}, p_i^m] \tag{1}$$

An equilibrium is any price between the "limit price" and the price firm i would charge as the monopolist.[15] In the second stage, firms match the lowest price in the first stage $\underline{p}^0$ as long as it is above marginal cost, eliminating the business stealing effect in Bertrand competition.

For intuition, consider the case of symmetric constant marginal costs in what follows. One possible equilibrium is the monopoly pricing equilibrium. That is, all firms set $p_i^0 = p^m$. Here there is no incentive to deviate. In the second stage, all firms split the profits (ignoring the potential of limit pricing). Cutting prices in the first stage merely reduces the size of the profits *without any change to the division.* Any upwards deviation in the first stage has no

[15] Again, it is worth noting that this is a single-period static game, and no Folk Theorem has been used.

effect because it doesn't change $\underline{p}^0$. Another possible equilibrium is marginal cost pricing. Here there is no incentive to cut one's price and earn negative profits. Also, no single firm can raise its price and increase $\underline{p}^0$ as long as at least one firm continues to set $p_i^0 = c$. There are a continuum of equilibria in between.

While it might appear to be ambiguous as to which equilibrium is played, there are several reasons to think that the monopoly pricing equilibrium is the most likely. First, this is obviously the most profitable equilibrium for all of the firms involved; that is, the monopoly pricing equilibrium Pareto dominates all others. However, Pareto dominance is often unsatisfying as a refinement because it need not imply stability. Second, the monopoly price is the only equilibrium to survive iterated weak dominance, Selten (1975)'s ε-perfect refinement, or Myerson (1978)'s proper equilibrium refinement. Third, this is a repeated game, played by the same participants month after month; there are no obvious benefits to deviating from monopoly pricing, and the regulator provides all of the monitoring and enforcement. It is important to note that Theorem 1 establishes the monopoly outcome as the unique equilibrium of a single stage game, without appealing to the repeated nature nor the folk theorem.

Thus we expect that firms will set their first-stage prices at their perceived monopoly price p_i^m given their costs c_i; and will set their second-stage prices at the lowest of the prices from the first stage $p_i = \max\{c_i, \underline{p}^m\}$.

Theorem 1. *In the case of symmetric costs $c_i = c\ \forall i$, then the unique equilibrium of the single-period game to survive (a) iterated weak dominance and (b) ε-perfection is the monopoly price: $\sigma(p_i^0, p_i) = (p_i^m, \underline{p}^0)$ where $\underline{p}^0 = \min_i p_i^0$. (Proof in Appendix).*

2.1.1 Single Product with Heterogeneous Costs

In the case of heterogeneous costs, the first stage becomes a bit more complicated. Begin by ordering the firms by marginal costs $c_1 \leq c_2 \cdots \leq c_N$. The market price $\hat{p}$ will be set by the lowest-cost firm (player 1). Other players play the iterated-weak-dominant-strategy $\sigma(p_i^0, p_i) = (p_i^m, \max\{\underline{p}^0, c_i\})$. Player 1 chooses p_i^0 to maximize the residual profit function:

$$\hat{p} = \arg \max_{p_1^0 \in \{p_1^m, c_2, \ldots, c_n\}} \pi_i(p_1^0) \quad = \quad \frac{(p_1^0 - c_1) \cdot Q(p_1^0)}{\sum_k I[c_k < p_1^0]}$$

Player 1 can choose either to play its monopoly price and split the market evenly with the number of firms for which $c_i \leq p_1^m$, or it can set a lower price to reduce the number of firms who split the market. When the cost advantage of player 1 is small, we expect to see outcomes similar to the collusive outcome. As the cost advantage increases, it becomes more attractive for player 1 to engage in limit-pricing behavior. Because our wholesalers buy the same products from the upstream manufacturer/distillers in roughly similar quantities, we ignore the possibility of heterogeneous marginal costs in our empirical example. In practice, as long as the dispersion between heterogeneous costs is not too large, firms will not have an incentive to engage in limit-pricing.

2.1.2 Heterogeneous Costs and Multiproduct Firms

We extend the single homogeneous good result to the case of heterogenous costs and multi-product firms, but continue to consider a single static Bertrand game. Now for each product j, the second stage admits the same form of a dominant strategy:

$$p_{ij}^{*} = \max\{c_{ij}, \underline{p_j^0}\} \quad \forall i, j$$

Firms now choose optimal strategies in first-stage prices, understanding what the outcome of the subgame will be, and facing both an *ad valorem* tax τ and a specific tax t:

$$\begin{aligned} \pi_i &= \max_{p_{ij}: j \in J_i} \sum_{j \in J_i} (p_{ij}(1-\tau) - c_{ij} - t) \cdot q_{ij} \\ \frac{\partial \pi_i}{\partial p_k} &= q_{ik}(1-\tau) + \sum_{j \in J_i} (p_{ij}(1-\tau) - c_{ij} - t) \cdot \frac{\partial q_{ij}}{\partial p_k} \quad \forall i \in \mathcal{I}_k \end{aligned} \tag{2}$$

The insight from the homogenous goods case is that firms will not all operate by setting their FOC to zero. The idea is that firms act as a monopolist when decreasing prices, but act as price-takers when increasing prices. For each firm $i \in \mathcal{I}_k$ (where $\mathcal{I}_k$ denotes the set of firms selling product k), only the weaker condition $\frac{\partial \pi_i}{\partial p_k} \geq 0$ holds, and it is not necessarily true that $\frac{\partial \pi_i}{\partial p_k} \leq 0$ for all $i \in \mathcal{I}_k$.

If firms have sufficiently similar marginal costs,[16] no firm will engage in limit pricing and there will be a constant division of the market on a product by product basis (depending on how many firms sell each product). Let λ_{ik} be the share that i sells of product k. Under a constant division, $\lambda_{ik} \perp p_k$, we can write $q_{ik} = \lambda_{ik} Q_k$ where Q_k is the market quantity

[16] Formally we need that $c_{ik} \leq \underline{p_k^0}$ for all firms $i \in \mathcal{I}_k$

demanded of product k, so that $\forall i = 1, \dots, N$:

$$Q_k \lambda_{ik}(1-\tau) + (p_k(1-\tau) - c_{ik} - t) \cdot \frac{\partial Q_k}{\partial p_k}\lambda_{ik} + \sum_{j \in J_i} (p_j(1-\tau) - c_{ij} - t) \cdot \frac{\partial Q_j}{\partial p_k}\lambda_{ij} \geq 0$$

$$\underbrace{Q_k(1-\tau) + (p_k(1-\tau) - c_{ik} - t) \cdot \frac{\partial Q_k}{\partial p_k}}_{\text{Single Product Monopolist}} + \underbrace{\sum_{j \in J_i} (p_j(1-\tau) - c_{ij} - t) \cdot \frac{\partial Q_j}{\partial p_k}\frac{\lambda_{ij}}{\lambda_{ik}}}_{\text{Cannibalization}} \geq 0$$

For each product k, except in the knife-edge case, the first-order condition holds with equality for exactly one firm i. This establishes a least upper bound:

$$\underbrace{Q_k(1-\tau) + (p_k(1-\tau) - t) \cdot \frac{\partial Q_k}{\partial p_k}}_{\text{Marginal Revenue}} + \min_{i: k \in J_i} \underbrace{\left[-c_{ik}\frac{\partial Q_k}{\partial p_k} + \sum_{j \in J_i} (p_j(1-\tau) - c_{ij} - t) \cdot \frac{\partial Q_j}{\partial p_k}\frac{\lambda_{ij}}{\lambda_{ik}} \right]}_{\text{Opportunity Cost of Selling}} = 0 \quad (3)$$

Intuitively, the firm that sets the price of good k under PH is the firm for which the opportunity cost of selling k is the smallest, either because of a marginal cost advantage, or because it doesn't sell close substitutes. Given the derivatives of the profit function, the other firms would prefer to set a higher price, the price they would charge if they were a monopolist selling good k. This arises because just as in the single good case, firms can unilaterally reduce the amount of surplus (by cutting their first-stage price), but no firm can affect the division of the surplus (since all price cuts are matched in the second stage).[17]

The competitive equilibrium under PH results in prices at least as high as the lowest-opportunity-cost single-product monopolist would have set, even though firms play a single period non-cooperative game, in which several firms distribute identical products. This also suggests a strategy we could observe in data. In the first stage, firms set their preferred "monopoly" price for each good, and in the second stage, firms update to match the lowest-opportunity-cost monopolist. In practice, we see very little updating in the second stage of the game, perhaps because the game is played month after month among the same players.

We can also do some simple comparative statics. Assume we increase the number of firms who sell product k. Normally this would lead to a decrease in price p_k. However, unless the entrant has a lower opportunity cost of selling than any firm in the existing market, prices would not decline, and we would expect the division of surplus λ_k to be reduced for the incumbents to accommodate the entrant. If this raises the opportunity cost of selling

[17]Again this presumes that λ is fixed, and that firms do not engage in limit pricing to drive competitors out of the market.

for the lowest-price firm, then more wholesale firms might counterintuitively lead to higher prices.[18] We consider additional implications of our theoretical framework – including the game played between upstream firms and wholesalers, and the role of exclusivity – in the Online Appendix.

2.1.3 Optimal Tax Alternatives

One benefit of PH regulations could be the partial correction of the negative externality of alcohol consumption as illustrated by Figure 1; the higher wholesale prices arising from PH may restrict consumption and bring it closer to the socially-optimal level. This still does not answer how effectively PH restricts quantity, and whether the relative prices set by non-competitive wholesale pricing behavior best accomplish the goal of reducing ethanol consumption.

There is a long established theory of optimal taxation in the presence of externalities via the Ramsey pricing solution. The logic of Dixit (1985)'s "Principle of Targeting" – as detailed by Sandmo (1975) and Oum and Tretheway (1988), and shown to be reasonably general by Kopczuk (2003) – is that when setting optimal taxes, correcting for externalities and hitting revenue targets can be seen as independent problems. Thus as prescribed by the "additive property," described by Kopczuk (2003), a state that has no revenue target would simply correct the negative externality of each product and not price products according to inverse demand at all. The relative markup of high- and low-quality products with the same ethanol content would be identical and equal to the negative externality. A fiscal authority that wanted to raise revenue above what was generated by the Pigouvian tax would set the Pigouvian tax equal to the marginal damage of the negative externality of alcohol consumption, and then set Ramsey prices for each product inversely-proportional to the elasticity of demand, accounting for cross-price elasticities. In the Online Appendix we provide a more detailed (though unoriginal) derivation of these results.

A monopolist would mark up each product according to the consumer's willingness to pay, but would not pay additional attention the ethanol content of various products. Thus, there would be no common tax flattening markups across goods of different qualities but similar ethanol content. For example Dubra Vodka and Grey Goose Vodka are both sold in 750mL bottles at 80 proof, and contain identical amounts of pure ethanol. Dubra does not spend any money on advertising and is available only in plastic bottles, and Grey Goose

[18] This is different from the mechanism in other work on price-increasing competition such as Chen and Riordan (2008).

spends almost \$15 million on advertising each year. While Grey Goose frequently sells for over \$29.99 per bottle, Dubra sells for \$7.99. Concerned about only the externality, the social planner would set similar price-cost margins for both goods. Concerned with profits, the monopolist might be inclined to set a relatively low margin on the more elastically-demanded Dubra, and a higher margin on the more inelasticially demanded Grey Goose. Even a social planner who aimed to raise revenue above the receipts from the Pigouvian tax would not mark Grey Goose up by the same margin as the monopolist would, since the social planner would already generate some revenue from the ethanol-content-based Pigouvian tax.

By undoing the distortion the monopolist creates in relative prices, we would expect to lower the price of the most inelastically-demanded goods. If those inelastically-demanded goods tend to be the kinds of premium products most often purchased by high-income consumers, this suggests that undoing PH would accrue the greatest benefits to higher-income people.

2.2 Data

Our study of the alcoholic beverages industry makes use of several data sources. The first source is Connecticut's Department of Consumer Protection (DCP). From the DCP we obtained posted prices for each wholesaler and for each product for the period August 2007 - December 2012. In many but not all cases, we also observe information about the second lookback stage of price updates. Overall, we find that less than 1% of prices are amended in the second stage.[19] We merge this with another proprietary data source obtained from the Distilled Spirits Council of the United States (DISCUS). The DISCUS data track monthly shipments from manufacturers to distributors for each product. Of the 506 firms that have submitted prices to the DCP since 2007, the majority sell exclusively wine, or beer and wine; only 159 have ever sold any distilled spirits. Among those firms, the overwhelming majority sell primarily wine and distribute a single small brand of spirits. Because the DISCUS data track only shipments from the largest distillers (manufacturers) to distributors, only 18 firms overlap between the DCP and DISCUS datasets.[20] However, these 18 firms include all of the

[19] The data we analyze are the first-stage prices because amendments are rare, and often arrive in handwritten facsimile format, instead of on the standardized price list

[20] The largest distillers who comprise the lion's share of the spirits market are DISCUS members. DISCUS members include: Bacardi U.S.A., Inc., Beam Inc., Brown-Forman Corporation, Campari America, Constellation Brands, Inc., Diageo, Florida Caribbean Distillers, Luxco, Inc., Moet Hennessy USA, Patron Spirits Company, Pernod Ricard USA, Remy Cointreau USA, Inc., Sidney Frank Importing Co., Inc. and Suntory USA Inc.

major distributors in Connecticut, and comprise over 80% of sales by volume.[21] Shipments from distillers to wholesalers do not necessarily happen for every product in every month. For lower-volume products, shipments are often quarterly, or irregular. Thus, we smooth the shipment data; details on the precise smoothing procedure can be found in the Online Appendix.

