Wholesale Prices, Retail Prices and the Lumpy Pass-Through of Alcohol Taxes (Preliminary and Incomplete- CITE WITH PERMISSION ONLY)

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Abstract

This paper examines the pass-through of alcohol taxes into distilled spirits prices using detailed UPC-level data from Nielsen Homescan, as well as new state specific wholesale product prices from the regulator in Connecticut. We find that an increase in the specific tax is roughly fully passed through into wholesale prices (pass-through rates of 1.301 (0.368) over the one-month horizon falling to 0.805 (0.255) over the six-month horizon) but over-shifted into retail prices, particularly for smaller products, with pass-through rates of 2.084 (0.503) for 750mL products, 1.586 (0.470) for 1L products and 1.009 (0.263) for 1750mL products. Over-shifting is difficult to rationalize with profit-maximizing behavior and commonly used demand functions. We offer an alternative explanation that incorporates dynamics in price adjustment and is consistent with the pricing patterns we observe. The high pass-through rates that we, like prior work, find are not generated by the exaggerated but smooth transmission of cost shocks but instead generated by infrequent but large, lumpy price changes in whole dollar increments. That is, when retailers, and to a lesser degree wholesalers, change prices they overwhelmingly do so in \$1.00 increments, meaning that small tax changes can trigger large price changes if firms are due to reset prices. We show that when firms follow such an *Ss* rule for price setting the pass-through rate and incidence of the tax is a non-monotonic function of the size of the tax increase and that larger taxes in some cases can generate less lost consumer surplus per dollar of revenue raised.

Keywords: Excise Tax, Incidence, Market Power, Price Adjustment.
JEL Classification Numbers:

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1 Introduction

> *Hartford Courant: June 28, 2011*
> Michael Bradley, manager at Crazy Bruce's Discount Liquors, says consumers will see the cost of their favorite alcoholic beverages go up, especially distilled spirits. Gov. Dannel P. Malloy's tax package raised the excise tax 20 percent on all alcoholic beverages. The excise tax is paid by wholesalers, but consumers will see the increase reflected in the shelf price of wine, beer and spirits.
>
> The increase amounts to 40 cents for most 1.75-liter bottles of spirits, and much less for beer and wine. But wholesalers and retailers will add a markup on that higher excise tax, because it becomes part of their cost, Bradley says. On top of that, manufacturers are imposing their annual price increases at the same time.
>
> The result: The cost of a bottle will rise by about $1, Bradley says.

The pass-through rate – a measure of how changes in costs are reflected in prices – is an subject of interest in many literatures in economics. Microeconomic theory has linked pass-through to the curvature of the demand function, whereby observing the pass-through can inform researchers about which demand specifications are most realistic in particular applications. Trade and macro economists examine pass-through to understand the extent to which shocks from monetary policy or exchange rates are transmitted through the economy. In part they consider whether firms dampen (or potentially magnify) these shocks, how much price volatility ensues, and the extent to which local non-tradeable costs affect prices. In public economics, how taxes are passed through into prices determines whether taxes are paid by consumers or by various firms in the supply chain. These literatures primarily consider the smooth transmission of cost shocks into prices, but nominal rigidities have been considered in the macro and trade literatures and have previously been found to play a minor role (Goldberg and Hellerstein 2008).

We study the pass-through of alcohol taxes into the prices of spirits products using product-level retail data from Nielsen Homescan and new and previously unused wholesale prices from a state regulator to document five features of the pass-through of alcohol taxes. The granularity of our product-level retail and wholesale price data allows us to unpack the pricing behaviors that underlie mean pass-through rates, which in turn offers new insight into how tax increases affect retail prices. We interpret the stylized facts we assemble as evidence of pricing frictions, and consider the implications for the incidence and efficiency of taxes on alcoholic beverages.

This paper makes three main contributions to the understanding of pass-through. First, the monthly product-level data let us better measure the timing, heterogeneity, and persistence of pass-through at different points in the supply chain for a larger number of products than prior studies and with better controls for seasonal and general price adjustments. Second, we show that, contrary to conventional wisdom, pass-through rates for alcohol taxes are not smooth and linear, but very lumpy. At the product level, sometimes they are zero, and sometimes they are over 100%. This is an artifact of retailers' tendencies to price in whole-dollar increments. Finally, we explore the implications of these pricing behaviors for tax incidence and efficiency. We show that these pricing behaviors, which may be present in other markets, render the excess burden a non-monotonic, rather than increasing, function of the size of the tax change.

We think alcohol tax incidence is particularly important for several reasons. The first is that alcohol (along with gasoline and cigarettes) is one of the most heavily-taxed commodities in the United States, and the overall tax burden can reach as high as 30-40% of the purchase price. The second is that alcohol taxes are extremely well-studied. For example, Wagenaar, Salois, and Komro (2009) perform a meta-analysis examining over 1,003 price-elasticity estimates. A smaller number of studies have examined the pass-through of alcohol taxes, but those that do usually find over-shifting of the tax—that the pass-through rate exceeds 100% and is often as high as 150-200%. A pass-through rate of 200% would imply that when faced with a $0.20 tax increase, firms respond by increasing retail prices by $0.40; this might suggest that not only are taxes paid exclusively by consumers, but also, paradoxically, firms may actually benefit from higher taxes. Finally, understanding the pass-through rate is important for current policy debates. Since the onset of the Great Recession, six states have increased their alcohol taxes and more than 30 states have proposed increasing their alcohol taxes. Understanding the welfare tradeoffs associated with alcohol tax increases is particularly relevant in this context.

Specifically, we consider Connecticut's July 2011 increase in state-specific taxes on spirits beverages from $4.50 to $5.40 per gallon. The 20% tax hike increased taxes by $0.178 on 750mL products, $0.238 for 1L products, and $0.416 for 1750mL products. We begin by examining how Connecticut's July 2011 increase in specific taxes, which was levied on on alcoholic beverage wholesalers, was passed-through to wholesale and retail spirits prices. The frequency of our data allows us to measure how prices reacted the very month of the tax increase.

The first fact we demonstrate is that both wholesale and retail alcoholic beverage prices rose sharply and immediately in reaction to the July 2011 tax increase. July is generally a time of price increases for spirits beverages in Connecticut, facilitating the adjustment of prices with respect to the tax. The average retail price rose by $0.422, and the average wholesale price rose by $1.462. The retail price reaction is much larger than both July price increases in other years and price changes in adjacent months, while the wholesale price reaction is actually less stark relative to average price increases in other months.

Building on this mean analysis, we estimate pass-through rates employing more systematic controls. Allowing for product-specific time trends as well as month and year fixed effects to account for trends and seasonal tastes, we use a first-difference regression model to estimate pass-through rates for wholesale and retail prices. We find that the tax is over-shifted into both wholesale and retail prices over a one-month horizon, with a wholesale rate of 1.302 (0.368) and a retail rate of 1.533

(0.271). Over three- and six-month horizons, the pass-through rates decline, suggesting that future cost shocks are not passed on at the typical rate once prices are adjusted for the tax. Estimated over a six-month horizon, the average wholesale pass-through rate is just 0.805 (0.255), while retail prices show full pass-through on average with a rate of 1.013 (0.264). Interestingly, smaller products, which faced smaller tax increases, experience higher pass-through rates. Wholesale and retail pass-through rates over a six-month horizon for 750mL products were 3.446 (0.579) and 2.084 (0.503), respectively, while they were only 0.816 (0.252) and 1.009 (0.263) for 1750mL products. The robust pattern of over-pass-through for smaller products and lower pass-through for larger products, which faced higher tax increases, is our second key fact.

Our wholesale price data only describe prices in Connecticut, thus much of our pass-through analysis focuses on the July 2011 tax increase in Connecticut. We do, however, examine the pass-through of Illinois' September 2009 $4.05 per gallon tax increase into retail prices to understand how the size and timing of a tax increase affect pass-through. Unlike Connecticut's tax increase, Illinois larger increase came after on set of seasonal price increases in July. We find that pass-through was slower in Illinois, staring below 50% over a one-month horizon but rising to over 125% by the six-month estimate. The pattern shows that when prices are eventually changed, the tax increase is passed through to retail prices but that when a tax increase follows a seasonal price adjustment it may take several months for enough prices to be adjusted to reflect the tax increase.

We find that pass-through rates also vary systematically across stores. Across several different relative price measures, retail stores with relatively low prices for a given product increase prices more following the tax increase. We find that at low-price stores, the tax is passed on at a rate of roughly 290-300%, while at high-price stores, the tax is passed on a rate of only 26-31%. The negative relationship between pass-through rates and relative initial prices is our third key fact. This variability amongst product sizes and stores provides further evidence of heterogeneity in pass-through, and suggests that prior work considering a uniform and smooth pass-through rate may be missing important frictions.

Making use of our unique combination of wholesale and retail price data, we then trace how the tax increase is passed through down the supply chain. Wholesale price changes, in months when the tax changed and in months when taxes were unchanged, are only partially passed through to retail prices at rates generally less than 30% overall and for all product sizes. Tabulations of price changes explain the disconnect between low wholesale to retail pass-through on one hand, and the large response of retail and wholesale prices to the tax on the other hand. Retail and wholesale prices changed for different products: only 17.5% of products with wholesale price changes also had retail price changes, and retail prices changed for more than 13.4% of products for which wholesale prices did not change. This dissonance, and the resulting modest estimated wholesale to retail pass-through rates, are the fourth fact we establish.

The retail and wholesale data we assemble describe the prices of a large set of products at frequent intervals, and allows us to better understand the underlying pricing mechanics that dictate pass-through. In the fifth, and final, fact we document, we show that even when the measured tax pass-through rate is large ($\geqslant 1$), a majority of products do not experience any price change at all; the measured pass-through rate is generated by a small number of large, whole-dollar price increases. An overwhelming majority of retail prices are set at only a small number of price points; nearly 91% of retail prices end in $0.99, and another 3.6% end in $0.49. Wholesale prices are also concentrated at particular price points, with 50.4% ending in $0.91 and another 10.7% ending in $0.41.[1] These common and limited price points mean that prices are changed in particular increments. The majority of retail prices, 83.7% overall and 63.6% in July 2011, are not changed in a given month; more than three-quarters of prices that are changed are increased or decreased by whole-dollar amounts. Although wholesalers do have preferred price change increments, wholesale price changes are not nearly as concentrated as retail price changes, and wholesalers are far more likely to raise prices by partial dollars. These pricing patterns show that retailers, and to a lesser degree wholesalers, do not smoothly pass on cost shocks but rather adjust prices in $1.00 increments. The combination of small tax changes and few but lumpy price changes leads to high pass-through rates, particularly for smaller products which experienced smaller tax changes.

Prior studies in public economics have found evidence of both partial and over pass-through of taxes. The studies of this literature vary as to the type and source of data collected: many of these studies have looked at either state average prices or price indices, though some have used product level scanner data. Examining price indices for clothing and personal care items across cities, Poterba (1996) found that retail prices rise by approximately the amount of sales taxes. Studying a broader array of goods, Besley and Rosen (1999) could not reject that prices increased by roughly the amount of the sales tax for some goods (including Big Macs, eggs, Kleenex, and, interestingly, the game of Monopoly), but for more than half of the commodities they studied, taxes were passed on at rates that exceeded unity. Marion and Muehlegger (2011) found that gasoline and diesel taxes are on average fully passed through to consumers, but when supply is inelastic or inventories are high, pass-through rates are lower. Studying temporary gas-tax holidays, Doyle Jr. and Samphantharak (2008) showed that while pass-through of the tax holiday happens within a week, the tax reduction is only partially passed on to consumers. In their assessment of the incidence of cigarette taxes, Harding, Leibtag, and Lovenheim (2012) found that the excise taxes were less than fully passed through to consumers. DeCicca, Kenkel, and Liu (2013) could not reject full pass-through of cigarette taxes on average, but found that consumers willing to shop faced significantly less pass-through.

Several studies focus on the pass-through of alcohol taxes. Cook (1981) used price data for leading brands to calculate average yearly prices for each state. He found that the median ratio of price change to tax change for the 39 state-years that had tax changes was roughly 1.2. Young

[1] An anti-loss leader provision in Connecticut requires all retailers to charge at least 8 cents above wholesale prices, except for a small number of pre-designated “clearance” items.

and Bielinska-Kwapisz (2002) followed the prices of seven specific alcoholic beverage products and estimated pass-through rates ranging from 1.6 to 2.1. Exploiting Alaska's massive increase in alcohol taxes in 2002 (the taxes on alcoholic beverage more than doubled), Kenkel (2005) reported that the large tax increases were associated with pass-through rates ranging from 1.40 to 4.09 for all alcoholic products, and between 1.47 to 2.1 for spirits products alone. These studies suggest that not all products experience the same pass-through rate even within a product category, but all find significant evidence that tax increases on alcoholic beverages are passed through at rates exceeding 100%.

Pass-through has also been the subject of literatures outside of public economics. Nakamura and Zerom (2010) examine the pass-through of cost shocks in the coffee industry, finding that pass-through is incomplete with rates of approximately 23%. Further, they found that pass-through is sluggish, with the delay almost entirely attributable to pricing behavior at the wholesale rather than retail level. In their work aimed at uncovering the factors contributing to the inertia of local currency prices of traded goods despite exchange-rate changes, Goldberg and Hellerstein (2013) find an average pass-through rate of just 7%. Generally these pricing dynamics are interpreted as a dampening of price volatility between wholesalers and retailers; they indicate that firms smooth out shocks and adjust markups rather than passing shocks on to consumers, suggesting that firms may play an important role in reducing volatility within the economy. There has also been a recent theoretical literature in industrial organization which has attempted to link cost pass-through to the price effects of mergers. Building on price theoretic work by Werden and Froeb (1994) and Farrell and Shapiro (2010), Jaffe and Weyl (2013) interpret mergers as increasing the opportunity cost of selling a product, and then use the pass-through to determine the extent of the price increase.

