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Cigarette Taxes and Illicit Trade in Europe

Online Appendix

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Appendix

This appendix contains more complete information about the data and additional regressions to which the article published in *Economic Inquiry* refers.

A. Are taxes lowered in response to IRTC?

As discussed in the text in section IV.B.1, reverse causality between IRTC and cigarette taxes may cause downward bias in the estimated price coefficient. Since there are claims in the literature that some countries have responded to rising illicit trade by lowering cigarette taxes (Joossens & Raw, 2000)—albeit not for our countries and period—and also because reverse causality may invalidate our tax instruments, we investigate this further. First, there are few examples of cigarette taxes falling by any appreciable amount in the data, even though IRTC has been rising, particularly in Western Europe (see Figure 1 in the main text). Figure A.4 shows the trends in the real excise tax yield per cigarette (variable *ExTax*, from European Commission data) by country. The only countries with nontrivial decreases in cigarette taxes are Denmark and the UK The dip in 2012 in the tax yield per stick in Denmark appears to be merely an error in the EC report.[1] The decrease in the real tax yield in the UK from 2007 to 2010 is an artifact of movements in the British pound versus the euro. The nominal tax rates (both specific and ad valorem) were either unchanged or increasing each of those years.[2]

Nevertheless, we repeat estimation IV 3.2 without these two countries. The results in Table A.10 show that the price coefficient is higher (and still highly significant) with the smaller sample. However, given the relatively small difference in the two price coefficients compared to

[1] Denmark switched from having a high ad valorem and a low specific tax to the opposite right around that time. The ad valorem rate is properly lowered in 2012 in the European Commission tax data, but the increase in the specific tax does not appear until the following year’s report.

[2] The ad valorem rate was 22% until November 2008, when it rose to 24%. The specific tax in nominal British pounds (the statutory currency) rose each year during the time in question.

their standard errors, there is no clear evidence against the consistency of the main estimates from IV 3.2.

We also investigate reverse causality by regressing the excise taxes on twice-lagged IRTC shares. The double lag is prompted by the timing of when the Euromonitor and KPMG reports on IRTC are released: the earliest the reports could affect a full year's worth of taxation is two years after the data year of the report. We explored many regression specifications, including two dependent variables (log hypothetical total excise tax, which is here named $ExTaxHypo$, and log actual excise taxes) and various controls (country and year fixed effects only, or adding country-specific linear trends, with or without the other control variables from the main regressions [corruption and GNI]). In none of the estimations was the coefficient on lagged IRTC significant at even the 10% level. Note that including the country-level trends also handles the potential criticism (raised by a referee) that officials do not lower the absolute level of taxes but limit how much they raise them in response to IRTC.

B. Construction of the hypothetical and actual total excise taxes

In section IV.B.1 of the text, a hypothetical excise tax is used as an instrument for cigarette prices. Here we describe how that variable, T^h as it is denoted here, is constructed. We begin with the following identities:

$$P^h = P_0^h + T^h \tag{A-1}$$

$$T^h = T_{as} + T_{av}^h \tag{A-2}$$

In the expression, h superscripts are for hypothetical quantities. P^h is the tax-included retail sales price (TIRSP) with the hypothetical tax, P_0^h is the pre-excise-tax base price to be used in constructing the hypothetical tax, and T^h is the hypothetical overall excise tax (i.e., the sum of the specific and ad valorem excise taxes). In equation (A-2), T_{as} is the actual amount-specific excise tax (taken to be exogenous, thus also used for the hypothetical tax) and T_{av}^{h} is the hypothetical ad valorem excise tax amount (not the rate). The actual ad valorem tax amount cannot be used since it was calculated from a base that was presumed to be endogenous.

To calculate P^{h}, define α to be the ad valorem excise tax rate as a percentage of TIRSP. Rate α may vary from years to year and country to country. Treating the ad valorem tax as a fraction of TIRSP may appear odd, since TIRSP itself includes excise taxes. However, in the EU the ad valorem component is based on the maximum retail selling price inclusive of all taxes, which is set by the manufacturer or importer.[3]

Then, from (A-1), (A-2), and by definition of α, we have

$$P^{h} = P_{0}^{h} + T_{as} + \alpha P^{h} \qquad \text{(A-3)}$$

or, after rearranging terms,

$$P^{h} = \frac{P_{0}^{h} + T_{as}}{1 - \alpha} \qquad \text{(A-4)}$$

Combining (A-1) and (A-4) and rearranging terms yields the final expression for the hypothetical total excise tax:

$$T^{h} = \frac{P_{0}^{h} + T_{as}}{1 - \alpha} - P_{0}^{h} \qquad \text{(A-5)}$$

Matching to the data described in the text, T_{as} is $SpecTax_{it}$ and α is $AVtax_{it}$, both given in the European Commission data (refer to Table A.2 for variable names and definitions). The base price P_{0}^{h}, which is required to be plausibly exogenous since T^{h} will be used as an instrument, remains to be chosen. Define P_{0}^{a} to be the actual TIRSP less the overall actual excise tax (i.e., $P_{0}^{a} = CigPrice_{it} - ExTax_{it}$). Then we choose P_{0}^{h} for all observations to be the average value of P_{0}^{a} in the sample. Since the result does not vary over time, it cannot be endogenous due to time-

[3] See Council of the EU's Directive 2011/64/EU (available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:176:0024:0036:EN:PDF).

varying factors affecting actual prices. Since P_0^h does not vary across countries, it cannot be correlated with endogenous country-specific factors. Instrument T_{it}^h varies over time and country because both T_{as} and α vary over both. As mentioned in the text, T_{it}^h can be viewed as a (nonlinear) combination of the two instruments *SpecTax* and *AVtax* to create a single instrument. Figure A.5 shows that log T_{it}^h is a highly relevant instrument for log cigarette prices and that the visual evidence for a monotonic relationship is strong.

C. The separate impact of cigarette prices and taxes

Since $CigPrice = P_{pre\text{-}excise\text{-}tax} + ExTax$, a linear additive specification is appropriate for the regressions in Table A.5. Therefore we switch to using price and tax levels instead of logs. In estimation FE A5.1, we first re-run the specification from FE 3.2 but with the price in levels instead of logs. The coefficient is not directly comparable to those in the previous tables due to switching away from the linear-log specification, but it is highly significant as before. The price coefficient of 0.733 means that a one euro cent increase in the cigarette price per stick would lead to an expected increase of 0.73 percentage points in illicit market share. That is a sizeable effect: the implied average price elasticity of illicit market share in the sample is 2.86.

