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Alcohol tax pass-through across the product and price range: do retailers treat cheap alcohol differently?

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ABSTRACT

Aims Alcohol duty increases are an effective intervention for reducing alcohol consumption and related harm through reducing affordability. The effectiveness of this tool partly depends on retailers passing duty increases on to consumers in the form of price increases; also known as 'pass-through'. This paper provides evidence of excise duty and sales tax (VAT) pass-through rates for alcohol products, at different price points, by UK supermarkets. **Methods** Panel data quantile regression of product-level price data for 254 products from four large UK supermarkets. Data was available for the period March 2008 to August 2011; five duty and three VAT changes were observed in this time. **Results** Within all four categories (beers, ciders/RTDs, spirits and wines) there exists considerable heterogeneity in the level of duty pass-through. Price increases of cheaper products fall below duty rises (under-shifting) while more expensive products are over-shifted (price increases are higher than duty increases). The level of under-shifting is greatest for the extreme lower end of the price distribution where the sales volume is largest. This pattern of pass-through is more pronounced for beers and spirits than for ciders/RTDs and wines. **Conclusions** The tax under-shifting for cheaper products and over-shifting for expensive products may reduce the effectiveness of duty increases in reducing alcohol-related harm, as those at greatest risk (i.e. heavier consumers and those on lower incomes) tend to purchase cheaper alcohol. Employing duty increases in conjunction with other policy interventions, such as minimum unit pricing, may mitigate the problem of tax under-shifting for cheap products.

Keywords Alcohol pass-through; alcohol excise duty; alcohol taxation; alcohol tax policy; alcohol prices; quantile regression.

INTRODUCTION

Alcohol misuse and associated disease, injury and death are of great concern for policy makers and health authorities. Globally, alcohol is estimated to be responsible for approximately 4% of deaths and 4.7% of injuries and diseases [1]. Price controls, and particularly taxation in the form of excise duties, are a common approach and have been shown to impact on alcohol consumption and related harm [2, 3].

The effectiveness of excise duty increases in reducing alcohol consumption and harm depends on a number of factors including the price elasticities of alcoholic products and on whether retailers fully pass on duty increases to consumers in the form of increased prices. From a public health perspective, there are concerns that retailers may adopt a number of pricing strategies following a duty increase. These include absorbing duty increases, using their bargaining power to pass them on to other points in the supply chain (e.g. producers), increasing the prices of non-alcoholic products, and differential pass-through for different products. Given the range of options available to retailers, quantitative evidence on the impact of excise duty increases on retail prices is of considerable importance for understanding and estimating variations in policy effectiveness over time and place. In this paper, we focus on analysing differential pass-through of duty increases across alcoholic product categories and the price distribution.

Drawing on the assumption of tax incidence theory [4, 5], as a baseline case, many empirical studies assume that taxes will be fully passed through to consumers such that a 1% increase in taxation is followed by a 1% increase in the proportion of prices accounted for by tax. However, in practice there could be under-shifting or over-shifting, such that the change in prices following duty changes are, respectively, lower or higher than the expected 1:1 relationship [6].

To date, there are few empirical studies focusing on tax pass-through. Two UK studies investigate tax pass-through of alcoholic products adopting a time series mean regression-based approach using aggregated price data for specific product categories (e.g. average price of a pint of beer) as a dependent variable and changes in excise duty as a covariate. In 2011, Hunt et al. [7] related changes in prices to changes in excise duty for both on- and off-trade products. The average rate at which tax is passed through to consumers within each beverage category varied; with full shifting or over-shifting in the on-trade and substantial under-shifting by large off-trade retailers. Similarly, in 1992, Baker and Brechling [8] employed time series average quarterly data to investigate the impact on alcohol (beers, wines and spirits), tobacco and petrol prices of changes in excise duties. The authors conclude that while wines are over-shifted on average, a hypothesis of full pass-through for beers, spirits and petrol could not be rejected.

Two US studies found evidence of duty over-shifting [9, 10], with the rate of over-shift varying by product type, brand and premise type. A study of tax pass-through of both alcohol and non-alcoholic products in Denmark found evidence of over-shifting in the event of tax increases and under-shifting for tax cuts [11], with considerable variations between stores and regions. A recent study also found evidence of differential tax pass-through across tobacco products at different price points [12].

In this article we add to the evidence base by testing the hypothesis that, within each beverage category, there are differential tax shifting strategies for lower priced versus more expensive alcoholic products. This evidence is crucial for understanding the effect of duty interventions on alcohol-related harm, as heavier drinkers have been shown to buy cheaper alcohol than moderate drinkers [13]. We employ a rich product-level panel dataset capturing off-trade weekly price transitions of alcoholic products across five episodes of excise duty changes and three value added tax (VAT, UK sales tax charged as a percentage of price)

changes.

METHODS

Data

The data consist of weekly alcoholic beverage prices for 254 products obtained from Mysupermarket.co.uk, an online UK supermarket price comparison web-site. These products represent every alcoholic beverage for which prices were available consistently on the site each week from March 2008 to August 2011 (178 weeks). Prices were available for four major supermarkets; Asda, Ocado (an online retailer in partnership with the grocery chain Waitrose), Sainsbury's and Tesco and are recorded at single item or Stock Keeping Unit (SKU) level. These retailers account for around half of all off-trade alcohol sales. They include higher (Ocado), middle (Sainsbury's) and lower (Asda, Tesco) price supermarkets. Each operates national pricing policies, such that price from one retailer applies across all their supermarkets (irrespective of size) and online shops. However, not all products are necessarily available in all their stores (e.g. due to store size differences). A more detailed description of the data collection method is available [14, 15].

Each Mysupermarket.co.uk record includes the following information: price, retailer, product ID, size of product (e.g. 4x 500ml), an indicator of whether a product is on special offer, product name and 8 broad and 55 narrow beverage categories. For this analysis the data was recoded into 4 categories, namely; beers, ciders/RTDs, spirits and wines which will be referred to throughout the paper. This was done to increase the number of products in each category and align more closely with the categories used when applying excise duties. Further, the aggregation of products into four categories controls for noise observed in individual product price changes. Noise is considerable due to the substantial use of short-run price promotions in UK supermarkets. Cider and RTDs are merged into one category as

the alcoholic volume contained within these products are roughly the same [16] and this is also how they are marketed by parts of the industry (e.g. http://www.webcitation.org/6Lf4z8VX4).

Over the 178 week period, five duty changes and three VAT changes are observed. The date and magnitude of the duty events are listed in Table 1 with the taxation method for each beverage provided in the footnote. The duty events are largely increases, correspond to weeks 1, 38, 59, 107 and 159 in the data and are referred to as duty events 0 to 4 hereafter. VAT was reduced from 17.5% to 15% on 1st December 2008, increased to 17.5% on 1st January 2010 and increased again to 20% on 4th January 2011. As RTDs make up less than 1% of total pure off-trade alcohol sold in the UK (AC Nielsen 2009, http://www.webcitation.org/6Lf5ICbgG) we assume that products falling under the cider/RTDs category are taxed at cider rates. Since the period of analysis is relatively short and prices are recorded on a weekly basis, we do not adjust for inflation in our analysis but we include results for inflation-adjusted prices as a sensitivity analysis.

<Table 1>

Sales Volume

Since our dataset does not capture sales volume we link each of the four categories' price distributions to off-trade sales data obtained from AC Nielsen. This allows us to supplement our estimates of pass-through at different points in the price distribution with sales volumes at those points in the distribution.

Variables

We obtained a reference period for which average price per unit (1 unit=10ml/8g of pure ethanol) for all products are calculated. Unit content of each product was calculated using alcohol by volume (ABV) data obtained from internet searches. We then calculated expected changes of these average unit prices as a result of subsequent tax changes. We used the 37 weeks between duty events 0 and 1 to calculate the average unit prices of each SKU.

Let x_i denote the average unit price of product i, after deducting VAT, calculated over the period from week 1 to week 37. We calculate the expected incremental changes in average price per unit of each SKU following duty events 1 to 4 as:

$$x_{it}^{*} = (1+\tau)\left(x_i + \sum_{j=1}^{4} I(t \geq E_j)\Delta_{it}\right), \quad t = 38, 39, \ldots, 178 \qquad (1)$$

where E = {38, 59, 107, 159} is a vector with elements denoting duty event weeks, τ is a VAT rate τ = {0.15, 0.175, 0.20}, $I(a)$ is an indication function taking a value of 1 if a is true and zero otherwise and categories j = 1, 2, 3, 4 correspond to beers, ciders/RTDs, spirits and wines respectively. The quantities Δ_{it} and x_{it} respectively denote the absolute change in price per unit of product i at time t as a result of tax change (duty, VAT or both) and expected price per unit of product i at time t. The unit tax difference between two events, Δ_{it}, is calculated for each product depending on the category in which the product falls. A numerical and pictorial illustration of the evolution of expected and observed unit prices for four example products are shown in Table S1 and Figure S1 (online supporting information, see the end for details).

Panel data quantile regression

To model tax pass-through we adopt a quantile panel regression approach [17, 18]. This technique provides flexibility for modelling the entire distribution of the dependent variable given a set of independent variables rather than just focusing on the mean, as is done for the classical mean regression. Hence, this methodology provides a framework for investigating differential pass-through for quantiles (i.e. price points) in the price distribution. A brief explanation of quantile regression is provided in the online supporting material.