We also use product-level data from the Kilts Center Nielsen Homescan Scanner dataset. This dataset reports weekly prices and sales at the UPC level for 34 (mostly larger) retail liquor stores in the state of Connecticut. Unlike the shipment data, this does not provide a full picture of quantity sold, as not all retailers are included in the dataset. These data provide relative quantity information on non-DISCUS members.[22] This weekly or monthly sales data is an important input into the smoothing procedure for the quarterly DISCUS shipment data discussed in the Appendix. We also use retail pricing information from other states (Florida and Texas) as instrumental variables in our full model.

In addition to product-level data for Connecticut, we use state aggregate data for some of the descriptive results. We use the National Institute on Alcohol Abuse and Alcoholism (NIAAA) *U.S. Apparent Consumption of Alcoholic Beverages*, which tracks annual consumption of alcoholic beverages for each state. These aggregate data do not provide brand-specific information. We utilize additional data from the *2013 Brewer's Almanac*. The Brewer's Almanac tracks annual shipments, consumption, and taxes at the aggregate level for each state for each of the three major categories: beer, wine and distilled spirits. We also use the *2012 Liquor Handbook*, provided by The Beverage Information Group. The Liquor Handbook tracks aggregate shipments and consumption at the brand and state level. It tracks information like national marketshares of spirits brands by category (vodka, rum, blended whisky, etc.), and relative consumption by states across spirits categories. Finally, we draw on data from the Census County Business Patterns (CBP), which tracks the number of retail package stores, distributors, and bars and restaurants, as well as employment.

Table 1 reports summary statistics for the data by product category. Prices are summarized collectively for 750mL, 1L, and 1.75L products by converting all sizes to one liter equivalents. Means reported for price and proof are weighted by sales. Market and size shares are the share of unit sales by category. Rum products offer the lowest prices on average at $16.54 per bottle. Tequilas are the most expensive, with an average price of $24.95.

[21]Some of the largest non-DISCUS members include: Heaven Hill Distillery and Ketel One Vodka.

[22]A major obstacle in dataset construction was matching products across the three (Nielsen Homescan, DISCUS, CT DCP) datasets, since there is no single system of product identifiers, and products had to be matched by name.

Alcohol content is fairly similar across products, ranging from 74.10 proof to 87.88 proof. The number of distinct products varies considerably across categories. While there are only 44 variety-sizes of gin, there are 196 whiskey products and 248 variety-sizes of vodka. These numbers, however, belie the true level of competition and are better considered a measure of product variety. For example, many vodka products largely consist of different flavors offered by a small set of distillers. In Connecticut, vodka sales comprise 42.53 percent of case sales—nearly 60 percent more than the market share of the next most popular category, rum. The most popular bottle size varies by category with 750 mL's accounting for most tequila sales while 1.75 L's are the most popular size for gin.

2.3 Descriptive Evidence

As the model presented in Section 2 makes clear, PH regulations promote non-competitive pricing behavior among wholesalers, potentially leading to higher prices. These elevated prices should have implications for aggregate consumption, the structure of the retail market, the prices faced by consumers, and the way wholesalers change prices. Below we present descriptive evidence on these potential consequences of the wholesale pricing behavior encouraged by PH in order to better understand the impact of PH regulations on the selling of alcoholic beverages.

2.3.1 Cross-State Evidence on Alcohol Consumption and Employment

The first piece of descriptive evidence we offer regarding PH laws relates to their impact on state-level aggregate consumption and features of the alcoholic beverage retail market. As PH provisions likely lead to non-competitive but uniform wholesale prices, it is natural to expect that these high prices may reduce consumption and affect the size distribution of liquor retailers. Work by Cooper and Wright (2012) has empirically shown that PH schemes are associated with lower alcohol consumption. We report the results of similar state panel regressions in Table 3 and related regressions regarding retail establishments and employment in Table 4. These state-year regressions share the form:

$$Y_{it} = \alpha + \beta PH_{it} + X_{it}\gamma + \delta_t + \eta_i + \epsilon_{it} \quad (4)$$

where PH_{it} is a dummy variable equal to one if state i has a PH law in place at time t; X_{it} is a vector of control variables; and δ_t and η_i are time and state fixed effects, respectively. The outcome of interest, Y_{it}, differs across the regressions. In Table 3 the coefficient on the

PH_{it} dummy variable describes the reduction in alcohol consumption associated with PH laws, while in Table 4 the coefficient on PH_{it} relates how the retail markets of states with PH laws differ from other states.

To assess the impact of PH laws on aggregate alcohol consumption, we assembled a panel of annual state data measuring wine, beer, and spirits consumption, as well as demographic characteristics. The existence and repeal of PH laws is described in Table 2, which is a reproduction of Table 1 of Cooper and Wright (2012).[23] For the alcohol consumption regressions reported in Table 3, the outcome of interest is the log of apparent consumption per capita, where consumption is in ethanol-equivalent gallons and the relevant population is state residents age 14 and older. The first column reports estimates from a specification that only includes time and state fixed effects. Although all PH coefficients are negative, suggesting that PH laws reduce consumption, only the coefficient on wine is significant. The identifying variation here arises from changes in PH laws. Over the relevant 1983-2010 period, there were seven changes in PH laws for wine but only five and four changes in the laws for beer and spirits, respectively. Essentially, we likely have more power to detect the effect of PH in the wine market versus the beer or spirits markets. In column two, state demographic controls are added,. These are the log of the share of the population under age 18, and log median household income—two underlying factors that likely affect alcohol demand. The estimated coefficients are similar but larger for wine and beer and much larger and now statistically significant for spirits. Alcohol consumption, particularly spirits consumption, declined during the 1980s, making controlling for state time trends potentially important. As column three shows, adding state time trends attenuates both the wine and beer coefficients, rendering the wine coefficient insignificant; interestingly, it increases the spirits coefficient, suggesting that PH laws reduce spirits alcohol consumption by nearly 8 percent.

Although the specification of column three includes state time trends, year fixed effects, and other controls, the identifying variation comes from the handful of states switching their PH status–namely, states moving away from PH. If states that adopt PH laws systematically differ from other states, this variation may be endogenous.[24] If this endogeneity drives the results, limiting the sample to subsamples of states that are thought to be more similar should yield smaller coefficients. Column 4 limits the sample to only states that have ever had PH

[23]The alcohol consumption data are from the National Institute on Alcohol Abuse and Alcoholism, which is part of the National Institutes of Health; the demographic information comes from the Census Bureau's intercensal estimates.

[24]There is reason to believe the end of PH may be exogenous, as in several cases the law was overturned through the judicial rather than the legislative process.

regimes. The coefficients are largely similar to column 3, though the wine coefficient is now statistically significant. Column five examines only states that ever had PH regimes and are located in the northeast. The results suggest that wine consumption is not significantly affected by PH laws—potentially because there is a smaller scope for collusion among the many and varied wine distributors–while both beer and spirits alcohol consumption are significantly affected. Estimates suggest that beer consumption is approximately 3 percent lower and spirits consumption is roughly 10 percent lower under PH.

Advocates for PH argue that the regulation benefits small retailers by ensuring that they pay the same wholesale prices as large retailers such as Costco or BevMo. If PH does indeed protect small retailers, PH states like Connecticut should be home to more small-scale retail establishments. The impact of PH on employment and the total number of establishments, however, is less clear. While under PH small retailers enjoy uniform pricing, they also pay the higher prices that result from non-competitive wholesaler pricing behavior. Having more small retailers in a retail sector that faces lower margins due to high wholesale prices could lead to either more or fewer establishments that overall employ more or fewer workers.

Table 4 provides some empirical evidence regarding these questions. The regressions presented in Table 4 are of the same form as equation 4 and describe the impact of PH regulations on three different outcomes: share of small retail establishments, log employment in the liquor retail sector, and log liquor stores per capita.[25]

The uppermost panel of Table 4 examines the impact of PH regulations on the prevalence of small liquor retailers (that is, establishments with between one and four employees). Column one uses only only data from 2010 and includes demographic controls—state population and median income—and finds no significant relationship between PH and share of small liquor retail establishments. Columns two through four use the full panel from 1986 through 2010. Adding state and year fixed effects does not yield a significant coefficient, as shown by column two. Column three adds state-specific time trends, which control for changes in spirits consumption that vary by state. Adding these additional controls reveals that states with PH regulations do in fact have a larger share—4.5 percentage points larger—of small retail establishments. Dropping all states outside of the northeast does not substantively affect the coefficient but increases the precision of the estimate.

The middle panel examines the impact of PH regulations on employment in the alcohol retail sector. The dependent variable is the log of employment in the liquor retail sector

[25] Panel data describing state liquor retail establishment counts and employment come from the Census County Business Patterns for 1986 through 2010.

per capita age 14 years and older. Again looking at data from only 2010 does not suggest a statistically significant relationship between employment and PH laws. Adding year and state fixed effects as shown in column 2 reveals that states with PH laws actually have lower per-capita liquor retail employment. Including state time trends reduces the magnitude and precision of the coefficient from -1.753 (0.198) to -0.482 (0.240). Focusing on northeastern states (column 4) does not have an appreciable further impact on the estimates.

The bottom panel assesses how the number of establishments per capita is affected by PH regulations. As in the upper panels, examining the 2010 data alone does not suggest a statistically significant relationship between number of retailers and PH laws. Column two uses the full panel with state and time fixed effects, yielding a significant and negative coefficient. Controlling for state time trends reduces the coefficient to -0.599 (0.0913). As in the other panels, examining only northeastern states doesn't appreciably change the coefficient.

Tables 3 and 4 show that PH regulations are associated with lower spirits and beer consumption, a higher share of small establishments, lower employment in the liquor retail sector, and fewer retail stores per capita. Higher wholesale and retail prices due to PH may make off-premise consumption a less cost-effective option in PH states, reducing the role of the sector in the state liquor market.

2.3.2 Price Comparisons Across States

The model presented in Section 2 shows that PH regulations facilitate non-competitive pricing; PH states should therefore feature higher prices than states that lack PH rules. The Kits Center Nielsen Homescan Scanner Data, which tracks retail prices in many states, affords us the opportunity to make exactly this price comparison. Table 5 describes the average product price for a fixed bundle of spirits products in different states.

The price-index consists of the 50 best-selling spirits products in Connecticut by sales volume. We construct the price index (using the Connecticut consumption bundle) as:

$$PI^{x,CT} = \frac{\sum_{i=1}^{50} p_i^x q_i^{CT}}{\sum_{j=1}^{50} q_j^{CT}} \tag{5}$$

We construct a second price index using the Massachusetts bundle, $PI^{x,MA}$, because Massachusetts is a license state without PH regulations but is otherwise demographically similar to Connecticut. States are ranked by the $PI^{x,CT}$ index value.

There are several notable facts about Table 5. First, weighting by Massachusetts quantities rather than Connecticut quantities does not affect the rank order substantially. The higher overall price of the Massachusetts bundle in nearly every state indicates that the Massachusetts bundle is weighted toward higher-quality products, which indicates a key distortion caused by the PH system. Figure 2 illustrates this point as well. The figure plots the consumption share (measured in liters) of vodka products of different prices per liter. Connecticut consumes far more of the cheapest vodkas while Massachusetts tilts toward products that retail for higher prices in Connecticut. Connecticut also consumes far less imported vodka than its neighbors; while imports comprise only 39.1 percent of vodka sales in Connecticut, imports make up 52.8 and 55.0 percent of vodka sales in Massachusetts and New York, respectively. Imported vodka in fact is less prevalent in Connecticut than any other northeastern state (other than Vermont) despite having the highest per-capita income of them all.

Second, despite the popular notion that taxes are a key determinant of spirits prices, there is little evidence in the cross-section presented here that higher-tax states have higher prices. For example, Minnesota—the highest tax state–ranks only 17th in terms of prices and Texas—the third lowest tax state—ranks third in terms of prices. This fact is made more explicit by the *Net of Tax* columns. Even after deducting the state excise tax from bottle prices, we see that Connecticut still ranks 11th out of the 25 license states listed when the bundle is weighted by Connecticut quantities, and has higher prices than surrounding states. This provides model-free evidence that suggests differences in prices across states are likely not due to excise taxes, but rather to differences in market structure.