Separating the total price into its components yields estimation FE A5.2. The first regressor is the price including VAT but excluding ad valorem and specific excise taxes on tobacco, and the second regressor is the total excise tax per stick. The results show that if a distinction is to be made between tobacco-specific taxes and the rest of the price, then taxes are more important, both numerically and in terms of significance. An increase of 1 euro cent in the tax per stick is associated with a statistically significant increase of 1.5 percentage points in illicit market share. The implied tax elasticity of illicit market share is 3.2, which is similar to the total-price elasticities from FE 3.1 and 3.2. On the other hand, the non-tax part of the price has a smaller, insignificant coefficient, with an associated elasticity of 0.48. Instrumenting the price with the *SpecTax*, *AvTax*, and their cross-product (estimation IV A5.1, also in A5) does not change the insignificance of the price coefficient, although it increases its size.

Switching from the linear-log specification in the previous section to the fully linear specification here increases the chance that outliers in prices or taxes unduly influence the estimates. To investigate this possibility, the extra terms in a quadratic expansion in the tax and the rest of the price variables are added to estimation FE A5.3.[4] The results indicate that the average marginal effect of taxes is 1.8 (asy. *p*-value = 0.04), compared to the linear coefficient of 1.49 from the otherwise comparable estimation FE A5.2; prices and taxes are jointly significant at the 10% level. Coefficients on the higher-order terms are not jointly significant (*p*-value = 0.84) and therefore do not appear to be necessary.

D. A consumption gap analysis of illicit trade

To complement the main estimations using the Euromonitor estimates of IRTC, we also calculated our own estimates of illicit market share. The consumption gap analysis in this section provides further evidence that higher licit cigarette prices have sizeable and statistically significant impacts on illicit market share, even when avoiding industry- and third-party estimates of IRTC. Following the approach suggested by Blecher (2010), we compare survey estimates of cigarette consumption within each country with licit sales and ascribe gaps between the two to consumption of illicitly obtained cigarettes. We begin with the identity that the quantity consumed in a country and year must equal the quantity supplied from all sources.[5] Sources of supply include Q^S, domestic licit sales (including domestic production sold in-

[4] Since log price was the original regressor, this procedure can be formally justified as a second-order expansion (using Taylor's Rule) of the function $\log p = \log(r + t)$, where *p* is the total price, *t* is the tax per stick, and *r* is the rest of the price.
[5] We thus set aside issues involving inventories, since cigarettes are perishable product.

country, legally imported and taxed foreign product sold in-country, and domestic sales purchased by foreign visitors). Another source of supply is Q^{FL}, foreign legal product that is brought into the market legally by consumers (such as during a cross-border trip). Domestic supply is reduced by X^{FL}, domestic licit sales taken out of country by visitors. The final source of supply is Q^{CC}, counterfeit and contraband illicit product (whether produced domestically or from abroad). If there is outflow of domestically produced illicit product, it is netted out of Q^{CC}. Defining net foreign legal supply as $N^{FL} = Q^{FL} - X^{FL}$, the identity between domestic consumption Q^D and supply is thus

$$Q^D = Q^S + N^{FL} + Q^{CC} \tag{A-6}$$

By definition, Q^D equals S, the number of smokers in the country, times A, the average smoking intensity. While S can be reasonably well estimated from survey data, it is well known that A is likely to be underreported (as $\tilde{A}$) by survey respondents (Warner, 1978; Merriman, 2000). Assume that underreporting is by a constant multiple $0 < \theta < 1$, so that estimated consumption ignoring the misreporting is $\tilde{Q}^D = \tilde{A}S$ but that actual consumption is

$$Q^D = \tilde{Q}^D / \theta \tag{A-7}$$

Rearranging the terms in equation (A-6) yields

$$Q^{CC} = Q^D - Q^S - N^{FL}$$

and so the illicit market share Q^{CC}/Q^D , denoted M^{CC}, is

$$M^{CC} = \frac{Q^D - Q^S - N^{FL}}{Q^D} = 1 - \frac{Q^S + N^{FL}}{\tilde{Q}^D}\theta \tag{A-8}$$

Assume a linear fixed-effects regression model for M_{CC}, so that

$$M_{it}^{CC} = \alpha_i + \beta' x_{it} + u_{it} \tag{A-9}$$

Equating the right sides of equations (A-8) and (A-9), we have:

$$1 - \theta \frac{Q^S + N^{FL}}{\tilde{Q}^D} = \alpha_i + \beta' x_{it} + u_{it} \tag{A-10}$$

$$\frac{Q_{it}^S}{\tilde{Q}_{it}^D} = \frac{1 - \alpha_i}{\theta} - \left(\frac{\beta}{\theta}\right)' x_{it} - \left(\frac{u_{it}}{\theta_i} + \frac{N^{FL}}{\tilde{Q}^D}\right) \tag{A-11}$$

Define y_{it} to be $Q_{it}^S/\tilde{Q}_{it}^D$ and let $\ddot{a}$ represent a variable a that has been demeaned by the within transformation: $\ddot{a}_{it} = a_{it} - \frac{1}{T}\sum_{t=1}^{T} a_{it}$. Then equation (A-10) after transformation becomes:

$$\ddot{y}_{it} = -\left(\frac{\beta}{\theta}\right)' \ddot{x}_{it} + v_{it} \tag{A-12}$$

where the new error term v_{it} is a mean-zero function of the terms in the final parentheses on the right side of equation (A-11) for all periods.