Model I

Given the observed prices per unit y_{it} together with the expected unit price post-tax event for each product identified by category, x_{it}^{*}, we adopt a panel data quantile regression approach where we consider a stream of quantiles $\theta \in \{0.05, 0.15, 0.25, \ldots, 0.95\}$ together with the median $\theta = 0.50$. We first estimate an aggregate measure of pass-through for each of the four categories across all duty and VAT changes using the following model:

$$y_{it} = \beta_{0,\theta} + \left(\sum_{j=1}^{4} \beta_{j,\theta} I(Category = j)\right) x_{it}^{*} + \epsilon_{it,\theta}, \quad t = 38, 39, \ldots, 178 \qquad (2)$$

where categories j = 1, 2, 3, 4 respectively correspond to beers, ciders/RTDs, spirits and wines and $\epsilon_{it,\theta}$ is quantile-specific error term. Using this approach, if tax changes are fully passed through across the price distribution then, for all quantiles, the estimated coefficients ($\hat{\beta}_{j,\theta}$'s) should equal one. Further, if $\hat{\beta}_{j,\theta} > 1$ or $\hat{\beta}_{j,\theta} < 1$ these correspond to over-shifting and under-shifting respectively. Consistent with other publications, our calculation of tax pass-through is equivalent to dividing the actual observed price by the expected price following an event [11, 9].

Model II

Since the period of analysis captures both separate and simultaneous duty and VAT changes, we further extend model I to account for duty, VAT and both duty and VAT changes. Let $e_1 = \{38 \leq t < 59\}$, $e_2 = \{59 \leq t < 95\}$, $e_3 = \{95 \leq t < 107\}$, $e_4 = \{107 \leq t < 147\}$, $e_5 = \{147 \leq t < 159\}$ and $e_6 = \{159 \leq t \leq 178\}$, thus denoting time intervals following tax events. We then partition tax events into three where $\delta_1 = e_1$ corresponds to simultaneous duty and VAT changes, $\delta_2 = \{e_2, e_4, e_6\}$ duty-only changes and $\delta_3 = \{e_3, e_5\}$ VAT-only changes. The model is as follows;

$$y_{it} = \beta_{0,\theta} + \left(\sum_{j=1}^{4} \sum_{h=1}^{3} \beta_{jh,\theta} I(Category = j) \times I(\delta_h) \right) x_{it}^{*} + \epsilon_{it,\theta}, \qquad t = 38, 39, \ldots, 178 \quad (3)$$

where, for $h = 1, 2, 3$, $\hat{\beta}_{jh,\theta}$ respectively denotes simultaneous VAT and duty, duty only and VAT only estimated tax pass-through of category j products and for a given quantile θ.

Model III

We further estimate tax pass-through for each of the differently sized tax events using the following model:

$$y_{it} = \beta_{0,\theta} + \left(\sum_{j=1}^{4} \sum_{f=1}^{6} \beta_{jf,\theta} I(Category = j) \times I(e_f) \right) x_{it}^{*} + \epsilon_{it,\theta}, \qquad t = 38, 39, \ldots, 178 \quad (4)$$

with estimates ($\hat{\beta}_{jf,\theta}$) of the coefficients $\beta_{jf,\theta}$ denoting tax pass-through value of category j observed within interval f. Note that, $\hat{\beta}_{j1,\theta}$, $\{\widehat{\beta}_{j2,\theta}, \hat{\beta}_{j4,\theta}, \hat{\beta}_{j6,\theta}\}$ and $\{\widehat{\beta}_{j3,\theta}, \hat{\beta}_{j5,\theta}\}$ respectively correspond to duty and VAT, duty only and VAT only tax pass-through.

RESULTS

Table 2 displays the absolute price per unit over the entire period of analysis (weeks 38 to 178) for each category and quantile, θ, together with number of products within each category. The table reveals that the unit prices of cider/RTDs are the most dispersed of the four categories with very low prices at the lower end (θ = 0.05) of the price distribution and very high prices (θ = 0.95) at the top end. The price distributions for beers and wines are much more compacted.

< Table 2>

Pass through estimates for model I, which aggregates pass-through for each beverage across all tax events, are shown in Figure 1.

<Figure 1 >

Tabulated quantile regression coefficients obtained from fitting this model together with their bootstrapped standard errors based on 500 replications are presented in the Table S2 (supporting material). All coefficients in the model are significant to at least 1% significance level.

Figure 1 shows that, for beers, ciders/RTDs and spirits, there is under-shifting (i.e. pass-through is less than 1) at the lower end (5%) of the price distribution and over-shifting (i.e. pass-through greater than 1) for products whose prices are above the lower quartile. The

magnitude of over-shifting increases for more expensive products. Spirits are the most under-shifted category with cheaper products up to the lower quartile being under-shifted. Spirits are closely followed by beer and cider/RTDs with the magnitude of under-shifting at the 5% quantile higher for beer (15%) than cider/RTDs (11%). For wines, the hypothesis of under-shifting cannot be rejected at both 5% and 15% quantile levels and, compared to the other three categories, a higher magnitude of over-shifting is observed for products sold above the lower quartile of the price distribution.

Model II estimates pass-through for duty, VAT and simultaneous duty and VAT events. Results of this model are presented in Figure 2 and Table S3 (supporting material), and the Figures shows that duty-specific and VAT-specific events closely resemble that of the aggregate pass-through presented in Figure 1 with spirits followed by beers and ciders having the most pronounced under-shifting and wines being the most over-shifted category. For simultaneous VAT and duty events, over-shifting appears to begin higher in the price distribution than in the aggregate model.

Model III estimates the pass-through rate of the four categories for each duty and VAT change separately and results are shown in Figure S2 (supporting material). The same pattern of under-shifting low-priced products and over-shifting high-priced products is seen across all tax events; however, the magnitude of these effects varies across events or over time. This appears more related to time than size of tax increase with more over-shifting and less under-shifting seen in later tax events.

Sensitivity analysis

We undertook a number of sensitivity analyses which (1) controlled for alcohol content in the form of ABV, (2) focus on duty-specific pass-through by deducting VAT from all prices,

(3) adjust prices for inflation using the all-item monthly retail price index smoothed into a weekly index. Results of these sensitivity analyses alongside information on which of Models I to III they were applied to are presented in Figures S3 to S7 and Tables S4 and S5 (supporting material). In all cases, the findings are not substantively difference to the base case analyses.

Volume of sales

In order to examine the proportion of total sales affected by under- and over-shifting, we employ off-trade sales volume data and pricing obtained from AC Nielsen for England and Wales for year 2009. The data capture sales volumes (in litres of pure alcohol) across price per unit distributions of all four beverage categories in our analysis.

Table 3 displays the percentage of sales volume in different price bands where the quantile price bands have been mapped to their actual prices shown in Table 2, such that, for example, beers sold in band $0.50 \leq \theta < 0.75$ correspond to products sold in the range from 59p to 67p inclusive. A large proportion of sales are generated from cheaper products. For instance, beers and ciders/RTDs sales generated in the bottom 5% of price the distribution (<36p for beers and <22p for ciders) account for more than a third and a quarter of total sales respectively. Similarly, for spirits and wines approximately 30% and 28% of respective sales are generated from products whose prices are in the bottom 15% of the price distribution.

<Table 3>

Figure 3 shows the relationship between tax pass-through, price per unit and percentage

of sales volume for each of the four categories together with 95% confidence intervals of pass-through at different quantile levels. Duty tax pass-through together with lower and upper bounds from Model II duty specific pass-through are also displayed. Figure 3 reveals that, in terms of percentage of total sales volume, beers are the most under-shifted category with approximately 68% of sales volume generated from products (sold below approximately 40p per unit) for which price increases are less than duty increases. Beers are followed by spirits and ciders/RTDs with 38% of sales volume of the former and close to a third of the latter obtained from under-shifted products.

<Figure 3>

For beers, approximately 17% of sales are generated from over-shifted products (price above 50p per unit) and 15% of sales are from full pass-through products (40p to 50p). For ciders/RTDs however, 65% of sales are from over-shifted products (>26p per unit) with about 5% of sales fully shifted (22p to 26p). For spirits, approximately 45% of the sales are generated from over-shifted (>39p per unit) and 17% from fully passed through products. Wines are the most over-shifted category with over 70% of total sales generated from over-shifted products and 28% from under-shifted products (<37p per unit) although the hypothesis of full pass-through cannot be rejected for these products.

DISCUSSION

This study provides the most in-depth investigation to date of UK retailers' pricing strategies following alcohol tax changes. Using a panel data quantile regression of weekly pricing data from major supermarkets, we estimate pass through of excise duty and sales tax on alcoholic products sold at different price points. Further, we used sales volumes at different intervals of the price distribution to indicate the proportion of sales of each beverage

type which are under-shifted, fully passed through or over-shifted.

