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Aria Ardalan · Sebastian G. Kessing

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Universität Siegen
Fakultät III
Wirtschaftswissenschaften, Wirtschaftsinformatik und Wirtschaftsrecht
Fachgebiet Volkswirtschaftslehre
Unteres Schloß 3
D-57072 Siegen
Germany

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Tax Pass-Through in the European Beer Market

Aria Ardalan* Sebastian G. Kessing †

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Abstract

We study the pass-through of indirect taxes on beer prices in the European Union (EU). Exploiting the variation of value added tax rates, beer excise tax rates, and beer prices in a panel of monthly data from 1996 to 2016 of all current 28 EU member states, we estimate the tax pass-through of specific beer excise taxes and ad valorem value added taxes (VAT). VAT is under-shifted at a rate of approximately 70%. Specific excise taxes are almost fully shifted to prices in the EU, but, in contrast to the empirical findings for the US, there is no evidence of over-shifting. The difference between the two tax pass-through rates points towards the importance of imperfect competition in the European beer market. Excise tax increases are passed through faster and at a higher rate than excise tax decreases.

Keywords: Tax incidence, Pass-through, VAT, Excise Taxes, EU, Beer.
JEL codes: H22, H23

*University of Siegen, aria.ardalan@uni-siegen.de
†University of Siegen and CESifo, kessing@vwl.wiwi.uni-siegen.de
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1 Introduction

All 28 member states of the European Union (EU) levy specific excise taxes as well as value added taxes (VAT) on the consumption of beer. This parallels the practice in many other countries that also apply a mix of specific and ad valorem taxes on beer.[1] This commonly observed tax pattern can be attributed to the externalities and internalities associated with the consumption of alcoholic beverages, the relatively inelastic demand for beer, and the administrative ease of levying such taxes. The present analysis investigates the pass-through of specific excise taxes and of the VAT to beer prices in the 28 EU member states over the time period from 1996 to 2016.

Our study provides several contributions. First, we provide evidence of pass-through rates of indirect taxes on beer in the EU. While there is substantial evidence regarding the pass-through rates of alcoholic beverages in the United States (US), including beer, the European evidence is sparse and, where it exists, only relates to the level of individual member states. Moreover, Kenkel (2005), Shrestha and Markowitz (2016), and Young and Bielińska-Kwapisz (2002) have found a substantial degree of over-shifting of beer excise taxes in the US. This raises the question whether such over-shifting is also present in the EU. Our results indicate that this is not the case, since we find that specific excise taxes on beer are almost fully shifted to beer prices in our sample.[2]

Second, we compare pass-through rates of specific excise taxes and of ad valorem value added taxes on beer prices. Under perfect competition, theory predicts that the pass-through of specific and ad valorem taxes should be equal, while under imperfect competition they typically differ (Keen (1998), Myles (1996), Anderson, De Palma and Kreider (2001*a*), Delipalla and Keen (1992)). These theoretical approaches conclude that the pass-through rates of specific taxes should exceed those of ad valorem taxes under imperfect competition. Intuitively, with ad

[1] Some countries also levy ad valorem excise taxes either instead of, or in addition to, specific excise taxes, as well as general consumption ad valorem taxes, such as the VAT or general sales taxes. In the EU this is not the case. As laid down in the Council Directive 92/83/EEC all EU member states should tax beer using specific excise taxes only, and refrain from ad valorem excise taxes.

[2] Theoretical approaches that allow for imperfect competition can explain such over-shifting, see Weyl and Fabinger (2013). More recently, Agrawal and Hoyt (2018) have developed a perfect competition framework which also allows, under certain considerations such as small markets, overshifting of indirect taxes.

valorem taxes the government receives a share of firms' gross revenue. Thus, each firm has to share the benefits of its ability to affect prices with the government. This reduces firms' incentives to increase prices in comparison to the case of specific taxes, which in turn results in lower pass-through rates. As a corollary, ad valorem taxes Pareto-dominate specific excise taxes under imperfect competition, see Denicolò and Matteuzzi (2000), Anderson, De Palma and Kreider (2001*a*) and Anderson, De Palma and Kreider (2001*b*). For the same amount of government revenues, prices are set at a lower level with ad valorem taxes implying higher consumer surplus.[3] However, excise taxes may have an advantage if the tax is thought to be corrective and the excise directly targets the externality, such as alcohol content, see Bonnet and Réquillart (2013). Such considerations are less important in the case of beer since alcohol content is closely related to the quantity of beer itself.

Finally, the third contribution of our study relates to our empirical strategy. We employ a panel of beer price indices and tax rates of the various EU member states in our analysis. This approach is similar to incidence studies in the US considering cities and states, see Evans, Ringel and Stech (1999), Besley and Rosen (1999) Harding, Leibtag and Lovenheim (2012), Shrestha and Markowitz (2016), Kopczuk et al. (2016), and Young and Bielińska-Kwapisz (2002). We argue that this strategy can also be employed to estimate pass-through rates in Europe. This approach is in contrast with most of the existing empirical literature on European countries, where tax pass-through rates have been estimated exploiting the time variation of within-country data. Carbonnier (2013) and Bonnet and Réquillart (2013) study the case of excise taxes and VAT reforms in France, while Bergman and Hansen (2016) provide evidence of the excise tax pass-through using Danish data, and Benzarti et al. (2017) discuss the Finish case of VAT changes. Our identification strategy is instead based on the assumption that, at least since the implementation of European Single Market on January 1st, 1993, input and product markets have become substantially integrated across EU member states. Accordingly, we focus on price developments in member states where taxes change

[3]Note that these theory findings can potentially be reversed, if firms have multiple products, see Hamilton (2009). Given that many consumption goods, including beer, are primarily sold via multi-product retailers, the potential difference between specific and ad valorem tax pass-through rates even under imperfect competition may be considered ambiguous a priori, and needs to be assessed empirically.

relative to other member state where taxes remain constant.[4]

In comparison to the US, beer markets of EU member states were traditionally more segmented at the consumer level, in particular with respect to the leading brands that dominate in each market. However, Fertő and Podruzsik (2016) document that member states' exports and imports have been growing dynamically, with the value of member states' imports and exports roughly doubling from 2000 to 2010. Moreover, several member states (Czech Republic, Denmark, Germany, Ireland, The Netherlands) have been important beer exporters for a long time, whereas other member states (Greece, Italy, Spain, Sweden, United Kingdom) are major importers of beer. Moreover, market concentration on average is high and similar to the US (the exception being Germany, with a beer market characterized by fierce competition between regional, national, and international breweries). In 2013, the market share of the leading brewery ranged from 6.21% in Germany to 73.95% in Slovenia, with an unweighted EU average of approximately 37% (Loretz and Oberhofer (2016)). In the US, the leading firm had a market share of 45.6% in the same year (Marketrealist (2015)). As a consequence of large scale cross-border mergers and acquisitions in the beer industry over the last 25 years, key market players are often the same across member states, even though they may sell different brands in different member states.[5] As regards the demand side, Fogarty (2010) provides an overview of estimated elasticities of the demand for beer in various countries, including many EU member states. He concludes that little support exists for the idea that demand for alcoholic beverages varies fundamentally across countries, with only wine, but not beer, potentially being an exception. Finally, due to the Single Market, breweries' input markets have been fully integrated since 1993.