If the original error u was strictly exogenous in equation (A-9), and there is either no net foreign legal supply ($N^{FL} = 0$) or it is also strictly exogenous, then v is exogenous in equation (A-12). However, if cigarette price is an element of x, it is likely correlated with v through the term $N^{FL}/\tilde{Q}^D$. When licit prices rises within the country, then N^{FL} may rise (as consumers obtain more cigarettes abroad and foreigners buy fewer cigarettes within the country) and $\tilde{Q}^D$ may fall (since demand is responsive to price). Since $N^{FL}/\tilde{Q}^D$ enters v negatively, price and the error term are therefore negatively correlated, and we thus expect there to be downward bias on the estimated coefficient $-\beta_p/\theta$ on price in equation (A-11). The bias thus would exaggerate the estimate of β_p, the causal impact of price on actual IRTC. Conceptually, the bias occurs because part of the impact on observed "illicit trade", as defined by the method above, will actually be increasing net foreign legal supply.

There are three potential responses to this potential bias. The first would be to ignore it, as appears to have been done in previous literature (e.g., Blecher, 2010). The second would be to gather data on net foreign legal supply, so that N^{FL} could be moved out of the error term v. Since the only consistently calculated estimates of which we are aware for the EU during our entire period are those from KPMG in the Project Star reports, we do not follow this approach, since we wish to avoid using KPMG data where possible in this estimation. The third response, which we adopt, is to recognize the issue but argue that the results are illustrative nonetheless. The KPMG data indicate that foreign legal supply from border-crossing by consumers happens, as shown in Figure A.6, where it is labeled "non-domestic legal". However, the figure also shows that it is a minor part of overall trade, more stable than illicit trade, and less responsive to price changes.[6] During 2009-2011, for example, prices sharply increased but non-domestic legal consumption did not change. We thus anticipate (but cannot prove) that any bias is limited.

Estimation of regression equation (A-12) yields estimates of coefficient vector β/θ, but the individual elements of β are identified only to scale. Estimation of equation (A-12) by itself therefore can show whether price has a statistically significant effect on illicit trade share but cannot reveal the magnitude of the effect. If data on domestic consumption from KPMG are allowed into the estimation, then scalar θ can be identified. KPMG estimates domestic consumption for the EU in its Project Star reports. The largest part of consumption is from legal domestic sales, which are readily observed from industry and tax data. KPMG then adjusts the figures to arrive at total consumption by adjusting for non-domestic consumption as estimated from empty discarded pack studies.[7] While the final consumption estimate relies on calculations and estimates by KPMG, the figures should be less contentious than the firm's direct estimates of

[6] The standard deviation of the non-domestic legal consumption figures in the graph is 0.6, whereas for illicit consumption it is 1.1.

[7] Empty pack surveys are based on a large sample of packs collected via formal sampling plans in various cities throughout the countries. Once packs are collected, they are examined to determine the proportion of packs that did not originate domestically.

IRTC. Treating the KPMG consumption data as Q^D, equation (A-7) in logs can be treated as a second regression equation to estimate θ.

Data for S and $\tilde{A}$ are taken from Eurobarometer (various years) surveys. Not all years are available.[8] Furthermore, in some years, $\tilde{A}$ was not directly reported because survey responses were instead quantized (i.e., instead of mean cigarettes per day reported, the fraction of smokers falling into various consumption ranges was given). For such years, mean smoking intensity was estimated from the quantal data by fitting a lognormal distribution to the data via MLE and calculating the implied mean based on the results.[9] With the resulting estimates of $\tilde{A}$ and S, estimates of $\tilde{Q}^D$ were formed as their product. Comparison of these estimates of $\tilde{Q}^D$ with the KPMG estimates of Q^D is in Figure A.7. The scatterplot shows that there is very high correlation between the two estimates (0.98). The slope of the line of best fit for the logged data, from estimation OLS A11.1 in the first column of Table A.11, is close to one, as it must be if equation (A-7) is correct.[10] The implied value of θ from the regression is 0.63.[11] Thus, for every 10 cigarettes apparently actually consumed, smokers claim on average to have smoked only 6.3.

The results of estimation of equation (A-12), with and without using KPMG data on domestic consumption, are in second and following columns of Table A.11. The dependent variable y in the first equation is constructed using domestic licit sales data from Euromonitor for Q^S. Estimation WI-OLS A11.1 (WI for within-transformed data) returns estimates of β/θ from OLS estimation on the pooled, demeaned data. The estimate-to-scale of the impact of cigarette price on illicit share is positive and statistically significant at the 5% level. Estimation WI-OLS A11.2 is similar except that year fixed effects are accounted for; the estimate-to-scale

[8] Eurobarometer surveys are available covering data from 1995, 2002, 2005, 2006, 2008, 2009, 2012, and 2014.
[9] Each country was allowed to have its own set of location and scale parameters for the lognormal distribution.
[10] The estimated slope of the line is 1.03, with 95% confidence interval spanning one [,1.097].
[11] Given the log form of equation (A-7), θ is the exponentiated constant from the log-log regression.

of the impact of price on illicit share is now significant at the 1% level. These results bolster the main conclusions of the paper, namely that price increases spur illicit trade, without indicating the magnitude of the marginal effect. However, if the previous estimate of θ (from estimation OLS A11.1) is employed, the implied estimates of β (the elasticity of illicit market share with respect to licit cigarette price) from estimations WI-OLS A11.1 and A11.2 are 0.30 and 0.47, respectively. These estimates are higher than the elasticities found from the fixed-effects estimates reported in Table 3 (perhaps due to the bias discussed above).

The final two columns of Table A.11 contains estimates of β and θ separately, estimated from nonlinear seemingly unrelated regression (NLSUR) estimation of equation (A-12) and the log form of equation (A-7).[12] Joint estimation can improve the precision of the estimates, as well as identifying β. Estimation NLSUR A11.1 does not include year fixed effects, while NLSUR A11.2 does. The implied elasticities of illicit market share with respect to price are 0.41 and 0.56. Again, these estimates are higher than those from Table 3. The estimates of θ are quite close to those from estimation OLS A11.1, and are significant at the 5% level.[13] In summary, the work here using the consumption gap analysis corroborates the finding in the paper that increasing the licit price of cigarettes (e.g., through taxation) has sizeable and statistically significant impacts on IRTC.