Estimated pass-through rates exceeding unity, like those we estimate, have been theoretically justified by the presence of imperfect competition among suppliers.[2] Most of those results employ a single-product homogenous good framework. Katz and Rosen (1985) Seade (1985), Stern (1987) all rely on Cournot competition with conjectural variations, which have more recently fallen out of favor with economic theorists. Besley (1989) and Delipalla and Keen (1992) employ a Cournot model with free entry and exit. This early literature is summarized by Fullerton and Metcalf (2002). Because Cournot competition may not be a realistic assumption for many taxed goods including distilled spirits, Anderson, De Palma, and Kreider (2001) develop similar results under differentiated Bertrand competition.[3] The main result is similar for all of these papers, in that demand must be sufficiently (log)-convex in order to generate overshifting. However, as Anderson, De Palma,

[2]For example, Besley and Rosen (1999) state: "An important implication of this literature is that in an imperfectly competitive market, varying degrees of shifting are possible in the long run. Indeed, even over-shifting is a distinct possibility; i.e., the price of the taxed commodity can increase by more than the amount of the tax. These results contrast markedly with those that emerge from a competitive model. With competition, after-tax prices increase by just the amount of the tax if the long-run supply curve is horizontal, and by less than the amount of the tax if the supply curve is upward sloping."

[3]Homogenous Bertrand competition leads to marginal cost pricing and hence $\rho = 1$, which is not particularly interesting.

and Kreider (2001) point out, many of these cases imply such convex demand that the marginal revenue curves may no longer be downward sloping. Fabinger and Weyl (2012) categorize the pass-through rate and marginal revenue properties of several well-known demand systems, and show that satisfying both properties is difficult but possible under certain forms of Frechet and almost ideal demand systems (AIDS) (Deaton and Muellbauer 1980). In a recent and notable departure from this theoretical literature, Hamilton (2009) finds that excise taxes can lead to overshifting when demand is sufficiently *concave* rather than convex when consumers purchase multiple (taxed) goods at the same time. The result depends on two things: higher taxes much lead to reduced variety of product offerings; and prices and variety are strategic complements, in the language of Bulow, Geanakoplos, and Klemperer (1985). Many of these results present a challenge for empirical work, in that they often rely on entry and exit of firms or products in order to generate pass-through rates in excess of unity. The stylized facts that we observe are that overshifting is observed generally within the first month, and that there is no evidence of any exit by firms or brands in response to the tax increase. The theoretical results make it easier to rationalize overshifting in the long run than in the short run.

Motivated by the empirical facts we establish, we propose a somewhat different mechanism for pass-through. The theory underlying pass-through involves smooth transmission of cost shocks to prices, and often assumes a homogenous treatment effect, or that the rate of pass-through is similar across products within a category. We suggest that patterns of pricing behavior play an important role in the rate of pass-through. Pass-through is not generated by the exaggerated but smooth transmission of cost shocks, but is instead the result of most prices remaining unchanged while a small share of products experience large price changes, typically in whole-dollar increments.

We offer an alternative explanation which incorporates dynamics in price adjustment, and suggests that pass-through is a nonlinear function of the size of the cost-shock. Infrequent, large price changes, particularly concentrated at stores that had been charging relatively low prices, suggest that firms are following some type of Ss rule where they wait for the wedge between the profits they would realize if they adjusted prices and the profits they accrue with unchanged prices to be sufficiently large before they change prices.

As such, instead of directly measuring the average pass-through rate, which may be highly nonlinear and vary substantially across products, researchers should directly measure the probability of a \$1.00 price increase. We show that large pass-through rates are an artifact of small tax increases and lumpy price adjustment via \$1.00 increments – but that larger tax increases in the same market might lead to substantially smaller estimated pass-through rates. We believe this provides a partial explanation for the wide range of pass-through rates documented in the empirical literature studying various products. Furthermore, when firms follow an Ss rule, and do not adjust prices until they are sufficiently far from their profit maximizing price, the relationship between taxes and lost consumer surplus can be non-monotonic. We argue that states should be cognizant of this non-monotonicity when levying taxes, and should target tax-increases that lead to round number increases in the tax burden at the individual product level in order to maximize revenue collected per unit of lost consumer surplus.

More broadly, an understanding of pass-through that accounts for pricing frictions may also have implications for the macro and trade literatures. If firms follow pricing rules that lead to infrequent but large price changes, these pricing frictions may provide one plausible explanation for the low and slow pass-through of cost shocks. The pricing frictions we document may both affect the incidence of taxes, and also have implications for the role of markups in dampening volatility of prices.

The paper proceeds as follows. Section 2 provides background on the alcoholic beverage industry and how it is taxed. In Section 3, we present a conceptual framework. Section 4 describes the data. We document our five key features of spirits product pricing and estimate pass-through rates in Section 5. The welfare implications of the infrequent, large price adjustments are explored in Section 6. Section 7 concludes.

2 Alcohol Taxation and Industry Background

Compared with other commodities, alcoholic beverages (along with cigarettes and gasoline) are subjected to unusually high taxes.[4] In 2010, federal and state specific taxes raised $15.5 billion in revenue on an industry in which production, distribution and retailing amount to roughly $100 billion revenue. States vary widely in how they regulate alcoholic beverage markets and how they raise revenue from alcoholic beverage sales.

States are free to levy their own taxes on spirits, as well as regulate the market structure in other ways. There are 18 *control states*, where the state has a monopoly on either the wholesale distribution or retailing of alcohol beverages (or both).[5] Connecticut and the other 31 states are *license states*. License states follow a three-tier system where vertically separated firms engage in the manufacture, wholesale distribution, and retailing of alcohol beverages. Almost all license states have restrictions that prevent distillers from owning wholesale distributors, or prevent wholesale distributors from owning bars or liquor stores. In Connecticut wholesalers and retailers are fully distinct. Further, the Connecticut state regulator forbids wholesalers from engaging in temporary sales, price promotions or giveaways; the retail price data reveal few if any temporary sales. The lack of temporary sales makes the distilled spirits market an attractive market in which to study

[4]The taxation of alcoholic beverages has a long history in the United States. The first taxes on domestic alcoholic beverage production were collected in 1791 in order to pay off the debts of the Revolutionary War.

[5]In some control states, the monopoly applies to all forms of alcohol beverages, in others it applies to only distilled spirits but not wine or beer. Control states can adjust markups or taxes to raise revenue and in a few control states, such as Maine and Vermont, the state nominally controls the distribution and sales of spirits but contracts with private firms which set prices. Control states have been the subject of recent empirical work examining the entry patterns of state-run alcohol monopolies (Seim and Waldfogel 2013) and the effects of uniform markup rules (Miravete, Seim, and Thurk 2014).

pass-through.[6]

Taxes are levied in a variety of ways: taxation of pure ethanol content, taxation of volume (independent of ethanol content), and taxation of sales revenue (such as with *ad valorem* or sales taxes). We focus primarily on distilled spirits, in part because they bear a substantially larger tax burden than beer or wine. Since 1991, the federal government has taxed distilled spirits at $13.50 per proof-gallon which works out to $4.99 for a 1.75L bottle of vodka at 80 proof.[7] The statutory incidence of federal excise taxes falls on the producers of distilled spirits or is due upon import into the United States. Like most state excise taxes, Connecticut's specific tax on spirits is levied on wholesalers and is based on volume rather than alcohol content.[8] In many states, retailers are expected to remit sales taxes on alcoholic beverage purchases to the state. In some states, there is an additional sales tax that applies only to alcoholic beverages, while in others alcoholic beverages are exempt from the general sales tax.

All of these taxes are of course levied in part to address the negative health and public safety externalities of alcohol. However, governments also tax alcohol for the explicit purpose of raising revenue.[9] Few states changed their alcohol taxes over the prior decade, but following the onset of the Great Recession seven states passed legislation between 2007 and 2013 affecting alcohol taxes. We report those tax changes along with the detail of the tax change in Connecticut in Table 1. Prior to July 1, 2011 the state of Connecticut levied a tax on the volume of distilled spirits (independent of proof) of $4.50 per gallon, which worked out $2.08 per 1.75L bottle.[10] After July 1, 2011 the tax increased to $5.40 per gallon or $2.50 on a 1.75L bottle. The September 2009 $4.05 per gallon tax increase in Illinois, where spirits are more widely available, is also examined in the empirical analysis on a more limited basis because we lack wholesale data outside of Connecticut.

An interesting provision of the Connecticut tax increase ensured that the tax was uniform on all units sold after July 1, 2011: retailers (and wholesalers) were subjected to a *floor tax* on unsold inventory as of July 1, 2011. This floor tax helps us measure the tax incidence as it makes the tax increase immediate on all units.[11] Most states tax the volume of alcoholic beverages without

[6]Several states have other restrictions on the number of retail licenses available, or the number of licenses a single chain retailer can own. States also differ on which types of alcoholic beverages, if any, can be sold in supermarkets and convenience stores, or are relegated to standalone liquor stores. Prior work on license states has examined the stickiness of retail pricing using beer prices as an example (Goldberg and Hellerstein 2013) and the welfare effects of exclusivity arrangements in the beer industry (Asker 2005).

[7]Converting products into proof-gallons is complicated. Taxes are stated in customary units of gallons, though products are sold internationally in standardized metric units of 750mL, 1L, and 1.75L bottles. A proof-gallon is 50% alcohol by volume (100 Proof) at 60 degrees Fahrenheit.

[8]Distillers, wholesalers and retailers are also subject to federal and state corporate income taxes.

[9]For example, in 2015 Governor Sam Brownback of Kansas proposed raising alcohol and tobacco taxes to help close the state's $648 million budget shortfall. For more details see http://www.kansas.com/news/politics-government/article6952787.html

[10]Many states levy lower tax on lower proof ready-to-drink products, or lower proof schnapps and liquers. Products less than 7% A.B.V. in Connecticut are subjected to a lower tax rate.

[11]The floor tax meant that any product not in the hands of consumers would be subjected to the new tax rate rather than the old tax rate, and prevented retailers from evading the tax by placing large orders in advance of the tax increase. It did not, however, prevent consumers from stockpiling alcoholic beverages in advance of the tax increase.

reference to the proof or ethanol content for a wide range of products. This provides valuable cross-sectional variation in the tax change. The tax increase amounted to \$0.178 for 750mL products, \$0.238 for 1L products and \$0.416 for 1750mL products.

It should be noted that Connecticut also increased its sales tax from 6% to 6.35% at the same time as the alcohol specific tax increase. Our empirical analysis examines the impact of the specific tax increase on sales tax-exclusive retail and wholesale prices, effectively abstracting from the impact of the sales tax on pre-tax prices. As the sales tax is levied at the time of retail sale, any pass-through of the 0.35% increase would lead to lower retail, and potentially wholesale, prices. Thus the pass-through rates we report potentially under-estimate the true pass-through rates if the sales tax is passed-through to retailers and wholesalers through lower prices; any price rigidities will limit pass-through. The small magnitude of the sales tax increase and the fact that estimates of the retail pass-through rate using sales tax inclusive prices are mechanically larger but statistically indistinguishable from the results presented here make this abstraction less concerning.[12]

3 Conceptual Framework

The empirical tax pass-through literature commonly treats the pass-through rate as a proxy for the incidence of a tax—that is, the relative reductions in surplus borne by consumers and producers—which is a simplification that may not hold in many circumstances. To see this, consider supply and demand in the spirits product market, and the introduction of a per-unit tax, τ, that must be remitted by suppliers. The two sides of the market could be wholesalers and retailers or retailers and consumers, but for now we will refer to retailers and consumers.[13]

Following the introduction of the tax, in equilibrium, quantity demanded will equal quantity supplied: $D(p_c) = S(p_c - \tau)$ where p_c is the price consumers pay that reflects any pass-through of the tax, τ, into higher retail prices. Retailers remit the tax and receive $p_c - \tau = p_r$ after tax.[14] The market will generate consumer surplus $CS(p) = \int_p^\infty D(x)\,\mathrm{d}x$ and producer surplus $PS(p-\tau) = \int_0^{p-\tau} S(x)\,\mathrm{d}x$.

An infinitesimal tax increase reduces consumer and producer surplus: $\frac{dCS}{d\tau} = -\frac{dp}{d\tau}Q$ and $\frac{dPS}{d\tau} = -(1 - \frac{dp}{d\tau})Q$, where Q is the equilibrium quantity. Using ρ to describe the pass-through rate, $\frac{dp}{d\tau}$,

[12] For example, over the one-month horizon the sales tax-inclusive retail pass-through rate is 1.856 (0.283), which is higher but statistically indistinguishable from the pass-through rate reported in column 1 of Table 11, 1.533 (0.271).

[13] A per unit tax that is not related to the price but only the quantity is common in specific or excise taxes for products such as gasoline, cigarettes, and alcoholic beverages. For general goods *ad valorem* or sales taxes are more common.

[14] The statutory incidence of the tax could of course be on consumers instead in which case the price charged by retailers could potentially be lower than the no-tax equilibrium price to reflect pass-through from consumers to producers. Because all state and federal alcohol taxes are remitted by suppliers, we focus on the case where the firms bear the statutory burden.

the incidence of an infinitesimal tax change will be

$$I = \frac{\frac{dCS}{d\tau}}{\frac{dPS}{d\tau}} = \frac{\rho}{(1-\rho)} \tag{1}$$

Fabinger and Weyl (2013) extend this well-known incidence formula to incorporate varying market structures:

$$I = \frac{\rho}{1-(1-\theta)\rho} \tag{2}$$

where θ functions as a conduct parameter with $\theta = 0$ indicating perfect competition ($I = \frac{\rho}{1-\rho}$); and $\theta = 1$ indicating monopoly ($I = \rho$).[15]

It is worth noting that though many rationalizations of tax over-shifting appeal to oligopoly competition as an explanation, for commonly used demand functions, imperfect competition alone does not yield over pass-through. More specifically, for taxes, or other cost shocks, to yield greater than one-for-one price increases it must also be true that demand is log convex. Some demand systems do feature log convexity, and can produce over-shifting under some forms of imperfect competition. One way to generate over-shifting is for firms to follow a fixed markup rule such that all costs are marked up at more than 100%, for example a 150% markup. This mark-up rule could be generated by a monopolist facing a CES demand system with a parameter of $\sigma = 3$ so that $\frac{\sigma}{\sigma-1} \approx 1.5$ (which would not exhibit declining marginal revenue curves). However, if observed margins are closer to 10%, as is true for distilled spirits retailers, it becomes difficult to explain why the dramatically larger markup applies only to the tax component of marginal cost.