Our analysis finds that excises taxes are almost fully shifted to beer prices, whereas ad valorem taxes (VAT) are shifted at a substantially lower rate of approximately 70%. These findings are robust to different specifications of our estimations. The difference suggests that imperfect competition plays a role in

[4]Note that we do not discuss and compare the salience of different taxes, similar to Chetty, Looney and Kroft (2009), since it is unlikely that salience plays an important role in the European context. Unlike in the U.S., prices in Europe are always labeled tax inclusive for the consumer, i.e., neither the tax component nor the net price are indicated.

[5]In 2013, Carlsberg A/S was the biggest brewing company in five member states, SAB Miller also in five (In 2015 SAB Miller was taken over by Anheuser Busch InBev, which was the biggest brewing company in one member state in 2013.), Heineken NV in four, and Molson Coors Brewing Co in three, see Loretz and Oberhofer (2016).

the European beer market, even though over-shifting does not occur. Excise tax increases are passed through faster and at a higher rate than excise tax decreases.

Our study relates to several strands of literature. The empirical analysis of indirect tax pass-through has been addressed by a number of studies over recent years, see Bergman and Hansen (2016) for a comprehensive overview. Two important reference points for our analysis are the contributions of Young and Bielińska-Kwapisz (2002) and Shrestha and Markowitz (2016) who both consider excise tax pass-through to beer prices in the US. Both studies find substantial over-shifting to prices. Shrestha and Markowitz (2016) conclude that a 10-cent increase in beer taxes translates into a 17 cents increase in the retail prices.

Using European data, Benedek et al. (2015) estimate the VAT pass-through for a group of commodities based on a panel of 17 selected EU member states over the period 1999 to 2013. Their results imply different effects for different VAT rates. For the standard rate, the accumulated effect of a tax change shows full-shifting. However, pass-through rates for reduced rates were only around 30%, and even zero for reclassifications. We also use a panel approach, but focus on the differences between specific and ad valorem taxes. In contrast to Benedek et al. (2015), we find that in the beer market, where the standard rate applies, the VAT pass-through rate is substantially below unity.

The next section sets out the conceptual framework. In Section 3 we describe our data and display the evolution of beer prices, beer consumption, the tax events, and macroeconomic conditions in selected member states. We then provide our empirical approach and the estimation results in Section 4. Section 5 presents several robustness checks and extensions, and Section 6 discusses the results and provides conclusions.

2 The framework

In general, the consumer price of beer P is given by $P = (q(t, \tau) + t)(1 + \tau)$, where t is the excise tax, τ indicates the value added tax rate, and $q = q(t, \tau)$ is the producer price, which itself is a function of both tax rates. Our conceptual approach takes this dependency into account, and also disentangles the role of the different taxes. To investigate the impact of tax changes on consumer prices, we rely on the approach introduced in Carbonnier (2013). This allows us to derive the

equations to be estimated in the case of VAT and specific excise taxes, respectively. We first discuss the VAT case and then consider excise taxes. In Section 4, we additionally consider a joint equation that includes both taxes.

2.1 Value added taxation

Define ϕ to be the consumer's share of the burden of an ad valorem tax. It represents the ratio of the tax-inclusive price variations with respect to VAT changes to the consumer price variation for constant producer prices

$$\phi \equiv \frac{\frac{\partial P}{\partial \tau}}{\frac{\partial P}{\partial \tau}\Big|_{q=const}} = \frac{\frac{\partial q}{\partial \tau}(1+\tau)+q+t}{q+t} = 1 + \frac{1+\tau}{q+t}\frac{\partial q}{\partial \tau}. \tag{1}$$

Full pass-through of the VAT implies $\phi = 1$, and $\phi = 0$ represents no shifting. We define q^0 as the hypothetical producer price that would prevail without any taxes. Furthermore, two proxy parameters m and n are defined so that

$$P = (q^0 + mt)(1 + n\tau) \tag{2}$$

Since we do not observe these proxy variables n and m, we need to determine the relationship between them and the pass-through rate ϕ. From (2) we have $\frac{\partial P}{\partial \tau} = n(q^0 + mt)$. In addition, since $q = \frac{P}{1+\tau} - t$, we have $\frac{\partial q}{\partial \tau} = \frac{\partial P}{\partial \tau}\left(\frac{1}{1+\tau}\right) - \frac{P}{(1+\tau)^2}$. Plugging these into (1), rearranging the relationship between ϕ and n, and applying $q + t = \frac{P}{1+\tau}$ and $q^0 + mt = \frac{P}{1+n\tau}$ generates

$$\phi = \left(\frac{P}{1+n\tau}\right)\frac{n(1+\tau)}{P} = \frac{n(1+\tau)}{1+n\tau}. \tag{3}$$

Equation (3) plays a key role in estimating VAT pass-through. Defining the operator $\delta_i(\tau) \equiv \tau_i - \tau_0$, where τ_i is the VAT rate in period i and τ_0 is the VAT rate in the base period, and applying it to the natural logarithm of equation (2) gives $lnP_i = ln(q_i^0 + mt_i) + ln\left(1 + n\tau_0 + n\tau_i - n\tau_0\right))$. Further rearranging yields

$$lnP_i = ln(1 + n\tau_0) + ln(q_i^0 + mt_i) + ln\left(1 + \frac{n\delta_i(\tau)}{1+n\tau_0}\right). \tag{4}$$

Since $\frac{n\delta_i(\tau)}{1+n\tau_0}$ is small compared to one, the Taylor expansion of $ln\left(1 + \frac{n\delta_i(\tau)}{1+n\tau_0}\right)$ in equation (4) will be $\frac{n}{1+n\tau_0}\delta_i(\tau)$ so that

$$lnP_i = \underbrace{ln(1+n\tau_0)}_{term1} + \underbrace{ln(q_i^0 + mt_i)}_{term2} + \underbrace{\frac{n}{1+n\tau_0}\delta_i(\tau)}_{term3}. \tag{5}$$

This is the baseline for our VAT pass-through estimations. *Term 1* in equation (5) is a constant term while *term 2* comprises determinants of producer prices including the excise tax. *Term 3* is the tax-shifting term and its coefficient, according to equation (3), will be used to derive the VAT pass-through.

2.2 Excise taxes

Consider now the case of an excise tax. Starting again from $P = (q(t,\tau)+t)(1+\tau)$, we define η as the consumer's share of burden from the excise tax

$$\eta \equiv \frac{\frac{\partial P}{\partial t}}{\frac{\partial P}{\partial t}\Big|_{q=const}} = 1 + \frac{\partial q}{\partial t}. \tag{6}$$

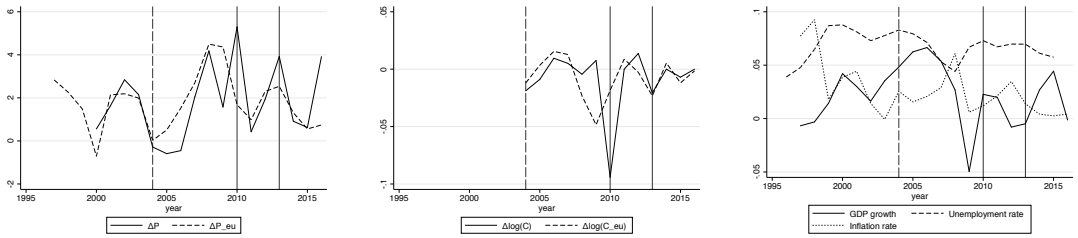
In addition, it holds that $q = \frac{P}{1+\tau} - t$, so that $\frac{\partial q}{\partial t} = \frac{\frac{\partial P}{\partial t}}{1+\tau} - 1$. According to equation (2) we have $\frac{\partial P}{\partial t} = m(1+n\tau)$. Together with equation (6) this gives the relationship between our measure of excise tax pass-through and the proxy variables