2.3.3 Post and Hold and Evidence of Non-Competitive Pricing

One consequence of the PH system is that we expect to observe very little price dispersion as wholesalers will update to match each other's prices. In Figures 3 and 4 we present price data for the 99 best-selling products between September 2007 and July 2013.[26] Since examining the prices that different wholesalers list for the same product in the same month provides the most compelling evidence of non-competitive pricing behavior, we limit our analysis to the 8,874 product-months in which multiple wholesalers price the same product.[27] Figure 3 plots the distribution of relative price spreads – that is, the spread between the highest and lowest price for a given product divided by the mean price in a given month. The overwhelming

[26]Our data of 11,596 wholesale price observations describe 6,327 product-months. Of these 11,596 wholesale price observations, 2,722 prices are the only wholesale price for that product-month while 8,874 observations are the wholesale prices of multiple firms offering the exact same product in the same month.

[27]For 4,348 of these product-months two wholesalers list the product in the same month; three wholesalers offer the product in 3,603 product-months; four or more wholesalers list the same product for the remaining 1,013 product-months.

majority—nearly three-fourths—of product-months feature identical prices among all the wholesalers. More than 80 percent have spreads of less than 2 percent. When multiple firms offer the same product, they nearly always price it almost identically.

We can also follow how different wholesalers price the same product over time. Figure 4 tracks the first-round prices of up to four different wholesale firms (Hartley, Allan S Goodman Inc., Brescome Barton, and Dwan & Co Inc.) for four products: Captain Morgan Original Spiced Rum (750 mL), Maker's Mark (1 L), Smirnoff Vodka (750 mL), and Johnnie Walker Black (1.75 L). The plots provide detailed evidence regarding the timing of price changes among the firms. In all cases firms seem to nearly always perfectly time price increases and decreases. The few exceptions include Eder's single over-increase of the price of Maker's Mark in February 2012, Barton's abrupt Smirnoff price reduction in December 2011, and Dwan's slight delay in changing Johnnie Walker Black prices. The plotted prices in Figure 4 show that, despite the fact there are multiple wholesale firms offering the same products in the same months, the first-round prices are strikingly similar.

3 Estimating Demand and Assessing Counterfactual Policies

3.1 Demand Specification

Our empirical specification examines the distilled spirits market. We estimate two sets of demand models. The first allows consumers to have correlated preferences across spirits categories (whiskey, gin, rum, tequila, and vodka), as well as to have unobservable heterogeneous preferences for both ethanol content (bottle size and proof) and willingness to pay. We estimate these models using aggregate data, and find that there is little substitution across product categories. Therefore, we estimate a second set of category-level demand models, in which we allow for increased flexibility and match additional moments from the Nielsen Homescan Panelist data that correlate price paid and ethanol content with household income for each product category. The hope is that this specification should be flexible enough to capture the relevant substitution patterns, as well as providing a mechanism that lets us make comparative statements about the relative progressivity/regressivity of PH laws and taxation.

In the first set of models, we estimate the RCNL model of Brenkers and Verboven (2006) or Grigolon and Verboven (2013). The RCNL model includes both nested logit and random coefficients logit models as special cases. We can think about a consumer of type i as having heterogeneous preferences β_i (in this case for ethanol content and price) and choosing a product $j \in J_t$ in month t. In our setting a product denotes a brand-flavor-size combination (i.e.: *1.75L of Grey Goose Orange Flavored Vodka at 60 Proof*). We also allow for an endogenous product market specific quality shifter ξ_{jt}, which is observed by firms when setting prices but not by the econometrician. The only deviation from the random coefficients model in Berry, Levinsohn, and Pakes (1995), or in Berry (1994), is that the error term ε_{ijt} has a GEV structure that allows for correlation within a spirits category g. This generates the following:

$$u_{ijt} = x_{jt}\beta_i + \underbrace{\xi_j + \xi_t + \Delta\xi_{jt}}_{\xi_{jt}} + \varepsilon_{ijt} \tag{6}$$

$$s_{jt}(\xi_{jt}(\theta), \theta) = \int \frac{\exp[(\beta_i x_{jt} + \xi_{jt})/(1-\rho)]}{\exp[I_{ig}/(1-\rho)]} \cdot \frac{\exp[I_{ig}]}{\exp[IV_i]} f(\beta_i|\bar{b}, \Sigma)\partial\beta_i \tag{7}$$

The primary difference from the nested logit is that the inclusive value term for all products in nest J_{gt} depends on the consumer's type i:

$$I_{ig} = (1-\rho)\ln\sum_{j\in J_{gt}} \exp\left(\frac{\beta_i x_{jt} + \xi_{jt}}{1-\rho}\right), \quad IV_i = \ln\left(1 + \sum_{g=1}^{G} \exp I_{ig}\right) \tag{8}$$

The heterogeneity modifies both the selection of product within nest, and also the selection of overall nest.[28] As is common we decompose the mean utility δ_{jt} of product j in month t into a function of observed characteristics x_{jt}, prices p_{jt} and unobserved quality ξ_{jt}.

$$\delta_{jt} = x_{jt}\beta_i + \underbrace{\xi_j + \xi_t + \Delta\xi_{jt}}_{\xi_{jt}} \tag{9}$$

The challenge, as pointed out by Berry (1994), is that the unobservable product quality ξ_{jt} is typically correlated with prices p_{jt}. That is, there is something about *Grey Goose Vodka* that consumers prefer to *Smirnoff Vodka* beyond what is captured by the observable x_{jt} characteristics (bottle size, flavor, proof, rating, etc.). One way to address the endogeneity problem is to allow for fixed effects, either for products or periods. Month-of-year fixed effects allow us to control for overall seasonality in the demand for spirits; year fixed effects let us control for longer-run trends in spirits consumption; and product fixed effects control for the persistent component of unobserved quality. If product fixed effects are included as

[28] For example: the most price sensitive consumers are less likely to prefer tequilas, which are on average substantially more expensive than other product categories

in Nevo (2000) then this changes the interpretation of the unobservable quality term, so that $\Delta\xi_{jt}$ represents the month-specific deviation from the average product quality. Estimation requires instruments z_{jt} that are correlated with prices but uncorrelated with unobserved quality so that $E[\Delta\xi_{jt}|z_{jt}] = 0$; we estimate $\theta = [\rho, \Sigma, \alpha, \beta]$ via two-step GMM.

In order to construct those moments, we consider three different sets of instruments. The first instrument set is the observed cost shifters which arise from the July 2011 increase in the specific tax. This tax depends on both the package size and the proof of the product, and thus provides cross-sectional variation across products. These kinds of taxes are close to the "ideal" cost-shifters and are frequently used in reduced-form contexts as an instrument for price. Furthermore, the state of Connecticut also instituted a "floor tax" so that all units held in inventory in July 2011 (at retail or wholesale level) were required to pay the additional tax, which mitigates some concerns about "leakage" or substitution across time.[29]

The next set of instruments is the "Hausman" instruments, or the retail prices of the same products in other states, which we obtain from the Nieslen Scanner dataset. These should serve as a measure of changes in the wholesalers' costs, as they may pick up changes in the prices charged by the upstream (multi)-national distillers such as Bacardi or Diageo, and possibly shocks to global supply, such as rising demand for Scotch whisky in China. Because states may have markedly different market structures, these instruments may be more effective in isolating cost shocks than they are in other settings. The downside is that they may also pick up changes in demand such as a national advertising campaign. To avoid spillovers from local advertising markets, we use retail prices of the same products in Florida and Texas as instruments for Connecticut prices, rather than retail prices in neighboring states such as New York or Massachusetts.[30]

The other available set of instruments are the so-called "BLP" instruments, which exploit variation in the number and characteristics of products in each category across time in order to proxy for the changes in the degree of competition. For example, over time, there may be increased entry into premium domestic whiskeys or flavored vodkas leading to lower markups within the segment. A standard approach might examine the counts of products within

[29]Consumers could still purchase in advance of the tax increase, though in separate work we do not find strong evidence of that behavior. In practice the tax increase is small – generally around 50-60 cents for a 1.75L bottle of vodka.

[30]Note: there is a tradeoff between including prices from more states as instruments for supply shocks, and the shrinking set of products that are available in all states. Florida and Texas are used because they are large states where many of the products available in Connecticut are also available. California is also very large and has a wide variety of products available, but fewer of them overlap with the products available in Connecticut.

each product category, or category-size pair. Because pricing segments are also important in alcohol sales, we generate instruments based on the number of products within a category, but also within a moving window of price-per-liter within category. This allows us to capture (for example) increased competition among similarly priced whiskeys. Another advantage is that, as the number of products becomes large, our instrument does not converge to a constant (as the average characteristics of competing products might). These "BLP instruments" are crucial in identifying the nesting parameter.[31]

We also construct instruments based on interactions between the Hausman-style instruments and the BLP-style instruments. One potential problem is that many of these instruments (especially product counts) are highly correlated within products over time, or across products within a category. Following the suggestion in Conlon (2014), we reduce our 47 instruments into 15 principal components. These principal components span at least 98% of the variance of the original instruments, and have the added benefit of forming an orthogonal basis. In all of our specifications there is evidence that the instruments are strong; first stage F-statistics for price exceed 100, and for the nesting parameter, ρ, they exceed 20.

Table 6 presents demand estimates from logit, nested logit, and random coefficients nested logit models. For all specifications, demand slopes downwards and the price parameter is statistically significant. Including instruments for price increases the magnitude of the price coefficient, indicating the importance of unobservable product demand shifters, $\Delta\xi_{jt}$, even after allowing for product fixed effects. Failing to instrument for the nesting parameter leads to attenuation bias in $\rho \to 1$. Once instrumented for, the nesting parameter is between 0.88 and 0.90. The findings are consistent with the hypothesis that most consumers substitute within a product category (i.e.: to other brands of vodka rather from vodka to rum). Including unobserved heterogeneity via random coefficients substantially improves the fit of the model, reducing the GMM objective from 1259 to 596. The random coefficients for price and ethanol content are perfectly negatively correlated. This indicates that consumers either prefer the cheapest source of ethanol possible, or are less price-sensitive and buy smaller bottles of potentially less alcoholic products.

3.2 Category Specific Estimates

Because the implied cross-price elasticities of products in different categories are very small, and because conversations with firms indicate pricing is done predominantly category by

[31]For additional informational information on this in the context of differentiated products demand estimation please consult Armstrong (2015) or Conlon (2014).

category, we consider estimating a separate (and more flexible) random coefficients model for each category. We estimate the same specification (including fixed effects, instruments, and random coefficients), but eliminate the nesting structure and produce a separate set of estimates for each category (whiskey, gin, rum, tequila, vodka). We allow the random coefficients to vary with income y_i so that: $\beta_i = \alpha + \Sigma\nu_i + \pi y_i$ for $(\beta_i^p, \beta_i^e, \beta_i^0)$. In order to separately identify the income component from the normally distributed random coefficients, we incorporate additional "micro-moments" from the Nielsen Homescan Consumer Panelist dataset.

From 2006-2012 in Connecticut, only 312 of 1,171 panelist households record a distilled spirits purchase.[32] We assign those households into 10 income groups. For each product category, we compute the slope of price paid per liter of spirits purchases with respect to income; the slope of ethanol content per purchase with respect to income; and the slope of the overall purchase probability (for the 1,171 households) with respect to income. For reference, we report those data aggregated across all product categories, along with the corresponding share of the population from Census data in Table 7. It is important to note that top-coding of income is an important issue, with 20% of households falling into the highest income group, in part because Connecticut is the the highest-ranking state in terms of per-capita income. Across all categories, we find that higher-income households are more likely to buy smaller or less alcoholic bottles conditional on purchase, and spend more for those bottles. We also find that higher-income households make purchases more frequently, such that there is no discernible pattern between overall ethanol consumption and income in the Nielsen Panelist data, though the magnitudes vary considerably across categories.

For our empirical analysis, we match (for each of our five product categories): the slope of price paid conditional on purchase, ethanol content conditional on purchase, and purchase probability with respect to income. We use these additional constraints to help pin down the income interaction parameters, (π_p, π_e, π_0).[33] This is similar to the approach taken in Berry, Levinsohn, and Pakes (2004) or Petrin (2002), though we depart slightly because we model

[32]We exclude two additional households which make a very large number of purchases per week when calculating the relationship between income and purchase behavior.

[33]We might want to include additional micro-moments, including shares of specific brands by income, however the Nielsen Homescan panelist data becomes thin once we condition on both state and income level. What appears to be important is that the slope with respect to income varies quite a bit. For example, preferences for tequila and rum vary very little with income, while the prices for whiskey and vodka appear to vary quite a bit. To us, this seems quite sensible. There are some very high-end single-malt scotches in the whiskey category, as well as some super-premium vodkas that are purchased almost exclusively by high-income households. For rum and tequila, the dominant brands are Bacardi and Jose Cuervo respectively, which are purchased by both high and low income households.

the micro-moments not as an additional set of moments but rather as a set of additional constraints, and estimate a constrained GMM estimator. We do this because we have only one "pseudo-observation" of the slope with respect to income for our three statistics.