In most empirical studies of tax pass through, $\hat{\rho}$ is estimated in a reduced form regression of changes in the prices, Δp_{jt}, of a particular product j on the changes in corresponding taxes, $\Delta\tau_{jt}$, with various fixed effects and other controls x_{jt}:

$$\Delta p_{jt} = \rho_{jt}(\mathbf{X}, \Delta\tau) \cdot \Delta\tau_{jt} + \beta\Delta x_{jt} + \gamma_j + \gamma_t + \epsilon_{jt} \tag{3}$$

Here we have written the pass-through rate $\rho_{jt}(X, \Delta\tau)$ as a general function that might depend on (j, t) as well as other covariates $\mathbf{X}$, or the size of the tax change itself $\Delta\tau$. Most of the literature on tax pass-through ((Besley and Rosen 1999) and (Harding, Leibtag, and Lovenheim 2012) for example) assumes that there is either a single pass-through rate $\rho_{jt}(X, \Delta\tau) = \rho$ or allows for different products to have different pass-through rates $\rho_{jt}(X, \Delta\tau) = \rho_j$. We could just as easily allow for the pass-through rate to depend on the size of the tax increase (in a dose-response framework): $\rho_{jt}(X, \Delta\tau) = \alpha_0 + \alpha_1\Delta\tau_{jt} + \alpha_2\Delta\tau_{jt}^2$, though identification of α might require additional variation in $\Delta\tau_{jt}$ either in the cross section j, or over time t.

[15] A well known challenge in the conduct parameter approach is that intermediate cases $\theta \in (0, 1)$ can be difficult to interpret, except for a few examples such as symmetric Cournot competition.

3.1 Pass-Through and Lumpy Price Changes

As is well-understood, this incidence measure in (2) holds for an infinitesimal change in taxes only. For a sufficiently small tax change this linear approximation may be very close to the true incidence, $\frac{\Delta CS(\tau)}{\Delta PS(\tau)}$, just as as the non-parametric pass-through function is well approximated by the constant: $\hat{\rho}_{jt}(\mathbf{X}, \Delta\tau) \approx \hat{\rho}$.[16] However this presumes that tax increases are smoothly passed-through to prices.

Suppose instead that prices are discrete. In the simplest example:

$$p_{jt} = \begin{cases} p_{jt} + 1 & \text{if } \Delta\tau_{jt} \geqslant \overline{\tau}_{jt}(\mathbf{X}) \\ p_{jt} & \text{if } \Delta\tau_{jt} < \overline{\tau}_{jt}(\mathbf{X}) \end{cases} \tag{4}$$

That is the firm can either increase its price by a single unit, or can keep the same price. For a large enough tax increase, the firm will always increase its price, and for a small enough tax increase the firm will keep its existing price. For each product there is a threshold level of the tax increase, $\overline{\Delta\tau}_{jt}$, which is unobserved to the econometrician. This would imply that the true function $\rho_{jt}(X, \Delta\tau) = \delta_{\overline{\tau}_{jt}(\mathbf{X})}(\Delta\tau_{jt})$ where $\delta_z(\cdot)$ is the Dirac delta function with point mass at z. Then for each product we can compute it's product specific pass-through rate as $\hat{\rho}_j = \frac{1}{\Delta\tau_{jt}} \int_0^{\Delta\tau_{jt}} \delta_{\overline{\tau}(X)}(\Delta\tau_{jt})$. This pass-through rate takes on only two values for each j: $\frac{1}{\Delta\tau_{jt}}$ or 0. Ignoring other covariates, $\hat{\rho} = \sum_{jt} w_{jt}\hat{\rho}_j$ is just a weighted average of product level pass-through.

In general we do not expect the econometrician to observe $\overline{\Delta\tau}_{jt}(\mathbf{X})$ directly, and instead it must be estimated. If we allow for some econometric error in $\overline{\Delta\tau}_{jt}(\mathbf{X})$ that is IID and normally distributed: then this suggests that the correct estimator for $\hat{\rho}_{jt}(X, \Delta\tau)$ is just the predicted probability from a logit (divided by the tax increase): $\frac{Pr(\Delta p=1|\mathbf{X},\Delta\tau)}{\Delta\tau}$. We illustrate in Figure 3 that the estimate of the pass-through rate, $\hat{\rho}$, is merely the slope of the line tangent to the logit S-curve for a particular tax increase, $\Delta\tau$. We draw the complete pass-through $\rho = 1$ line in yellow for reference. For a small tax increase (red line), it might be that very few products change prices so that the estimated pass-through rate is small. For a very large tax increase (blue line) it might be that most products increase their prices by \$1, but this might be smaller (or larger) than the denominator, $\Delta\tau$. For some intermediate value of the tax increase, it might be that most products increase their prices, but that $\Delta\tau$ is not so large, leading to a higher estimate of the pass-through rate.

We believe this is what is observed in the market for distilled spirits. If we assume that $\Delta\tau \approx 0.25$ (which is similar to the observed tax increase for 750mL bottles in Connecticut) and equal weights $w_j = \frac{1}{J}$, then $\hat{\rho}$, our reduced-form estimate of pass-through, would be a weighted average of $\rho_j = 4$ and $\rho_j = 0$. As long as more than $\frac{1}{4}$ products increase their price in response to the tax then it is possible to estimate $\hat{\rho} \geqslant 1$ without imposing log-convexity on the demand function, while if fewer products increase their price we could find incomplete pass-through.

[16] If supply and demand are linear, then the above incidence measure will also hold because the slopes of demand and supply and thus the pass-through rate are constant.

The challenge with this approach is that if we were to increase the $\Delta\tau$ by \$0.05, we might expect that some products where $\hat{\rho}_j = 0$ increase their price while we would not expect to see any products with $\hat{\rho}_j = 4$ increase their price an additional $\$0.05 \cdot 4 = \$0.20$. Nor would we expect that using the average over products $\hat{p}$ would yield more accurate results.

3.2 Dynamic Structural Version

In this section we relate our simple statistical model of logit or ordered logit for round-dollar price changes as a key step in the estimation of a more complicated dynamic structural model of price setting retailers. We begin by considering the (static) model of price adjustment in Goldberg and Hellerstein (2013) where retailers maximize:

$$\Pi_t^r = \sum_j (p_{jt}^r - p_{jt}^w - mc_{jt}^r) \cdot q_{jt}^r(p_{jt}^r) - A_{jt}^r \cdot I[p_{jt}^r \neq p_{j,t-1}^r]$$

Retailer r sells product j in period t at price p_{jt}^r, pays a wholesale price p_{jt}^w and has a marginal cost of selling mc_{jt}^r (sometimes referred to as a "non-tradeable cost" in the exchange rate pass-through literature). The main addition is the adjustment cost A_{jt}^r that the retailer pays when the changing the price. The goal of Goldberg and Hellerstein (2013) was to use revealed preference arguments to bound A_{jt}^r and then to recover the non-traded mc_{jt}^r.

We can consider the retailer's dynamic problem as:

$$\max_{\mathbf{p_t^r}} \sum_{t=0}^{\infty} \beta^t \Pi_t^r(\mathbf{p_t^r}, \mathbf{p_t^{-r}}, \mathbf{p_t^w}, \mathbf{mc_t^r})$$

which we can write in recursive form:

$$V^r(\mathbf{p_t^r}, \mathbf{p_t^{-r}}, \mathbf{p_t^w}, \mathbf{mc_t^r}) = \max_{\mathbf{p_t^r}} \quad \Pi_t^r(\mathbf{p_t^r}, \mathbf{p_t^{-r}}, \mathbf{p_t^w}, \mathbf{mc^r}) + \beta E_{t+1}[V^r(\mathbf{p_{t+1}^r}, \mathbf{p_{t+1}^{-r}}, \mathbf{p_{t+1}^w}, \mathbf{mc_{t+1}^r})]$$

This dynamic setup more closely resembles the setup of Nakamura and Zerom (2010). Again, in that paper the objective was to recover the adjustment costs A_{jt}^r, and to understand how the frequency and size of price adjustment responded to changes in the underling stochastic process of cost shocks. They employed the Pakes and McGuire (1994) algorithm to compute the Markov-Perfect Equilibrium (MPE) of the above game.

The main distinction between our setup and the setup in Nakamura and Zerom (2010) or Goldberg and Hellerstein (2013) is that our data suggests prices are restricted to a discrete grid of points that end in \$0.99. In other words, $p_{j,t+1} = \{p_{jt} - k, \ldots, p_{jt} - 1, p_{jt}, p_{jt} + 1, \ldots, p_{jt} + k\}$.[17]

[17] In contemporaneous work, Ellison, Snyder, and Zhang (2015) employ an approach in the spirit of Bajari, Benkard, and Levin (2007) to estimate a model of discrete price changes with menu costs in order to quantify managerial inattention.

This has the implication that multiplicity of equilibria in the dynamic pricing game are not just a theoretical possibility but inevitable. The second difference is that we have over 30 retailers and over 500 products. It would be computationally infeasible to keep track of all prices of all competitors $\mathbf{p_t^{-r}}$, or even all products at the same firm $\mathbf{p_t^r}$.

Instead consider the two-step approach of Bajari, Benkard, and Levin (2007) where the goal is to recover the parameters of the payoff function. Implicitly they assume that an MPE exists, and only one equilibrium is played (even though there could be multiple equilibria). In the first stage of the approach is to estimate the policy functions of the agents: $\hat{\sigma}_r(a_t, S_t)$, and the transition densities of the exogenous variables: $\hat{f}(S_{t+1}|S_t)$. The second stage considers deviations from the policy functions to recover the parameters of the payoff function $\Pi^r(\theta)$. However, in order to compute the incidence of taxation at alternative $\Delta\tau$, we do not need to perturb agents beliefs about the future transition of the exogenous state variables $Pr(S_{t+1}|S_t)$, nor the contents of the per-period profit function $\Pi^r(\theta)$. Instead we only need to consider the policy functions of firms at different state variables.[18] The point is that we do not need to solve the full dynamic game to understand how incidence varies with tax changes. Instead we need only the estimated policy functions evaluated at a different state variable $\hat{\sigma}_r(a_t, S_t')$.[19] Moreover, solving the full dynamic game wouldn't provide any additional information beyond the estimated policy functions.

This approach has some caveats. Namely, that a larger tax increase would not effect the stationary Markovian strategies of firms, nor would it affect future transition rules $f(S_{t+1}|S_t)$. While the first might be reasonable, the second is more likely to be problematic. In the long-run, if manufacturers bear some of the incidence we might expect the rate of future upstream price increases to decline in response to a larger tax.

The preferred policy function would be a non- or semi-parametric estimate of the $Pr(\Delta p_{jt}^r|X_t)$, which is exactly what our flexible logit or ordered logit would recover.

4 Data Description

One of the reasons we chose to revisit the literature on pass-through of alcohol taxes is that researchers have generally not had access to both high-quality product level scanner data and wholesale price data during an observed increase in the excise tax rate. Our primary data source is the Kilts Center Nielsen Homescan Scanner dataset. These are weekly scanner data, which track prices and sales at the UPC (universal product code) level for a (non-random) sample of stores in all fifty states, though in practice we only have sufficient data from 34 states.[20] These weekly data

[18]There is a growing literature which formally explores identification of counterfactuals dynamic discrete choice models when the full model is underidentified Kalouptsidi, Scott, and Souza-Rodrigues (2015).

[19]The analog in the single agent case would be if we had estimated the bus replacement model of Rust (1987) but were only interested in how the replacement probabilities would look if all buses had 10,000 extra miles.

[20]We lack sufficient data from 15 states, many of which are control states (in bold): **Alabama**, Alaska, Hawaii, **Idaho**, Kansas, **Montana, New Hampshire, North Carolina**, Oklahoma, Oregon, **Pennsylvania**, Rhode Island, Tennessee, **Utah, Vermont, Virginia**.

are available from 2006-2012, and include data from both standalone liquor stores as well as from supermarkets and convenience stores. However, participation in the Nielsen dataset is voluntary, and not all stores participate. Supermarkets are much more likely to be included in the Homescan dataset than stand alone liquor stores, and larger chain stores are more likely to participate than smaller mom-and-pop stores. This leads to there being better coverage for states where spirits are sold in supermarkets. We examine the effect of the July 2011 tax-increase in the state of Connecticut, where we observe 34 (mostly larger) retailers. For the sake of comparison, we also include data from 715 retailers in Illinois where spirits are more widely available.

We also gathered data on posted prices for each wholesaler and each product for the August 2007 to August 2013 period from the Connecticut Department of Consumer Protection (DCP). Wholesalers agree to charge retailers these prices for the entire month, and are legally not allowed to provide quantity discounts or price discriminate.[21] Most of the 506 firms who have submitted prices to the state of Connecticut DCP since 2007, exclusively sell wine, or beer and wine; only 159 wholesale firms have ever sold distilled spirits. Among these 159 wholesale firms, the overwhelming majority sell primarily wine and distribute a single small brand of spirits. Only 18 wholesale firms have ever sold brands of distilled spirits that we observe in the Nielsen dataset, and more than 80% of sales come from just six major wholesalers.

There were two important considerations in the construction of our dataset. The first was how to match products across competing wholesalers, or from wholesalers to Nielsen UPC's. Here we consolidate products so that a product is defined as brand-flavor-size such as *Smirnoff Orange Vodka 750mL*. Sometimes a "product" may aggregate over several UPC's, as changes in packaging can result in a new UPC.[22] In total, these consolidations help us to construct a more balanced panel of products over time, and avoid gaps during holiday periods, or products going missing when packaging changes.

The second consideration relates to the time component of our dataset. Connecticut's tax changes took effect July 1, 2011 and we observe (fixed) wholesale prices for each calendar month. The Nielsen scanner data are recorded weekly, and some weeks span two months. Because wholesale prices vary at the monthly level, we aggregate our retailer data to the store-month. We allocate weeks to months based on the month of the end date but drop the first week of the month since we cannot completely assign weeks that span two months to one month or the next. We aggregate

[21] Connecticut is one of 12 states with a set of regulations known as *Post and Hold*, which mandates that all wholesalers post the prices they plan to charge retailers for the following month. Wholesalers must commit to charging these prices for the entire month (after a look-back period when wholesalers can view one another's initially posted prices and adjust their prices downwards without beating the lowest price for the product). For a detailed analysis of these regulations please see (Conlon and Rao 2014).

[22] UPC changes most commonly arise with special promotional packaging such as a commemorative bottle, or a holiday gift set. At other times, the change in UPC may be purely temporal in nature. Second, a "product" may have one UPC for 2007 and 2008, but a different UPC in 2009 and 2010 if the packaging was redesigned. The third most common occurrence is that the same product may be available in both glass and plastic bottles at the same time. We rarely observe price differences for glass and plastic packaging within a product-month, so we also consolidate these UPCs.

to monthly store data by taking the sales weighted median price for each product-store; in practice there is rarely disagreement among the weeks within a month for a product at a given store. Another feature of Connecticut law is that temporary retail sales are not allowed, and retail "sales" must be registered with the DCP in advance. This provides a substantial advantage over other states in that weekly prices are more likely to accurately describe the prices consumers face.