$$\eta = \frac{m(1+n\tau)}{1+\tau}. \tag{7}$$

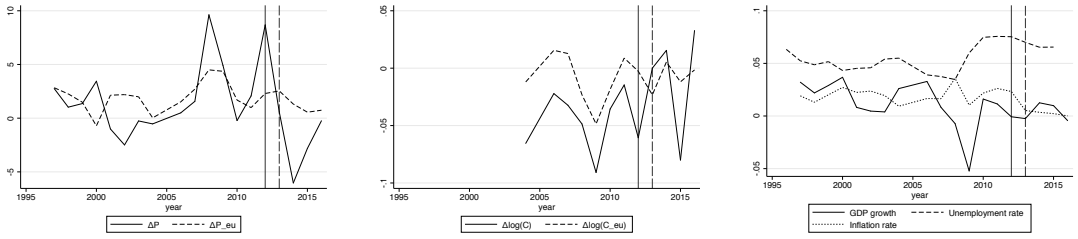
Subsequently, with t_0 changing to t_1, given equation (2), Δt can be written as $\Delta t = \frac{1}{m}\left(\frac{P_1 - P_0}{1+n\tau} - \Delta q\right)$. Further rearranging generates the relationship between an excise tax change and the corresponding price change

$$\Delta P = \underbrace{m(1+n\tau)\Delta t}_{term1} + \underbrace{(1+n\tau)\Delta q}_{term2}. \tag{8}$$

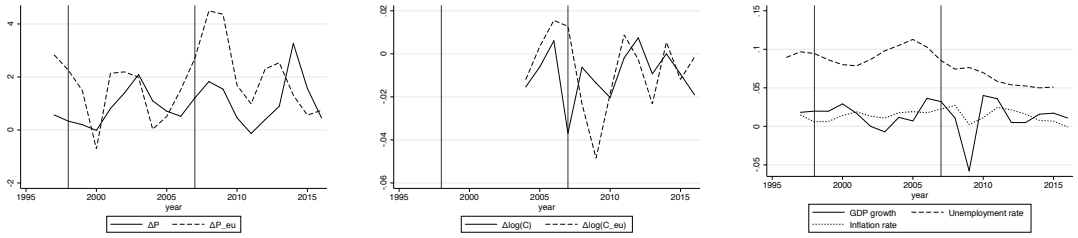
This is the second baseline for our estimation. In equation (8), *term 1* represents our tax shifting term and *term 2* includes all other controls. The coefficient of *term 1*, according to equation (7), determines the excise tax pass-through.



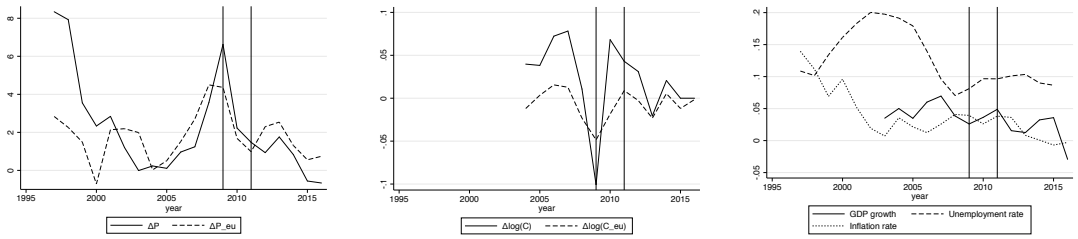
Czech Republic (CZ)



Denmark (DK)



Germany (DE)



Beer price | Beer consumption per capita | Macroeconomic variables

Poland (PL)

Figure 1: Beer prices, consumption, and macroeconomic variables.
Notes: Left panel: change in yearly beer price (in member state and the EU average). Middle panel: growth rate of beer consumption per capita. Right panel: macroeconomic variables. Solid vertical lines indicate tax increases (VAT or excise) and dashed vertical line show tax decreases (VAT or excise). Excise tax changes are, increase: CZ (2010), DK (2012 and 2013), PL (2009), and decrease: DK (2013). VAT changes are, increase: CZ (2010 and 2013), DE (1998 and 2007), PL (2011), and decrease: CZ (2004).

3 Data

We employ a monthly dataset from Jan-1996 to July-2016 which is comprised of VAT standard rates, beer excise taxes, macroeconomic variables, and member state level price indices (HICP hereafter), harmonized at the European level. Eurostat is the main source for all our price series.[6] Aside from beer prices, we use price indices of transport and energy as controls to account for possible variations of producer prices. Moreover, we use inflation, GDP growth and unemployment as further macroeconomic controls.[7] Table 1 provides summary statistics of our data as well information on the tax rate changes.

The webpage of the European Commission's Directorate-General Taxation and Customs Union offers detailed information on the evolution of VAT standard rates together with the respective dates of change for each member state.[8] Excise tax data and the corresponding historical tables are retrieved from the same source. Dates of tax changes are partly exploited according to the historical tables of excise duties but, unfortunately, in many cases this information is not indicated in the table, especially during the 1990s. To overcome this issue, and to capture the correct month of change for each country, we additionally compile this information from the *Reform Database* of the European Commission. For the few cases where neither of the two sources offer the required information, the start of the corresponding calendar year is considered as the time of the tax change. Finally, we re-scale all the excise tax rates so that these rates in each member state correspond to the price index of the same member state, see the Appendix for details.

Figure 1 displays the behavior of key variables over our sample period for four selected EU member states. For each of these, we provide three panels. The first panel displays the development of beer prices in the respective country and in the EU. We plot prices in first differences in line with our theoretical and empirical approach. The second panel shows the growth rate of per capita consumption in the member state and in the EU. The consumption data is at the annual frequency level and only starts from 2003, so that 2004 is the first observation for the growth

[6] `ec.europa.eu/eurostat`

[7] The macroeconomic variables are taken from the Federal Reserve Economic Data (FRED). GDP growth and unemployment rate are of quarterly frequency.

[8] `ec.europa.eu/taxation_customs/business`

Table 1: Summary statistics and the number of tax rates

Variable	Mean	Std. Dev.	Min.	Max.	N
Beer(HICP)	83.393	14.56	5.2	112.4	6585
VAT rate	20.015	3.019	8	27	6842
GDP growth(%)	0.218	4.546	-41.184	27.02	6635
Unemployment rate(%)	0.09	0.044	0.017	0.279	6306
Inflation rate (%)	0.29	1.782	-4.049	123.091	6853
Transport(HICP)	84.298	17.709	2.03	116.88	6880
Energy(HICP)	77.408	23.267	6.59	127.12	6556
Number of tax changes			**Increases**	**Decreases**	**Total**
VAT			50	13	63
Excise tax			101	9	110

Notes: The upper panel presents summary statistics of our sample of 28 EU countries from *Jan-1996* to *July-2016*. The lower panel provides information regarding tax rate changes within these countries in the sample period. The reference year for all our price indices is 2015 (2015=100). GDP growth and unemployment are originally quarterly data.

rates.[9] Finally, the last panel provides the macroeconomic conditions in terms of GDP growth, inflation, and the unemployment rate in each country. Moreover, in each of the three panels we indicate tax increases by a solid vertical line, and tax decreases by a dashed vertical line. Further details about the nature of the tax changes are provided directly in the caption of Figure 1. The displayed data indicate that, in the absence of tax changes, beer prices and beer consumption of individual member states and the entire EU move broadly together. Following tax increases, prices increase relative to the EU and consumption decreases relative to the EU. Finally, the evidence regarding the relationship between macroeconomic conditions and tax changes is somewhat inconclusive from these graphs. We assess the latter aspect in Section 5.