We report the estimates of the category-by-category random coefficients models in Table 8. For each category, we also report the slope of price-per-liter and ethanol-content that we match via our micro-moments. Because the parameters are in the space of utilities and have no obvious scale, we also report the distribution of own and cross-price elasticities. Several important patterns emerge. For all categories except gin, higher income consumers have a weaker preference for ethanol content, implying they purchase smaller bottles or are more likely to purchase flavored products (with lower alcohol content).[34] For all categories except tequila, higher-income consumers spend more on each purchase. The parameter estimates imply that π_p is positive for all categories, implying that price sensitivity is decreasing with income. Likewise π_e is negative for all categories, implying that poorer consumers have a higher taste for ethanol content. The probability of purchase has a positive correlation with income, though its corresponding parameter π_0 is negative for all categories except tequila, implying higher-income consumers are less likely to make a purchase (all things being equal). The π_0 term helps to counterbalance the effect that declining price sensitivity increases purchase frequency. Instead, higher-income consumers purchase more smaller, more expensive bottles on average, but at only slightly elevated frequency.

As in the RCNL model, we estimate random coefficients on price and ethanol content, and allow for correlation in those tastes. The parameters we report are those corresponding to the Cholesky root so that $\sigma_p \nu_i^1$ is the corresponding term for price and $\sigma_{pe}\nu_i^1 + \sigma_e \nu_i^2$ for ethanol. Much like the RCNL model, we find the σ_e component is generally zero and there is perfect negative correlation in unobserved tastes. However, for several categories, once we allow for heterogeneous preferences correlated with income, we do not find any presence of additional unobserved taste heterogeneity ($\sigma_p \approx 0$).

3.3 Supply Side

We use our system of first-order conditions derived in (3) to recover the marginal costs on a category by category basis. We are modeling the strategic decisions of wholesalers (using wholesale prices and statewide quantities), and we interpret the wholesalers' marginal cost as containing two components: the unit price paid by the wholesaler to the manufacturer/distiller, and the marginal cost incurred by the wholesaler in storage and transportation

[34] Only rum and vodka have substantial numbers of lower proof flavored products available.

to the retailers. Our system of necessary conditions produces a first-order condition for each product that holds with equality for exactly one wholesale firm. Because our data do not allow us to directly identify which firm behaves as the price-setter, we assume that wholesalers face symmetric marginal costs $c_{ik} = c_k$, but differ in their opportunity cost of selling. We obtain the relative importance of products j, k to i's profits $\frac{\lambda_{ij}}{\lambda_{ik}}$ directly from the DISCUS data. The DISCUS data document all shipments from manufacturer/distillers to individual wholesalers, and we let λ_{ik} be the fraction of product k shipped to firm i over the entirety of 2012. We do not disaggregate the shipment data to the monthly level because shipments are often lumpy or irregular with large shipments followed by several months of no shipments, and those patterns may vary across wholesalers. For independent products not tracked in the DISCUS shipment data, we assume that all wholesalers *among those who offer the product that month* split the market evenly.[35] We obtain the cross price derivatives $\frac{\partial Q_j}{\partial p_k}$ from our demand system. Then, given a conjecture for the vector of marginal costs $\mathbf{c}$, we evaluate $i_k^* = \arg\min_{i:k \in J_i} \sum_{j \in J_i} (p_j(1-\tau) - c_{ij} - t) \cdot \frac{\partial Q_j}{\partial p_k} \frac{\lambda_{ij}}{\lambda_{ik}}$ to determine the lowest opportunity cost wholesaler.

$$Q_k(1-\tau) + (p_k(1-\tau) - t) \cdot \frac{\partial Q_k}{\partial p_k} - c_k \frac{\partial Q_k}{\partial p_k} + \min_{i:k \in J_i} \left[\sum_{j \in J_i} (p_j(1-\tau) - c_j - t) \cdot \frac{\partial Q_j}{\partial p_k} \frac{\lambda_{ij}}{\lambda_{ik}} \right] = 0$$

It is common to represent the system of K equations defined by (10) in matrix form, where $\Omega(\mathbf{p})$ represents the $J \times J$ Jacobian matrix of price derivatives $\frac{\partial Q_j}{\partial p_k}$.[36] The tradition is to pre-multiply Ω element-wise by a $J \times J$ indicator matrix, which has an entry of one if the two products are controlled by the same firm, and zero otherwise. In our case, we pre-multiply by the matrix Λ where the (k, j)-th entry corresponds to $\frac{\lambda_{i_k^*, j}}{\lambda_{i_k^*, k}}$. Here Λ acts as a weighted version of the ownership matrix, in which some weights may be greater than one and others may be less than one. It is also worthwhile to point out that $\Lambda. * \Omega(\mathbf{p})$ need not be symmetric. We can then solve the modified linear system of equations at the observed prices under the PH law $\mathbf{p_{ph}}$:[37]

$$\mathbf{c} = \mathbf{p_{ph}} + (\Lambda. * \Omega(\mathbf{p_{ph}}))^{-1} (\mathbf{q}(\mathbf{p_{ph}}). * diag(\Lambda)) \tag{10}$$

[35] As a robustness test we estimate a wholesaler specific fixed effect using the DISCUS data and use those wholesaler fixed effects to estimate the λ_{ik} for products whose shipments we do not observe. Those results are not qualitatively different from assuming uniform across firms.

[36] To ensure existence of the pricing equilibria, we require that $\beta_i^p < 0$ for all simulated individuals. In practice this is violated less than 0.5% of the time.

[37] This only requires element wise multiplication and matrix inversion to solve.

where $diag(\Lambda)$ is a vector with entries $\lambda_{i_k^*,k}$. Operationally, this means that given a guess of the vector $\mathbf{c}$, we can examine each product and obtain the lowest-cost seller i_j^* to obtain the matrix Λ; this acts as the ownership matrix in the sense of Nevo (2001). We do not assume a functional form for c_{ij} as in Berry, Levinsohn, and Pakes (1995), but instead recover costs non-parametrically for each product-month in 2012.[38]

There is a direct correspondence between the distribution of own price elasticities and median implied markups in Table 8. We find that wholesalers face the most elastic consumers on vodka and gin, and thus the smallest markups. Likewise, consumers of tequila and whiskey tend to be less elastic, and thus those products tend to have higher markups. We think that markups between 25-40% are reasonable for the industry—especially compared to state monopolies, which often have a fixed markup rule on the order of 30-40% over the unit cost.[39] The estimated markups for tequila seem somewhat large, though this may be because we do not observe many tequila purchases in our panelist data, where we observe lower-income consumers spending more per bottle of tequila conditional on purchase. Additionally, because all tequilas are imported from Mexico, even the least expensive tequilas are more expensive than counterparts in other categories.

It is important to note that we assume conduct follows the equilibrium behavior implied by our theoretical model of PH. If we had data on unit costs paid by wholesalers to manufacturer/distillers, we could test different conduct assumptions. Instead, we recover implied markups and marginal costs under alternative conduct assumptions and compare them. While PH eliminates competition within product, it does not necessarily allow for full coordination across products. One possibility is to assume that the firms play a fully collusive equilibrium. If all prices were set by a single monopolist, then all entries of the matrix Λ would be equal to one. Likewise if each product were controlled by a separate firm (or wholesalers ignored cannibalization effects), then Λ would be an identity matrix. We refer to the first case as the *integrated monopoly* solution, and the second case as the *single product monopoly* solution, even though the second case resembles an oligopoly solution as in Nevo (2001). Because almost all products are sold by multiple wholesalers, the competitive oligopoly solution would imply zero markups on the majority of products. We report the distribution of recovered markups under the single product monopoly, PH (empirical Λ

[38]For a few products, the implied marginal cost may be below zero. We experiment with two lower bounds on marginal costs: one at zero, and a second at the federal and state excise burden for the product. The results we report use the tax burden as the lower bound on implied costs. Less than 5% of products have implied marginal costs below the bound.

[39]For example Miravete, Seim, and Thurk (2014) studies the state monopoly in Pennsylvania which charges a 35% fixed markup above cost, plus an 18% sales tax on alcohol sales.

matrix), and integrated monopoly in Figure 5. We find that our estimated markups using the observed Λ matrix are similar to the single-product monopoly markups.[40]

3.4 Counterfactual Policy Experiment

One way to understand the welfare effects of the PH system is to consider a counterfactual policy that holds the consumption of ethanol fixed. We do not view this as a normative prescription for what the state should do in the absence of the PH laws, but rather as a convenient benchmark. This is not an optimal policy, in the sense that the social planner might want to choose a different level of ethanol consumption than the pre-existing level.

Under this policy, we eliminate the PH system and assume wholesalers engage in marginal cost pricing.[41] In order to keep ethanol consumption fixed at PH levels, we would levy an additional tax. We consider two possible forms of the tax: a standard *ad valorem* sales tax that applies only to distilled spirits, or an increase in the specific tax rate (on proof gallons of pure ethanol). We choose to keep the pre-existing level of ethanol consumption fixed because if the negative externality associated with ethanol consumption is atmospheric (i.e., it doesn't depend on which products are consumed or by whom, just aggregate ethanol content), then our counterfactual policies would hold fixed that externality.

We hold the strategic behavior of other tiers (distillers and retailers) fixed; because of the presence of double (or triple) marginalization, it is likely those tiers would have an incentive to increase markups when wholesale markups are eliminated. We do not observe any information about the prices that distillers charge wholesalers. We do observe retail margins, and find that retail margins are often fixed at \$1.00-\$2.00 depending on the product.

In practice, if more than one wholesaler offers the same product, we would expect $\mathbf{p_w} = \hat{\mathbf{c}}$. We assume this is true for all products (even those with exclusive distributors).[42] Implicitly, we assume that products currently distributed by a single wholesaler are offered by at least

[40] Recall, our solution concept assumes a single period competitive pricing equilibrium, in which the result is that the PH rule eliminates the *intra-brand* competition. In a fully repeated game, it might be possible to sustain markups in excess of single-product monopoly markup and closer to the fully integrated monopoly markup.

[41] In practice we view this as a long-run equilibrium benchmark. In the short run, with a small number of players that have been playing a collusive outcome for several decades, we do not expect the market to immediately transition to marginal cost pricing. This implicitly ignores the repeated nature of the game, which may make it possible to sustain a collusive outcome absent the PH law.

[42] Under the PH system there are some strategic incentives for exclusive distribution, but note that exclusive distribution may not be a stable outcome of a game between multiple distillers and wholesalers in Section 2. It is hard to address how these incentives might change absent a much more complicated model of distiller-wholesaler interactions.

two in the counterfactual world.[43] In order to cover the fixed costs of the wholesaler, we provide the wholesalers with a fixed margin of \$1 per bottle for 1L and 750mL bottles, and \$2 per bottle on 1.75L bottles. We label this vector $\mathbf{m_w}$. These margins are chosen to reflect the modal observed retailer margins in the data (since we observe both wholesale and retail prices), so that wholesalers would have margins in line with a typical retailer.

Under an additional sales tax τ, the counterfactual prices are $\mathbf{p_{st}}(\tau) = \hat{\mathbf{c}}(1+\tau) + \mathbf{m_w}$. Under an additional ethanol specific tax t, the counterfactual prices are $\mathbf{p_{et}}(t) = \hat{\mathbf{c}} + t \cdot \mathbf{e} + \mathbf{m_w}$, where $\mathbf{e}$ is a vector that represents the ethanol content of each product (in proof gallons). We then search for values τ and t so that $\mathbf{e} \cdot \mathbf{q}(\mathbf{p_{et}}(t)) = \mathbf{e} \cdot \mathbf{q}(\mathbf{p_{ph}})$ and $\mathbf{e} \cdot \mathbf{q}(\mathbf{p_{st}}(\tau)) = \mathbf{e} \cdot \mathbf{q}(\mathbf{p_{ph}})$.

We report the level of τ and t that solve the aforementioned equations in Table 9. In order to hold ethanol consumption fixed, Connecticut could eliminate PH and raise sales taxes by an additional 35.1% (not including the general sales tax retailers charge on all goods). Such a tax would increase government revenue by 382% when compared to the current tax of \$5.40 per proof gallon. Likewise, we find that the state could increase the specific tax by \$19.68 per proof gallon, which would increase revenue by 364%. At first glance these numbers seem implausibly large. However Miravete, Seim, and Thurk (2014) analyze the state monopoly in Pennsylvania, which follows a 35% fixed markup rule on all products (and also levies and additional 18% sales tax). In other words, our counterfactual taxes are in line with what a control (monopoly) state might do. Table 9 also provides a breakout of existing specific taxes and new specific taxes for a 750mL bottle of Smirnoff Vodka, one of the best-selling products nationwide. Currently, the federal government collects \$1.87 for each bottle, and Connecticut receives \$0.75. Our counterfactual specific tax would roughly double the overall tax burden by increasing it by \$2.72 per bottle.

As an additional exercise, we calculate the variable profit of the wholesale tier under PH $(\mathbf{p_{ph}} - \mathbf{c})\mathbf{q}(\mathbf{p_{ph}})$ and compare that to the additional government revenue raised. The wholesalers are able to charge different prices for different products, but may not fully internalize the cannibalization effects across products (especially for products they do not distribute). Thus in theory it would be possible for the additional government revenue to exceed the wholesaler variable profits under PH. However we find that the government would be able to capture only between 74%-78% of wholesaler variable profit, depending on the type of tax employed.