We construct price changes at both the retail and the wholesale level over different time horizons. For example, we compute 1 month, 2 month, 3 month, 6 month, and 12 month price changes. This lets us measure potential pass-through effects over different time horizons, and allows for the fact that pass-through may not happen instantaneously. Later we mention when we restrict our prices to cases where we observe an unambiguous retail price

5 Results

5.1 Descriptive Evidence

We begin by summarizing the price changes we observe in Connecticut around July 2011 when state alcohol taxes on spirits increased by \$0.178 for 750mL products, \$0.238 for 1L products and \$0.416 for 1750mL products. Table 2 reports mean monthly retail and wholesale price changes weighted by sales from 2008 through 2012. The mean retail price change is taken over all products and stores while the mean wholesale price change is calculated over all products and all wholesalers. Table 2 demonstrates two patterns. The first is that the most price increases appear to take place in January and July, irrespective of tax increases; and that distributors often discount products in October in preparation for the holiday season. This supports anecdotal evidence that this coincides with when major distillers (and wholesale distributors update their prices). The second pattern than emerges is that the price increases in reaction to the July 2011 tax hike were substantially larger even when compared to other July observations. Wholesale and retail prices immediately and sharply increased in reaction to the tax hike in July 2011 with a mean wholesale price change of \$1.462 and a mean retail price change of \$0.422 . The pattern shows that the Connecticut tax increase arrived at a time when wholesalers and retailers were poised to adjust prices anyway. The timing of Connecticut's tax increase may have facilitated the immediacy of the price impact.

In addition to the average level of price increases, the frequency of price changes is an important component to our story about rigidities. Even during the period of the July 2011 tax increase, more than half of retail prices remained unchanged. Figures 4 and 5 plot the sales-weighted fraction of wholesale and retail products experiencing price changes and price increases each month. As the figures show not only did products experience a large change in the average price, a much higher fraction of both retail and wholesale prices changed and increased in July 2011. Wholesalers changed an 90.0 percent of prices in July 2011 and increased 68.1 percent of prices. Retailers changed somewhat fewer prices, 44.3 percent, and increased 36.4 percent of prices. July 2011 saw more price changes and increases at both the wholesale and retail level than any other month.

We hypothesize that the source of the rigidity in retail prices is that the overwhelming majority of prices end in \$0.99. Table 3 reports the frequencies of the cents part of retail and wholesale prices. Approximately 91% of retail prices end in \$0.99 and another 3.6% end in \$0.49. In Illinois, almost 81% of prices end in \$0.99 and 5.3% end in \$0.97, though the bulk of the \$0.97 prices are found in a single large retail chain. There is also evidence of some "focal prices" at the wholesale level, 50.4% end in \$0.91 and another 10.7% end in \$0.41.[23] One potential behavioral explanation for this phenomenon might be that consumers suffer from left-digit bias and are unable to process the cents component of price such as Lacetera, Pope, and Sydnor (2012). The left-digit bias explanation is somewhat less persuasive as an explanation for the small number of price points at the wholesale level, as we would expect firms to be less susceptible to these sorts of biases. Another explanation might be that firms consider only a smaller number of discrete price points for cost or information processing reasons, or may simply lack the technology to display prices that do not end in \$0.99 (perhaps because the last two digits are permanently printed). Our objective is not to explain why firms choose to employ a small number of discrete price points, but rather to take that behavior as given, and explore the implications of discrete pricing on pass-through and taxation.

These few and concentrated price points lead to interesting patterns in price changes. Table 4 reports the frequency of various retail and wholesale price change increments in all months and in the month of the tax change, July 2011. There are several things to notice about the table. First, the majority of retail prices are not changed in a given month—roughly 83.7 percent of retail prices overall and 63.6 percent in July 2011. Second, more than three-quarters of retail prices are adjusted in whole dollar increments both in the entire sample and for July 2011. Nearly all of these whole dollar retail price changes are from prices that end in \$0.99 to prices that end in \$0.99. Third, the eight most common retail price change increments account for nearly 70 percent of all non-zero changes overall and nearly 80 percent in July 2011. Price increases of exactly one dollar comprise 20.1 percent of retail changes overall and 38.6 percent of changes in July 2011.

Finally, wholesale prices are adjusted more frequently and the changes are in less concentrated increments. In general only 37.4 percent of wholesale prices are left unchanged with only 10 percent left unchanged in July 2011. The eight most common increments account for less than half of all non-zero price changes in July 2011 and otherwise. Further, whole dollar price changes overall and in July 2011 are less common than in retail data, accounting for 43.8 percent of changes overall and just 30.2 percent of changes in July 2011. Although wholesalers do have preferred price change increments, wholesale price changes are not nearly as concentrated as retail price changes and wholesalers are more likely to raise prices by partial dollars. The fifth, and final, fact we document,

[23] The 91 cent wholesale price mirrors the 99 cent retail price due to an unusual feature of Connecticut law governing alcohol sales. Retailers are legally prevented from selling below cost, and cost is interpreted as the wholesale per unit price plus 8 cents. Additionally, wholesale prices are generally quoted in cases rather than a per-bottle equivalent pricing.

is that even when the measured tax pass-through rate is large ($\geqslant 1$), a majority of retail prices are not changed at all; the measured retail pass through rate is generated by a small number of large, whole-dollar price increases. Wholesalers tend to change prices in whole dollar increments but not quite as overwhelmingly frequently as retailers. These pricing patterns show that retailers, and to a lesser degree wholesalers, do not smoothly pass on cost shocks but rather adjust prices in $1.00 increments.

5.2 The Pass-Through of Alcohol Taxes into Spirits Prices

In this subsection, we employ a standard regression based estimated of the pass-through rate controlling for covariates, but ignoring the rigidities in retail prices. We use a pass-through regression specification that is similar to those used in the rest of the literature and presented as equation (3):

$$\Delta p_{jt} = \rho_{jt}(\mathbf{X}, \Delta\tau) \cdot \Delta\tau_{jt} + \beta\Delta x_{jt} + \gamma_j + \gamma_t + \epsilon_{jt}$$

where j indicates products and t indicates time periods. Here $\rho_{jt}(\mathbf{X}, \Delta\tau)$ represents the pass-through rate, the parameter of interest. It measures how changes in the specific tax measured in dollars, $\Delta\tau_{jt}$, affect changes in price, Δp_{jt}. Similar to the existing literature we begin by assuming constant pass-through $\rho_{jt}(\mathbf{X}, \Delta\tau) = \rho$, which we later relax. A value of $\rho = 1$ implies full or 100 percent pass-through, while a value $\rho > 1$ implies over-shifting of the tax burden and $\rho < 1$ indicates incomplete pass-through. We allow for product fixed effects α_j, which in the differenced model have the interpretation of a product-specific time trend. We also include time fixed effects γ_t; we employ month of year fixed effects, and year fixed effects, but cannot allow for month-year fixed effects and still identify the impact of the tax change. These time controls will account for seasonal pricing differences as well as year-to-year trends.

We report our estimates of the pass through of taxes into wholesale prices in Table 5. The first row reports average pass-through rates across all products while the subsequent rows report pass through rates separately for each bottle size. Because the only variation in the size of the tax change comes through the bottle size, this is a "non-parametric" estimate of $\rho_{jt}(\Delta\tau)$. Because the data we assembled are reported monthly, unlike most prior pass-through studies on alcohol taxes we are able to investigate how the rate of pass-through varies over these different time horizons. Columns (1) through (3) report the average pass-through rate using all wholesaler observations over one, three and six month time intervals, respectively. Columns (4) through (6) report how the lowest price for a product chosen across wholesalers each month reacts to the change in tax over the same time intervals. As column (1) reports, over a one-month interval the tax increase is over-shifted to wholesale prices at a rate of 1.302 (0.368) or more than 130 percent. Over three-month and six-month horizons, however, the point estimates decline, with a six-month pass-through rate of just 0.805 (0.255). While the estimates reported in columns (1) through (3) are not statistically different from one another, the declining point estimates suggest that relative to other years and months, prices were not increased at the typical pace three and six months after the tax increase. The tax increase led to an immediate large increase in prices that was subsequently modulated by slower price hikes. Examining the change in the lowest price charged by any wholesaler shows higher but statistically similar pass-through rates over all three intervals (columns (4) through (6)), that also decline over longer horizons.

Table 5 also reports wholesale pass-through rates separately for each bottle size. A clear pattern emerges: smaller products, which were subject lower tax increases, had higher wholesale pass-through rates. Pass-through rates on 750mL products, which comprise nearly 56 percent of products, exceed 300 percent over all three time horizons. The largest products, 1750mL units, make up roughly 35 percent of products and experience pass through rates that decline from 1.274 (0.487) over the one-month horizon to 0.870 (0.298) and 0.816 (0.252) over the three- and six month horizons, respectively. Less than 10 percent of products are 1L units, reducing our power to measure the pass through rate as evidenced by the lack of statistically significant pass through coefficients over one and three months; over six-months the pass-through rate for these medium size products, 1.664 (0.544) lies between the pass-through rates for smaller and larger products. Size-specific analysis of the lowest price charged by any wholesaler (columns (4) through (6)) shows similar patterns as the full set of wholesale prices.

Table 11 reports pass thorough regressions of equation **??** for retail prices in Connecticut. Columns (1) through (3) report the average pass-through rate across all retailers while columns (4) through (6) restrict the sample to only those stores where prices changed. Average retail prices reacted strongly to the tax increase with a one-month pass-through rate of 1.533 (0.271) that declines to 1.013 (0.264) at the six-month horizon, implying that taxes were first over-shifted and then fully passed through to retail prices, though the estimates are statistically indistinguishable. As the size-specific estimates show, again smaller products faced higher pass-through rates with six-month pass-through rates of 2.084 (0.503), 1.586 (0.470) and 1.009 (0.263) for 750mL, 1L and 1750mL products, respectively. Columns (4) through (6) show that conditional on a retail price change we find large pass through rates that are greater than two and potentially above three. These higher conditional pass-through rates also decline with product size. The robust pattern of over pass-through for smaller products and lower pass-through for larger products, which faced higher tax increases, is our second key fact.

Although we only have wholesale price data for Connecticut (and thus much of our analysis centers on Connecticut's July 2011 tax increase), we also examine the impact of tax increases during our sample period on retail prices in another state as well to understand how the size and timing of a tax increase affect pass-through. Table 7 reports the results of regressions examining the impact of Illinois' September 2009 $4.05 per gallon tax increase. Illinois' large increase came after the typical seasonal price increase in July and as column (1) shows, pass through is incomplete over the one-month interval. As the interval expands, however, pass-through rises. Over the six-month interval pass-through exceeds unity with an estimated rate of 1.267 (0.052). Looking at pass-through rates by product size, we see that like Connecticut, in Illinois 750s experience much higher pass through rates than 1750s with a six-month pass-through rate of 1.828 (0.079) versus 1.062 (0.059). Conditional on a price change, pass-through rates are moderately higher and exceed unity over all horizons. These patterns suggest that when prices are changed, the tax increase is passed through to retail prices but that when a tax increase follows a seasonal price adjustment it may take several months for enough prices to be adjusted to reflect the tax increase. Our ability to delve deeper into this explanation is limited by the lack of wholesale pricing data for Illinois. Taken together the results of Tables 11 and 7 show that average pass-through rates can range widely but when prices are changed the increases outpace the tax increase, though the timing of the price increase may affected by when in the pricing cycle a tax increase arrives.

We can also pool data across Connecticut and Illinois. We report those results for just the 3 month window in Table 8. These results largely mimic those in Tables 11 and 7, and when we fully interact all of the variables with state indicators as we do in Column (5), we get identical results. These pooled regressions are helpful to demonstrate that the measured pass-through rate is in general declining in the size of the tax increase $\Delta\tau$. The only tax tax increase that appears to be undershifted is the tax increase of Illinois of \$1.872 on 1.75L bottles (coefficient of 0.830), meanwhile the tax increase of \$1.07 on 1L bottles by Illinois appears to be fully passed-through (coefficient of 1.061). These are much smaller than the estimated pass-through rate of a \$0.17 tax increase on 750mL bottles in Connecticut (coefficient of 1.936). Here, we believe that the relationship between the size of the tax and the \$1 price increase is not coincidental. We attempt to recover the nonlinear structure of $\rho_{jt}(\mathbf{X}, \Delta\tau)$ by allowing $\Delta\tau_{jt}$ to enter the regression for Δp_{jt} as a polynomial function. Rather than report those estimates as a table, we display them in Figure 6. We plot the estimated pass-through rates from Column (5) with their standard errors, along with polynomial functions of $\Delta\tau_{jt}$: the dotted black line represents a regression of Δp_{jt} on $\Delta\tau_{jt}, (\Delta\tau_{jt})^2$, while the dotted line also includes $(\Delta\tau_{jt})^3$.

We also find that pass-through varies systematically across stores as reported in Table 9. We use two different discrete measures of high and low-price stores: one splits stores into sets that charge above and below median prices for a given a product (in a particular month) while the second compares the prices of the highest-priced and lowest-priced stores for a given product (in a particular month). Retail stores that charge a relatively low price for a product at the beginning of the period increase prices more following the tax increase, regardless of how relative price is measured. Again these regressions include product-specific time trends and month and year fixed effects. For both measures we find that at low-price stores the tax is passed on at a rate of roughly 290 to 300 percent while at high-price stores the tax is passed on a rate of only 26 to 31 percent. The negative relationship between pass-through rates and relative initial prices is our third key fact. Stores that charged lower prices at the time of the tax change were able to pass-on the tax to consumers at ten times the rate of high-price stores and were able to mark up prices by multiple times the actual tax increase. For robustness we also employ a continuous measure of relative price as well and find consistent estimates.

Higher pass-through rates at stores that initially charge lower prices effectively compresses the distribution of prices for a given spirits product and thus limits the ability of consumers to reduce pass-through rates by shopping. More broadly, the variation in pass-through rates across product sizes and stores evidences substantially heterogeneity in pass-through rates. This heterogeneity suggests that prior work considering a uniform and smooth pass-through rate may be ignoring important frictions.