E. Alternative measures of corruption and governance

The estimations in Table A.7 employ alternative regressors to *NotCorrupt*, which is from the World Bank. Here these alternatives are described. Two measures from Transparency International are employed.[14] The first is the Corruption Perceptions Index, for which higher values indicate less corruption. Before a methodological change in 2012, the index was valid for

[12] Estimation is with the `nlsur` command in Stata 14.1.
[13] The transformation from the estimated ln(θ) to the reported θ is accomplished with the `nlcom` command.
[14] Data are from transparency.org, from which the Excel spreadsheet "cpi 1995_2013.xls" was obtained.

cross-sectional comparison of countries but not across years. Therefore in estimation FE A7.1 using this variable, year fixed effects are included to remove the changes over time due solely to the noncomparability of the data across years. The other variable from the same source is the country's cross-sectional rank of its Corruption Perceptions Index. The ranks are rescaled to the unit interval to account for differing number of countries in different years. This variable is another attempt to account for the inherent noncomparability of the index across years. This variable is used in estimation FE A7.2.

The World Bank dataset from which *NotCorrupt* was drawn, World Governance Indicators, also contains indices of the rule of law and the effectiveness of government in the country. The former measure reflects perceptions of the extent to which "agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence."[15] The latter measures "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies."[16] For both indices a higher score indicates stronger governance. Years 1999 and 2001 are unavailable and were linearly interpolated. These data are constructed to be appropriate for use in panel data, and are comparable in the cross-section and the time-series. The rule of law variable is used in estimation FE A7.3. Similar estimations with the government effectiveness index yielded nearly identical results (which is unsurprisingly, given the 95% correlation between the two regressors) and therefore are not shown in the tables.

[15] See info.worldbank.org/governance/wgi/rl.pdf.

[16] While the government effectiveness index may appear to be less germane to IRTC than the other corruption and governance measures, we included it because Melzer (2010) found it to be significant in some of her cross-sectional regressions of illicit cigarette consumption share.

Data from the United Nations on total police personnel at the national level per 100,000 people are taken from UN Office on Drugs and Crime (UNODC).[17] The counts include personnel in public agencies whose principal functions are the prevention, detection and investigation of crime and the apprehension of alleged offenders, excluding administrative support staff. Since there were many missing values, linear interpolation was used to fill in the gaps in the data. See estimation FE A7.4.

The results employing these alternative measures, in Table A.7, are highly similar to estimation FE 3.2. Whether the alternative regressors are included singly or jointly (the latter in the last column), the coefficient on price remains highly significant.[18] Furthermore, the size of the price coefficient is similar as that found in estimation OLS 2.3, ranging from 0.18 to 0.23.

F. Alternative IRTC-relevant factors in other countries

As mentioned in the main text, many IRTC-relevant variables reflecting conditions outside the home country have been proposed in the literature. Rather than arbitrarily choosing one of the available measures, we computed many alternatives to show that the regression results are generally similar regardless of which measures are included. The variables explored here are:

1. *LowPrDistEU*: The distance (in 1000 km) to the closest EU country with lower real cigarette prices.[19] EU countries are differentiated from other countries between this variable and the next because travel and transport of goods is easier within most of the EU, due to the lack of border control and free trade among states. Transcrime (2015)

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[17] See unodc.org/unodc/en/data-and-analysis/United-Nations-Surveys-on-Crime-Trends-and-the-Operations-of-Criminal-Justice-Systems.html.

[18] Results for the index on government effectiveness are not shown in the tables since they are nearly identical to those for the index on the rule of law.

[19] Distances for this and succeeding variables are calculated between the closest major cities (defined as having population greater than 500,000 or the largest in the country) in the pair of countries, per shortest driving distance found from Google Maps.

states that the most frequent (but not the highest volume) illicit flows are characterized by geographic proximity. The top two such countries are Poland and the Netherlands.

2. *LowPrDistNonEU*: The distance (in 1000 km) to the closest country outside the EU with lower cigarette prices. For about half of the data, the closest such country is Switzerland, Bosnia-Herzegovina, or Algeria.
3. *CChubDist*: The distance (in 1000 km) to the closest major hub for contraband and counterfeit (CC) cigarettes in Europe, where the three such areas are Russia, Turkey, and the Northeast Criminal Hub of Lithuania, Estonia, Latvia, and the Russian exclave of Kaliningrad.[20] Transcrime (2015) finds that the highest volume of illicit cigarette flows originate mainly from outside the EU, often entering through these hubs.
4. *MaxPdiff*: The maximum difference in cigarette prices between the home country and contiguous countries (whether or not the other countries are in the EU). Contiguous countries are the easiest sources to access for bootlegging and casual smuggling. Cross-border prices have been found to be associated with cigarette smuggling by Baltagi and Levin (1986), Saba et al. (1995), Thursby and Thursby (2000), Stehr (2005), Chiou and Muehlegger (2008), and Goel (2008).
5. *MinPratio*: The minimum over all contiguous countries of the ratio of the other country's price to the home country's price.
6. *MaxPdiffKM*: The maximum price difference per km between the home country and any other European country in the dataset (whether or not the other countries are in the EU).

If *IllicitMktShare* is a true measure of IRTC and prices increase IRTC, then we expect *LowPrDistEU*, *LowPrDistNonEU*, *CChubDist*, and *MinPratio* to have negative coefficients and

[20] There are other areas of significant smuggling activity, for example in and through the Balkans, but the chosen three areas supply most of the illicit product for other areas. For example, the product often reaches the Balkan countries from Turkey via Greece (Europol, 2011).

MaxPdiff and *MaxPdiffKM* to have positive coefficients. The first regression results with these additional IRTC-relevant variables are in Table A.8, where the new regressors are added singly to the regression specification from estimation OLS 2.3. The coefficients all have the expected sign, although some are significant only at the 10% level. Further investigation of *MaxPdiff* revealed nonlinearities in its marginal effect on IRTC, and so in regression OLS A8.5 it enters the specification with a three-part linear spline.[21] Up to its median in the sample (a real price difference of 0.074€/stick, or 1.48€/pack, in licit prices), *MaxPdiff* has the expected positive, significant marginal effect on IRTC share. Between the median and the 90th percentile (0.16€/stick) there is no significant effect of *MaxPdiff*, while beyond the 90th percentile, the marginal effect again turns positive ($p = 0.077$). Note also that the own-country price effect is highly significant and about the same magnitude in all these regressions as in OLS 2.3.