We find evidence of significant heterogeneity in tax pass-through across the price distribution. In particular, we observe a clear contrast in pass-through for cheap versus expensive products, with the former being under-shifted and the latter over-shifted. Duty pass-through ranges from 78% (lower priced beers) to 124% (higher priced cider/RTDs). This differential pass-through is visible to varying degrees across all beverage categories and appears to persist for different magnitudes of duty change. Approximately two-thirds of beers and one third of ciders/RTDs and spirits are under-shifted while one-sixth of beers, two-thirds of wines and ciders/RTDS and over half of spirits are over-shifted. By comparing pass-through for a series of tax changes, our results indicate that retailers may not always apply the same approach and other factors, such as previous pass-through, wider economic conditions or prices of other products, may be influencing decisions on the magnitude of pass-through. Beers were under-shifted to the greatest degree and this may reflect the retailers attempting to mitigate the impact of tax increases on a key product category for promotional activity and pricing competition. In contrast, under-shifting of wines was less common, potentially reflecting retailers' ability to conceal price increases as customers tend to buy different wines at a particular price point rather than being loyal to specific brands.

The main strengths of the paper lie in the usage of quantile regression together with a longitudinal panel of product-level price transitions which permits a comprehensive understanding of pass-through for different parts of the price distribution and linkage with sales volumes which allows quantification of the proportion of products being under- or over-shifted. An important limitation is our data only cover four of the UK's major supermarkets who account for approximately half of UK off-trade alcohol sales (http://www.webcitation.org/6Lf5ICbgG). We have no data on the UK's 4th largest supermarket chain, Morrison's, budget supermarket chains such as Aldi and Lidl and other, often independent, off-trade retailers. The latter in particular sell fewer products and have

less bargaining power with their supply chain than major supermarkets and, therefore, may have less scope for avoiding full pass-through. As our sales volume data do capture a wider sample of shops and supermarkets, the derived price/sales distributions are not a perfect match for our estimates of pass-through.

Our results show tax increases do lead to price increases across the price distribution and thus support evidence that duty increases are effective in reducing consumption [2]; however, additional measures may be required to ensure such policies are well-targeted. Additional price-based interventions such as minimum pricing or restrictions on promotional offers may be complementary measures by restricting retailers' capacities to engage in price competition on low-cost alcohol. In turn, this may afford policymakers greater influence over the full price distribution.

Beneficial extensions to this work may include investigating the role of other factors such as package sizes, differential tactics between retailers' own brands and major brands, differential strategies between retailers and cross-product pass-through such that wine duty increases are passed onto beer products. Further data allowing examination of whether price increases on non-alcoholic products subsidise under-shifting would also be valuable. These analyses would all require a larger dataset covering a wider range of products.

Conclusion

The effectiveness of employing alcohol taxation as a tool for controlling alcohol consumption is well documented in the literature. However, from a public health perspective, the success of this intervention, relies heavily on the pass-through of duty from retailers to consumers in the form of increased prices. Our findings demonstrate that, across four beverage categories, tax increases lead to lower than expected price increases for cheaper products and higher than expected price increases for more expensive products. In order to off-set the under-shifting of cheaper products a duty rise could be implemented in

conjunction with other interventions, such as minimum unit pricing, in order to maximise public health benefits.

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Supporting information

Additional Supporting Information may be found in the online version of this article:

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Table 1 Changes in excise duty

Event	Mar 08	Dec 08			Apr 09			Mar 10			Mar 11		
Category	Duty	Duty	ΔDuty	%Δ	Duty	ΔDuty	%Δ	Duty	ΔDuty	%Δ	Duty	ΔDuty	%Δ
Beers[a]	14.96	16.15	1.19	7.95	16.47	0.32	1.98	17.32	0.85	5.16	18.57	1.25	7.22
Ciders[b]	28.9	31.21	2.31	7.99	31.83	0.62	1.99	36.01	4.18	13.13	35.87	-0.14	-0.39
Ciders[c]	43.37	46.83	3.46	7.99	47.77	0.94	2.01	54.04	6.27	13.13	53.84	-0.2	-0.37
Spirits[d]	21.35	22.2	0.85	3.98	22.64	0.44	1.98	23.8	1.16	5.12	25.52	1.72	7.23
Wines[e]	194.8	209.82	15.54	8.00	214.02	4.2	2.00	225	10.98	5.13	241.23	16.23	7.21
Wines[f]	259.2	279.74	20.72	8.00	285.33	5.59	2.00	299.97	14.64	5.13	321.61	21.64	7.21

[a] £ per hectolitre per cent of alcohol

[b] Ciders/RTDs _ 7.5% abv - £ per hectolitre of product

[c] Ciders/RTDs > 7.5% abv

[d] £ per litre of pure alcohol

[e] Wines ≤ 15% abv - £ per hectolitre of product

[f] Wines > 15% abv

Table 2 Prices (pence per unit) at different quantiles

θ	Beers	Ciders/RTDs	Spirits	Wines
0.05	36	22	29	31
0.15	45	26	34	37
0.25	50	31	39	41
0.35	53	52	47	46
0.45	57	64	53	49
0.5	59	72	57	50
0.55	61	76	60	53
0.65	64	85	71	59
0.75	67	87	80	64
0.85	71	91	92	74
0.95	82	104	109	85
Number of Products	70	39	103	42

Table 3 Percentage of sales volume (million litres of pure alcohol) for different quantile price bands

Quantile Price Band	Beers (%)	Ciders/RTDs (%)	Spirits (%)	Wines (%)
$\theta \leq 0.05$	38.07	28.22	16.27	9.48
$0.05 < \theta \leq 0.15$	29.16	5.77	15.2	18.71
$0.15 < \theta \leq 0.25$	13.82	6.39	16.4	13.11
$0.25 < \theta \leq 0.35$	6.66	28.21	22.68	15.6
$0.35 < \theta \leq 0.45$	4.82	3.32	9.00	12.28
$0.45 < \theta \leq 0.50$	0.67	3.45	0.40	1.16
$0.50 < \theta \leq 0.55$	1.72	2.00	0.39	7.49
$0.55 < \theta \leq 0.65$	0.79	4.15	2.80	6.61
$0.65 < \theta \leq 0.75$	0.73	0.69	2.26	4.32
$0.75 < \theta \leq 0.85$	0.88	2.03	2.97	4.39
$0.85 < \theta \leq 0.95$	2.49	6.22	4.32	5.09
$\theta > 0.95$	0.19	9.53	7.32	1.76

The AC Nielsen data is publicly available from http://www.healthscotland.com/documents/4557.aspx where for 2009 the total sales volume, (million litres of pure alcohol) of beers, ciders/RTDs, spirits and wines are 76.00, 9.43, 60.58 and 220.50 respectively.

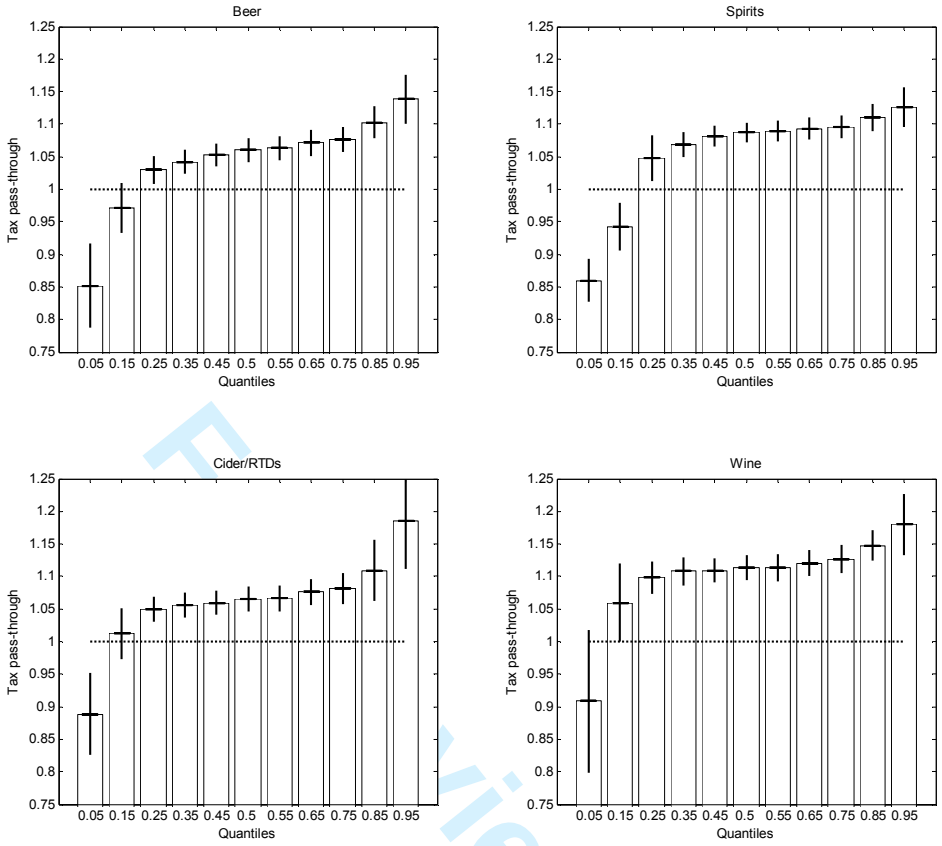

Figure 1 Model I - duty and VAT inclusive tax pass-through together with 95% confidence intervals