Another benchmark might be to consider the full Ramsey pricing solution, which holds

[43] Otherwise we have no double marginalization on some products and substantial double marginalization on others.

ethanol consumption fixed. I.e., there is some Lagrange multiplier λ or revenue constraint R of the Ramsey problem for which the ethanol consumption would match the consumption under the PH system. This problem more closely resembles the problem of the fully integrated multiproduct monopolist from Figure 5. Compared to this benchmark, our additional taxes would raise only around half as much revenue as the Ramsey solution. Likewise, the Ramsey solution would earn more revenue than wholesalers currently do under PH, because it is able to fully incorporate cannibalization effects. As the Ramsey solution requires setting a different tariff on each product, this represents a theoretical benchmark rather than a practical option.

3.5 Counterfactual Welfare

We also report the welfare effects of replacing the PH system with an additional specific tax; we choose the specific tax because this is the tool most commonly employed by policymakers.[44] Using the estimated demand system, we are able to compute the change in consumer surplus as we move from $\mathbf{p_{ph}}$ to $\mathbf{p_{et}}$. We report welfare effects in percentage terms for each product category, and each of our ten income buckets in Table 10.

Some important patterns emerge in the welfare effects. We begin with the vodka category, in part because it represents 45% of overall sales, and in part because the welfare effects are representative for the market as a whole. Most consumers are better off under the additional specific tax than under the PH system, especially those households with income between \$100K-\$125K. These households benefit because the relative margins under the PH system were higher on the premium products, and they are able to substitute to higher quality products at lower prices. For products consumed by these households, the additional tax increase is substantially smaller than the wholesaler's margin on products such as a 750mL bottle of Grey Goose Vodka. The highest income households (\$150K+ in annual income) are so price-insensitive that they are only slightly better off when their preferred products become less expensive. Meanwhile, the very poorest households that were often consuming the least expensive vodka under the PH system are substantially worse off under the counterfactual tax, because the implied markups on the least expensive products were smaller than the additional tax required to hold consumption fixed. The welfare patterns for consumers of rum are qualitatively similar to those of vodka. Because tequila is a relatively expensive product without a substantial low-end segment, and implied markups are large, eliminating the wholesale markup increases utility for all consumers. This increase in utility is roughly

[44] Similar results are available for the sales tax upon request, but omitted for space considerations.

similar for all income groups, because our micro-data indicated that there was no apparent correlation between price paid for tequila and income. Whiskey follows a similar pattern with across-the-board welfare gains, because the tax increase is generally smaller then the wholesale margin under PH. Gin has the opposite pattern: a relatively small number of products, low prices on average, few premium brands, and more elastic demands imply the smallest markups of any product category. Paired with the fact that the alcohol content in gin is always 40% or more, this means the the tax increase often exceeds the wholesale markup under PH, and thus consumers are worse off in the counterfactual world independent of income level.

Overall welfare results indicate that on average, consumers of all income groups fare better under the alternative tax rather than with the PH system. Households earning less than $25K per year are $4.89 better off, while households earning more than $150K per year are around $77.20 better off. These estimates seem reasonable, given that the average annual per-capita consumption of distilled spirits is 1.7 gallons, or approximately 16 liters per household. This results in a benefit of about $0.25 per liter for the lowest-income households and around $4.50 per liter for the highest-income households. If we looked at the vodka market in isolation (rather than aggregating welfare changes across categories), this implies that households in the lowest three income groups (less than $25k, $25-30K, and $30-45K) would be worse off by a respective $2.10, $0.30, $0.44 per household per year. The highest-income households (over $150K) would be better off by $16.52.

The primary source of the welfare gains comes not from marginal consumers choosing between spirits purchases and the outside good, but rather from infra-marginal allocation of consumers to products. We summarize this substitution for the vodka category in Table 11. We find that when we move from PH to the additional specific tax (holding ethanol consumption fixed), we see that the share of 1.75L bottles falls by nearly a third as consumers reallocate to smaller 750mL and 1L bottles. Likewise the share of flavored vodka purchased (which is usually 60 proof or 30% alcohol by volume (A.B.V.) instead of 80 Proof or 40% A.B.V) increases from 18% to 30%. Strikingly, even though the average bottle size falls in the counterfactual world, the average price per bottle increases almost 15% from $18.81 to $22.16 (in PH system pricing).[45] Thus consumers are substituting away from large bottles of the least expensive vodka towards higher priced premium branded products, and towards less alcoholic flavored vodkas. Even by employing a sales tax that does not directly target

[45] Recall that our price indices indicated that the bundle of spirits in Connecticut was around 8% less expensive than the bundle purchased by consumers in Massachusetts. See Table 5.

ethanol content, consumers still shift towards flavored vodkas and smaller package sizes, and away from the least expensive vodka brands.

To see more clearly how consumers reallocate among products, Table 12 describes the five products with the largest increase and the five products with the largest decrease in marketshare. We label these the *winners* and *losers*, respectively. Three of the top five winners are super-premium vodkas (two Grey Goose, and one Ciroc Peach). The share of 750mL Grey Goose essentially triples from 0.26% to 0.85% as the price goes from $26.50 to $17.83. In the least expensive states, this product is available for around $21.99 at retail, which suggests a $17.83 wholesale price might be reasonable. The biggest change is for Macallan 12-year (a premium single-malt Scotch whisky). Here the price drops from $42.16 to $14.46. This seems too large to justify using prices in other states; however this represents the largest change for any of our 660 products.

Similarly 1750mL bottles of Dubra Vodka go from $10.20 under PH to $17.27 when we increase the specific taxes, and the market share falls from 0.33% to 0.03%. Using specific taxes rather than market power to reduce consumption essentially eliminates the market for Dubra, the least expensive source of ethanol in our sample. This may actually be more reasonable than it appears, as Dubra is currently sold only in Connecticut and maintains no advertising presence (no website, no social media profile). Dubra Vodka competes solely on price, yet is one of the top products by volume in the Nielsen dataset. Because it is consumed primarily by less affluent, more price-sensitive consumers, and the value end of the vodka market is quite crowded (with Sobieski and Popov), the implied wholesaler markup is quite small, while the high ethanol content means the additional tax burden would be very large. By using taxes rather than PH to discourage alcohol consumption, we see that the least expensive sources of ethanol get pushed out of the market.

4 Discussion and Conclusion

This paper demonstrates how PH legislation, which governs wholesale alcohol pricing in many states, acts as a device to facilitate collusion. The collusive outcome emerges as the unique iterated-weak-dominant equilibrium of a single period (non-repeated) game. Using panel regressions exploiting variation in when states have repealed their PH laws, we find that states that eliminate PH regulations see an increase in consumption of around 8-10%. Using the same identification strategy, we find no positive relationship between PH regulations and retail employment within the spirits industry. If anything, PH laws are associated with fewer retail establishments and a lower share of employment in the alcohol retailing sector, but are possibly associated with small increases in the fraction of retailers that operate very small stores. Using a detailed dataset on posted prices, scanner data, and wholesale shipments for the state of Connecticut, we estimate a structural model and find that that eliminating PH laws would lead to a similar increase in purchases and consumption as the panel regressions predict. At the same time, our structural model indicates an important additional source of welfare loss created by these pricing distortions. Because market power leads firms to price to inverse elasticities, relative markups are higher on higher-quality premium products, and consumers distort their purchase decisions downwards on the quality ladder. If we could eliminate the PH system, we could raise taxes and hold ethanol consumption fixed, while making consumers better off. This result is not typically predicted in the public finance literature on optimal taxation. It can be achieved because consumers substitute towards smaller bottles of higher-quality products, or from higher-proof products towards lower-proof flavored products.

Our intuition from the case of homogenous products indicates that it is largely irrelevant whether consumption is restricted via market power (such as a monopolist) or taxation. Our results indicate, however, that for differentiated products, the consequences can be quite substantial. We show that a lack of competition in the wholesale tier doesn't just lead to higher prices and lower quantities, but that a monopolist or cartel has incentives to distort relative prices. It is worth noting that the standard Harberger (1954) or sufficient statistics approach would not predict any deadweight loss from misallocation of consumers to goods, because for small changes in taxes, inframarginal allocation of consumers to goods does not affect welfare. In those settings, a policy that holds aggregate consumption fixed would necessarily hold consumer surplus fixed. This highlights an important difference between market structure and incremental tax increases when used as regulatory tools for discouraging consumption. This also highlights the important policy implication: as a tool designed to further the state interest of reducing alcohol consumption, the PH system is a particularly costly and ineffective mechanism.

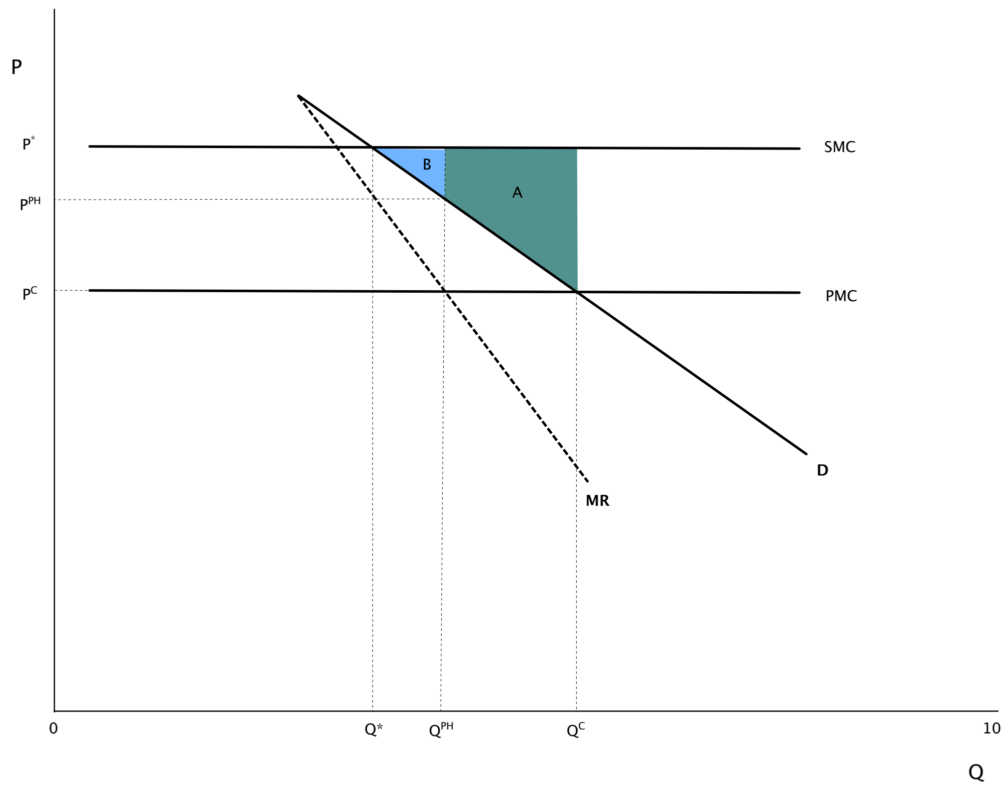

Figure 1: Post and Hold in a Market with a Negative Externality

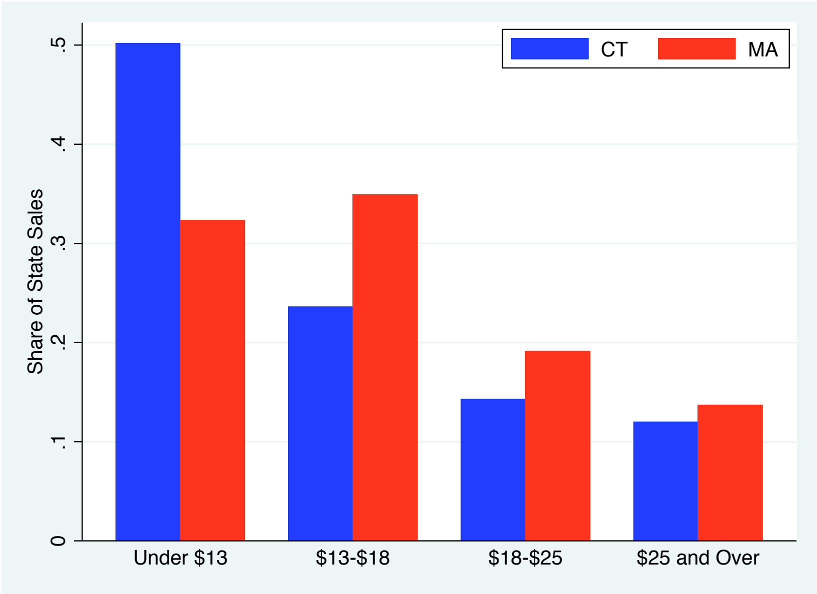

Figure 2: Comparison Vodka Consumption by Price Per Liter, Connecticut vs. Massachusetts