4 Empirical analysis and results

Based on equations (5) and (8), we estimate VAT and excise tax pass-through on beer prices. However, before estimating equation (5) all our series are tested for the presence of a unit root to avoid spurious regressions. Applying the Im-Pesaran-Shin test (Im, Pesaran and Shin (2003)) indicates that our dependent variable as well as the other price indices used as controls are highly persistent and non-stationary in levels. Therefore, we carry out the regression for the VAT

[9]The data is compiled from various issues of The Brewers of Europe (2016).

pass-through in first differences. The estimated equation is

$$\Delta ln(P_{ci}) = \alpha_c + \alpha_i + \alpha_t + \gamma^1 \Delta ln X_{ci} + \gamma^2 M_{ci} + \sum_{j=-k}^{k} \beta_j^\tau \Delta \tau_{ci}^j + \varepsilon_{ci}, \qquad (9)$$

where i and c refer to the month and member state, respectively. Moreover, α_c and α_i correspond to member states (not necessarily included) and time fixed effects, and α_t is a vector of dummies indicating changes in excise taxes. The set of cost controls, X_{ci}, comprises the indices of energy and transport cost. The macro controls, M_{ci}, are GDP growth, inflation and unemployment. The coefficients to be estimated are γ^1, γ^2 and β_j^τ. Moreover, k is the number of leads and lags for the tax change term. Thus, $\Delta\tau^j$ denotes the change in the VAT rate j periods ago (or ahead if j is negative). With $k = 1$, estimation of equation (9) provides a value for $\beta^\tau \equiv \sum_{j=-1}^{1} \beta_j^\tau$, which is the coefficient of the entire tax-shifting term. We consider a single lead and a single lag here, since the complete effect of the tax change may not occur contamporaneously within the same period.[10] We are interested in the VAT pass-through ϕ from equation (1), i.e. the consumers' share of the tax burden. Based on (3), it holds that $\frac{\phi}{1+\tau_0} = \frac{n}{1+n\tau_0}$. Comparing this term to the coefficient of our tax-shifting term in (9), the estimated pass-through is

$$\hat{\phi} = \hat{\beta}^\tau (1 + \bar{\tau_0}), \qquad (10)$$

where $\bar{\tau_0}$ is the average of τ_0 in all member states, i.e. the average VAT rate at the beginning of our sample period, and $\hat{\beta}^\tau$ is calculated from the estimation of equation (9). Finally, comparing equations (5) and (9), note that using the first differences is fully in line with our theoretical framework. For the first difference $\Delta\left[\frac{n}{1+n\tau_0}\delta(\tau_i)\right] = \frac{n}{1+n\tau_0}\left[\delta(\tau_i) - \delta(\tau_{i-1})\right]$. Subtracting the tax rate τ_0 yields the new tax shifting term $\frac{n}{1+n\tau_0}\Delta(\tau_i)$.

Similarly structured to equation (9), but directly based on (8), we estimate the following equation for the excise tax pass-through,

$$\Delta P_{ci} = \alpha_c + \alpha_i + \alpha_\tau + \gamma^1 \Delta X_{ci} + \gamma^2 M_{ci} + \sum_{j=-k}^{k} \beta_j^t \Delta t_{ci}^j + \varepsilon_{ci}, \qquad (11)$$

where α_c and α_i again capture country and time fixed effects, respectively. In addition, α_τ is a vector of dummy variables to capture the impact of VAT rate

[10] We discuss extensions to several leads and lags further below.

changes. Potential controls are again the price indices of transport and energy in each member state in first differences, ΔX_{ci}, as well as the macro controls, M_{ci}, comprising GDP growth, inflation and the unemployment rate, and γ^1, γ^2 and β^t are the coefficients to be estimated, and k is the number of leads and lags for the tax change term. With $k = 1$, $\beta^t \equiv \sum_{j=-1}^{1} \beta_j^t$ is the coefficient of our tax-shifting term. Given equation (7), the coefficient of Δt corresponds to $\eta(1 + \tau)$, so that

$$\hat{\eta} = \frac{\hat{\beta}^t}{1 + \bar{\tau}} \tag{12}$$

indicates the consumers' share of the excise burden, where $\bar{\tau}$ is the average VAT rate across all periods and member states.

Equations (9) and (11) are created following the framework laid out in Section 2, and changes in the respective other tax are dummied out to address potential omitted variable bias. Additionally, given that $\Delta log(P) \approx \%\Delta P$, we estimate the following regression that includes both taxes

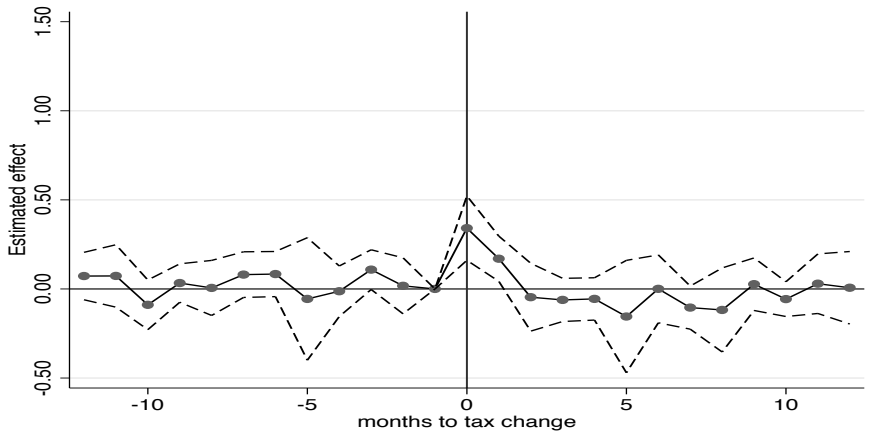
$$\Delta P_{ci} = \alpha_c + \alpha_i + \gamma^1 \Delta X_{ci} + \gamma^2 M_{ci} + \sum_{j=-k}^{k} \beta_j^{\tau} \Delta \tau_{ci}^j + \sum_{j=-k}^{k} \beta_j^t \Delta t_{ci}^j + \varepsilon_{ci}, \tag{13}$$

and we compare the corresponding results to those from equations (9) and (11).[11]

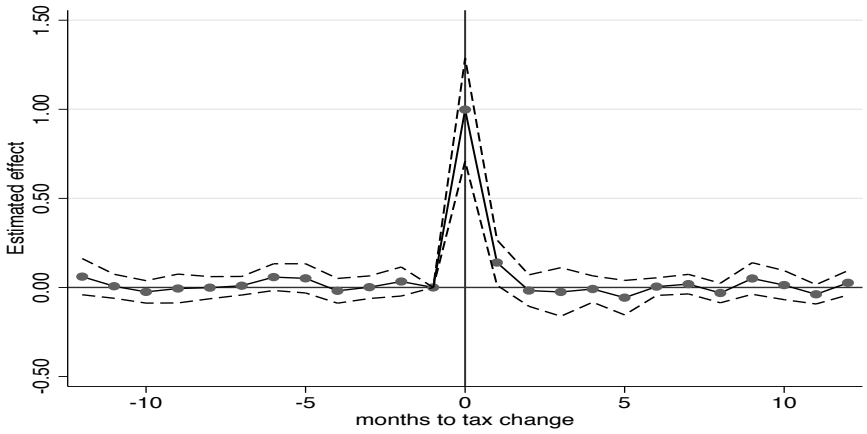
Subsequently, we extend our regressions (9), (11), and (13) by including 12 periods of lead and lag for the tax change, turning our approach into an event study design. The inclusion of lead terms allows to observe systematic price effects before tax changes, which may occur because firms are adjusting their prices beforehand. All of the lead and lag terms are interacted with the magnitude of the tax change, following the suggested procedure by Sandler and Sandler (2014) for events with different treatment intensity. Sub-figures *a* and *b* in Figure 2 correspond to equations (9) and (11). Additionally, sub-figure *c* depicts the event study graph related to equation (13). The month prior to the event is set as the reference period in all of these graphs.