In the next set of regression results (Table A.9), groups of other-country variables enter the regression at once. Since some of these variables are proxies for similar notions, it does not make sense to add all of them at once.[22] Examining all possible combinations among these choices yields the four regressions in Table A.9.[23] We show the results for all combinations of these variables to show that the choice of which to include does not affect the results. The most relevant statistic in Table A.9, shown in the last row, is the *p*-value from the joint hypothesis test that the coefficients on all the included other-country variables are zero. This is our omnibus test of whether these other-country variables have no impact on IRTC. In two of the regressions, OLS A9.1 and OLS A9.3, the hypothesis is rejected at better than the 1% level. In the other two,

[21] The knots were place at the median and 90th percentiles based on visual inspection of the partial fit resulting from a Generalized Additive Model estimation with specification like OLS **Error! Reference source not found.**.3 with the addition of *MaxPdiff* entering flexibly.

[22] Although if we do, the *F*-test for their joint significance has a *p*-value of 0.004.

[23] To avoid near multicollinearity, only a single variable pertaining to the distance to a source outside the EU for illicit product (*LowPrDistNonEU* or *CChubDist*) is used in any one regression. Similarly, only a single variable comparing the home country's price with prices in its contiguous neighbors (*MaxPdiff* or *MinPratio*) enters any one specification.

rejection is at the 5% level. The results of all these estimations and tests strongly support the conclusion that higher licit prices and price differentials with other locations lead to higher illicit market shares due to smuggling.

G. Calculation of change in illicit share due to a 1€ tax increase

For the market share, the estimated change due to the price increase for a country and year is

$$\Delta E(IllicitMktShare_{it}) = \beta_{LogCigPrice}\Delta LogCigPrice_{it}$$

and the average discrete change is

$$E_N(\Delta E(IllicitMktShare_{it})) = \beta_{LogCigPrice}E_N(\Delta LogCigPrice_{it})$$

where E_N denotes the (unweighted) empirical average operator. The confidence interval is calculated by multiplying the endpoints of the wild cluster bootstrap confidence interval for $\beta_{LogCigPrice}$ by the second term in the above expression.

For the illicit quantity, the calculation is more involved since the dependent variable is in logs. Since

$$IllicitQty_{it} = \exp(\beta' x_{1it} + \varepsilon_{it})$$

it follows that the percentage change in quantity due to the price increase is

$$\exp\left(\beta_{LogCigPrice}\Delta LogCigPrice_{it}\right)$$

where the simplifying assumption that ε_{it} does not change is maintained. Applying this expression to the actual quantities and averaging yields

$$E(\Delta IllicitQty_{it}) = E_N\, IllicitQty_{it}\exp\left(\beta_{LogCigPrice}\Delta LogCigPrice_{it}\right)$$

Asymptotic standard errors for these estimates are calculated via plugging the endpoints of the bootstrap confidence interval for $\beta_{LogCigPrice}$into the above expression before averaging.

H. Information about cigarette excise taxes

In the EU, most countries have a minimum excise duty (MED) for cigarettes. These vary widely among countries. For example, in 2014 Bulgaria, Croatia, Lithuania, and Romania has MEDs below €80 per 1,000 cigarettes, while the MED in Finland, Ireland, and the Netherlands was more than twice that level.[24] Actually excise yields also vary widely, from €76.3 per 1,000 cigarettes in Lithuania to 289.9 per 1,000 cigarettes in the UK (also in 2014). Taxes also change greatly over time in some countries: the real total excise yield in 2014, compared to levels in 1999, rose 89% in the Netherlands, 92% in France, and 159% in Spain. On the other hand, the real 2014 total excise yield in Denmark was 3% lower than in 1999 and was only 12% higher in Finland. There is thus good variation in taxes across years and countries to help identify the marginal effects of prices on IRTC. The large variation in actual taxes is reflected in variation in the hypothetical total excise tax instrument, which has an overall s.d. of 0.043 in the data, a "between country" s.d. of 0.038, and a "within country" s.d. 0.017 (compared to a mean value of € 0.109 per cigarette).

All countries in the data have both ad valorem and specific excise taxes. There is a negative correlation between the two; some countries have higher specific taxes and lower ad valorem taxes, and vice versa. The fraction of the total excise tax that comes from the specific per-unit component therefore varies widely. A scatter plot of the two, using data from Euromonitor, is shown in Figure A.8. The VAT is applied on top of "taxes, duties, levies and charges, excluding the VAT itself" per EU rules of taxation,[25] and so the impact of the excise taxes on final consumer prices is multiplied. The tax rates change frequently. In 44% of the observations, the

[24] See footnote **Error! Bookmark not defined.** for the data source.
[25] See http://ec.europa.eu/taxation_customs/business/vat/eu-vat-rules-topic/taxable-amount_en.

ad valorem rate changed in the country since the previous year. The specific tax changed 85% of the time.

Additional References

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Appendix Tables

Table A.1: Countries and years included in the data

Country	First year	Country	First year
Austria	1999	Italy	1999
Belgium	1999	Latvia	2004
Bulgaria	2007	Lithuania	2004
Croatia	2013	Netherlands	1999
Czech Republic	2004	Poland	2004
Denmark	1999	Portugal	1999
Estonia	2004	Romania	2007
Finland	2000	Slovakia	2004
France	1999	Slovenia	2004
Germany	1999	Spain	1999
Greece	1999	Sweden	2000
Hungary	2004	United Kingdom	1999
Ireland	1999		

Note: The last year of data is 2014 for all countries. The differing first years are generally due to countries joining the EU. Not all country-years appear in all estimations, due to missing values of regressors.