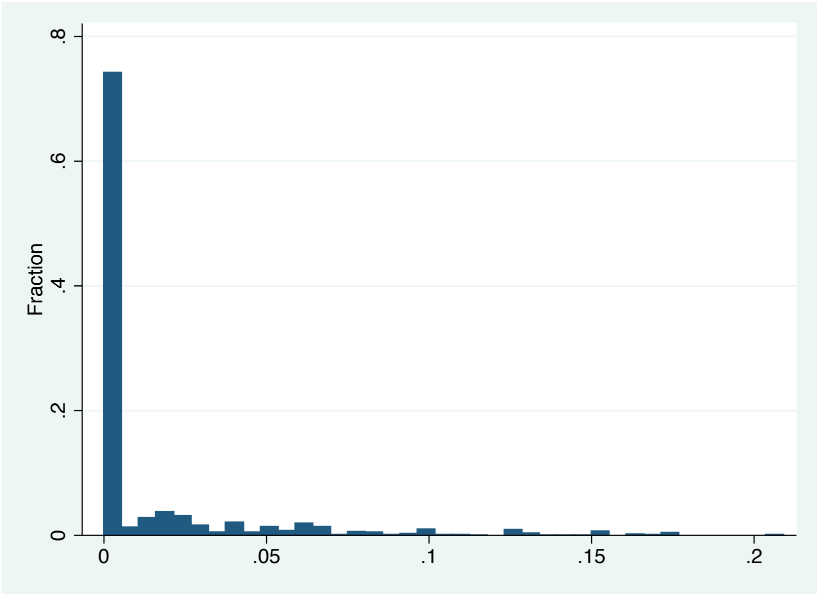

Figure 3: Price Spreads As A Fraction of Mean Bottle Price for Each Product-Month

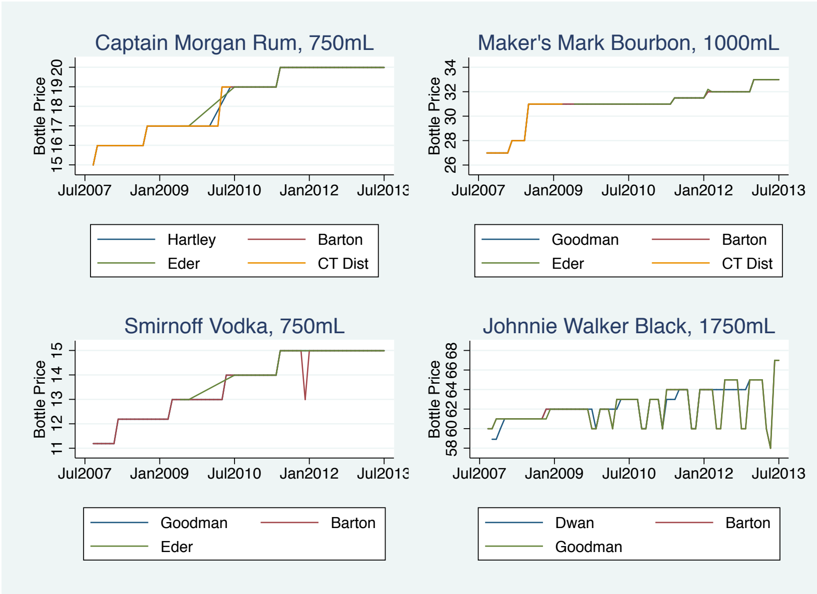

Figure 4: Bottle Price Over Time, by Product

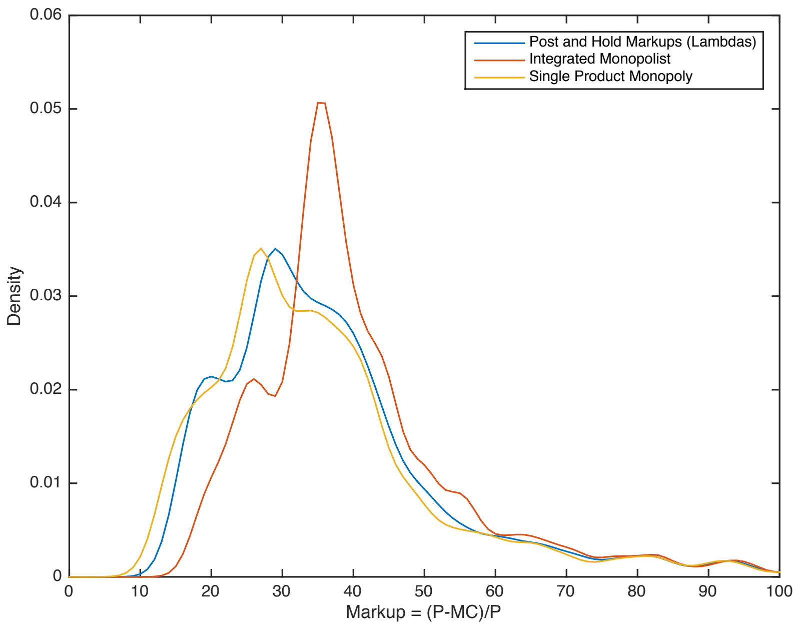

Figure 5: Distribution of Markups Under Different Conduct Assumptions

Table 1: Product Characteristics

Spirit Category	Price	Proof	Products	Market Share	Size Shares		
					750s	1Ls	1750s
Gin	$ 18.92	87.88	44	7.70%	27.27%	24.85%	47.88%
Rum	$16.54	74.10	119	18.14 %	38.61%	30.10%	31.29%
Tequila	$ 24.95	80.09	53	4.67%	48.26%	33.09%	18.64%
Vodka	$ 17.84	79.04	248	42.53%	32.14%	23.78%	44.09%
Whiskey	$ 23.64	81.52	196	26.96%	34.19%	25.90%	39.91%

Note: Price and Proof are category means weighted by units sold. Products is the count of distinct brands and sizes. Market Share is the fraction of all of cases sold. Size Shares are the fraction of category sales attributable to each container size. Prices are converted to December 2012 dollars using CPI-U.

Table 2: States with Post and Hold Laws

	Wine	Beer	Spirits
Connecticut	Y	Y	Y
Delaware	End 1999	End 1999	End 1999
Georgia	N	Y	Y
Idaho	Y	Y	N
Maine	Y	Y	N
Maryland	End 2004	End 2004	End 2004
Massachusetts	End 1998	End 1998	End 1998
Michigan	Y	Y	Y
Missouri	Y	N	Y
Nebraska	End 1984	N	End 1984
New Jersey	Y	Y	Y
New York	Y	Y	Y
Oklahoma	End 1990	End 1990	Y
Pennsylvania	N	End 1990	N
South Dakota	Y	N	Y
Tennessee	N	Y	N
Washington	End 2008	End 2008	N
West Virginia	N	N	Y

Note: Y denotes a state with PH provisions. N denotes states that never had PH laws. The year of repeal is is denoted for states that changed their PH regulations. No state adopted PH after the start of sample period, 1983. This table is a reproduction of Table 1 of Cooper and Wright (2012).

Table 3: Post and Hold Laws and State Alcohol Consumption

	(All)	(All)	(All)	(PH only)	(PH NE)
Wine					
PH	-0.0545***	-0.0623***	-0.0229	-0.0345*	-0.00430
	(0.0183)	(0.0183)	(0.0192)	(0.0190)	(0.0340)
R^2	0.965	0.966	0.984	0.986	0.984
Beer					
PH	-0.0155	-0.0283***	-0.0242**	-0.0201**	-0.0276**
	(0.0113)	(0.0107)	(0.0095)	(0.0081)	(0.0129)
R^2	0.891	0.905	0.969	0.960	0.991
Spirits					
PH	-0.00702	-0.0423**	-0.0787***	-0.0854***	-0.0979***
	(0.0175)	(0.0168)	(0.0180)	(0.0187)	(0.0278)
R^2	0.950	0.955	0.982	0.976	0.986
Year FE	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y
Demog. Controls	N	Y	Y	Y	Y
State Time Trends	N	N	Y	Y	Y
PH States	N	N	N	Y	N
NE States	N	N	N	N	Y
Observations	1,428	1,428	1,428	513	243

Note: The table presents coefficients from regression 4. The outcome of interest is the log of apparent consumption per capita, where consumption is in ethanol equivalent gallons and the relevant population is state residents age 14 and older. Column 1 only includes state and time fixed effects. Column 2 adds state demographic controls and column 3 adds state-specific time trends. Column 4 limits the sample to states that have had PH laws. Column 5 restricts the sample further to only northeastern states that once had PH laws. Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Post and Hold Laws and Alcohol Retailing

	2010 Only	All	All	Northeast
Share of 1-4 Employee Retailers	0.0705	0.0334	0.0454*	0.0466**
	(0.0436)	(0.0209)	(0.0262)	(0.0227)
R-Squared	0.129	0.868	0.940	0.962
Log(Alcohol Employment/Pop 14+)	0.451	-1.753***	-0.482**	-0.431*
	(0.336)	(0.198)	(0.240)	(0.224)
R-Squared	0.066	0.467	0.739	0.819
Log(Liquor Stores Per Capita)	0.337	-1.336***	-0.599***	-0.514***
	(0.201)	(0.0866)	(0.0913)	(0.103)
R-Squared	0.149	0.855	0.954	0.963
Obs	51	1275	1275	300
Demog Controls	Y	Y	Y	Y
State FE	N	Y	Y	Y
Year FE	N	Y	Y	Y
State Specific Trends	N	N	Y	Y

Note: The table presents coefficients from regression 4. The outcome of interest is the share of retailers with 1-4 employees in the uppermost panel, the log of employment in the liquor retail sector per capita in the middle panel, and log of liquor stores per capita in the bottom panel. Column 1 uses only data from 2010 and includes demographic controls. Columns 2 through 4 use the full 1986 - 2010 panel. Column 2 adds state and year fixed effects. Column 3 adds state specific time trends and column 4 limits the sample to only northeastern states. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Price Indices and Excise Taxes by State (License States)

State	Index (CT Q)	Index (MA Q)	Excise Tax	Net of Tax (CT)	Net of Tax (MA)
ME	26.95	29.60	5.80	25.10	27.64
NE	26.31	28.93	3.75	25.11	27.66
NM	26.51	29.45	6.06	24.58	27.40
TX	25.91	28.01	2.40	25.15	27.20
SC	25.12	27.28	5.42	23.39	25.45
AR	25.39	27.90	6.57	23.29	25.69
LA	25.04	27.37	2.50	24.25	26.52
CT	25.03	27.17	5.40	23.31	25.35
WI	25.37	28.12	3.25	24.33	27.02
IL	24.79	26.73	8.55	22.06	23.85
IN	25.23	28.00	2.68	24.38	27.09
MO	25.05	27.50	2.00	24.41	26.82
SD	25.22	27.79	4.68	23.72	26.21
KY	24.79	27.02	6.76	22.63	24.74
NJ	24.42	25.99	5.50	22.66	24.13
NY	24.19	25.66	6.44	22.13	23.49
MD	24.53	26.91	4.41	23.12	25.42
MN	24.27	26.82	8.71	21.49	23.88
NV	23.57	25.28	3.60	22.42	24.07
MA	23.32	24.71	4.05	22.02	23.35
AZ	23.49	25.49	3.00	22.53	24.48
GA	23.50	25.45	3.79	22.29	24.17
DE	22.52	24.48	3.75	21.33	23.21
FL	22.14	23.82	6.50	20.06	21.62
CO	22.10	23.79	2.28	21.37	23.02
CA	21.85	23.60	3.30	20.80	22.48

Table 6: Demand Estimates, Logit and Nested Logit, RCNL

	Logit	LogitIV	NLogit	NLogitIV	RCNL
α_p	-2.1814***	-4.6013*	-5.0775***	-4.5171***	-11.3268***
	(0.4483)	(2.4471)	(0.6442)	(0.6673)	(0.2474)
ρ			0.9923***	0.8830***	0.8936***
			(0.0041)	(0.0365)	(0.0037)
σ_p					5.4082***
					(0.0869)
σ_e					-7.6563***
					(0.1046)
ρ_{pe}					-1
					(n/a)
Price Instrumented	No	Yes	Yes	Yes	Yes
(σ, ρ) Instrumented	n/a	n/a	No	Yes	Yes
Observations	27,027	27,027	27,027	27,027	27,027
R^2	0.2789	0.2736	0.9346	0.9308	n/a
# Prod FE	660	660	660	660	660
GMM Obj				1259	596

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Distribution of Connecticut Households By Annual Income

Income Range	MidPoint	Population Share	Purchase Prob.	Mean Price	Mean Proof-Gallon
$0 to $24,999	$12,500	13.60	0.0083	$15.31	0.300
$25,000 to $29,999	$27,500	3.37	0.0098	$16.47	0.329
$30,000 to $44,999	$37,500	10.28	0.0108	$18.14	0.236
$45,000 to $49,999	$47,500	3.11	0.0119	$21.51	0.314
$50,000 to $59,999	$55,000	6.76	0.0126	$20.67	0.288
$60,000 to $69,999	$65,000	6.28	0.0136	$19.10	0.334
$70,000 to $99,999	$80,000	17.68	0.0156	$18.90	0.315
$100,000 to $124,999	$112,500	11.12	0.0184	$28.90	0.339
$125,000 to $149,999	$137,500	7.90	0.0210	$17.53	0.328
$150,000 +	$200,000	19.90	0.0273	$25.20	0.241

Note: The population shares reported above come from the 2012 American Community Survey for Connecticut and are weighted by the Census-provided household weight. The Purchase Probability, Mean Price and Mean Proof-Gallon are tabulated from the Nielsen household panel and are weighted by Nielsen projection factors. Purchase Prob is the average predicted probability of spirits purchase in a given month from a bivariate regression of a purchase dummy on the midpoints of each income bucket. Mean Price is the average purchased product price for each income group and Mean Proof Gallon is the average proof gallon of ethanol of purchased products by income group.