The event study sub-graphs in Figure 2 show that, for excise tax changes, the effects are concentrated in the first two months in which the tax change is

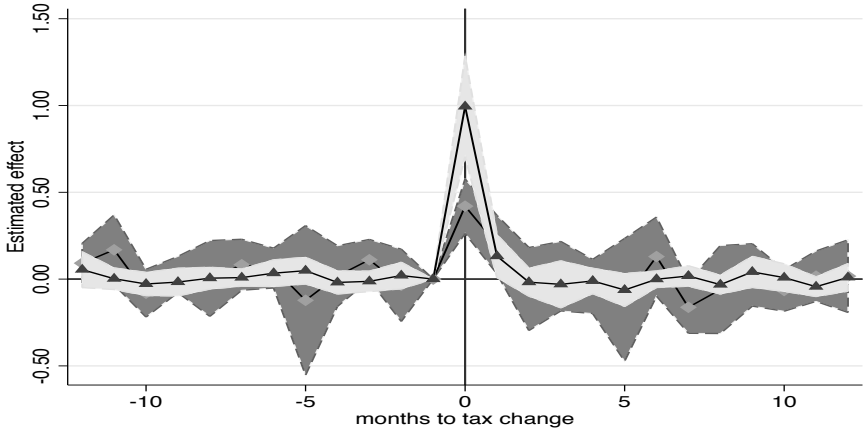
[11] We also extend equation (9) for the inclusion of both tax rates. The results (not reported) are very similar to those from estimating (13).



(a) VAT (equation 9)



(b) Excise tax (equation 11)



(c) Excise tax and VAT (equation 13)

Figure 2: Event study graphs.

Notes: Sub-figure (a) shows the event study for VAT changes with twelve leads and lags. Sub-figure (b) displays the event study for excise tax changes. Sub-figure (c) corresponds to the event study with changes in both tax rates. All estimations include time and member state-fixed effects as well as cost controls. Estimations corresponding to (a) and (b) also include dummies for changes in the other tax. The dashed lines indicate 95% confidence intervals and the vertical lines in $t = 0$ show the month when the tax change occurs. *Source:* authors' calculations.

implemented. For VAT changes, which are substantially less frequent, the effects are also concentrated in these first two months. Additionally, there are some preceding price increases, which are marginally significant (the price change three month before the tax change, in particular). More generally, there is no sign of systematic differences more than four months before the tax events.

Table 2 summarizes our results of estimating different forms of equation (9). The dependent variable is the first-differenced natural logarithm of beer prices (HICP-beer). Standard errors are clustered at the member state level. Note that, in line with our notation above, the subscript -1 corresponds to the month *after* the tax change. As discussed in Section 2, and according to equation (10), our estimated VAT pass-through $\hat{\phi}$ is computed according to the estimated coefficients of the tax shifting term in (9), which are provided in the last row. Since the variables are first-differenced, we also consider an alternative version of (9) without member states fixed effects. Columns 6, 7 and 9 in Table 2 indicate the corresponding results, which are very similar to the estimates with member states fixed effects.[12]

The comparison of the contemporaneous VAT pass-through, in Columns 5 and 7 of Table 2, to the pass-through computed by including lead and lag terms, in Columns 4 and 6, again shows that the full effect of a tax reform does not occur instantaneously. The total VAT pass-through rate, taking the previous, the following, and the month in which the tax change occurs into account, is approximately 70%. But the contemporaneous pass-through, according to Column 5, only implies a pass-through rate of around 40% to beer prices. The computed values of pass-through indicate under-shifting of beer prices with respect to VAT changes in the EU.[13]

Table 3 presents the results of estimating different forms of equation (11) for the pass-through of excise taxes where the dependent variable is the beer HICP in first differences. The standard errors are again clustered at the member state level. Based on equation (12) our measure of excise tax pass-through $\hat{\eta}$ is computed

[12]Using member states fixed effects, which imply member state-specific trends, corresponds to the diverse medium term macroeconomic developments across member states.

[13]This conclusion also holds if we add further leads and lags of the tax rate change to the regression in Column 4. More specifically, considering a 1 year time horizon around the month of the tax rate change (6 leads and 6 lags of the tax rate change) as well as considering a 2 year time horizon around the month of the tax rate change (12 leads and 12 lags of the tax rate change) result in a cumulative VAT pass-through rate of 0.51 and 0.44, respectively.

Table 2: VAT pass-through in the European Union

	(1) $\Delta ln(P)$	(2) $\Delta ln(P)$	(3) $\Delta ln(P)$	(4) $\Delta ln(P)$	(5) $\Delta ln(P)$	(6) $\Delta ln(P)$	(7) $\Delta ln(P)$	(8) $\Delta ln(P)$	(9) $\Delta ln(P)$
Δ VAT	0.380***	0.338***	0.341***	0.344***	0.344***	0.347***	0.348***	0.323***	0.317***
	(0.102)	(0.0891)	(0.0865)	(0.0887)	(0.0888)	(0.0878)	(0.0880)	(0.0846)	(0.0828)
Δ VAT$_{-1}$	0.130*	0.132*	0.162**	0.164**		0.163**		0.173**	0.166**
	(0.0716)	(0.0709)	(0.0611)	(0.0605)		(0.0600)		(0.0628)	(0.0617)
Δ VAT$_{+1}$	0.0204	0.0509	0.0789	0.0798		0.0807		0.0909	0.0868
	(0.0577)	(0.0553)	(0.0617)	(0.0610)		(0.0600)		(0.0629)	(0.0613)
macro controls								yes	yes
cost controls				yes	yes	yes	yes	yes	yes
excise tax D.			yes	yes	yes	yes	yes	yes	yes
time f.e.		yes	yes	yes	yes	yes	yes	yes	yes
country f.e.	yes	yes	yes	yes	yes			yes	
adj. R^2	0.001	0.013	0.192	0.192	0.190	0.192	0.190	0.203	0.201
$\hat{\phi}_{EU}$	0.631	0.620	0.693	0.700	0.409	0.703	0.414	0.699	0.678

Notes: Robust standard errors in parentheses clustered at the member state level. In all regressions, the dependent variable is the first-differenced beer HICP in logs. ϕ is our measure of tax pass-through and reflects the consumer's share of burden for ad valorem tax and is computed according to $\phi = \hat{\beta}_3(1 + \bar{\tau}_0)$ with $\bar{\tau}_0 = 19.12\%$. Cost controls are the price indices of transport and energy. Macroeconomic controls are GDP growth, inflation, and unemployment. The coefficients of inflation and unemployment are statistically significant in (8) and (9) with a positive sign and a negative sign, respectively. The subscript -1 corresponds to the month *after* the tax change. * $p < 0.10$,** $p < 0.05$, *** $p < 0.01$

according to the estimated coefficients of the tax shifting term in (11), which are indicated in the last row. The $\bar{\tau}$ used in the calculation is the VAT average across all periods and member states. Similar to our VAT analysis, we allow for a single period of lead and lag of the tax change since the effect may not occur instantaneously. Moreover, we again estimate equation (11) without member state fixed effects. The corresponding results, which are very similar, are shown in Columns 5, 6 and 8 of Table 3.