Table A.2: Variables and definitions

Variable Name	Definition	Source
LicitQty	licit cigarette quantity (million sticks)	Euromonitor
IllicitQty	illicit cigarette quantity (million sticks)	Euromonitor
IllicitMktShare	illicit market share: IllicitQty/(LicitQty + IllicitQty)	Authors' calculations
CigPrice	cigarette price per stick, calculated as average revenue	Euromonitor
PriceLessTax	cigarette price per stick, not including excise tax	Euromonitor
ExTaxHypo	hypothetical total excise tax	European Commission
LaborTax	total revenue from taxes on employed labor income as a percentage of GDP	TCU Eurostat (2014)
FiscalFreedom	index of fiscal freedom from the Index of Economic Freedom	Heritage Foundation
VAT	general VAT as a percentage of retail sales price	Euromonitor
SpecTax	specific excise tax per stick	European Commission
AVtax	ad valorem excise tax rate on cigarettes, as a percentage of retail sales price	European Commission
ExTax	excise tax on cigarettes per stick (does not include VAT)	European Commission
Pop15	Population age 15 and up	World Bank
LowPrDistEU	the distance (in 1000 km) to the closest EU country with a lower cigarette price.	Authors' calculations
LowPrDistNonEU	the distance (in 1000 km) to the closest country outside the EU with a lower real average cigarette price	Authors' calculations
CChubDist	The distance (in 1000 km) to the closest major hub for contraband and counterfeit cigarettes in Europe: Russia, Turkey, or the Northeast Criminal Hub of Lithuania, Estonia, Latvia, and the Russian exclave of Kaliningrad	Authors' calculations
MaxPdiff	the maximum difference in cigarette prices between the home country and contiguous countries	Authors' calculations
MinPratio	the minimum over all contiguous countries of the ratio of the other country's price to the home country's price	Authors' calculations
MaxPdiffKM	the maximum price difference per km between the home country and any other country included in the dataset	Authors' calculations
GNIpc	gross national income (GNI; Atlas method) per capita (€1,000)	World Bank WGI
NotCorrupt	control of corruption, an index measuring "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests" (the index ranges from -2.5 [governance] to 2.5 [g governance]).	World Bank WGI

Note: all monetary amounts are converted to real 2010 euros.

Table A.3: Summary statistics for additional variables

Variable	Obs	Mean	S.d.	Min	Max
PriceLessTax	262	0.075	0.034	0.006	0.196
LowPrDistEU	287	0.479	0.537	0.065	3.610
LowPrDistNonEU	302	0.587	0.372	0.065	2.450
CChubDist	302	1.130	0.779	0.088	3.270
MaxPdiff	301	0.070	0.063	-0.094	0.243
MinPratio	301	0.589	0.325	0.109	1.376

Data cover years 1999 to 2014; some years are unavailable for some variables. See Table 1 for statistics for the main set of variables.

Table A.4: First-stage regressions for the IV regressions of IRTC share on cigarette prices

Y = Log(real cigarette price)	**IV 3.1, 1st stage**	**IV 3.2, 1st stage**
Hypothetic excise tax (*ExTaxHypo*)	0.474	
	(0.057)***	
Ad valorem tax rate (*AdVal*)		0.029
		(0.004)***
Specific tax (*SpecTax*)		0.406
		(0.057)***
AdVal × *SpecTax*		-0.005
		(0.001)***
Freedom from Corruption (WGI)	0.136**	0.175
	(0.067)	(0.074)**
Income (GNI) per capita (€1,000)	0.013	0.008
	(0.013)	(0.011)
GNI per capita squared	-0.000	-0.000
	(0.000)	(0.000)
N	327	327

* p<0.1; ** p<0.05; *** p<0.01; asymptotic SE's (in parentheses) account for clustering by country.

Note: Both estimations include country and year fixed effects.

Table A.5: Fixed-effects panel regressions of IRTC share on cigarette prices and taxes

Y = illicit market share	**FE A5.1**	**FE A5.2**	**IV A5.1**	**FE A5.3**
Real cigarette price, including tax	0.733			
	(0.224)***			
Real cigarette price, not including excise tax		0.312	-2.268	0.216
		(0.378)	(2.502)	(0.954)
p-value from wild bootstrap		[0.443]	[0.411]	[0.786]
Real excise tax per stick		1.490	3.362	2.608
		(0.616)**	(1.354)**	(1.878)
p-value from wild bootstrap		[0.007]	[0.464]	[0.352]
Freedom from Corruption (WGI)	0.021	0.025	-0.003	0.040
	(0.029)	(0.037)	(0.045)	(0.034)
Income (GNI) per capita (€1,000)	-0.002	0.002	0.003	-0.005
	(0.008)	(0.019)	(0.016)	(0.012)
GNI per capita squared	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Real cigarette price, not including excise tax, squared				-10.065
				(11.088)
Real excise tax per stick, squared				-8.738
				(10.260)
(Cigarette price w/o excise tax)×(excise tax per stick)				14.806
				(17.221)
Joint test of all price & tax coefficients (asy. *p*-value)				0.073
Joint test of price & tax higher-order coefficients (asy. *p*-value)				0.842
N	327	262	261	262

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; asymptotic SE's (in parentheses) account for clustering by country.

Note: In estimation IV A5.1, the instruments for price are as in IV 3.2. All estimations include country and year fixed effects.

Table A.6: Fixed-effects panel regressions of IRTC share on cigarette prices (WLS and alternative dependent variable)

Y = illicit market share	**FE A6.1**	**FE A6.2**	**FE A6.3**	**IV A6.1**	**IV A6.2**
	Country FE + Year FE	Country fixed effects (FE)	Country FE + Year FE	Instrument: total tax	Instruments: Tax components
Source for dependent variable:	Euromonitor	KPMG	KPMG	KPMG	KPMG
Log(real cigarette price)	0.167	0.148	0.192	0.233	0.256
	(0.018)***	(0.072)*	(0.098)*	(0.131)*	(0.127)**
p-value from wild bootstrap:	[0.000] ***	[0.019] **	[0.041] **	[0.222]	[0.153]
Freedom from Corruption (WGI)	-0.002	0.009	-0.008	0.003	-0.002
	(0.014)	(0.027)	(0.031)	(0.035)	(0.034)
Income (GNI) per capita (€1,000)	-0.012	0.002	0.002	-0.007	-0.006
	(0.004)***	(0.003)	(0.005)	(0.008)	(0.008)
GNI per capita squared	0.000	-0.000	-0.000	0.000	0.000
	(0.000)***	(0.000)	(0.000)	(0.000)	(0.000)
Implied price elasticity		3.45	4.49	5.47	6.03
Weighted least squares estimation	Y	N	N	N	N
Year fixed effects	Y	N	Y	Y	Y
1st stage *F* statistic on excluded instruments				105.32	43.61
Sargan-Hansen statistic (*p*-value)					0.045
N	302	187	187	184	184

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; asymptotic SE's (in parentheses) account for clustering by country.