Table 8: Demand Estimates, Random Coefficients with Micro-moments

	Whiskey	Gin	Rum	Tequila	Vodka
α_p	-17.94	-55.83	-36.35	-7.68	-35.33
	[1.05]	[13.76]	[7.75]	[4.64]	[5.62]
π_p	13.08	15.88	16.03	1.36	40.23
	[0.002]	[4.26]	[5.15]	[0.02]	[5.25]
π_e	-10.21	-4.58	-10.00	-7.17	-19.99
	[0.002]	[1.21]	[2.00]	[0.03]	[0.37]
π_0	-0.73	-1.79	-0.52	1.30	-2.16
	[0.0002]	[0.43]	[0.58]	[0.006]	[0.86]
σ_p	0.00	17.38	8.80	0.00	0.00
	n/a	[3.83]	[5.86]	n/a	n/a
σ_{pe}	0.00	-3.79	-0.47	0.00	7.58
	n/a	[1.74]	[3.40]	n/a	[1.55]
GMM Obj	203.07	40.93	105.31	34.08	281.57
Product FE	196	44	119	53	248
Observations	8944	2097	4721	2247	9018
Price/Inc Slope	1.53	1.22	1.08	0.91	1.91
Ethanol/Inc Slope	0.78	1.01	0.78	0.79	0.84
Purchase/Inc Slope	1.30	1.30	1.30	1.30	1.30
Elas 75%	-1.93	-2.74	-2.62	-1.22	-3.35
Elas 50%	-2.61	-3.69	-3.00	-1.70	-3.80
Elas 25%	-3.13	-5.04	-4.33	-2.27	-5.75
Median Implied Markup	39.58	26.73	35.34	58.80	28.15

Table 9: Raising Taxes to Hold Alcohol Consumption Fixed

	Specific Tax	Sales Tax
Tax Increase	$19.68 per p.g.	35.1%
Per 750mL Smirnoff at 80PF		
Pre-Existing	2.62	
Federal	1.87	
State	0.75	
New Revenue	2.72	
Grand Total	5.35	
Change in Alcohol Consumption	0%	0%
Change in Gov't Revenue	364%	382%
Fraction of Wholesaler Variable Profit	74.4%	78.1%

Table 10: Percentage Change in Consumer Surplus by Category and Income Group (Post and Hold system replaced by Specific Tax)

	Whiskey	Gin	Rum	Tequila	Vodka	Overall CV
$0 to $24,999	37.0	-17.3	-2.7	15.1	-20.7	$4.89
$25,000 to $29,999	39.1	-16.0	-0.7	15.1	-11.0	$10.14
$30,000 to $44,999	39.9	-15.0	0.5	15.0	-4.9	$13.81
$45,000 to $49,999	40.2	-14.1	1.6	14.9	0.9	$17.65
$50,000 to $59,999	40.1	-13.5	2.4	14.9	5.1	$20.65
$60,000 to $69,999	39.6	-12.6	3.2	14.8	10.4	$24.83
$70,000 to $99,999	37.6	-10.9	4.7	14.6	19.4	$33.92
$100,000 to $124,999	32.5	-8.5	6.0	14.3	24.8	$48.05
$125,000 to $149,999	25.8	-6.5	6.6	14.0	13.2	$61.84
$150,000 +	3.8	-2.3	5.9	12.9	1.4	$77.20

Overall Compensating Variation aggregates compensating variation across categories and is reported in dollars per household per year.

Table 11: Product Level Effects of Alternative Policies: Vodka

	Post and Hold	Specific Tax	Sales Tax
Flavored Share	18.77	30.82	24.42
750mL Share	36.06	56.32	47.36
1750mL Share	47.20	15.12	19.93
Avg PH Price	18.81	22.16	18.91

Table 12: Individual Products with Largest Changes (Post and Hold system replaced by Specific Tax)

Winners	Size	PH Price	Alt. Tax Price	PH Share	Alt. Tax Share
MACALLAN 12YR	750	42.16	14.46	0.07	0.85
JOHNNIE WALKER BLACK	1750	60.40	34.81	0.08	0.64
GREY GOOSE VODKA 80	750	26.50	17.83	0.26	0.85
GREY GOOSE VODKA 80	1000	31.99	22.06	0.34	1.05
CIROC PEACH VODKA 60	750	27.22	15.84	0.16	0.76
Losers					
DUBRA VODKA 80PF	1750	10.20	17.27	0.33	0.03
SOBIESKI POLAND 80PF	1750	16.16	23.00	0.49	0.05
SVEDKA VODKA 80PF	1750	20.20	26.29	0.32	0.06
POPOV VODKA 80PF	1750	14.40	20.89	0.30	0.03
SMIRNOFF VODKA 80PF	1750	20.62	26.65	0.81	0.16

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Print Appendix

Proof for Theorem 1(a)
Consider a two-stage strategy of the form $\sigma_i(p_i^0, p_i^1)$. The second stage admits the unique dominant strategy where all players set $p_i^{1*} = \max\{c_i, \underline{p_i^0}\}$ where $\underline{p_i^0} = \min_i p_i^0$. For strategies of the form: $\sigma_i(p_i^0, \underline{p_i^0})$: $\sigma_i(p_i + \epsilon, \underline{p_i^0}) \geq \sigma_i(p_i, \underline{p_i^0})$ for $p_i \in [c_i, p_i^m)$. By induction the unique Nash Equilibrium to survive iterated weak dominance is $\sigma_i(p_i^m, \underline{p_i^0})$.

A. Online Appendix

A.1 Extensions of Theoretical Result

Consider the case of two upstream firms A and B, who manufacture products and sell via distributors. Assume that A and B employ a uniform price schedule, and distributors sell via a post and hold system. We can analyze the effect of different distribution arrangements. First, the post and hold system eliminates *intrabrand* competition. That is, without an opportunity cost advantage, adding distributors will not result in lower prices. If A and B share a common distributor, this softens the *interbrand* competition, as the distributor internalizes the effect that selling more of A may be stealing business from B (it increases the opportunity cost). Under post and hold, an exclusive distributor for each product might actually result in lower prices than under *common agency*.[46] At the same time, A can raise its rival B's cost, by selling products through B's previously exclusive distributor, which now internalizes the cannibalization effect. This might not increase A's prices if A's exclusive distributor remains the lowest opportunity cost seller. In this case, exclusive arrangements follow a prisoner's dilemma; thus exclusive dealing arrangements might be welfare enhancing though unstable as an equilibria.

The *meet but not beat* or *look back* provision in the CT post and hold system simplifies the equilibrium by creating a dominant strategy sub-game. Policymakers might be interested in the effect of maintaining the post and hold system but eliminating the *meet but not beat* provision. In that case, each period firms submit a uniform price schedule, and are unable to adjust for 30 days, but without a second stage where prices are updated.

In general, analysis would require considering a repeated game, though the market would still have several features that facilitate non-competitive pricing. The price posting system provides both commitment and monitoring for wholesalers. This removes much of the difficulty (stemming from uncertainty) associated with maintaining a cartel such as in Green and Porter (1984), and is more similar to the stylized case of Stigler (1964). In addition, the stages of the game are relatively large discrete intervals. Given that the same firms repeatedly engage in the same pricing game month after month, it is reasonable to think that the folk theorem applies. Firms could employ the grim-trigger strategy of marginal cost pricing, and use this as a threat to deter firms from deviating from the collusive price. This prediction is less strong than under *meet but not beat* where we can

[46]Note: Common agency in general may increase or decrease prices, though usually it depends on hidden actions by downstream firms or multiple periods or more complicated contracts. For example, Rey and Vergé (2010) show how resale price maintenance can be used to eliminate both interbrand and intrabrand competition and cartelize the entire market with a series of nonlinear bilateral contracts.

refine away all but the monopoly pricing equilibrium in a single static game. From now on, we confine our analysis to the static game with the *meet but not beat* provision.

A.2 Optimal Alcohol Taxes with a Negative Externality and a Revenue Constraint

States raise substantial revenue from taxing alcoholic beverages through both specific and ad valorem taxes. Connecticut raised over \$60M in 2012 from its specific tax alone.[47]. In taxing alcoholic beverages, the state could be advancing two potential goals. The first is to correct for the negative public health externalities arising from excessive consumption summarized by Cook and Moore (2002). The second is to raise revenue. We consider the optimal structure of alcohol taxes in the case where the state has only the single goal of addressing the externality and the case where the state has dual goals of correcting the public health externality and raising revenue for budgetary reasons.

Consider the case where the state may want to raise tax revenue from alcohol purchases in addition to correcting the "atmospheric" negative externality arising from alcohol consumption. The negative externality here arises from the ethanol in alcoholic beverage products, $x_1, x_2, .., x_n$. Ethanol content may vary across products. The marginal damage of an additional unit of ethanol, however, is assumed to be identical across products–that is, while proof may vary across products the externality of ethanol consumption does not vary across alcoholic beverages. Each individual's consumption decision is unaffected by the atmospheric externality.

The problem of optimally setting Ramsey taxes in the presence of externalities has been the subject of extensive previous work. We draw heavily on Diamond and Mirrlees (1971)'s discussion of optimal commodity taxation rules as well as Sandmo (1975)'s construction of the optimal tax on a single good in the presence of a production externality and independent demands, and Bovenberg and Goulder (1996)'s formulation in the presence of environmental externalities.

Here, a representative agent derives utility from his alcohol purchases, $x_1, x_2, ...x_n$ but the ethanol content of each of these alcohol products also inflicts a negative externality. The state sets consumer prices, $p_1, p_2, ..., p_n$, to maximize social surplus given its revenue requirement. The social benefit of consumption is the sum of the areas under the product demand curves, $SB = SB(x_1, x_2, ..., x_n) = \sum_{j=1}^{n} \int_0^{x_j} p_j(x_1, x_2, ..., x_{j-1}, Z_j, x_{j+1}, ..., x_n) dZ_j$, where $p_j(\cdot)$ is the inverse demand for product j and Z_j is the dummy of integration. The social cost, $SC = SC(x_1, x_2, ..., x_n)$, is the sum of the private cost to producers, $C(x_1, x_2, ..., x_n)$ plus whatever damage to public health and safety the negative externality of consumption inflicts. The state's objective is to maximize the following Lagrangian expression:

$$L = SB(x_1, x_2, ..., x_n) - SC(x_1, x_2, ..., x_n) + \lambda[\sum_{j=1}^{n} p_j x_j - C(x_1, x_2, ..., x_n) - R]$$

where R is the revenue is the state's revenue requirement and λ is the shadow cost raising the marginal dollar of revenue.

[47]From http://www.bloomberg.com/visual-data/best-and-worst/most-tax-revenue-from-alcohol-tobacco-betting-states. The state of Connecticut does not separately track sales tax revenue from alcohol sales.

There are two sets of first-order conditions for this constrained optimization problem. The first applies to the Lagrangian multiplier, λ:

$$\frac{\partial L}{\partial \lambda} = 0 = \sum_{j=1}^{n} p_j x_j - C(x_1, x_2, ..., x_n) - R$$

meaning that the budget constraint must be satisfied. The second set of conditions applies to the prices, $(p_1, p_2, ..., p_n)$:

$$\frac{\partial L}{\partial p_i} = 0 = \sum_j p_j \frac{\partial x_j}{\partial p_i} - \sum_j \frac{\partial SC}{\partial x_j}\frac{\partial x_j}{\partial p_i} + \lambda \left[x_i + \sum_j p_j \frac{\partial x_j}{\partial p_i} - \sum_j \frac{\partial C}{\partial x_j}\frac{\partial x_j}{\partial p_i} \right]$$

If we denote the marginal social cost by $MSC_j = \frac{\partial SC}{\partial x_j}$ and the marginal private cost by $MPC_j = \frac{\partial C}{\partial x_j}$ and collect terms, the expression becomes:

$$0 = \sum_j (p_j - MSC_j) \frac{\partial x_j}{\partial p_i} + \lambda \left[\sum_j (p_j - MPC_j) \frac{\partial x_j}{\partial p_i} + x_i \right]$$

Or in elasticity terms,

$$0 = \sum_j (p_j - MSC_j) \eta_{ji} \frac{x_j}{p_i} + \lambda \left[\sum_j (p_j - MPC_j) \eta_{ji} \frac{x_j}{p_i} + x_i \right]$$

Separating product i from the rest of the j products, and dividing through by $\eta_{ii} x_i$ yields:

$$0 = \sum_{j \neq i} \frac{p_j - MSC_j}{p_i} \frac{\eta ji}{\eta ii} \frac{x_j}{x_i} + \lambda \sum j \neq i \frac{p_j - MPC_j}{p_i} \frac{\eta ji}{\eta ii} \frac{x_j}{x_i} + \frac{p_i - MSC_i}{p_i} + \lambda \frac{p_j - MPC_j}{p_i} + \frac{\lambda}{\eta ii}$$

which can be rearranged into:

$$\frac{p_i - \left(\frac{1}{1+\lambda} MSC_i + \frac{\lambda}{1+\lambda} MPC_i \right)}{p_i} = -\frac{\lambda}{1+\lambda} \frac{1}{\eta_{ii}} - \sum_{j \neq i} \frac{\eta_{ji} p_j x_j}{\eta_{ii} p_i x_i} \left[\frac{p_j - \left(\frac{1}{1+\lambda} MSC_j + \frac{\lambda}{1+\lambda} MPC_j \right)}{p_j} \right]$$

Since the marginal social cost is the sum of the marginal private cost and the marginal external cost (the decline in public health and safety from marginally more consumption of product i), $MSC_i = MPC_i + MEC_i$, we can simplify the expression:

$$\frac{p_i - (MPC_i + \frac{1}{1+\lambda}MEC_i)}{p_i} = -\frac{\lambda}{1+\lambda}\frac{1}{\eta_{ii}} - \sum_{j\neq i}\frac{\eta_{ji}}{\eta_{ii}}\frac{p_j x_j}{p_i x_i}\left[\frac{p_j - (MPC_j + \frac{1}{1+\lambda}MEC_j)}{p_j}\right]$$

where η_{ji} is the uncompensated cross-price elasticity of demand for product j with respect to price p_i.