The comparison of the contemporaneous excise tax pass-through, in Columns 5 and 7 of Table 3, to the pass-through computed by including lead and lag terms in Columns 4 and 6, again shows that the effect of a tax reform does not only occur

Table 3: Excise tax pass-through across the European Union

	(1) ΔP	(2) ΔP	(3) ΔP	(4) ΔP	(5) ΔP	(6) ΔP	(7) ΔP	(8) ΔP	(9) ΔP
Δ Excise	0.977***	0.941***	0.930***	0.933***	0.931***	0.931***	0.930***	0.927***	0.924***
	(0.135)	(0.122)	(0.121)	(0.122)	(0.122)	(0.122)	(0.122)	(0.118)	(0.117)
Δ Excise$_{-1}$	0.128**	0.124*	0.121*	0.122*		0.121*		0.115*	0.113*
	(0.0608)	(0.0600)	(0.0602)	(0.0602)		(0.0589)		(0.0609)	(0.0593)
Δ Excise$_{+1}$	0.00474	0.0133	0.00997	0.0115		0.0109		0.0158	0.0150
	(0.0162)	(0.0136)	(0.0117)	(0.0121)		(0.0121)		(0.0130)	(0.0128)
macro controls								yes	yes
cost controls				yes	yes	yes	yes	yes	yes
VAT D.			yes	yes	yes	yes	yes	yes	yes
time f.e.		yes	yes	yes	yes	yes	yes	yes	yes
country f.e.	yes	yes	yes	yes	yes			yes	
adj. R^2	0.136	0.158	0.164	0.164	0.161	0.164	0.161	0.173	0.172
$\hat{\eta}_{EU}$	0.925	0.899	0.885	0.889	0.776	0.887	0.775	0.881	0.876

Notes: Robust standard errors in parentheses clustered at the member state level. In all regressions the dependent variable is the first-differenced beer HICP. $\hat{\eta}$ is our measure of tax pass-through, $\hat{\eta} = \frac{\hat{\beta_3}'}{1+\bar{\tau}}$ with $\bar{\tau} = 20.016\%$. Cost controls are the price indices of transport and energy. Macroeconomic controls include GDP growth, unemployment, and inflation. The coefficients of inflation and unemployment are statistically significant in (8) with a positive sign and a negative sign, respectively. In (9) the coefficient of inflation is positive and significant. The subscript -1 corresponds to the month *after* the tax change. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

instantaneously. Namely, a one unit increase in the excise tax rate, according to Column 4, increases prices by around 90 percent while the contemporaneous pass-through according to Column 5, implies a 77 percent increase in beer prices.[14] Overall, the values of $\hat{\eta}$ under different specifications in Table 3 indicate that excise taxes are almost fully-shifted to prices.

Table 4 shows the results of estimating equation (13), where both of the tax rates are included. In all joint estimations the VAT pass-through rates are consistently lower than those of specific excise tax rates, and they are under-

[14]The inclusion of up to 6 or 12 leads and lags in the regression corresponding to Column 4, does not alter this conclusion, as doing so results in a cumulative excise tax pass-through of 0.86 and 1.06, respectively.

Table 4: Tax pass-through across the European Union

	(1) ΔP	(2) ΔP	(3) ΔP	(4) ΔP	(5) ΔP	(6) ΔP	(7) ΔP	(8) ΔP
Δ Excise	0.976***	0.941***	0.943***	0.940***	0.942***	0.940***	0.937***	0.935***
	(0.135)	(0.122)	(0.122)	(0.122)	(0.122)	(0.122)	(0.118)	(0.118)
Δ VAT	0.416***	0.379***	0.394***	0.398***	0.397***	0.401***	0.363***	0.359***
	(0.0738)	(0.0537)	(0.0639)	(0.0649)	(0.0634)	(0.0645)	(0.0628)	(0.0608)
Δ VAT$_{+1}$	0.0223	0.0510	0.0564		0.0590		0.0683	0.0694
	(0.0561)	(0.0577)	(0.0571)		(0.0567)		(0.0603)	(0.0585)
Δ VAT$_{-1}$	0.159*	0.181**	0.186**		0.189**		0.196**	0.195**
	(0.0780)	(0.0751)	(0.0772)		(0.0769)		(0.0798)	(0.0789)
Δ Excise$_{-1}$	0.124*	0.120*	0.121*		0.120*		0.113*	0.112*
	(0.0609)	(0.0600)	(0.0600)		(0.0587)		(0.0606)	(0.0591)
Δ Excise$_{+1}$	0.00837	0.0162	0.0177		0.0171		0.0217	0.0208
	(0.0175)	(0.0153)	(0.0156)		(0.0148)		(0.0165)	(0.0155)
macro controls							yes	yes
cost controls			yes	yes	yes	yes	yes	yes
time f.e.		yes	yes	yes	yes	yes	yes	yes
country f.e.	yes	yes	yes	yes			yes	
adj. R^2	0.142	0.163	0.163	0.160	0.163	0.160	0.172	0.171
$\hat{\phi}_{EU}$	0.711	0.727	0.758	0.474	0.768	0.477	0.747	0.742
$\hat{\eta}_{EU}$	0.924	0.898	0.902	0.784	0.900	0.784	0.892	0.889

Notes: Robust standard errors in parentheses clustered at the member state level. The dependent variable is the first-differenced beer HICP. ϕ and η are the pass-through rates of VAT and excise taxes, respectively. Their calculation follows the same procedures as in Tables 2 and 3. Cost controls are the price indices of transport and energy. The coefficients of inflation and unemployment are statistically significant in (8) with a positive sign and a negative sign, respectively. In (9) the coefficient of inflation is positive and significant. The subscript -1 corresponds to the month *after* the tax change. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

shifted to prices.[15] This is also in line with the graphical evidence from Figure 2. Finally, the inclusion of macroeconomic controls hardly changes the estimated pass-through rates of VAT and excise taxes in all specifications, as is evident from Tables 2, 3, and 4. The substantial difference between the excise tax and VAT

[15] A post-estimation F-test on the estimated coefficients of VAT and excise taxes in our encompassing specification (Column 3 of Table 4) rejects the hypothesis that these are equal at the one percent level.

pass-through rates continues to hold.

5 Robustness and Extensions

To assess the robustness of our results we carry out several additional checks. These alternative estimates concern the inclusion of further controls as well as restrictions of our sample. The first approach aims at minimizing omitted variable bias, the second addresses potential concerns about the validity of using the EU member states as counterfactuals for each other. In particular, market integration may not have been very close between certain member states. Thus, price developments may have been rather different in individual member states due to market fragmentation even in the absence of tax changes.

Based on Figure 2, we observe that, for both taxes, it typically takes two months for the pass-through to take place. This raises concerns about omitted variable bias in our benchmark estimations which only control for contemporaneous change of the other tax.[16] We therefore re-estimate equations (9) and (11) with the given structure but also dummy out the period after the tax change in the respective other tax. The results are provided in Columns 1 and 2 of Table 5 for the VAT pass-through, and in the same columns of Table 6 for the excise tax pass-through. The results are very similar to the benchmark estimates.