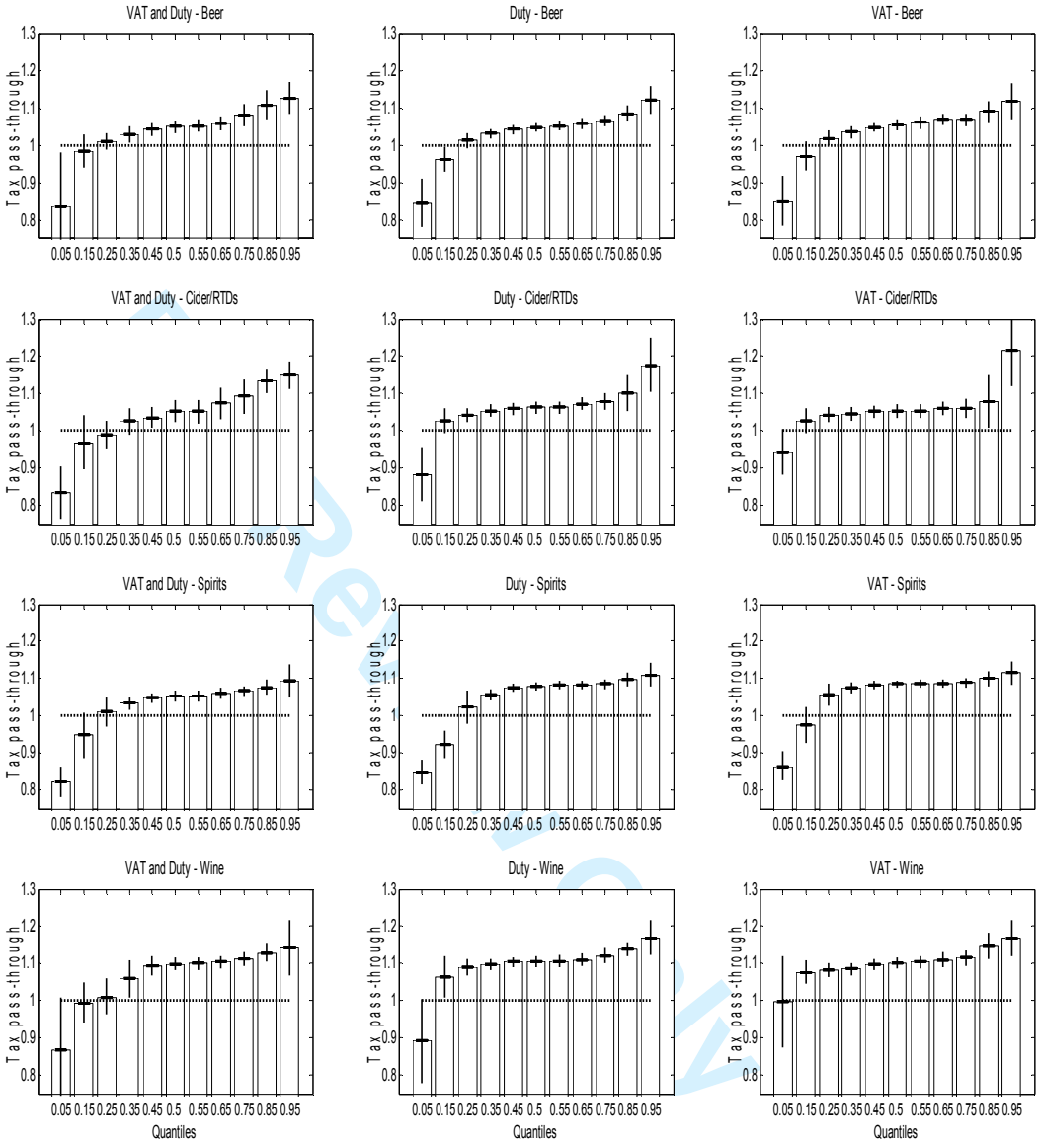

Figure 2 Model II duty and VAT tax pass-through together with 95% confidence intervals

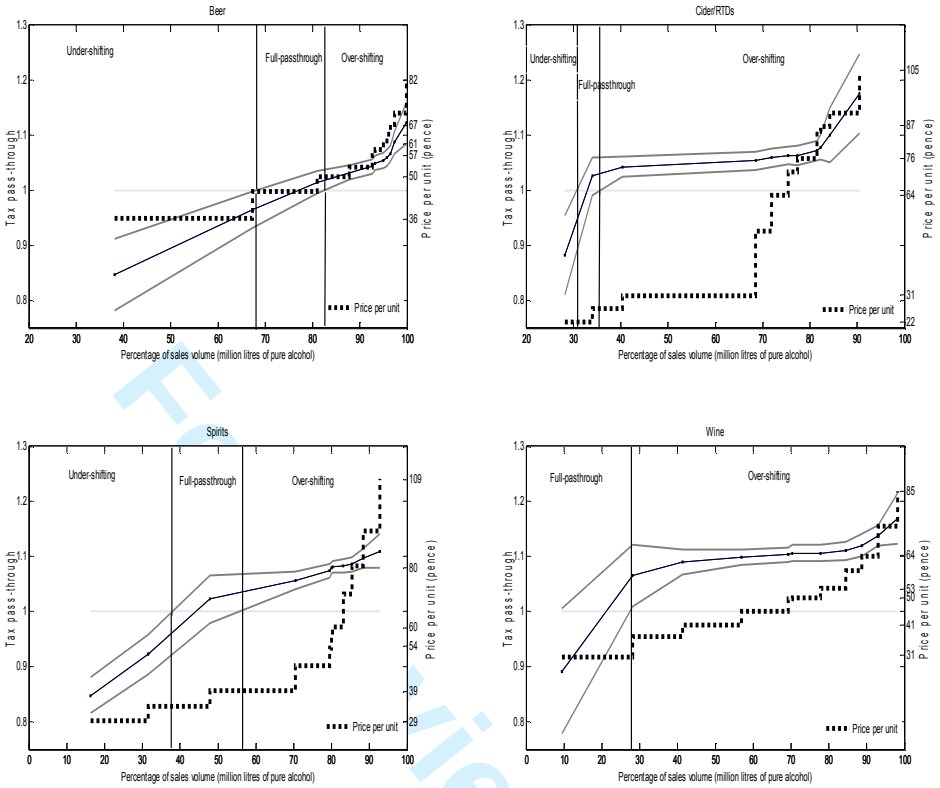

Figure 3 Duty pass-through at different prices per unit and sales volumes. Tax pass-through (black with dots) with 95% confidence intervals in grey

Alcohol tax pass-through across the product and price range: do retailers treat cheap alcohol differently?

Supplementary document

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EXPECTED AND OBSERVED UNIT PRICES

Table S1 Illustration of tax difference calculation Δ_{it} using four example products

	Beer 4 ×568ml	Cider/RTDs 4 ×275ml	Spirits 500ml	Wine 750ml
ABV (%)	5	5	35	13.5
Units	11.36	5.5	17.5	10.13
Base prices x_i (pence per unit)	43.57	66.08	79.49	44.38
$\Delta_{it,E_{1\leq t<E_2}}$	1.19	0.46	0.85	1.15
$\Delta_{it,E_{2\leq t<E_3}}$	0.32	0.12	0.44	0.31
$\Delta_{it,E_{3\leq t<E_4}}$	0.85	0.84	1.16	0.81
$\Delta_{it,\geq E_4}$	1.25	-0.03	1.72	1.2

Note that $\Delta_{it,E_{1\leq t<E_2}}$ denotes the expected (price per unit) duty change of product i following event 1 until the week before event 2.

Note that in the formulation given by equation (1) incremental duty changes of each of the 254 products, identified by their categories, are added on an event week and remain constant up until when the following event is observed. Further, the final VAT and duty inclusive unit price at time t is calculated by multiplying the duty inclusive price with appropriate VAT rate. Table S1 displays an illustration of the calculation of duty difference, Δ_{it}, for four randomly chosen example products following each of the four duty events and where the expected duty differences are calculated using the duty tax changes displayed in Table 1 in the article.

A pictorial illustration of the evolution of expected and observed unit prices of the four example products shown in Table S1 are depicted in Figure S1 which also captures changes in VAT. From the figure one can observe that retail prices on individual items can

be quite volatile because of promotional pricing with regular prices punctuated by deep temporary price reductions as well as price changes driven by changing demand, cost and competitive conditions.

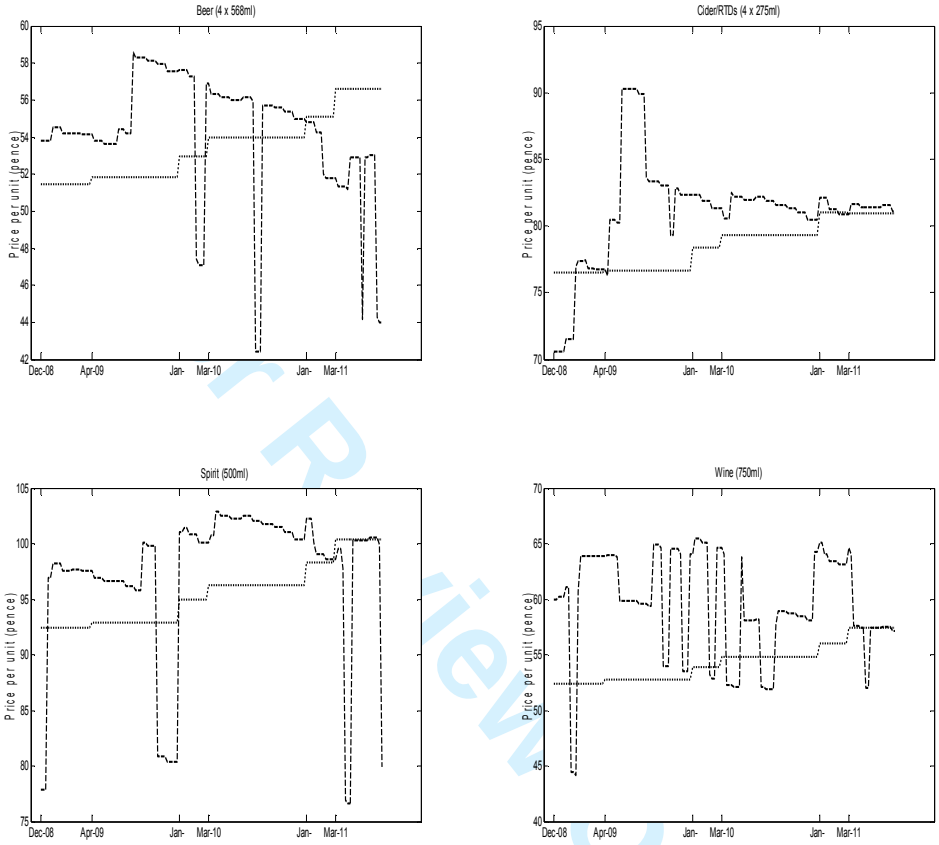

Figure S1 Expected prices illustration, expected (dotted) observed (dashed).