The cross-price elasticities are not assumed to be zero, so the above expression does not reduce to the familiar Ramsey "inverse elasticity" rule. Markups depend not only on the production costs and own-price elasticities, but also on some fraction of the social cost, as well as cross-price elasticities. This means that we expect the planner to set relatively lower markups on goods that compete closely with products that contribute more to the negative externality. A good example is that flavored vodkas are usually 60 Proof (30% Alcohol by Volume), standard vodka is usually 80 Proof, and overproof vodka is usually 100 Proof. If these are all close substitutes and the externality is large, the planner may want to reduce the price of the flavored vodka relative to the overproof or regular vodka. As the planner becomes more concerned with revenue ($\lambda \uparrow$), markups should rise on less elastically demanded products and those with fewer close substitutes.

In the case where the state seeks to only correct the negative externality of alcohol consumption, there is no revenue constraint, $\lambda = 0$, and the expression becomes:

$$\begin{aligned}\frac{p_i - (MPC_i + MEC_i)}{p_i} &= -\sum_{j\neq i}\frac{\eta_{ji}p_j x_j}{\eta_{ii}p_i x_i}\left[\frac{p_j - (MPC_j + MEC_j)}{p_j}\right] \\ \rightarrow p_i &= MPC_i + MEC_i \quad \forall i\end{aligned} \tag{11}$$

Without the revenue constraint, the optimal prices are equal to the marginal social cost.

A.3 The Additive Property and Principle of Targeting

In equation **??** the state's mark-ups address both the externality and raise sufficient revenue across the n products to meet the state's revenue requirement R. Equation 11 provides some intuition for a two-step approach to the problem. As has been detailed by Sandmo (1975) and Oum and Tretheway (1988) and shown to be reasonably general by Kopczuk (2003), Dixit (1985)'s "Principle of Targeting" renders the correcting of externalities a problem that is independent of the optimal allocation of taxes across commodities to meet a revenue target.

The "additive property" yields the following policy prescription: first correct the externality using a Pigouvian tax so as to set the effective marginal cost equal to the marginal social cost, then apply optimal tax rates to the goods, taking into account the fact that the prices of the externality producing goods have been corrected by the Pigouvian tax and these Pigouvian taxes raise revenue, reducing the amount to revenue the optimal commodity taxes must raise. The second part of the policy prescription is simply the standard second-best optimal Ramsey commodity tax problem where the price of alcohol has been increased to reflect its social cost and the revenue requirement has been reduced to reflect collections from the Pigouvian taxes. In other words the state can set a tax according to equation 11 to address the externality, then solve the typical Ramsey problem to raise revenue $R - R_P$ where R_P is the revenue resulting from the Pigouvian taxes. The higher the marginal external cost of alcohol consumption, the higher the revenue resulting from the Pigouvian taxes and the smaller the Ramsey taxes as a share of the mark-ups.

A.4 Optimal Taxes vs. Monopoly Prices

A monopolist would of course solve a different problem; he or she would sets mark-ups to maximize profit without regard to the externality of alcohol consumption: $\lambda \to \infty$. The monopolist's optimal mark-ups satisfy:

$$\frac{p_i - MPC_i}{p_i} = -\frac{1}{\eta_{ii}} - \sum_{j \neq i} \frac{\eta_{ji} p_j x_j}{\eta_{ii} p_i x_i} \left[\frac{p_j - MPC_j}{p_j} \right] \tag{12}$$

The state cannot feasibly raise revenue beyond monopoly levels as Equation (12) is strictly nested by (**??**).

Imagine that the negative externality arises entirely from the ethanol content of a product ($proof \times size$). The planner takes the externality in account when setting prices, and the monopolist does not. Meanwhile, imagine consumers derive utility from other features of the product such as taste or branding. Here a planner concerned only with the externality would ignore branding, and a planner concerned with both revenue and the externality $0 < \lambda < \infty$, would trade off pricing against the MEC and the elasticity of demand according to λ.

A.5 Surplus Calculations

Given estimates of $\mathbf{c_t}$, under random coefficients logit demands we obtain the tax level t^* (where p_{kt} denotes the tax inclusive market price) which sovles:

$$\int \frac{1}{1 + \sum_k \exp[\alpha_i^x x_{kt} - \alpha_i^p p_{kt} + \xi_{kt}]} f(\alpha_i|\alpha, \Sigma) = \int \frac{1}{1 + \sum_k \exp[\alpha_i^x x_{kt} - \alpha_i^p (c_{kt} + t^*) + \xi_{kt}]} f(\alpha_i|\alpha, \Sigma) \tag{13}$$

As an aside, the proportional substitution property of the logit model implies that:

$$\log\left(1 + \sum_k \exp[\alpha^x x_{kt} - \alpha^p p_{kt} + \xi_{kt}]\right) = \log\left(1 + \sum_k \exp[\alpha^x x_{kt} - \alpha^p (c_{kt} + t^*) + \xi_{kt}]\right) \tag{14}$$

Or that in the absence of heterogeneity, any tax which replaces post and hold that maintains fixed aggregate consumption, also implies that it holds fixed consumer surplus; which also implies that it decreases social surplus since the monopolist was revealed to prefer a different price. For each of these counterfactual experiments we calculate the consumer surplus, producer surplus and government revenue at equilibrium prices and quantities. Given the tax level, we can trivially compute the change in revenue as $\Delta GR = (t^* - t^{PH})Q$ after eliminating the post and hold regulation, any product sold by more than one wholesaler results in $p_j = mc_j$ which implies that there are no wholesaler profits $\Delta PS = -(\mathbf{p} - \mathbf{c}) \cdot \mathbf{q}(\mathbf{p})$. Under a given regulation and tax regime, consumer surplus (CS) is given by:

$$\Delta CS = \int \log\left(\frac{1 + \sum_k \exp[\alpha_i^x x_{kt} - \alpha_i^p p_{kt} + \xi_{kt}]}{1 + \sum_k \exp[\alpha_i^x x_{kt} - \alpha_i^p (c_{kt} + t^*) \xi_{kt}]}\right) f(\alpha_i|\alpha, \Sigma) \tag{15}$$

By holding aggregate consumption fixed we don't worry about the externality $H(Q)$ or $H'(Q)$.

A.6 Alternative Vertical Model

Though it is not our main empirical specification, the vertical model of Breshnahan (1987) provides a helpful simplification, where we can obtain some analytic results for the role of taxation. In this setting a consumer i has utility for brand j as given by:

$$u_{ij} = \delta_j - \alpha_i p_j \tag{16}$$

This model makes sense if consumers agree on a vertical ordering of products, but differ in their willingness to pay for quality. The potential advantage/disadvantage of this setup is that each product only competes with two other products (the next higher product and the next lower product) whereas with the logit error ε_{ijt} all products technically compete with one another. In general this model has trouble capturing substitution patterns when products have multiple dimensions of heterogeneity (like automobiles), but may be better in a product category like Vodka where the products are traditionally sorted by price points (Value, Well, Call, Premium, Super-Premium).

The vertical model is very easy to solve, and admits a convenient sufficient statistic representation *in the case where all products have the same ethanol content.*

The consumer chooses j if and only if:[48]

$$\frac{\delta_{j+1} - \delta_j}{p_{j+1} - p_j} \leq \alpha_i < \frac{\delta_j - \delta_{j-1}}{p_j - p_{j-1}} \tag{17}$$

And the share of consumers choosing product j is :

$$s_j = F\left(\frac{\delta_j - \delta_{j-1}}{p_j - p_{j-1}}\right) - F\left(\frac{\delta_{j+1} - \delta_j}{p_{j+1} - p_j}\right) \tag{18}$$

And the share of consumers choosing any product is:

$$1 - s_0 = \sum_{\forall j} s_j = 1 - F\left(\frac{\delta_1}{p_1}\right) \tag{19}$$

This model of competition makes a few important points to guide our analysis. The first is that the total quantity of alcohol consumed depends only on $\frac{\delta_1}{p_1}$ or the price-quality ratio of the lowest quality (price) product. Moreover, since quality δ, is fixed, the total quantity will depend only on the lowest price in the market, p_1, thus any intervention which leaves this price unchanged, will not affect overall sales and specific tax revenue if ethanol content is identical across products. Consumer welfare, however, still depends on inframarginal substitution among products.

Consider abolishing the PH pricing system and increasing the per unit tax on liquor to hold the consumption of alcohol fixed. This counterfactual lets us measure the distortion caused by the post and hold system, without worrying about possible externalities associated with increased consumption of alcohol. Equation (19) tells us that any tax that keeps the p_1 constant will accomplish this goal.

The vertical model also suggests that if margins are larger in absolute terms on high-quality products than they are on low-quality products, a specific tax which holds quantity fixed will nec-

[48]Note: this implies that any product with positive marketshare must have a higher δ_j than all products with a lower price.

essarily decrease the price of high quality goods (undoing the downshifting) and increase consumer surplus. This of course comes at the expense of reduced producer surplus since the flat specific tax may be quite far from the monopoly (Ramsey) prices.

A.7 Smoothing Procedure

The DISCUS shipment data tracks the number of cases shipped from major distiller/manufacturers to individual wholesalers. We use this data for two purposes. One is to ascertain the fraction of each products sales attributed to each retailer, which we model as λ_{ij}. We calculate λ_{ij} using the total shipments for 2012.

We also use the annual DISCUS shipment data to inflate the retail quantity data for the 34 retailers we observe in the Nielsen dataset to correspond to statewide sales. This is a small fraction of all retailers in the state of Connecticut. It is also important to note that statewide wholesale sales include not only products purchased in retail stores but also products served by bars and restaurants. The primary challenge is that DISCUS shipments are observed monthly but are very lumpy, with not every wholesaler ordering every product in every month. Because our wholesale prices and Nielsen data are observed monthly we must construct a monthly product level series of the shipment data.

We consider the following possibilities for annual shipment data:

1. Nielsen Sales > 300 units
2. Nielsen Sales > 30 units AND $\frac{DiscusSales}{NielsenSales} \leq 50$
3. None of the above and Discus Sales ≥ 3000.
4. No DISCUS data observed.

For the first two cases we take a 3-month moving average of the Nielsen Sales, and use the annual DISCUS sales to construct an annual scaling factor so that the rescaled monthly Nielsen sales match the annual DISCUS Sales. For case #3 we take a 5-month moving average of the DISCUS data and use that for the monthly sales. For case #4 we do not have any DISCUS data in order to scale up the Nielsen sales to statewide numbers. Here we partition the data by category (Whiskey, Gin, Rum, Tequila, Vodka) and size (750mL,1000mL, 1750mL) and within each partition we run a local linear regression of annual DISCUS sales on annual Nielsen sales and interpolate the observations for which the annual DISCUS sales are missing. From there we follow the same smoothing procedure as in (1) and (2).

We do not get qualitatively different demand parameter estimates when we smooth all observations at the 5-month moving average though we lose some precision in the standard errors. When we smooth the case #3 DISCUS data using a 3-month moving average instead of a 5-month window, we run into trouble with zero sales arising from spaced out shipments and find overall sales patterns to be implausibly lumpy when compared with the scanner data.

There are some products that may be neither manufactured by DISCUS affiliates, nor sold in our sample of Nielsen stores, and those products are unobserved. There are a relatively small number of products for which we lack DISCUS shipment data and observe very low sales in the Nielsen Scanner data. We exclude such products from our analysis.

We then calibrate the marketsize to be the number of individuals in Connecticut over legal drinking age, and make sure that the overall annual ethanol consumption in our dataset matches the annual ethanol consumption (in proof gallons) reported by the NIAA (around 9 Liters per year).