Second, in the baseline model we estimate the tax pass-through employing data from all 28 EU member states. Some of these member states may not be sufficiently integrated with each other to be included in the analysis. Therefore, we change our sample to the current Eurozone countries, where economies are arguably more integrated than those of the entire EU, and re-estimate tax pass-through using equation (9) for VAT and equation (11) for excise taxes. The results are provided in Columns 3 and 4 of Table 5 and Table 6, respectively. Pass-through rates drop very slightly for the VAT, and increase very slightly for specific excise taxes, increasing the difference between the two pass-through rates.

Finally, in a further step, we restrict our sample of the Eurozone countries by only including those periods in which the Euro had already been adopted as the national currency in the respective member state. This check should address concerns about incomplete exchange rate pass-through in the period before the

[16] This issue does not apply to the joint estimation (equation (13)).

Table 5: Robustness check for VAT pass-through

	(1) $\Delta ln(P)$	(2) $\Delta ln(P)$	(3) $\Delta ln(P)$	(4) $\Delta ln(P)$	(5) $\Delta ln(P)$	(6) $\Delta ln(P)$
ΔVAT	0.344***	0.345***	0.298**	0.297**	0.300*	0.304**
	(0.0919)	(0.0922)	(0.128)	(0.128)	(0.144)	(0.144)
ΔVAT$_{-1}$	0.143*		0.208*		0.0551	
	(0.0739)		(0.118)		(0.0984)	
ΔVAT$_{+1}$	0.0796		0.0519		-0.0836	
	(0.0620)		(0.0949)		(0.0649)	
cost controls	yes	yes	yes	yes	yes	yes
excise tax dummies	yes	yes	yes	yes	yes	yes
time f.e.	yes	yes	yes	yes	yes	yes
country f.e.	yes	yes	yes	yes	yes	yes
adj. R^2	0.192	0.192	0.186	0.184	0.220	0.220
$\hat{\phi}$	0.674	0.410	0.658	0.350	0.322	0.361

Notes: Robust standard errors in parentheses clustered at the member state level. The dependent variable is the first-differenced beer HICP in logs. ϕ is the ad valorem tax pass-through measure, $\hat{\phi} = \hat{\beta}_3(1 + \bar{\tau}_0)$ with $\bar{\tau}_0$ equal to 19.12% for regressions 1 and 2, 17.95% for regressions 3 and 4, and 18.84% for regressions 5 and 6. Cost controls are the price indices of transport and energy. The subscript -1 corresponds to the month *after* the tax change. $^{*}p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

adoption of the Euro. Moreover, Greece is also not included in this sample, given the low degree of integration of this member state with the rest of the Eurozone. We display the corresponding results in Columns 5 and 6 of Table 5 and Table 6, respectively. The VAT pass-through is even lower in this case, and the pass-through of specific excise taxes is again slightly higher than in the benchmark. To sum up, all additional estimates point at the robustness of our results.

We now turn to two further aspects, the asymmetry of tax pass-through, and the times in which tax changes occur, respectively. First, tax increases may be passed-through at a different rate or speed relative to tax decreases. Table 7 provides some mixed results for the VAT case. For the estimation using only the contemporaneous tax changes shown in Column 1, only the tax increase coefficient is significant, and it is substantially larger than the insignificant coefficient of

Table 6: Robustness check for excise tax pass-through

	(1) ΔP	(2) ΔP	(3) ΔP	(4) ΔP	(5) ΔP	(6) ΔP
ΔExcise	0.931***	0.930***	1.034***	1.032***	1.029***	1.028***
	(0.122)	(0.122)	(0.142)	(0.143)	(0.169)	(0.171)
ΔExcise_{-1}	0.120*		0.122		0.144	
	(0.0618)		(0.0856)		(0.0854)	
ΔExcise_{+1}	0.0113		0.0287		0.0265	
	(0.0121)		(0.0203)		(0.0279)	
cost controls	yes	yes	yes	yes	yes	yes
excise tax dummies	yes	yes	yes	yes	yes	yes
time f.e.	yes	yes	yes	yes	yes	yes
country f.e.	yes	yes	yes	yes	yes	yes
adj. R^2	0.163	0.161	0.155	0.153	0.193	0.190
$\hat{\eta}$	0.89	0.78	1.00	0.86	1.00	0.87

Notes: Robust standard errors in parentheses clustered at the member state level. The dependent variable is the first-differenced beer HICP. η is the excise tax pass-through measure, $\hat{\eta} = \frac{\hat{\beta_3}'}{1+\bar{\tau}}$ with $\bar{\tau}$ equal to 20.016% for regressions 1 and 2, 19.03% for regression 3 and 4, and 19.38% for regressions 5 and 6. Cost controls are the price indices of transport and energy. The subscript -1 corresponds to the month *after* the tax change. $^{*}p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

VAT reductions. However, for the estimations using an additional lead and an additional lag, the results look somewhat different. The overall effect appears larger for the VAT decreases, and, in the case of the tax decreases, the lead and the lag are both significant, but the coefficient of the contemporaneous tax change is not. Table 8 provides more conclusive evidence for the case of excise taxes. These are passed-through at a slightly higher rate in case of tax increases relative to decreases. Moreover, the pass-through of increases is faster, occurring within the same month of the tax change, whereas the pass-through of tax decreases is spread out over the contemporaneous and the following month.

As a final point, we investigate whether tax changes occur at specific times. It is usually assumed in the tax pass-through literature that tax changes are exogenous. However, it may be argued that VAT or excise tax changes occur at particular instances. Both, excise taxes or VAT may be increased to balance the

Negative and positive tax changes

Table 7: VAT

	(1) $\Delta log(P)$	(2) $\Delta log(P)$	(3) $\Delta log(P)$
Δ VAT $^{+}$	0.384***	0.384***	0.385***
	(0.110)	(0.110)	(0.107)
Δ VAT $^{+}_{+1}$		-0.0198	-0.0211
		(0.0527)	(0.0517)
Δ VAT $^{+}_{-1}$		0.137**	0.137**
		(0.0635)	(0.0625)
Δ VAT $^{-}$	0.0865	0.0896	0.110
	(0.197)	(0.195)	(0.182)
Δ VAT $^{-}_{+1}$		0.347*	0.354*
		(0.193)	(0.198)
Δ VAT $^{-}_{-1}$		0.244**	0.242**
		(0.101)	(0.103)
country f.e.	yes	yes	
time f.e.	yes	yes	yes
cost controls	yes	yes	yes
excise tax D.	yes	yes	yes
adj. R^2	0.190	0.193	0.193
$\hat{\phi}^{+}_{EU}$	0.457	0.597	0.596
$\hat{\phi}^{-}_{EU}$	0.103	0.810	0.841

Table 8: Excise tax

	(1) ΔP	(2) ΔP	(3) ΔP
Δ Excise $^{+}$	0.990***	0.993***	0.988***
	(0.147)	(0.146)	(0.145)
Δ Excise $^{+}_{+1}$		0.0117	0.00772
		(0.0186)	(0.0192)
Δ Excise $^{+}_{-1}$		0.161	0.154
		(0.0978)	(0.0964)
Δ Excise $^{-}$	0.851***	0.852***	0.855***
	(0.200)	(0.200)	(0.200)
Δ Excise $^{-}_{+1}$		0.0125	0.0161
		(0.0214)	(0.0221)
Δ Excise $^{-}_{-1}$		0.0792***	0.0827***
		(0.0271)	(0.0279)
country f.e.	yes	yes	
time f.e.	yes	yes	yes
cost controls	yes	yes	yes
VAT D.	yes	yes	yes
adj. R^2	0.162	0.164	0.164
$\hat{\eta}^{+}_{EU}$	0.824	0.971	0.957
$\hat{\eta}^{-}_{EU}$	0.709	0.786	0.794