5.3 Discrete Price Changes

We focus on the case where price changes are discrete, rather than continuous. In order to appropriately match the frequency of price changes, we aggregate the data to the quarterly level. We choose a quarterly interval because it corresponds with the three-month pass-through rate in our least squares estimates. We aggregate the data, rather than using a moving window like we did in the pass-through regressions, in order to capture the frequency aspect of price changes. Suppose the price changed only in August 2011 in response to the July 2011 tax hike. Using a three month rolling window, we would notice that taxes were higher in July (no price change), August (price change), and September (price change due to August's change). If we aggregate to the quarterly level, then we say that there was both a tax change in 2011:Q3 and a price change. This helps to reduce the size of the data, though we still have around 224,000 observations for Connecticut and 2.4 million observations for Illinois.

We begin by considering the simplest possible model we presented in equation (4) where firms choose to increase prices by \$1 or to keep their existing prices. That is, there exists some latent threshold of tax increase $\overline{\tau}_{jt}(\mathbf{X})$ above which the firm raises its price by \$1 and below which it does stays put. This suggests a flexible logit or probit specification in order to predict whether or not a \$1 price increase takes place. For now, we consider all price changes $\geqslant$ \$1.00 as $y = 1$ and everything else $y = 0$. In a world without menu-costs, but with rigidities around \$0.99 price increments, this might not be an unreasonable a priori restriction on the price responses to a small tax increase. That is, we rule out the firms can respond to tax increases of $\leqslant$ \$1 with price changes $\geqslant$ \$2, or by decreasing their price. We might worry that price decreases, or price increases of \$2 or more are being driven by exogenous factors other than the tax and in a sense we are eliminating outliers. For the period around the tax change, more than 40% of observed price changes are exactly \$1.00 increases.[24]

We present the parameter estimates and counterfactual welfare estimates from a binary logit

[24]If we allow for menu costs that firms must pay in order to adjust their prices, they may prefer to adjust prices in \$2 or larger increments and "save up" for price changes if they are sufficient expensive to implement.

first. Later, we relax this and restrict the firm's prices to the following options $\Delta p_{jt} \in \{-2, -1, 0, 1, 2\}$ which comprise roughly 65% of observed price increases from Table 4 using an ordered logit model. There are two ways to interpret our logit model. One is as a purely statistical model that captures the nonlinearity of discrete price changes. The second is as a policy function of a larger dynamic game in the spirit of Bajari, Benkard, and Levin (2007). Unlike the larger literature on dynamic games, we are not interested in recovering the price adjustment or menu cost, or analyzing equilibrium counterfactuals. We are merely interested in how the "policy" of the firm would vary at different levels of $\Delta\tau_{jt}$. Thus whether we wish to interpret our logit as a structural model or a reduced form model is largely irrelevant for the counterfactual predictions we are interested in.

We estimate four binary logit models and present those results in Table 10. We estimate using the Connecticut data only, and using pooled data from both Connecticut and Illinois. Just as in the pass-through regressions, the primary advantage of including the Illinois data is that it provides us a much larger support for $\Delta\tau_{jt}$ (the tax change is approximately 4.5x as large) and lets us estimate specifications that are nonlinear in the size of the tax change. Looking at specifications (1) and (3) we find that larger tax increases are associated with a higher probability of a price increase. We also see that products with higher prices in previous periods are more likely to experience a price increase (thus a \$1 price increase is more likely on an \$80 bottle of scotch than an \$8 bottle of Vodka). We see that products with higher sales during the previous year, or products sold by larger stores are more likely to experience price increases. We also see that products that are stocked by more stores (# Competitors) are more likely to experience price increases. We also include a 4th order orthogonal polynomial in the cumulative change in the wholesale price since the last retail price increase, which we label Δp_w. We think that this is an important state-variable that emerges from the retailer's dynamic optimization problem. If costs have not changed at all since the last retail price change $\Delta p_w = 0$, and thus we would not expect the retailer to have a different optimal retail price $p*$. If wholesale prices have risen dramatically since the last retail price increase, then we expect the retailer to be more eager to adjust prices. The polynomial effects are hard to interpret on their own, but we find that the probability of a price increase is generally increasing in Δp_w for all specifications. Because they were relevant in Table 9, we also include variables describing where a particular retailers price was relative to its competitors for the same product. Again we find that firms with the highest price were substantially less likely to increase prices, and firms with the lowest price were substantially more likely to increase prices in all specifications. Finally, we also include a cubic orthogonal polynomial in the difference between a retailers price and the state-wide median price for that product; which also picks up the effect that relatively high priced firms were less likely to increase prices than relatively low priced firms. We get roughly similar estimates for specifications (1) and (3) with the only difference being that we allow for a cubic polynomial in $\Delta\tau_{jt}$ once we include the Illinois data; and that the Illinois data does not allow us to control for changes in the wholesale price because it is not observed. All of the reported coefficients are significant at

1% and all of the polynomials have been chosen to minimize the BIC criteria.

We also allow for some "endogenous" regressors in columns (2) and (4). Here we include the fraction of competing stores that have changed their prices of that product during the same period. This might help to capture changes in the wholesale price when it is unobserved (in the Illinois data). It might also capture major repricing events by the upstream distillers if they are not perfectly predicted by quarter or year fixed effects. The downside is that these additional variables are very likely to be endogenous is the traditional sense: they are outcomes of other observations. Without an instrument (or a control function) we worry that including these may bias the effect on $\Delta\tau_{jt}$. For this reason we do not use these estimates to conduct counterfactual simulations.

In addition to the parameter estimates, we report the model fit criteria using the classification accuracy of "best guess" predictions. That is if the predicted probability is $p(\mathbf{X}, \theta) > 0.5$ then we set $\hat{y}_i = 1$ and otherwise we set $\hat{y}_i = 0$. We report the classification accuracy rate of the models in 10 using data only from the period of the Connecticut tax increase.Using only CT data in specification (1) we correctly predict approximately 81% of the observations. We also report the Null Accuracy or No Information rate, which is the accuracy we would obtain by predicting zero for all observations. This is 67.5%. We can see that including the endogenous regressors only improves the accuracy to around 85%. We also see that including data from Illinois obviously cannot improve in-sample prediction accuracy on the Connecticut data. However, we believe it is important in improving out of sample forecasts for larger changes in $\Delta\tau_{jt}$ than we observe. The disadvantage of the model in specification (3) is that it lacks information about the change in wholesale prices. Thus we also consider a model that averages the prediction of specification (1) and (3) with 50-50 weights on each. We report the predicted probabilities for model (1), model (3) and the average of the two models in Figure 7. We report both the predicted probabilities and the "best guess" estimates. For the two models (and the averaged model) we find the predictions are quite similar for different levels of $\Delta\tau_{jt}$.[25] We also report the implied incidence in the same figure. In general we find that the probability of a price increase (under the best guess criteria) is monotonically increasing in the size of the tax in all models, and that it varies from around 20-25% at the observed tax increase for CT to nearly 75% for the observed tax increase in IL. We also compute the pass-through rate of the tax, which we estimate to vary between 60-80%. Using the predicted probability criteria we obtain much smoother plots, and the pass-through rate is declining in the side of the tax from around 125% at the observed tax increase in CT down to around 65% for the observed tax increase in IL.

6 Welfare Implications of Lumpy Pass-Through

Beyond understanding how the incidence varies with the magnitude of the tax change, we can also assess how welfare losses and tax revenue vary with the size of the tax change taking into account

[25] If we extrapolate only the CT data far out of sample using a polynomial in $\Delta\tau_{jt}$ we can find some less believable predictions, such the probability of price increases decreasing in the size of the tax. This is not unexpected.

the discreteness of price changes.

In the standard set up tax changes lead to smooth continuous price changes and the measured pass-through rate can be expressed by familiar expression of demand and supply elasticities. Here firms either change prices in large, discrete increments, typically much larger than the tax increase, or leave prices unchanged and fully bear the taxes themselves. The result is pass-through rates that vary with the size of the tax change: logit best-guess estimates suggest that the pass-through rate is in fact U-shaped with very small tax increases triggering few price increases and thus very low pass-through, very large tax increases leading to many price changes but also much higher taxes and thus lower pass-through rates, and between the two, moderate tax changes yielding many price increases such that pass-through rates are in fact the highest.

Varying pass-through rates will of course mean that the surplus losses of consumers and producers will vary with the tax change as well; when there are many price increases consumers will lose more surplus while more unchanged prices will mean that producers bear more of the tax. Higher taxes will generally mean more revenue but less so when prices are changed and quantities react.

To better understand welfare and revenue implications of the pricing behaviors we document and U-shaped pass-through rates they yield we simulate the consumer and producer surplus lost at different tax rates as well as the amount of government revenue raised. For illustrative clarity we simulate surplus losses with linear demand. We also model marginal costs as constant.[26]

Consider Figure 8 which describes the welfare changes resulting from the introduction of a tax on a single product j, when producers do not change their price. Here producers are initially selling product j at a price P_0 with marginal cost MC and thus earning variable profits of $(P_0 - MC) * Q_0$. When the tax τ is levied the firm chooses not to raise prices and thus bears the full tax. Because the price is unchanged, quantity remains at Q_0. Variable profits decline to $(P_0 - \tau - MC) * Q_0$ and the government collects $\tau * Q_0$ in tax revenue.[27]

Figure 9 models welfare changes when the tax increase results in a price increase. Producers raise prices form P_0 to P_1, which overshoots the tax increase of τ and results in a quantity decline to Q_1. Consumers lose the rectangle $(P_1 - P_0) * Q_1$ as well as the deadweight loss triangle arising from the reduction in units sold, $0.5 * (P_1 - P_0) * (Q_1 - Q_0)$. Producers gain the additional margin from the price increase on the units still sold, less the tax, $(P_1 - \tau - P_0) * Q_1$ but lose the margin they earned on the units no longer sold following the price increase $(P_0 - MC) * (Q_0 - Q_1)$.[28] The government raises, $\tau * Q_1$—less than when prices are not changed.

[26]Because we examine the effects of tax changes in Connecticut, which accounts for a very small fraction of overall sales for spirits products, it seems reasonable to assume that wholesalers face constant marginal costs—in other words, that the quantity changes resulting from the tax increases we model do not affect the marginal production costs for distilling firms. Given the global scale of distilling firms, this approach seems reasonable.

[27]Note that because the producers price above marginal there is existing dead weight loss; we ignore this inefficiency because it does not factor in we focus on changes in surplus due to the tax.

[28]Of course firms also face some kind of cost to changing prices that generates the infrequent, large price changes that we observe; we do not model these costs.

To estimate these components of the welfare impact of the tax we draw on a combination of data, parameter estimates and an assumed demand elasticity, which we vary to understand the sensitivity of our results. We assess the losses to the joint wholesale and retail tiers, and as such we use the marginal cost estimates recovered from the structural model of the Connecticut spirits markets considered in (Conlon and Rao 2014). The initial prices and quantities, P_0 and Q_0 for each product j, come from the data we assemble; we use the quantities and retail prices observed in the quarter prior to Connecticut's July 2011 tax increase (2011Q2). Our estimated pass-through function, $\frac{\widehat{Pr(\Delta P=1|X)}}{\Delta\tau}$, is used to generate estimates of P_1 for each product j.

We assume a uniform elasticity across all j products to determine the new quantity, Q_1 when producers choose to change prices. Importantly we assume that all cross-product elasticities are zero. This will have the effect of exaggerating the surplus lost by consumers as some spirits products are likely seen as substitutes by consumers and consumers can adjust to large price changes over a limited set of products by switching to products with unchanged prices. The assumption of zero cross-price elasticities will matter only to the degree that the welfare gain from switching products varies substantially with the size of the tax change. If for large tax changes nearly all prices are increased the scope for product switching will narrow and this assumption may matter less.

Figure 10 displays simulated welfare effects for three demand elasticities, -0.5, -1 and -1.5, and shows the consequences for 750mL and 1750mL products separately in addition to the overall effect for all product sizes. The vertical dotted lines note the tax increases in Connecticut and Illinois that generate the logit parameter estimates that undergird the simulations. The simulation is more reliable within this range.

In each plot the red line measures the fraction of products that are estimated to experience a price increase; larger tax increases beget more price increases. The green line tracks how the incidence, that is $\frac{\Delta CS}{\Delta PS}$, varies over the range of tax increases considered. The ratio of consumer to producer surplus losses is not monotonic. Comparing the green and red lines it is clear that when the share of price increases increases more steeply, the consequence is a much higher incidence on consumers. As the prices of more products increase by \$1 consumers bear disproportionately more of the tax burden. The blue line describes one concept of tax efficiency, the ratio of consumer surplus losses to tax revenue raised, $\frac{\Delta CS}{\Delta Rev}$. Although deadweight loss is the better measure of wholly forgone surplus, it's sensitivity to the assumed elasticity rather than the pass-through rate makes it less illustrative of the role of variable pass-through than the lost consumer surplus. A government sensitive to the consequences of tax increases for consumers may also find this measure more useful. The tax increases with the highest ratio of lost consumer surplus to revenue raised largely track the tax increases with the worst incidence, but elsewhere more revenue is raised per dollar of lost surplus as the tax increase grows.

Comparing the different plots three patterns emerge. First, when demand is less elastic, for example the top row where $\epsilon_D = -0.5$, the relative incidence on consumers is more variable across the range of tax increases than when demand is more elastic, for example the bottom row where $\epsilon_D = -1.5$. As the elasticity of demand grows, the surplus lost to forgone trades grows for both consumers and producers and the relative incidence becomes more comparable. Second, the highest incidence on consumers largely tracks the highest incidence for 1750mL products, which is unsurprising since these products comprise the bulk of sales. Finally the ratio of $\frac{\Delta CS}{\Delta Rev}$ makes clear that if governments need revenue but are primarily concerned with the welfare of consumers, they are better off enacting large tax increases since the ratio of consumer surplus lost relative to revenue raised declines with the tax increase.