PANEL DATA QUANTILE REGRESSION

Suppose one observes a dependent (y_{it}) and a corresponding independent variable x_{it}^{*} of n products ($i = 1, 2, \ldots, n$) at different time points $t = 1, 2, \ldots, T$. In order to model the relationship between the dependent and independent assume a simple linear panel regression model is employed. Then the general presentation of the mean one way fixed effects panel model is

$$y_{it} = \alpha_i + \beta_1 x_{it}^{*} + \epsilon_{it},$$

where α_i and β_1 are the respective panel specific intercept and slope coefficients and ϵ_{it} is the error term. An alternative representation of model (2) is in terms of aggregated intercept, $y_{it} = \alpha_i + \beta_1 x_{it}^{*} + \epsilon_{it}$, rather than the panel specific structure. In terms of quantile regression the model can be written as follows:

$$y_{it} = \beta_{0,\theta} + \beta_{1,\theta} x_{it}^{*} + \epsilon_{it,\theta},$$

where, for each quantile of interest $\theta \in [0, 1]$, different quantile-specific estimates of the parameters $\beta_{0,\theta}$ and $\beta_{1,\theta}$ are obtained and where the conditional quantile of the error term ($\epsilon_{it,\theta}$) given a set of covariates is zero. Throughout the rest of the paper all panel data quantile regressions are fitted using the rqpd package in the R program which implements the penalised fixed-effects approach [16].

ADDITIONAL RESULTS

Table S2 Model I - duty and VAT inclusive quantile regression coefficients (standard errors in parentheses)

Quantile	Beers	Ciders/RTDs	Spirits	Wines
0.05	0.852 (0.033)	0.889 (0.032)	0.860 (0.017)	0.908 (0.056)
0.15	0.971 (0.019)	1.012 (0.020)	0.942 (0.019)	1.06 (0.031)
0.25	1.030 (0.011)	1.050 (0.010)	1.048 (0.018)	1.099 (0.013)
0.35	1.042 (0.009)	1.056 (0.010)	1.069 (0.010)	1.108 (0.011)
0.45	1.053 (0.009)	1.060 (0.009)	1.082 (0.008)	1.109 (0.009)
0.50	1.060 (0.009)	1.065 (0.010)	1.087 (0.008)	1.113 (0.010)
0.55	1.063 (0.010)	1.067 (0.010)	1.089 (0.008)	1.113 (0.010)
0.65	1.072 (0.010)	1.076 (0.010)	1.093 (0.008)	1.120 (0.010)
0.75	1.077 (0.010)	1.082 (0.012)	1.096 (0.009)	1.127 (0.011)
0.85	1.103 (0.013)	1.109 (0.024)	1.110 (0.011)	1.147 (0.012)
0.95	1.139 (0.019)	1.185 (0.038)	1.126 (0.016)	1.180 (0.024)

p-values and associated t-statistics can be provided by the authors upon reques

Table S3 Model II - duty and VAT inclusive quantile regression coefficients (standard errors in parentheses)

	Beers			Ciders/RTDs			Spirits			Wines		
	VAT+Duty	Duty	VAT	VAT+Duty	Duty	VAT	VAT+Duty	Duty	VAT	VAT+Duty	Duty	VAT
0.05	0.837	0.847	0.851	0.832	0.882	0.943	0.821	0.848	0.865	0.867	0.892	0.996
	(0.074)	(0.033)	(0.034)	(0.036)	(0.037)	(0.031)	(0.021)	(0.017)	(0.021)	(0.072)	(0.058)	(0.063)
0.15	0.985	0.965	0.973	0.968	1.026	1.027	0.947	0.922	0.975	0.995	1.065	1.075
	(0.023)	(0.017)	(0.021)	(0.037)	(0.018)	(0.018)	(0.031)	(0.019)	(0.024)	(0.027)	(0.029)	(0.016)
0.25	1.013	1.015	1.020	0.990	1.043	1.043	1.011	1.023	1.056	1.010	1.090	1.084
	(0.011)	(0.01)	(0.010)	(0.019)	(0.009)	(0.010)	(0.020)	(0.022)	(0.014)	(0.025)	(0.012)	(0.01)
0.35	1.032	1.033	1.036	1.026	1.054	1.046	1.033	1.056	1.076	1.059	1.099	1.086
	(0.011)	(0.007)	(0.008)	(0.018)	(0.009)	(0.010)	(0.008)	(0.008)	(0.008)	(0.026)	(0.007)	(0.009)
0.45	1.044	1.044	1.051	1.036	1.059	1.052	1.048	1.074	1.082	1.093	1.103	1.097
	(0.009)	(0.007)	(0.007)	(0.015)	(0.008)	(0.009)	(0.007)	(0.006)	(0.006)	(0.013)	(0.007)	(0.007)
0.5	1.053	1.050	1.055	1.052	1.064	1.053	1.052	1.079	1.085	1.098	1.107	1.102
	(0.008)	(0.007)	(0.008)	(0.015)	(0.008)	(0.009)	(0.007)	(0.006)	(0.006)	(0.009)	(0.007)	(0.008)
0.55	1.054	1.054	1.063	1.052	1.064	1.053	1.054	1.081	1.085	1.100	1.106	1.104
	(0.008)	(0.007)	(0.008)	(0.017)	(0.009)	(0.010)	(0.007)	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)
0.65	1.061	1.060	1.071	1.074	1.072	1.062	1.059	1.083	1.086	1.104	1.110	1.110
	(0.010)	(0.007)	(0.008)	(0.022)	(0.009)	(0.009)	(0.008)	(0.006)	(0.006)	(0.009)	(0.008)	(0.010)
0.75	1.082	1.067	1.071	1.093	1.078	1.062	1.066	1.086	1.089	1.112	1.120	1.115
	(0.015)	(0.007)	(0.008)	(0.024)	(0.011)	(0.013)	(0.007)	(0.007)	(0.007)	(0.010)	(0.010)	(0.010)
0.85	1.110	1.088	1.092	1.134	1.101	1.080	1.077	1.097	1.101	1.129	1.138	1.147
	(0.020)	(0.010)	(0.014)	(0.016)	(0.025)	(0.036)	(0.010)	(0.009)	(0.010)	(0.012)	(0.009)	(0.018)
0.95	1.129	1.123	1.120	1.149	1.176	1.218	1.093	1.110	1.115	1.141	1.169	1.168
	(0.021)	(0.019)	(0.025)	(0.020)	(0.037)	(0.051)	(0.023)	(0.015)	(0.016)	(0.037)	(0.023)	(0.024)