Note: *p*-values (in square brackets) are calculated using the wild cluster bootstrap (see notes to Table 2). In estimation FE A6.1, the observations are weighted by the population aged 15 years or more. In estimation IV A6.1, the instruments for price are the hypothetical total excise tax as described in the text; in IV A6.2 instruments are the ad valorem excise tax rate, the specific tax rate, and their product. All estimations include country fixed effects.

Table A.7: Fixed-effects panel regressions of IRTC share on cigarette prices (alternative corruption and rule of law regressors)

	FE A7.1	**FE A7.2**	**FE A7.3**	**FE A7.4**	**FE A7.5**
Y = illicit market share	Coef. (se)	Coef. (se)	Coef. (se)	Coef. (se)	Coef. (se)
Log(real cigarette price)	0.184	0.199	0.178	0.226	0.231
	(0.086)**	(0.095)**	(0.084)**	(0.092)**	(0.094)**
Wild bootstrap *p*-value	[0.017]	[0.018]	[0.012]	[0.008]	[0.018]
Corruption Perceptions Index (TPI)	-0.000				-0.000
	(0.001)				(0.001)
Corruption Rank (TPI)		0.154			0.114
		(0.195)			(0.165)
Rule of Law (WGI)			0.025		0.098
			(0.053)		(0.056)*
Police per 100,000 people				-0.000	-0.000
				(0.000)	(0.000)
Income (GNI) per capita (€1,000)	-0.008	-0.005	-0.009	-0.013	-0.019
	(0.011)	(0.016)	(0.004)**	(0.005)***	(0.015)
GNI per capita squared	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)*	(0.000)
N	302	302	327	305	281

* p<0.1; ** p<0.05; *** p<0.01; asymptotic SE's (in parentheses) account for clustering by country.

Note: All estimations include country and year fixed effects.

Table A.8: Pooled OLS regressions of IRTC share on other-country IRTC-relevant variables

	OLS A8.1	**OLS A8.2**	**OLS A8.3**	**OLS A8.4**	**OLS A8.5**	**OLS A8.6**	**OLS A8.7**
Y = illicit market share	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)	Coef. (s.e.)
Log(real cigarette price)	0.091	0.115	0.115	0.080	0.081	0.095	0.097
	(0.032)***	(0.031)***	(0.034)***	(0.029)**	(0.029)**	(0.030)***	(0.028)***
Distance to closest EU	-0.035						
country with lower price	(0.011)***						
Distance to closest non-EU		-0.043					
country with lower price		(0.023)*					
Distance to closest			-0.025				
smuggling area			(0.012)*				
Max. price difference with				0.258			
contiguous countries (X_1)				(0.137)*			
Max. price difference					0.586		
(X_1) below its median					(0.277)**		
Max. price diff. (X_1) between its					-0.368		
median and 90th percentile					(0.493)		
Max. price diff. (X_1) above its					0.802		
90th percentile					(0.435)*		
Minimum ratio: other contiguous						-0.056	
country price ÷ own price						(0.032)*	
Max. price difference/KM							66.682
							(27.686)**
Freedom from Corruption	0.003	-0.006	-0.010	-0.010	0.000	-0.008	-0.020
(WGI)	(0.013)	(0.014)	(0.015)	(0.016)	(0.019)	(0.015)	(0.017)
Income (GNI) per capita	-0.020	-0.021	-0.017	-0.018	-0.018	-0.018	-0.020
(€1,000)	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.004)***
GNI per capita squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
constant	0.547	5.66	0.581	0.470	0.456	0.538	0.528
	(0.115)***	0.352	(0.118)***	(0.101)***	(0.106)***	(0.106)***	(0.093)***
F	4.15	0.341	4.54	4.50	8.66	4.52	6.25
R^2	0.375		0.368	0.361	0.377	0.367	0.377
Adjusted R^2	0.364		0.357	0.350	0.362	0.356	0.366
N	287	302	302	301	301	301	302

* p<0.1; ** p<0.05; *** p<0.01; SE's (in parentheses) account for clustering by country.

Table A.9: Additional Pooled OLS regressions of IRTC share on other-country IRTC-relevant variables

	OLS 9.1	OLS 9.2	OLS 9.3	OLS 9.4
Y = illicit market share	Coefficient (s.e.)	Coefficient (s.e.)	Coefficient (s.e.)	Coefficient (s.e.)
Log(real cigarette price)	0.079	0.084	0.100	0.101
	(0.043)*	(0.040)**	(0.023)***	(0.027)***
Distance to closest EU country with	-0.031	-0.034	-0.030	-0.035
lower price	(0.012)**	(0.011)***	(0.013)**	(0.011)***
Distance to closest non-EU country with	0.014	0.017		
lower price	(0.050)	(0.048)		
Distance to closest smuggling area			-0.015	-0.011
			(0.014)	(0.016)
Max. price difference with contiguous	0.131		0.022	
countries (X_1) below its median	(0.282)		(0.333)	
Max. price diff. (X_1) between its	-0.330		-0.519	
median and 90th percentile	(0.550)		(0.480)	
Max. price diff. (X_1) above its	0.753		0.981	
90th percentile	(0.431)*		(0.421)**	
Minimum ratio: other contiguous country's		-0.004		0.020
price ÷ home country price		(0.046)		(0.042)
Maximum price difference/KM	73.389	71.191	65.407	64.642
	(30.507)**	(35.014)*	(31.829)*	(36.316)*
Freedom from Corruption (WGI)	-0.011	-0.013	-0.011	-0.013
	(0.020)	(0.017)	(0.019)	(0.016)
Income (GNI) per capita (€1,000)	-0.020	-0.020	-0.019	-0.021
	(0.005)***	(0.005)***	(0.005)***	(0.004)***
GNI per capita squared	0.000	0.000	0.000	0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
_cons	0.495	0.518	0.564	0.567
	(0.140)***	(0.125)***	(0.106)***	(0.106)***
F (all regressors)	5.76	3.33	6.40	3.68
R^2	0.426	0.418	0.432	0.420
Adjusted R^2	0.405	0.401	0.411	0.403
N	287	287	287	287
P-value for H_0: all other-country coefficients are zero	0.0050	0.0302	0.0022	0.0189

* p<0.1; ** p<0.05; *** p<0.01; asy. SE's (in parentheses) account for clustering by country.