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Figure 1: Timing of Alcohol Tax Changes in Connecticut and Neighboring States

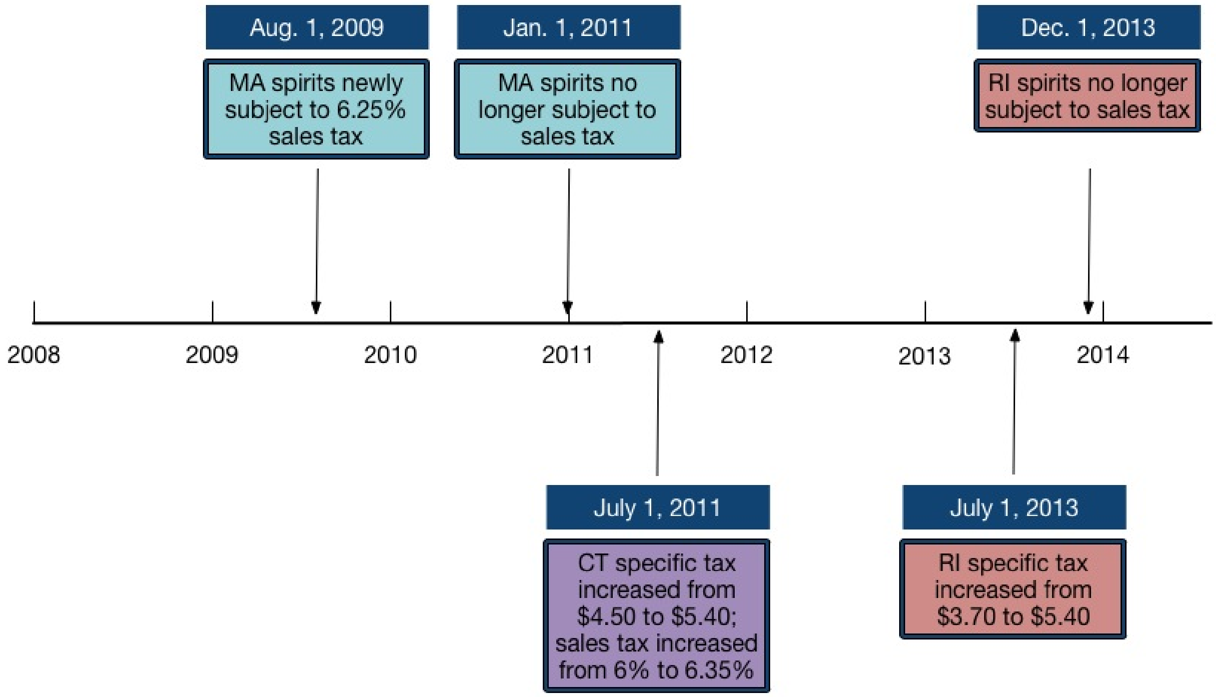


Figure 2: Perceived Demand as an (s, S) rule

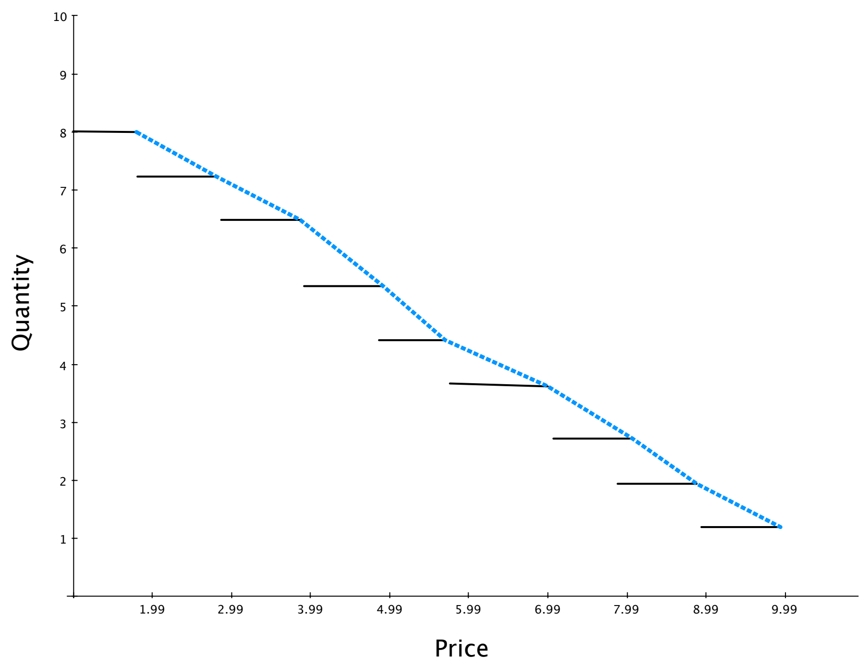


Figure 3: Probability of $1 Tax increase at different tax sizes

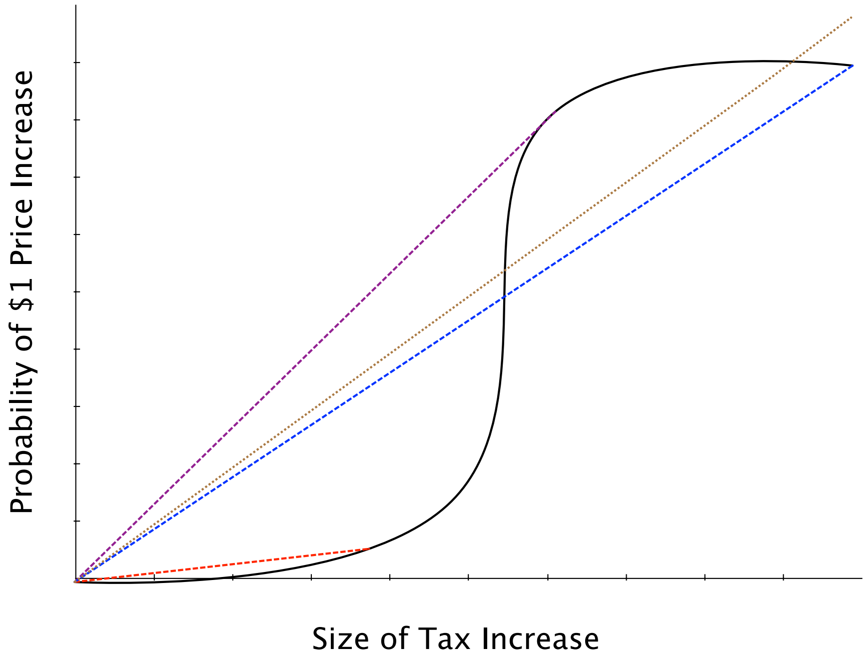
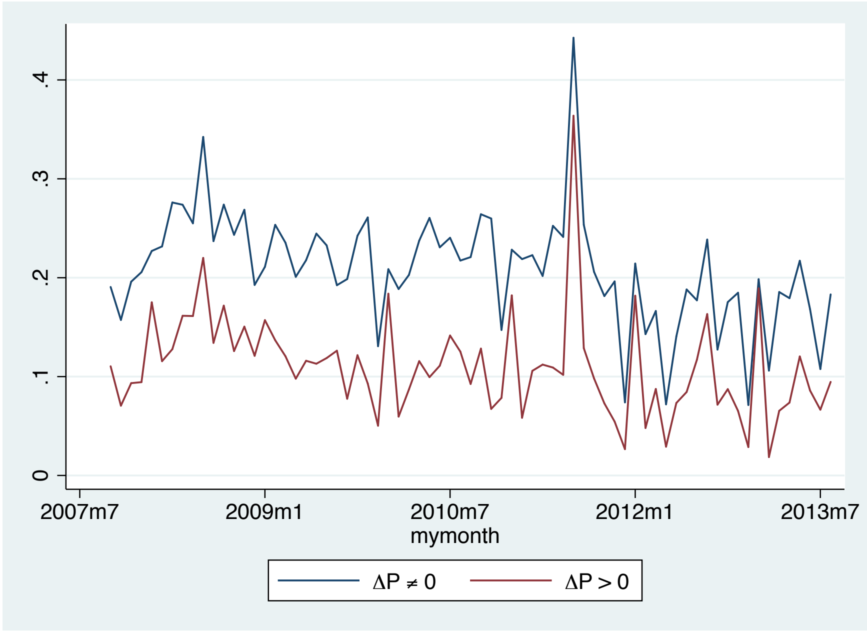


Figure 4: Frequency of Wholesale Price Adjustment by Month, CT

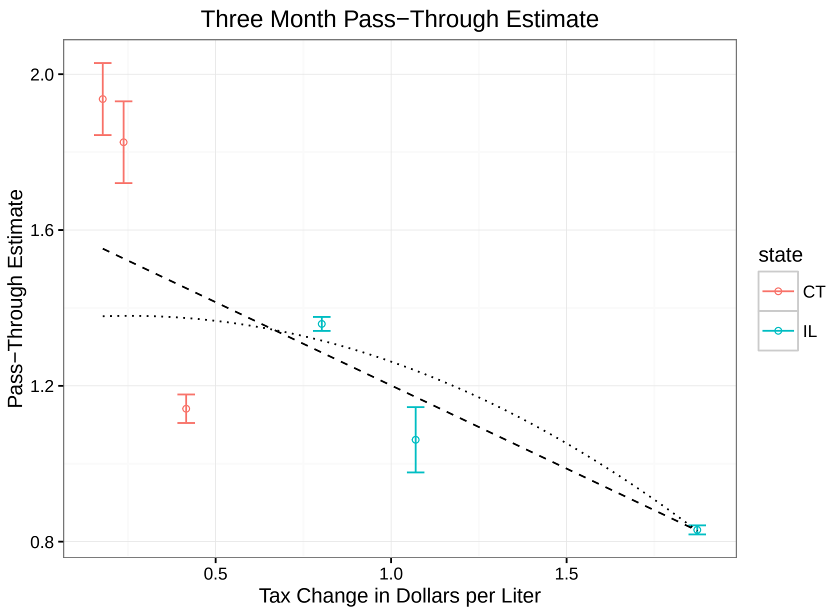
The figure above reports the share of wholesale prices that change and that increase for each month between 2008 and 2012, weighted by retail units.

Figure 5: Frequency of Retail Price Adjustment, CT



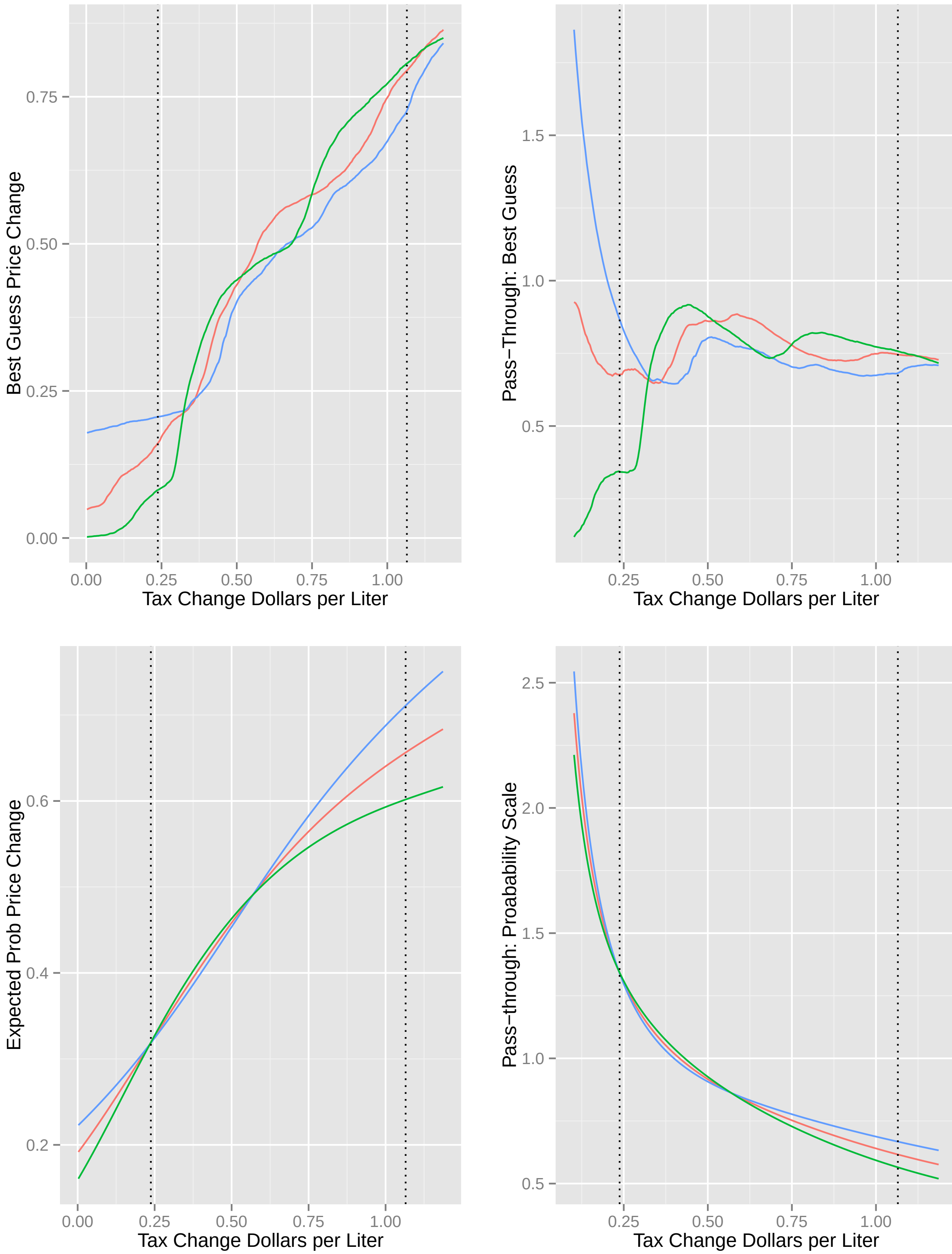
The figure above plots the share of retail prices that change and that increase for each month between 2008 and 2012, weighted by retail units.

Figure 6: Pass-Through Estimates



The figure above plots the estimated pass-through rates for different size tax increases. The dashed line estimates the pass-through rate as a linear function of the tax, and the dotted line estimates the pass-through rate as a quadratic function of the tax.

Figure 7: Logit Fit Comparison



The figure above plots the fit for the binary logit using both predicted probability, and best-guess criteria. Vertical lines denote the observed tax change in CT and IL respectively. Blue: CT data, linear specification. Green: CT and IL, Cubic Specification. Red: 50-50 averaged model.