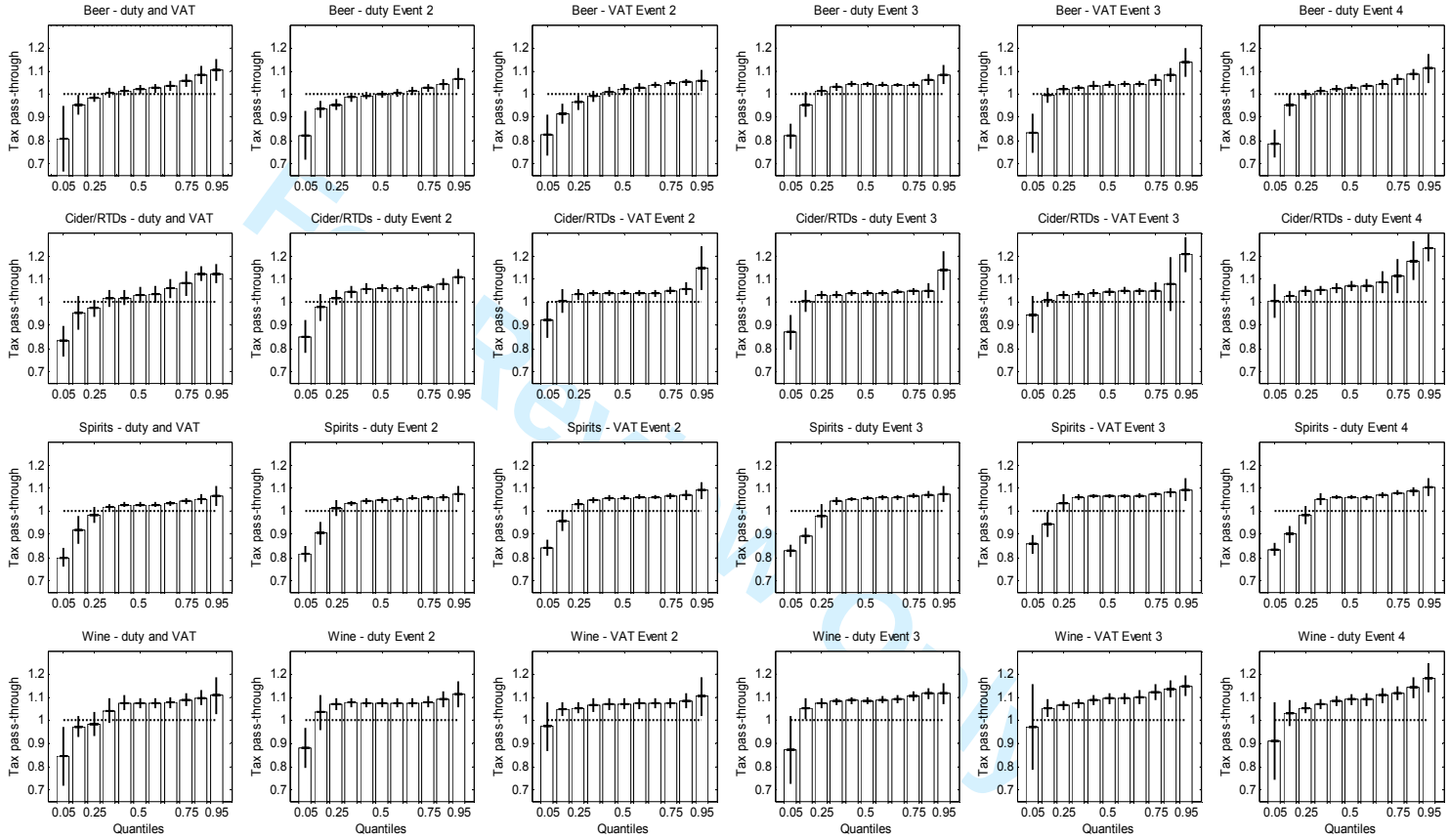

Figure S2 Model III tax pass-through together with 95% confidence intervals. Column 1 (duty and VAT), columns 2, 4 and 6 duty only and columns 3 and 5 VAT only changes

SENSITVITY ANALYSES

In order to test the sensitivity of our results we re-fit models I, II and III after controlling for alcohol content in the form of ABV and the results, not shown here, are robust to this change.

For a second phase of our sensitivity analysis we focus on duty specific pass-through. To accomplish this we harmonise the prices over the period of analysis by deducting VAT from both the observed and expected prices and then re-fit model I and a reduced version of model III where for the latter the intervals are now $\{38 \leq t < 59\}, \{59 \leq t < 107\}$, $\{107 \leq t < 159\}$, $\{159 \leq t < 178\}$ corresponding to periods following duty events 1 to 4. Results obtained from fitting these models are graphically presented in Figure S3 and Figure S4 tabulated in Table S4 and Table S5. On comparing the pass-through of the duty specific models (Figure S3 and Figure S4) together with results from VAT inclusive models (Figure 1 and duty events of model II, shown in Figure 2) one can observe that the overall pattern of magnitudes of tax pass-through are very similar with spirits and beer under-shifted more compared with cider and wine.

The coefficients presented in Figure S4 and Table S5 Model II (duty only) quantile regression coefficients (standard errors in parentheses) are obtained from fitting the following model:

$$y_{it} = \beta_{0,\theta} + \left(\sum_{j=1}^{4} \sum_{k=1}^{4} \beta_{jk,\theta} I(Category = j) \times I(\varphi_k) \right) x_{it}^{*} + \epsilon_{it,\theta}, t = 38, 39, \ldots, 178$$

Where $\varphi_1 = \{38 \leq t < 59\}$, $\varphi_2 = \{59 \leq t < 107\}$, $\varphi_3 = \{107 \leq t < 159\}$, $\varphi_4 = \{159 \leq t \leq 178\}$ with VAT deducted from both y_{it} and x_{it}^{*} prior to fitting the model.

For our final sensitivity analysis we re-fit model I, II and III after adjusting for inflation

using the official all item monthly retail price index (RPI). Since our dataset contain weekly prices, in order to align the observation period of prices together with the RPI we smooth the RPI monthly index to derive a weekly RPI. This approach is adopted because it circumvents making RPI adjustment redundant as would be the case if monthly RPI were used and discontinuity from duty and VAT changes occur mid-month. Similarly, if duty and VAT changes coincide with RPI this will result in greater impact on adjusted prices than mid-month. Results obtained from fitting these models are presented graphically in Figure S5, Figure S6 and Figure S7 in the appendix, again showing the same pattern of under- and over-shifting.

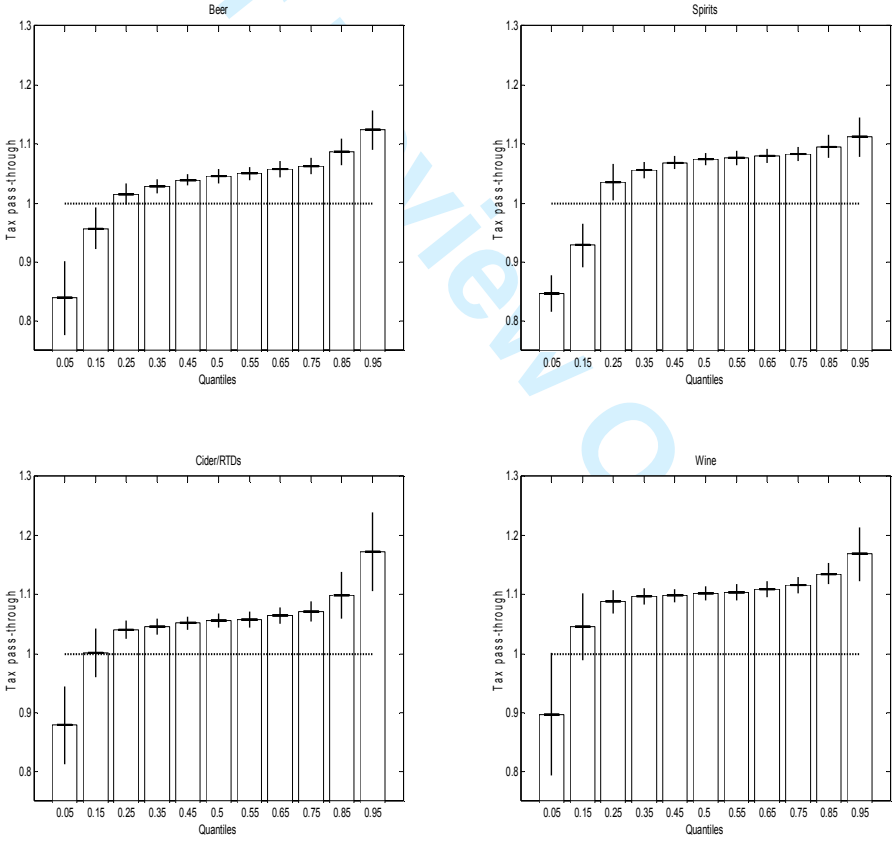

Figure S3 Model I (duty only) tax pass-through together with 95% confidence intervals