Notes: Robust standard errors in parentheses clustered at the member state level. The subscript -1 corresponds to the month *after* the tax change. * $p < 0.10$,** $p < 0.05$, *** $p < 0.01$

government budget, which, particularly in Europe with its relatively high level of welfare state provisions, is often driven by the dynamics of social spending. The latter typically arises in economic downturns, which by themselves may attenuate price dynamics. Similarly, VAT or excise tax reductions may be used as counter-cyclical policy instruments to jump-start the economy in an economic slump. Thus, if the VAT changes were to occur at different times relative to the excise tax changes, this could bias the estimations and potentially explain the different pass-through rates, as well as the different findings for tax increases and decreases. Table 9 shows the result of regressing changes in the VAT and excise tax rates on GDP growth, inflation, and unemployment. These regressions

Table 9: Tax changes and macroeconomic conditions

	(1) Δ Excise	(2) Δ VAT
GDP growth	-0.353	0.194
	(0.411)	(0.277)
Unemployment rate	0.0384	0.0276
	(0.235)	(0.0695)
Inflation rate	1.079	0.963
	(1.562)	(0.704)
season-year f.e.	yes	yes

Notes: Robust standard errors in parentheses clustered at the member state level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

include season-year fixed effects, since tax changes are more likely to occur during particular times of the year. Neither for the VAT nor the excise tax changes, the results indicate any significant correlation. This provides some evidence that tax changes may not occur too systematically at particular times during which beer prices could be affected in particular ways through other channels, or in which the transmission from taxes to prices may be systematically different from "normal" times.

6 Discussion and conclusion

We investigate beer price responses to changes in specific beer excise taxes and VAT exploiting the tax and price variation in a panel of the 28 EU member states. The approach thus emulates the research design that has been used to estimate pass-through rates of indirect local and state taxes in the US. We find that the ad valorem VAT is less than fully shifted to beer prices at a pass-through rate of approximately 70%. Using a similar approach for the case of excise taxes, we estimate that these are almost fully shifted to beer prices. Thus, while the excise tax pass-through rate is substantially larger, we do not find evidence of over-shifting. This can be contrasted to the US beer market where excise taxes are substantially over-shifted to prices. The results, both for VAT and excise taxes, are found to be robust under different specifications. Moreover, the pass-through

of excise tax increases occurs faster and tends to be somewhat higher relative to the pass-through of excise tax decreases.

In our analysis we have compared the pass-through of ad-valorem VAT to the specific excise taxes on beer. It is important to realize that these taxes not only differ along the ad valorem versus specific tax dimension, but also with respect to the consumption goods for which they apply. An increase in VAT also affects other products, whereas an increase in beer excise taxes only affects other goods indirectly. In general, it should be easier to pass-on the tax increase to consumers in a situation where other consumption goods, including important substitutes, also experience a tax increase. However, it could be that monetary policy is not sufficiently accommodating to the VAT increase, so that part of the VAT increase is pushed back to workers. This could be an alternative explanation of the lower VAT pass-through rates observed, besides imperfect competition.

Our findings of differential pass-through rates of specific and ad valorem taxes can thus, with some caveats, be interpreted in the sense that imperfect competition plays an important role in the European beer market.[17] This is in line with the relatively high market concentration in many European countries. Moreover, concentration is, on average, lower than in the US, which can explain the somewhat lower excise tax pass-through rates. From a policy perspective, relying more heavily on ad valorem taxes may therefore be able to generate substantial welfare gains. Welfare could be increased by a policy that replaced specific excise taxes by ad valorem taxes such that consumption levels remain unchanged. This can raise higher tax revenues without reducing consumer surplus and without compromising public health concerns or other negative externalities originating from alcohol consumption.

Compliance with Ethical Standards

Conflict of interest: Aria Ardalan declares that he has no conflict of interest. Sebastian Georg Kessing declares that he has no conflict of interest. Ethical approval: This article does not contain any studies with human participants or

[17] In addition to the presented results we also estimated an equation where we interacted the market share of the largest firm in 2013 as provided by Loretz and Oberhofer (2016) with the tax changes. However, the coefficient of interest did not turn out significant. These results could, however, be just due to the particular, potentially ill-suited, concentration measure, or due to the fact that we did not have access to a time-varying concentration measure.

animals performed by any of the authors.

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7 Appendix: Re-scaling of excise tax rates

As reported by Eurostat, member states compute the harmonized indices of consumer prices separately and according to their national consumption basket. Therefore, the structure of the underlying consumption basket in the reference period can potentially be different across various member states. To assess the pass-through of excise taxes on the respective price indices thus requires to relate the taxes to the quantities in the consumption baskets underlying each index. Furthermore, beer excise taxes are imposed on a specific quantity. According to article 3 of directive 92/83/EEC[18], the excise duties on beer can be levied per hectoliter/degrees Plato or per hectoliter/degrees of actual alcoholic strength by volume, in each member state. Thus, an additional concern stems from varying units of measure of the excise tax rate in different countries.

To address these issues, we make use of the so-called harmonized index of consumer prices at constant tax rates (HICP-CT thereafter) which are available

[18] "Council Directive 92/83/EEC of 19 October 1992 on the harmonization of the structures of excise duties on alcohol and alcoholic beverages"

for most of the member states from 2005 onwards. The difference between the HICP and the HICP-CT is as follows. For each country HICP-CT is computed for hypothetical fixed tax rates under the assumption of a one-to-one pass-through while the HICP allows for the actual tax variations in each period. Therefore, the difference among the two indices captures the extent to which price changes correspond to a particular value of excise tax changes assuming instantaneous and full pass-through in each country (European Commission (2011)).

We exploit the differences between the values of HICP and HICP-CT with an identical reference year (2015 = 100) relative to the value of effective tax change to identify the tax. Consider a period in which t_0 changes to t_1, based on the definition of HICP-CT, $P_1 = (q_1^0 + m\Delta t + mt_0)(1 + n\tau_1)$ and $P_1^{ct} = (q_1^0 + mt_0)(1 + n\tau_1)$ we have $P_1 - P_1^{ct} = m\Delta t(1 + n\tau_1)$. Rearranging and multiplying both sides by $\frac{1}{(1+\tau_1)\Delta t}$ gives

$$\frac{P_1 - P_1^{ct}}{(1 + \tau_1)\Delta t} = \frac{m(1 + n\tau_1)}{1 + \tau_1} = \eta. \tag{14}$$

The term on the right hand side corresponds to the pass-through of excise tax (η). The underlying assumption of Eurostat's HICP-CT is full and instantaneous pass-through and therefore $\eta = 1$, which means $\frac{P_1 - P_1^{ct}}{(1+\tau_1)\Delta t} = 1$ should hold. Computing this ratio for all the countries and for all those periods where the difference between HICP and HICP-CT is induced based on a single excise tax change reveals that for none of them the ratio $\frac{P_1 - P_1^{ct}}{(1+\tau_1)\Delta t}$ equals one. This implies that our excise tax rates should be re-scaled, and we use this ratio for this purpose.

The term $\frac{P_1 - P_1^{ct}}{(1+\tau_1)\Delta t}$ in a period with an excise tax change (Δt) and a fixed value of VAT rate (τ_1), captures the relationship between the variations of excise tax (measured either by hectoliter per degree alcohol or hectoliter degree Plato) and the price index which are used as a weight in each country to re-scale excise tax rates. Finally, for all periods in which a member state had already adopted the Euro as the national currency, all excise tax rates are converted into pre-existing national currencies using the irrevocably fixed conversion rates.