Figure 8: Change in Surplus When Price is Unchanged

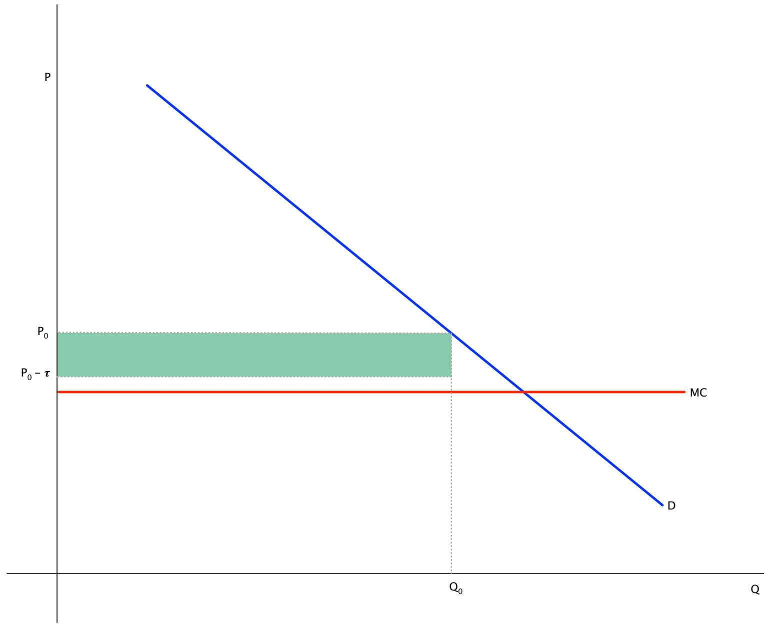


Figure 9: Change in Surplus When Price is Changed

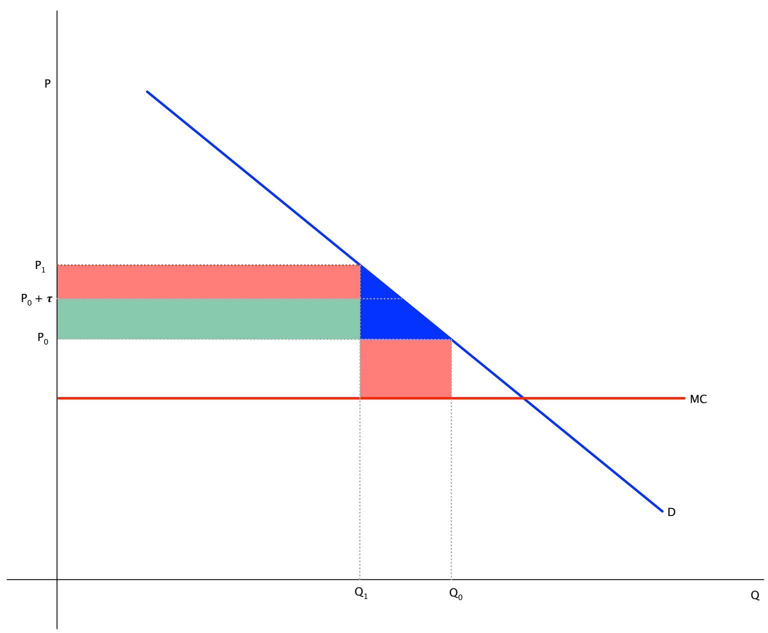
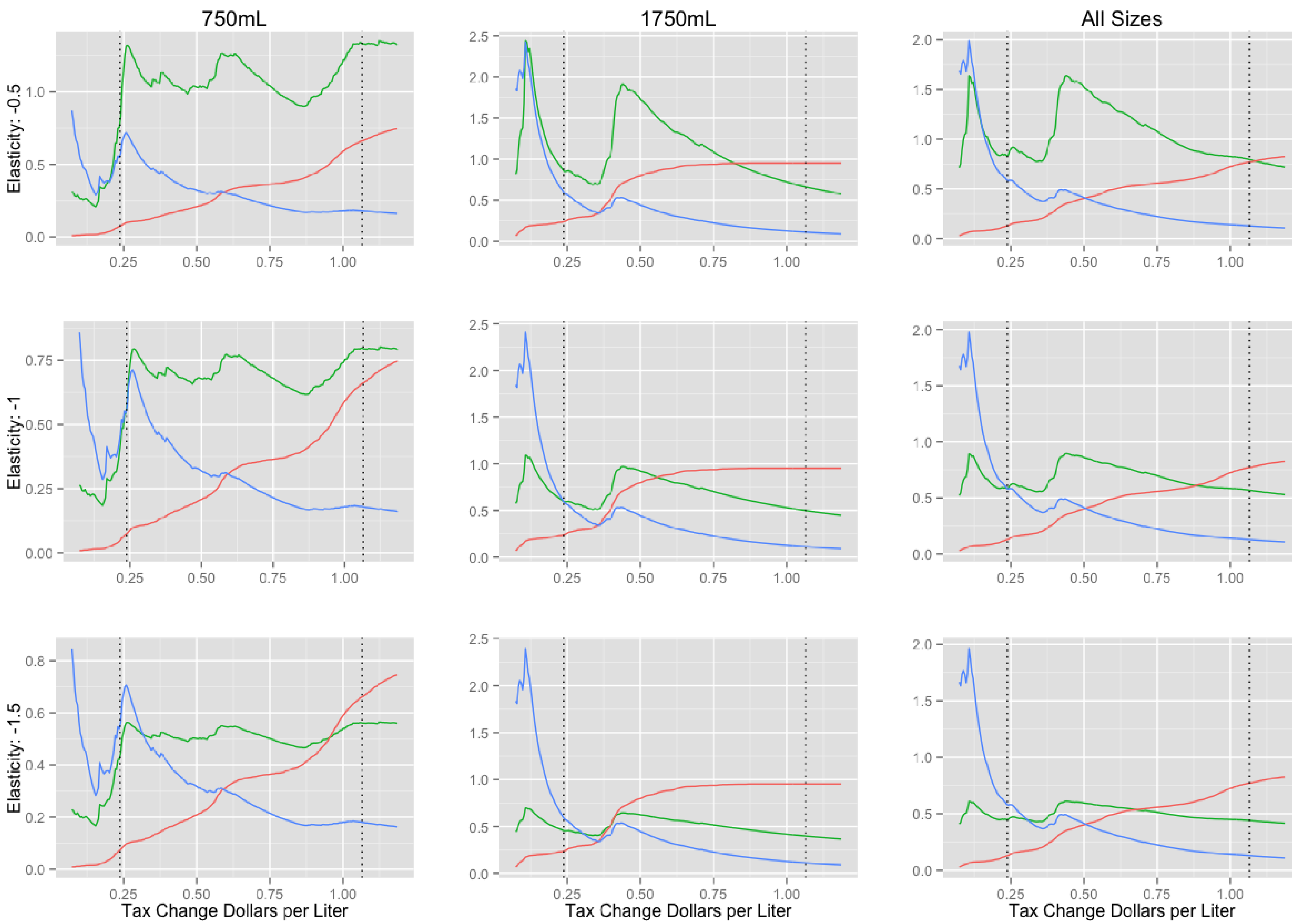


Figure 10: Counterfactual Welfare



Red Line: Probability of a Price Increase; Green Line: Incidence $\Delta CS/\Delta PS$; Blue Line: $|\Delta CS|/\Delta GovRev$.

Table 1: Recent Changes in Distilled Spirits Taxes

State	Old Tax	New Tax	Effective Date	Notes
Connecticut	\$4.50/gal + 6% sales tax	\$5.40/gal + 6.35% sales tax	July 1, 2011	
Illinois	\$4.50/gal + 6.25% sales tax	\$8.55/gal + 6.25% sales tax	Sept 1, 2009	additional local sales tax
Kentucky	\$1.92/gal	\$1.92/gal + 6% sales tax	April 1, 2009	additional 11% wholesale tax
Maryland	\$1.50/gal + 6% sales tax	\$1.50/gal + 9% sales tax	July 1, 2011	
Massachusetts	\$4.05/gal	\$4.05/gal + 6.25% sales tax	September 1, 2009	Ended Jan 1, 2011
New Jersey	\$4.40/gal + 7% sales tax	\$5.50/gal + 7% sales tax	August 1, 2009	sales tax was 6% before 7/1/06
Rhode Island	\$3.75/gal + 7% sales tax	\$5.40/gal + 0% sales tax	December 1, 2013	

Note: The table above describes the nature and timing of the tax changes for each of the seven states that have altered their taxation of alcohol since 2007.

Table 2: Mean Change in Retail and Wholesale Prices, CT

	Wholesale Prices					Retail Prices				
month	2008	2009	2010	2011	2012	month	2008	2009	2010	2011	2012
1	0.381	0.421	0.460	0.338	0.469	1	-0.018	0.241	0.350	0.362	0.350
2	-0.923	-1.258	-1.110	-0.899	-1.050	2	0.139	-0.221	-0.317	-0.197	-0.166
3	0.694	0.850	0.714	0.420	0.822	3	-0.042	-0.058	-0.139	-0.105	0.014
4	-0.222	-0.180	-0.220	0.011	-0.017	4	-0.029	-0.018	-0.024	-0.010	-0.073
5	0.244	0.077	0.002	-0.102	-0.023	5	-0.046	-0.129	-0.194	-0.134	-0.009
6	-0.836	-0.927	-1.030	-0.760	-0.707	6	0.080	-0.146	-0.152	-0.121	-0.090
7	0.878	1.089	1.348	**1.462**	0.991	7	0.097	-0.042	0.070	**0.422**	0.020
8	0.124	-0.100	-0.188	-0.340	-0.165	8	0.048	0.124	-0.112	-0.106	0.160
9	-0.108	-0.124	-0.119	0.173	0.189	9	0.004	-0.199	-0.062	0.000	-0.019
10	-0.745	-0.785	-0.563	-0.790	-0.836	10	0.003	-0.023	-0.112	-0.098	-0.044
11	0.204	0.102	-0.270	0.271	0.465	11	-0.040	-0.323	-0.317	-0.303	-0.175
12	0.710	0.480	0.750	0.207	0.121	12	0.009	-0.113	-0.075	-0.097	-0.095

Note: The table above reports the average monthly change in retail and wholesale prices for each month between 2008 and 2012, weighted by retail units.

Table 3: Cents Portion of Retail and Wholesale Prices

Retail Prices: CT			Wholesale Prices: CT			Retail Prices: IL		
99	416,736	90.6%	91	32,435	50.4%	99	4,223,452	80.7%
49	16,419	3.6%	41	6,893	10.7%	97	277,847	5.3%
59	7,666	1.7%	58	2,194	3.4%	49	246,216	4.7%
89	7,447	1.6%	16	2,074	3.2%	98	89,935	1.7%
93	2,064	0.4%	24	1,992	3.1%	79	53,477	1.0%
69	1,531	0.3%	74	1,925	3.0%	0	26,298	0.5%
95	1,089	0.2%	79	1,537	2.4%	29	25,029	0.5%
79	822	0.2%	8	1,402	2.2%	48	23,263	0.4%
Other	6,342	1.4%	Other	13,844	21.5%	Other	269,321	5.1%
Total	460,116		Total	64,296		Total	5,234,838	

Note: The table describes the count of the cents portion of retail prices for each UPC-store observation and wholesale prices for each product-wholesaler in Connecticut between 2008 and 2012 and for other states between 2006 and 2012. Connecticut's minimum pricing law requires all 750mL, 1L, and 1.75L bottles be priced at least 8 cents above the wholesale price. Thus a wholesale price ending in 91 cents reflects a minimum retail price ending in 99 cents.

Table 4: Retail and Wholesale Monthly Price Change Increments

Retail Prices			Retail Prices, 07/2011			Wholesale Prices			Wholesale Prices, 07/2011		
0	384,889	-	0	3,566	-	0	24,013	-	0	124	-
1	15,154	20.1%	1	788	38.6%	-2	2,738	6.8%	1	125	11.3%
2	7,372	9.8%	2	253	12.4%	2	2,695	6.7%	0.25	61	5.5%
-1	7,141	9.5%	-1	152	7.5%	1	1,681	4.2%	0.5	55	5.0%
-2	5,849	7.8%	4	80	3.9%	-1	1,680	4.2%	4	50	4.5%
3	4,121	5.5%	-2	77	3.8%	-4	1,621	4.0%	2.5	47	4.2%
-3	3,638	4.8%	3	72	3.5%	4	1,619	4.0%	0.67	40	3.6%
4	2,665	3.5%	0.6	54	2.6%	3	1,514	3.8%	3	29	2.6%
-4	2,357	3.1%	0.5	50	2.5%	-3	1,427	3.5%	5	29	2.6%
0.5	1,602	2.1%	1.5	41	2.0%	-1.5	1,308	3.2%	-1	28	2.5%
5	1,313	1.7%	-3	33	1.6%	1.5	1,213	3.0%	0.3	20	1.8%
Other	24,015	31.9%	Other	439	21.5%	Other	22,787	56.6%	Other	627	56.4%
Number $\neq$ 0	75,227	100.0%	Number $\neq$ 0	2,039	100.0%	Number $\neq$ 0	40,283	100.0%	Number $\neq$ 0	1,111	100.0%
Whole Dollar	56,580	75.2%	Whole Dollar	1,577	77.3%	Whole Dollar	17,647	43.8%	Whole Dollar	336	30.2%
.99 to .99	55,963	74.4%	.99 to .99	1,565	76.8%	.91 to .91	13,295	33.0%	.91 to .91	287	25.8%
Total	460,116		Total	5,605		Total	64,296		Total	1,235	

Note: The table describes the price change increments for retail and wholesale prices for all months and then for just July 2011. The percentages are the percent of the number of non-zero price changes (Number $\neq$ 0). These counts are unweighted.

Table 5: Pass-Through: Taxes to Wholesale Prices

	All Wholesalers			Lowest Price Wholesaler		
Δ Wholesale Price	1m	3m	6m	1m	3m	6m
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Tax	1.302***	0.960***	0.805***	1.616***	1.290***	1.135***
	(0.368)	(0.278)	(0.255)	(0.465)	(0.297)	(0.252)
Δ Tax*I[size=750mL]	3.598	3.265***	3.446***	2.932	3.330***	3.486***
	(2.562)	(1.035)	(0.579)	(2.333)	(0.976)	(0.502)
Δ Tax*I[size=1L]	-2.295	0.047	1.664***	-0.990	0.927	2.217***
	(1.946)	(0.899)	(0.544)	(1.957)	(0.865)	(0.516)
Δ Tax *I[size=1.75L]	1.274***	0.870***	0.816***	1.609***	1.189***	1.127***
	(0.487)	(0.298)	(0.252)	(0.585)	(0.317)	(0.251)
Observations	64,296	60,841	56,798	42,988	41,080	38,538
Product FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by 2011 Nielsen units and include month and year fixed effects.