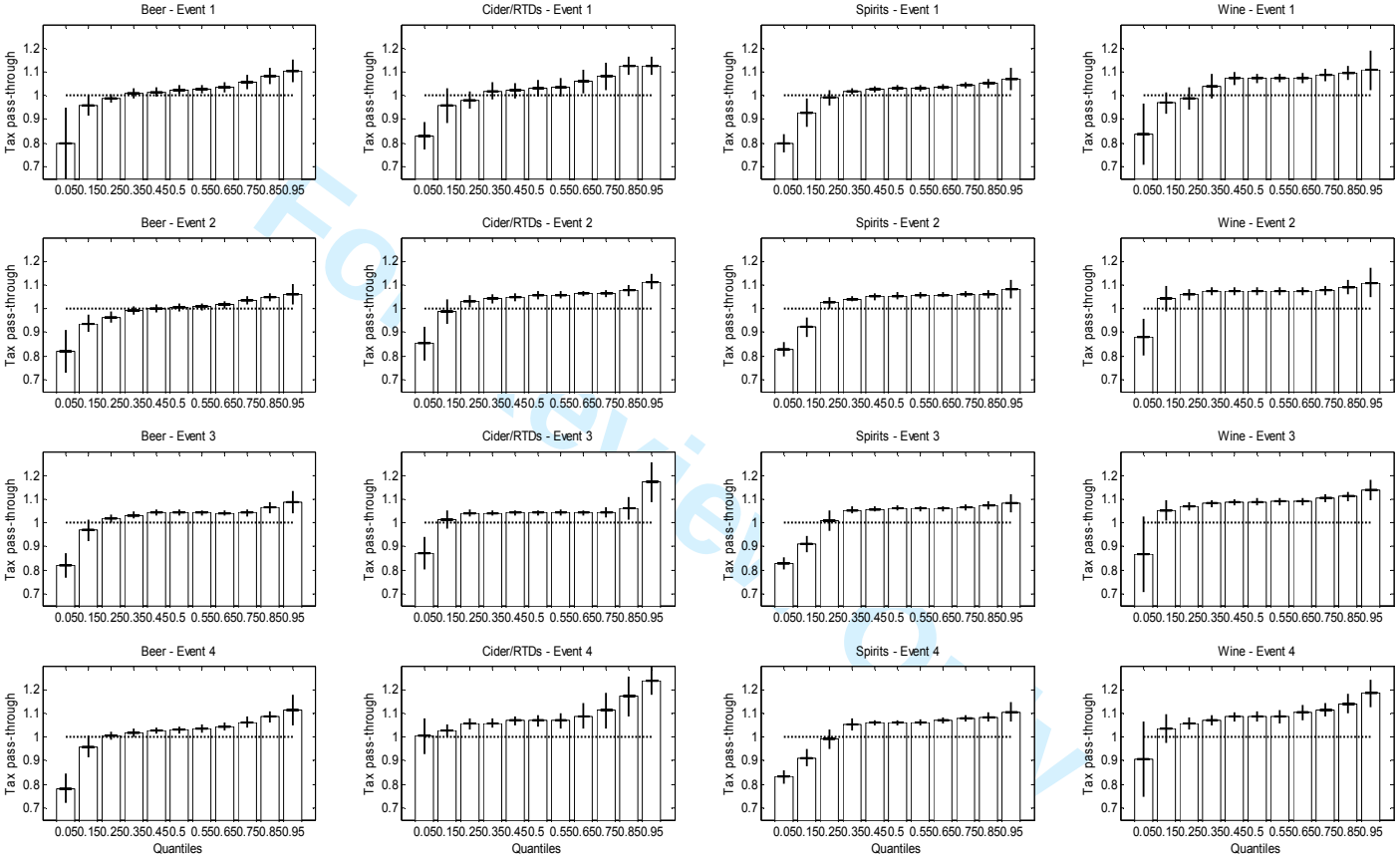

Figure S4 Duty-specific tax pass-through together with 95% confidence intervals

Table S4 Model I (duty only) quantile regression coefficients (standard errors in parentheses)

	Beer	Cider/RTDs	Spirits	Wine
0.05	0.840	0.879	0.847	0.897
	(0.032)	(0.034)	(0.016)	(0.053)
0.15	0.957	1.001	0.929	1.045
	(0.018)	(0.021)	(0.019)	(0.029)
0.25	1.016	1.040	1.035	1.088
	(0.009)	(0.008)	(0.016)	(0.01)
0.35	1.029	1.045	1.055	1.097
	(0.006)	(0.007)	(0.007)	(0.007)
0.45	1.039	1.052	1.069	1.098
	(0.005)	(0.006)	(0.006)	(0.006)
0.50	1.046	1.056	1.075	1.102
	(0.006)	(0.006)	(0.005)	(0.006)
0.55	1.050	1.058	1.077	1.104
	(0.006)	(0.007)	(0.006)	(0.007)
0.65	1.058	1.064	1.080	1.109
	(0.007)	(0.007)	(0.006)	(0.007)
0.75	1.063	1.071	1.083	1.116
	(0.007)	(0.009)	(0.006)	(0.007)
0.85	1.087	1.099	1.096	1.136
	(0.011)	(0.020)	(0.010)	(0.009)
0.95	1.124	1.173	1.112	1.168
	(0.017)	(0.034)	(0.017)	(0.023)

Table S5 Model II (duty only) quantile regression coefficients (standard errors in parentheses)

	Beer				Cider/RTDs				Spirits				Wine			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
0.05	0.798	0.820	0.819	0.782	0.831	0.854	0.872	1.003	0.798	0.827	0.829	0.831	0.839	0.880	0.868	0.906
	(0.077)	(0.046)	(0.027)	(0.032)	(0.030)	(0.036)	(0.035)	(0.038)	(0.020)	(0.015)	(0.013)	(0.014)	(0.066)	(0.039)	(0.081)	(0.082)
0.15	0.959	0.937	0.969	0.959	0.958	0.988	1.013	1.027	0.927	0.922	0.910	0.911	0.970	1.042	1.054	1.035
	(0.021)	(0.018)	(0.023)	(0.023)	(0.038)	(0.026)	(0.019)	(0.014)	(0.030)	(0.022)	(0.017)	(0.019)	(0.023)	(0.028)	(0.022)	(0.030)
0.25	0.989	0.963	1.018	1.004	0.981	1.032	1.040	1.056	0.991	1.025	1.011	0.991	0.988	1.060	1.069	1.056
	(0.009)	(0.012)	(0.010)	(0.009)	(0.019)	(0.013)	(0.008)	(0.012)	(0.017)	(0.011)	(0.022)	(0.021)	(0.024)	(0.012)	(0.009)	(0.013)
0.35	1.009	0.992	1.032	1.019	1.020	1.042	1.041	1.059	1.020	1.040	1.054	1.053	1.040	1.075	1.081	1.069
	(0.011)	(0.009)	(0.008)	(0.008)	(0.019)	(0.009)	(0.006)	(0.009)	(0.007)	(0.006)	(0.008)	(0.013)	(0.026)	(0.009)	(0.007)	(0.010)
0.45	1.015	0.999	1.044	1.026	1.020	1.049	1.043	1.068	1.027	1.050	1.058	1.060	1.073	1.074	1.087	1.085
	(0.010)	(0.009)	(0.007)	(0.007)	(0.017)	(0.009)	(0.006)	(0.010)	(0.006)	(0.007)	(0.006)	(0.005)	(0.014)	(0.008)	(0.007)	(0.010)
0.5	1.024	1.005	1.043	1.029	1.031	1.056	1.043	1.069	1.030	1.054	1.062	1.060	1.073	1.074	1.088	1.085
	(0.010)	(0.008)	(0.006)	(0.008)	(0.018)	(0.009)	(0.006)	(0.012)	(0.006)	(0.007)	(0.006)	(0.005)	(0.010)	(0.008)	(0.007)	(0.011)
0.55	1.026	1.008	1.042	1.035	1.037	1.058	1.043	1.068	1.032	1.058	1.061	1.062	1.074	1.073	1.090	1.085
	(0.010)	(0.008)	(0.006)	(0.008)	(0.020)	(0.008)	(0.006)	(0.017)	(0.006)	(0.006)	(0.005)	(0.006)	(0.009)	(0.008)	(0.008)	(0.013)
0.65	1.036	1.017	1.041	1.043	1.060	1.064	1.042	1.088	1.033	1.058	1.060	1.070	1.074	1.072	1.090	1.103
	(0.011)	(0.008)	(0.005)	(0.009)	(0.025)	(0.006)	(0.006)	(0.028)	(0.007)	(0.005)	(0.005)	(0.007)	(0.011)	(0.009)	(0.008)	(0.016)
0.75	1.057	1.035	1.042	1.063	1.081	1.063	1.044	1.111	1.044	1.062	1.066	1.079	1.088	1.076	1.104	1.114
	(0.015)	(0.008)	(0.008)	(0.012)	(0.029)	(0.007)	(0.010)	(0.039)	(0.007)	(0.006)	(0.006)	(0.007)	(0.013)	(0.011)	(0.009)	(0.015)
0.85	1.082	1.048	1.064	1.086	1.127	1.077	1.060	1.172	1.051	1.062	1.074	1.084	1.096	1.091	1.112	1.140
	(0.018)	(0.009)	(0.012)	(0.012)	(0.020)	(0.012)	(0.024)	(0.043)	(0.010)	(0.008)	(0.008)	(0.010)	(0.016)	(0.016)	(0.010)	(0.021)
0.95	1.104	1.061	1.087	1.113	1.126	1.114	1.172	1.238	1.069	1.082	1.083	1.106	1.107	1.110	1.139	1.184
	(0.023)	(0.023)	(0.024)	(0.032)	(0.019)	(0.016)	(0.043)	(0.031)	(0.024)	(0.019)	(0.020)	(0.021)	(0.044)	(0.032)	(0.023)	(0.030)

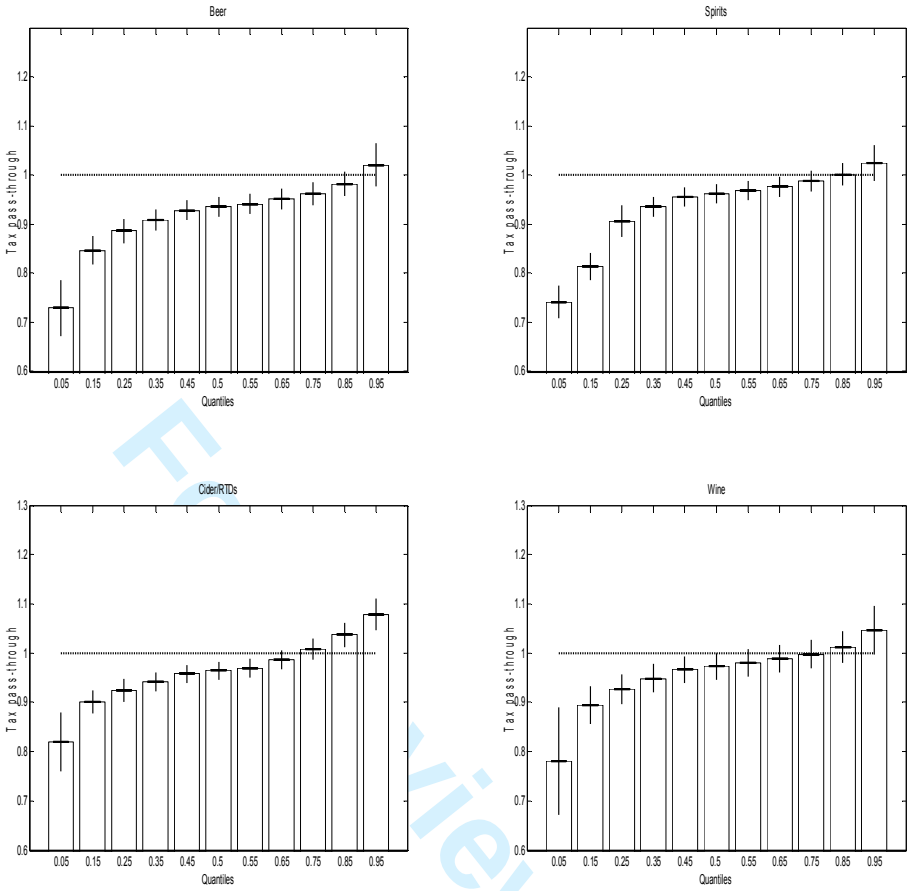

Figure S5 Model I tax pass-through together with 95% confidence intervals for RPI adjusted prices.

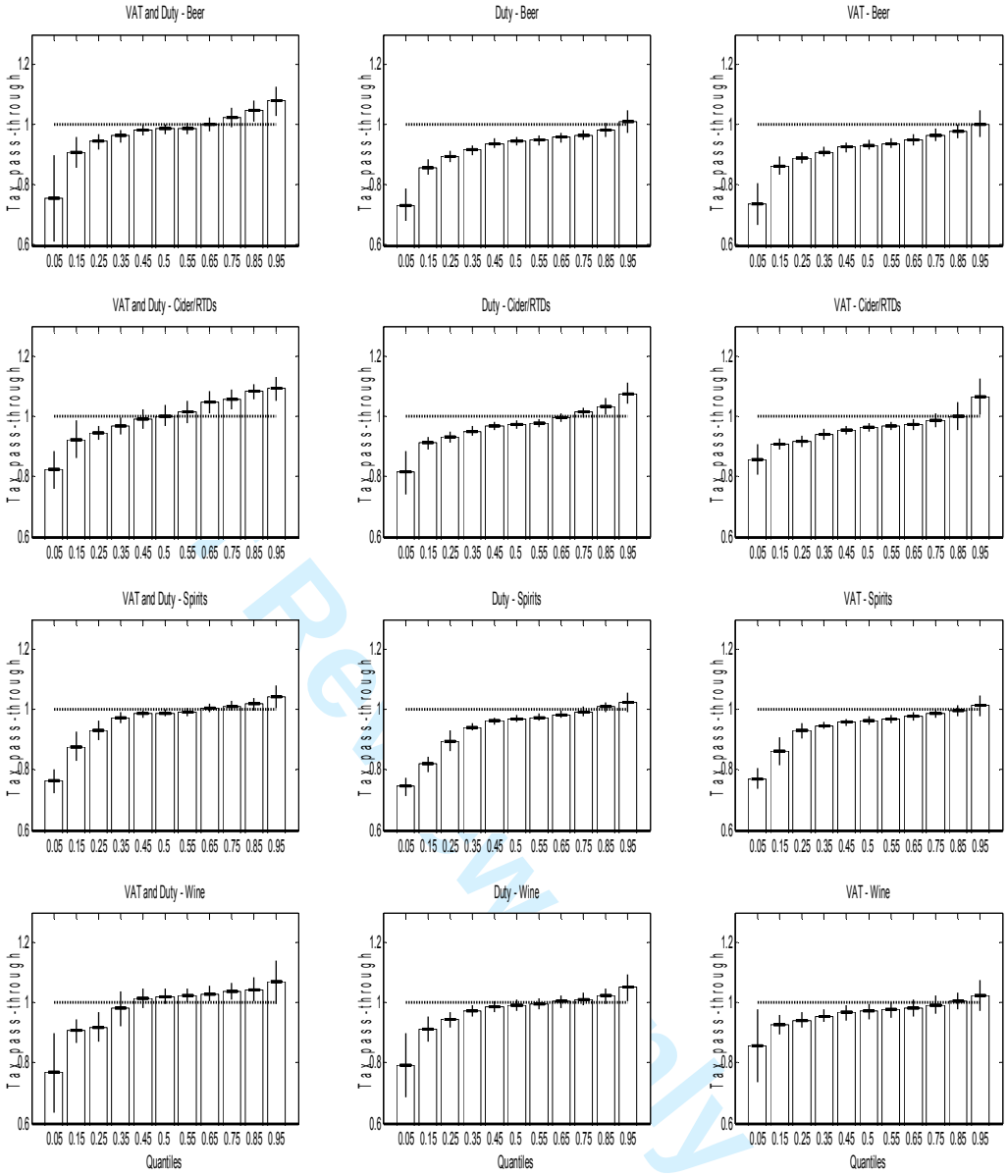

Figure S6 Model II duty and VAT tax pass-through together with 95% confidence intervals for RPI adjusted prices.

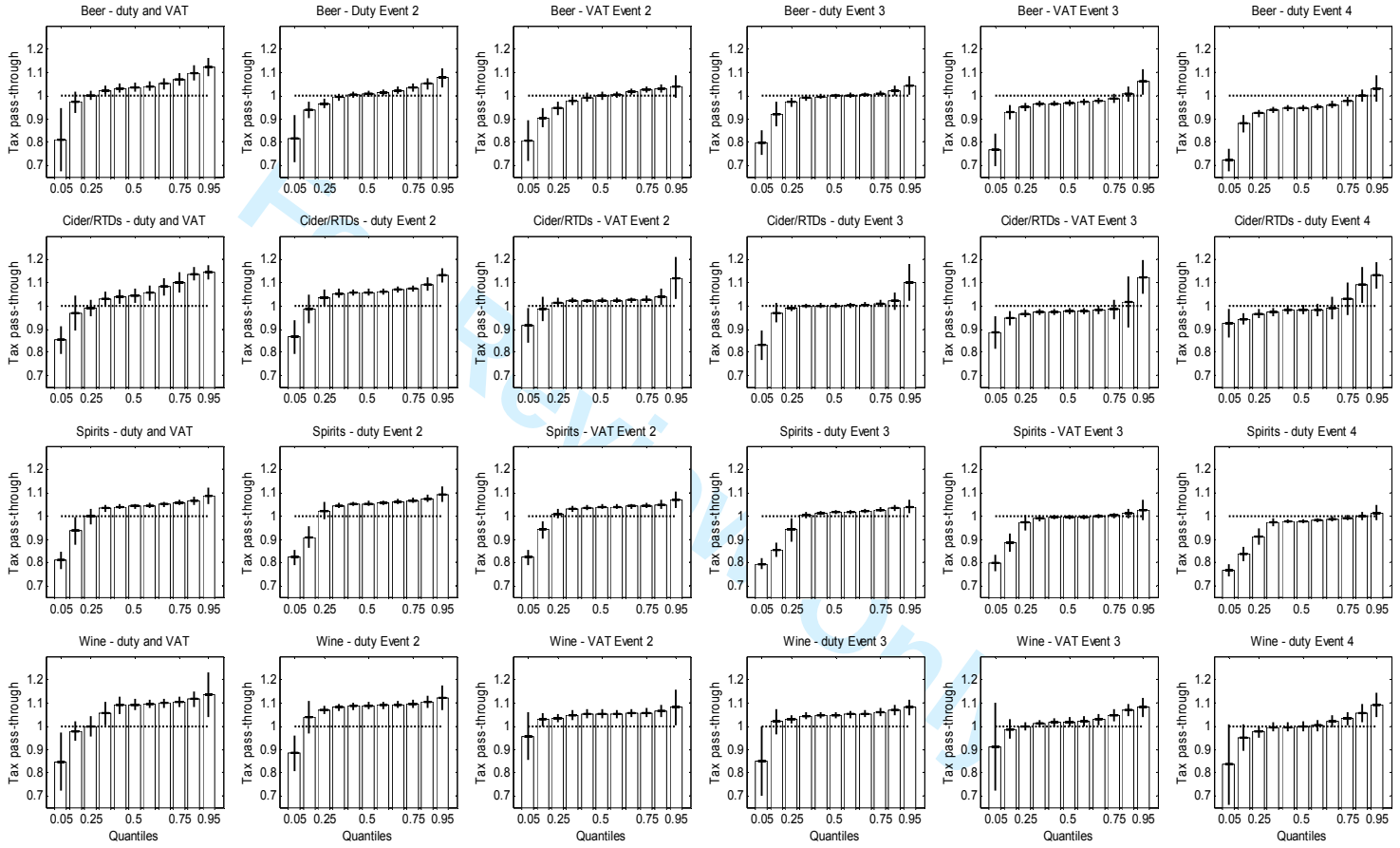

Figure S7 Model III tax pass-through together with 95% confidence intervals for RPI adjusted prices. Column 1 (duty and VAT), columns 2, 4 and 6 duty only and columns 3 and 5 VAT only change