Table 6: Pass-Through: Taxes to Retail Prices

	All Retailers			Δ Retail Price≠ 0		
Δ Retail Price	1m	3m	6m	1m	3m	6m
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Tax	1.533***	1.257***	1.013***	3.096***	2.301***	2.016***
	(0.271)	(0.202)	(0.264)	(0.706)	(0.479)	(0.553)
Δ Tax*I[size=750mL]	1.168***	1.900***	2.084***	3.191**	3.822***	4.072***
	(0.432)	(0.387)	(0.503)	(1.577)	(0.899)	(1.144)
Δ Tax*I[size=1L]	2.146***	1.833***	1.586***	5.550***	3.376***	3.553***
	(0.650)	(0.383)	(0.470)	(1.663)	(0.920)	(1.132)
Δ Tax *I[size=1.75L]	1.520***	1.154***	1.009***	2.985***	2.191***	2.027***
	(0.309)	(0.227)	(0.263)	(0.718)	(0.502)	(0.570)
Observations	460,116	437,057	410,288	75,227	113,098	142,220
Product FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by 2011 Nielsen units and include month and year fixed effects. Standard errors are clustered at the UPC level.

Table 7: Pass-Through: Taxes to Retail Prices (Other States)

	All Retailers			Δ Retail Price≠ 0		
	Illinois Sept 1, 2009 Tax Increase of $4.05/gal					
Δ Retail Price	1m	3m	6m	1m	3m	6m
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Tax	0.487***	0.965***	1.267***	1.092***	1.251***	1.493***
	(0.044)	(0.045)	(0.052)	(0.107)	(0.069)	(0.065)
Δ Tax*I[size=750mL]	0.575***	1.363***	1.828***	0.977***	1.780***	2.239***
	(0.082)	(0.083)	(0.079)	(0.175)	(0.134)	(0.095)
Δ Tax*I[size=1L]	0.904***	1.046***	1.307***	1.145***	1.188***	1.443***
	(0.144)	(0.134)	(0.125)	(0.123)	(0.091)	(0.102)
Δ Tax *I[size=1.75L]	0.442***	0.826***	1.062***	1.157***	1.091***	1.256***
	(0.050)	(0.049)	(0.059)	(0.108)	(0.069)	(0.064)
Observations	5,234,838	4,974,620	4,687,529	2,206,133	2,907,497	3,200,085
Product FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by 2009 Nielsen units and include month and year fixed effects. Standard errors are clustered at the UPC level.

Table 8: Three Month Pass-through Using Pooled Data (CT,IL)

	Δ Price				
	(1)	(2)	(3)	(4)	(5)
$\Delta\tau$	1.048***		1.023***		
	(0.044)		(0.043)		
$\Delta\tau \cdot I[750]$		1.400***		1.399***	
		(0.062)		(0.070)	
$\Delta\tau \cdot I[1000]$		1.514***		1.365***	
		(0.167)		(0.161)	
$\Delta\tau \cdot I[1750]$		0.875***		0.864***	
		(0.050)		(0.049)	
$\Delta\tau \cdot I[750] \cdot CT$					1.936***
$\Delta\tau = .1783$					(0.386)
$\Delta\tau \cdot I[1000] \cdot CT$					1.825***
$\Delta\tau = .2377$					(0.382)
$\Delta\tau \cdot I[1750] \cdot CT$					1.141***
$\Delta\tau = .4161$					(0.226)
$\Delta\tau \cdot I[750] \cdot IL$					1.359***
$\Delta\tau = .8024$					(0.083)
$\Delta\tau \cdot I[1000] \cdot IL$					1.061***
$\Delta\tau = 1.070$					(0.127)
$\Delta\tau \cdot I[1750] \cdot IL$					0.830***
$\Delta\tau = 1.872$					(0.049)
Constant	0.023***	0.021***			
	(0.005)	(0.005)			
UPC FE	No	No	Yes	Yes	Yes
Month FE	No	No	Yes	Yes	x State
Year FE	No	No	Yes	Yes	x State
N	5,411,677	5,411,677	5,411,677	5,411,677	5,411,677
R^2	0.011	0.011	0.026	0.026	0.029

Notes: All reported standard errors are clustered at the UPC level
All regressions are weighted by state-level shares (rather than units)

Table 9: Pass-Through: Taxes to Retail Prices Relative to Other Stores

	Above/Below Median (1)	Min/Max (2)	Continuous (3)
Δ Tax	1.532***	1.516***	1.522***
	(0.280)	(0.270)	(0.248)
Δ Tax * High	-1.218***	-1.252***	
	(0.366)	(0.380)	
Δ Tax * Low	1.357***	1.460***	
	(0.500)	(0.496)	
Δ Tax * Relative			-0.174***
			-0.026
High Price	-0.423***	-0.382***	
	(0.043)	(0.039)	
Low Price	0.198***	0.287***	
	(0.042)	(0.040)	
Relative to Median			-0.042***
			(0.004)
Observations	460,116	460,116	460,116
Product FE	Yes	Yes	Yes
Month+Year FE	Yes	Yes	Yes
High Measure	Above Median	Maximum	Continuous
Low Measure	Below Median	Minimum	% Deviation

Note: All regressions are weighted by total Nielsen units in 2011 and consider one month deviations. Relative prices are from PRIOR month
All reported standard errors are clustered at the UPC level.
Columns (1)+(2) use indicator variables. Column (3) uses percentage deviation from median price.

Table 10: Quarterly $1 Price Change, Logit Estimates

	$Pr(\Delta Price \geqslant \$1 \mid X)$			
	CT Only		CT and IL	
	Exog.	Endog.	Exog.	Endog.
	(1)	(2)	(3)	(4)
$\Delta\tau$	2.695***	0.924***	4.285***	2.128***
	(0.131)	(0.154)	(0.254)	(0.305)
$\Delta\tau^2$			−2.505***	−3.060***
			(0.455)	(0.546)
$\Delta\tau^3$			0.483***	1.140***
			(0.171)	(0.205)
$\log(p_{j,t-1})$	0.401***	−0.057***	0.054***	−0.254***
	(0.015)	(0.017)	(0.004)	(0.004)
log(2010 Sales)	−0.031***	0.065***	−0.016***	0.010***
	(0.004)	(0.005)	(0.001)	(0.001)
log(Store Size)	0.016***	−0.012***	−0.040***	−0.044***
	(0.003)	(0.004)	(0.001)	(0.001)
log(# Competitors)	0.163***	0.256***	0.325***	0.337***
	(0.011)	(0.016)	(0.002)	(0.003)
$\Delta p_w = 0$	−3.131***	−2.804***		
	(0.070)	(0.083)		
Δp_w	−27.051***	−34.271***		
	(6.256)	(7.483)		
Δp_w^2	43.770***	57.804***		
	(10.782)	(12.500)		
Δp_w^3	−40.008***	−63.272***		
	(10.847)	(13.108)		
Δp_w^4	42.240**	81.986***		
	(18.678)	(22.186)		
Highest Price	−0.463***	−0.377***	−0.103***	−0.179***
	(0.028)	(0.031)	(0.005)	(0.007)
Lowest Price	0.286***	0.564***	0.459***	0.726***
	(0.023)	(0.026)	(0.005)	(0.006)
Relative Price	−149.273***	−227.526***	−735.393***	−1,023.625***
	(6.087)	(6.801)	(5.063)	(6.355)
Relative Price^2	42.626***	27.415***	79.554***	108.615***
	(4.815)	(5.182)	(4.150)	(19.317)
Relative Price^3	−12.762**	10.365**	10.535**	223.008***
	(5.455)	(4.901)	(4.094)	(20.737)
Constant	0.153	−0.146		
	(0.093)	(0.124)		
Year FE	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes
Polynomial: Competitor $Pr(\Delta P \geqslant 0)$	No	5th	No	5th
Classification Accuracy	0.808	0.846	0.692	0.797
Null Accuracy	0.675	0.675	0.675	0.675
N	224,276	224,276	2,693,076	2,693,076
Log Likelihood	−79,632.270	−59,412.640	−1,369,850.000	−968,791.700
Akaike Inf. Crit.	159,318.500	118,893.300	2,739,772.000	1,937,669.000

Appendix

Imperfect Competition and Pass-Through

Over pass-through has been rationalized by suggestions that markets where prices rise by more than the amount of the tax increase are characterized by imperfect competition.[29] Market power, however, is not alone sufficient to generate over pass-through. Consider a simple derivation of the pass-through rate for a monopolist facing downward sloping demand $Q(p)$ who sets the price p. Using the implicit function theorem, it is possible to consider the comparative static of how the optimal price p^* changes as we vary the constant marginal cost c of the monopolist. This derivation for the pass-through rate of dates back to the time of Cournot, but our derivation more closely follows that in Bulow and Pfleiderer (1983):

$$Q(p) + (p - c)Q'(p) = 0 \leftrightarrow (p - c) = -\frac{Q'(p)}{Q(p)} \equiv \mu(p)$$

Implicit differentiation w.r.t c (adding τ) yields:

$$\frac{dp}{dc} - 1 = \mu'(p)\frac{dp}{dc} \Rightarrow \rho = \frac{1}{1 - \mu'(p)}$$

The pass through rate ρ depends on:

$$\begin{aligned} \log Q' &= \frac{1}{Q}\frac{dQ}{dp} = -\frac{1}{\mu(p)} \\ \log Q'' &= \frac{\mu'(p)}{\mu(p)^2} \end{aligned}$$

Therefore $\rho > (<)1$ implies that the log-curvature of demand is $\mu' > (<)0$. It is well known that log-concavity is a sufficient (but not necessary) condition for profit maximization in the monopoly case.[30]

Most (though not all) demand models in the literature assume log-concavity of demand, because it implies globally declining marginal revenue curves. For example, demand systems described by multinomial Probit or multinomial Logit are log-concave and imply incomplete pass-through $\rho < 1$. Some forms of Frechet demand (as used in the Trade literature) as well as the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) have parameter dependent pass-through rates and can rationalize pass through rates $\rho > 1$ as well as $\rho < 1$. Fabinger and Weyl (2013) extend

[29] For example, Besley and Rosen (1999) state "An important implication of this literature is that in an imperfectly competitive market, varying degrees of shifting are possible in the long run. Indeed, even overshifting is a distinct possibility; i.e., the price of the taxed commodity can increase by more than the amount of the tax." DeCicca, Kenkel, and Liu (2013) also assert "The observed over-shifting in many goods markets is consistent with theoretical analyses of tax shifting under oligopoly and imperfect competition."; they also go on to say that market conditions other than perfect competition can lead potentially lead to both over and under pass-through.

[30] It is also worth noting that the above results are for a monopolist selling differentiated products under Bertrand competition. In other contexts, such as Cournot competition with free-entry it is possible to allow for pass-through rates in excess of one. This literature employs a conjectural variations approach and dates back to Katz and Rosen (1983). Seade (1985) demonstrated the possibility of profitable cost increases $\rho > 1$ in the Cournot with entry framework and generalized in later work by Hamilton (1999). It is not obvious that Cournot is a sensible framework to understand retail purchases of distilled spirits, however.

the derivation of the pass-through rate to the case of symmetric imperfect competition so that $\rho = \frac{1}{1-(1-\theta)\cdot\mu'(p)}$ where θ is the Lerner conduct parameter. Anderson, De Palma, and Kreider (2001) provide results similar to those above for a Logit-CES model under differentiated products Bertrand competition that also produce over-shifting of taxes. Because CES demands generate fixed markups it is possible to generate a markup of 150% with a CES parameter of $\sigma = 3$, what is more difficult is explaining why taxes are marked up more than 100% when overall margins are small (as they are in distilled spirits).

A common explanation of $\rho > 1$ in the empirical literature is to attribute the effect to market power. It is worth pointing out that as $\theta \to 1$ we have that $\rho \to 1$ but whether it approaches 1 from the left or the right depends only on the sign of $\mu'(p)$ not the value of θ. In other words when tax increases lead to smooth price increases, over pass-through can only be explained by demand characterized by uncommonly used demand functions not the presence of market power alone.

Pass-Through with Compressed Prices Changes

Table 11: Pass-Through: Taxes to Retail Prices, Compressed

	All Retailers			Δ Retail Price≠ 0		
Δ Retail Price	1m	3m	6m	1m	3m	6m
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Tax	1.367***	1.068***	0.737***	2.795***	1.894***	1.247**
	(0.260)	(0.177)	(0.236)	(0.605)	(0.407)	(0.504)
Δ Tax*I[size=750mL]	1.207***	1.765***	1.784***	3.661***	3.597***	3.195***
	(0.297)	(0.302)	(0.371)	(0.987)	(0.594)	(0.727)
Δ Tax*I[size=1L]	1.531***	1.502***	1.363***	3.746***	2.487***	1.891***
(	0.390)	(0.274)	(0.311)	(0.958)	(0.538)	(0.655)
Δ Tax *I[size=1.75L]	1.371***	0.972***	0.683***	2.723***	1.803***	1.282**
	(0.300)	(0.201)	(0.252)	(0.626)	(0.433)	(0.519)
Observations	460,116	437,057	410,288	75,227	113,098	142,220
Product FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: All regressions are weighted by 2011 Nielsen units and include month and year fixed effects. Standard errors are clustered at the UPC level.

To estimate the multinomial probit model with modestly transform the data. We round all price increases and decreases of more than two dollars to two dollars in magnitude, effectively truncating the data. The table above confirms that transforming the data this way has little impact on the estimated pass-through rates. The one-month average pass-through rate is 1.367 (0260) versus a statistically indistinguishable rate of 1.533 (0.271) in the unmodified sample. Differences between estimates from the transformed and modified samples are statistically similar over longer horizons as well as conditional on a price change. Pass-through rate estimates by bottle size are also indistinguishable. For example, over the one-month horizon pass-through rates of 1.207(0.297), 1.531 (0.390) and 1.371 (0.300) for 750s, 1Ls and 1750s are comparable and not statistically different from the rates estimated for full sample, 1.168 (0.432), 2.146 (0.650) and 1.520 (0.309), respectively.

Example Price Changes

Table 12: Price Frequency By Store and Product for 2011

	April	May	June	July	August	September
	Burnett's Vodka 1750mL @ 80PF					
14.99	13	13	9	6	0	0
15.49	0	0	0	1	0	0
15.59	0	0	0	1	0	0
15.62	0	0	0	1	0	0
15.66	0	0	1	0	0	0
15.74	0	0	1	0	0	0
15.99	1	1	3	5	14	14
	J and B Rare Whiskey 1750mL @ 86PF					
36.99	5	5	5	0	0	0
37.66	0	0	0	1	0	0
38.99	0	0	0	4	5	5
39.99	8	7	7	7	6	6
41.99	2	2	2	2	1	2