Table A.10: Fixed-effects panel regressions of IRTC share on cigarette prices (reduced sample)

Y = illicit market share	**IVA10.1** Instrument: Total tax	**IVA10.2** Instruments: Tax components
Log(real cigarette price)	0.465	0.488
	(0.176)***	(0.182)***
p-value from wild bootstrap:	[0.016]**	[0.0198]**
Freedom from Corruption (WGI)	-0.054	-0.060
	(0.062)	(0.065)
Income (GNI) per capita (€1,000)	-0.019	-0.020
	(0.007)***	(0.007)***
GNI per capita squared	0.000	0.000
	(0.000)*	(0.000)*
Implied price elasticity	7.717	8.104
1st stage *F* statistic on excluded instruments	55.25	29.80
Sargan-Hansen statistic (*p*-value)		0.756
N	295	295

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; SE's (in parentheses) account for clustering by country using the standard asymptotic formula.

Note: Sample excludes Denmark and the UK. The instruments are as in Table 3; see notes to that table. Country and year fixed effects are included.

Table A.11: Estimations for the consumption gap analysis

	OLS A11.1	WI-OLS A11.1	WI-OLS A11.2	NLSUR A11.1	NLSUR A11.2
	θ	β/θ	β/θ	β	β
Equation (A-12)					
Log(real cigarette price)		0.481	0.745	0.406	0.558
		(0.184)**	(0.215)***	(0.200)**	(0.272)**
Income (GNI) per capita (€1,000)		0.017	0.023	0.019	0.021
		(0.018)	(0.028)	(0.013)	(0.016)
GNI per capita squared		-0.000	-0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.000)*	(0.000)*
Equation (A-7) in log form					
Coefficient on $\tilde{Q}^D$	1.029			1.028	1.028
	(0.033)***			(0.032)***	(0.033)***
Log(θ)	-0.460			-0.476	-0.482
	(0.308)			(0.302)	(0.311)
θ	0.631			0.621	0.617
	(0.194)†*			(0.188) †**	(0.192) †**
Within-transformed data	N	Y	Y	Y	Y
Year fixed effects	N	N	Y	N	Y
N	98	103	103	74	74

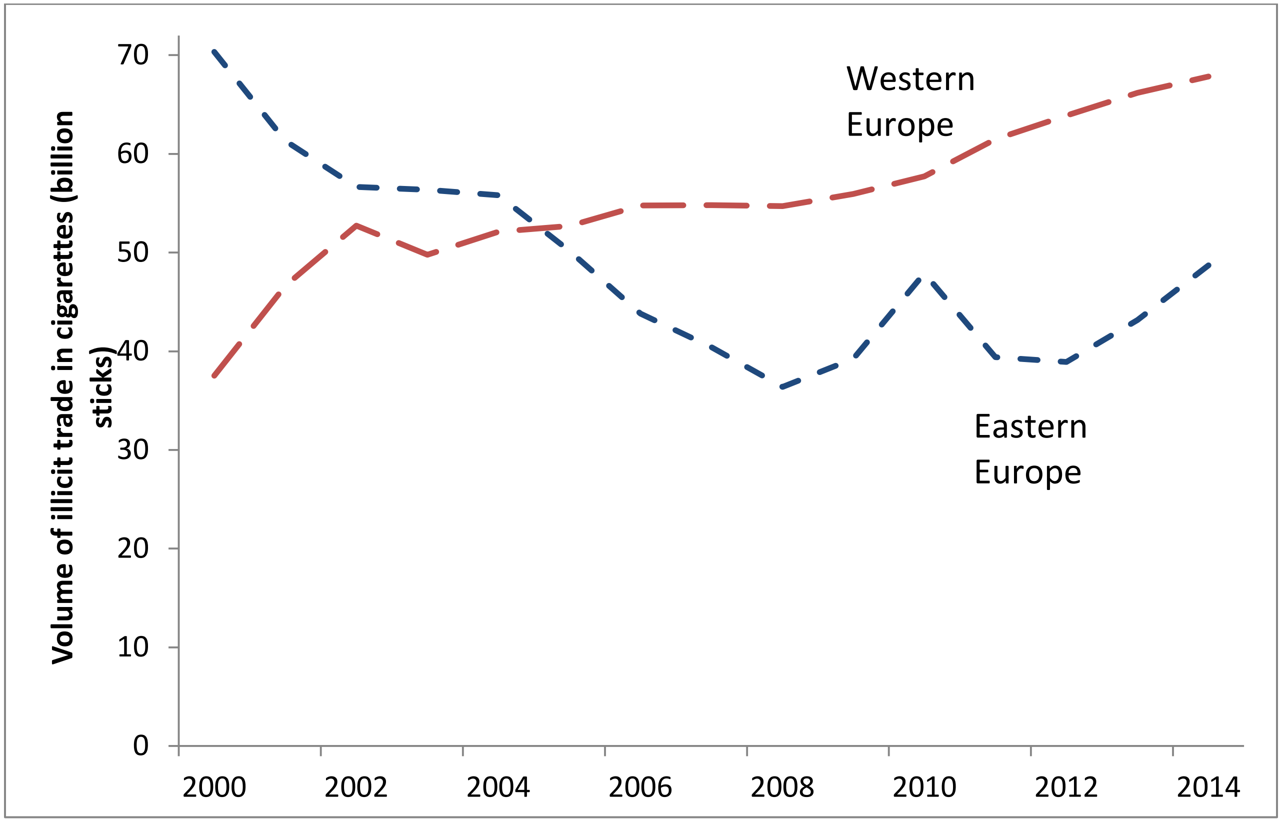
* *p*<0.1; ** *p*<0.05; *** *p*<0.01; SE's (in parentheses) account for clustering by country.

† Significance stars for θ are for the null hypothesis that θ = 1.

Note: Estimates from the WI-OLS estimation are for β/θ from equation (A-12), and thus are not comparable to the direct estimates of β from the NLSUR estimations. The within-transformation and year fixed effects are for equation (A-7) only, when included.

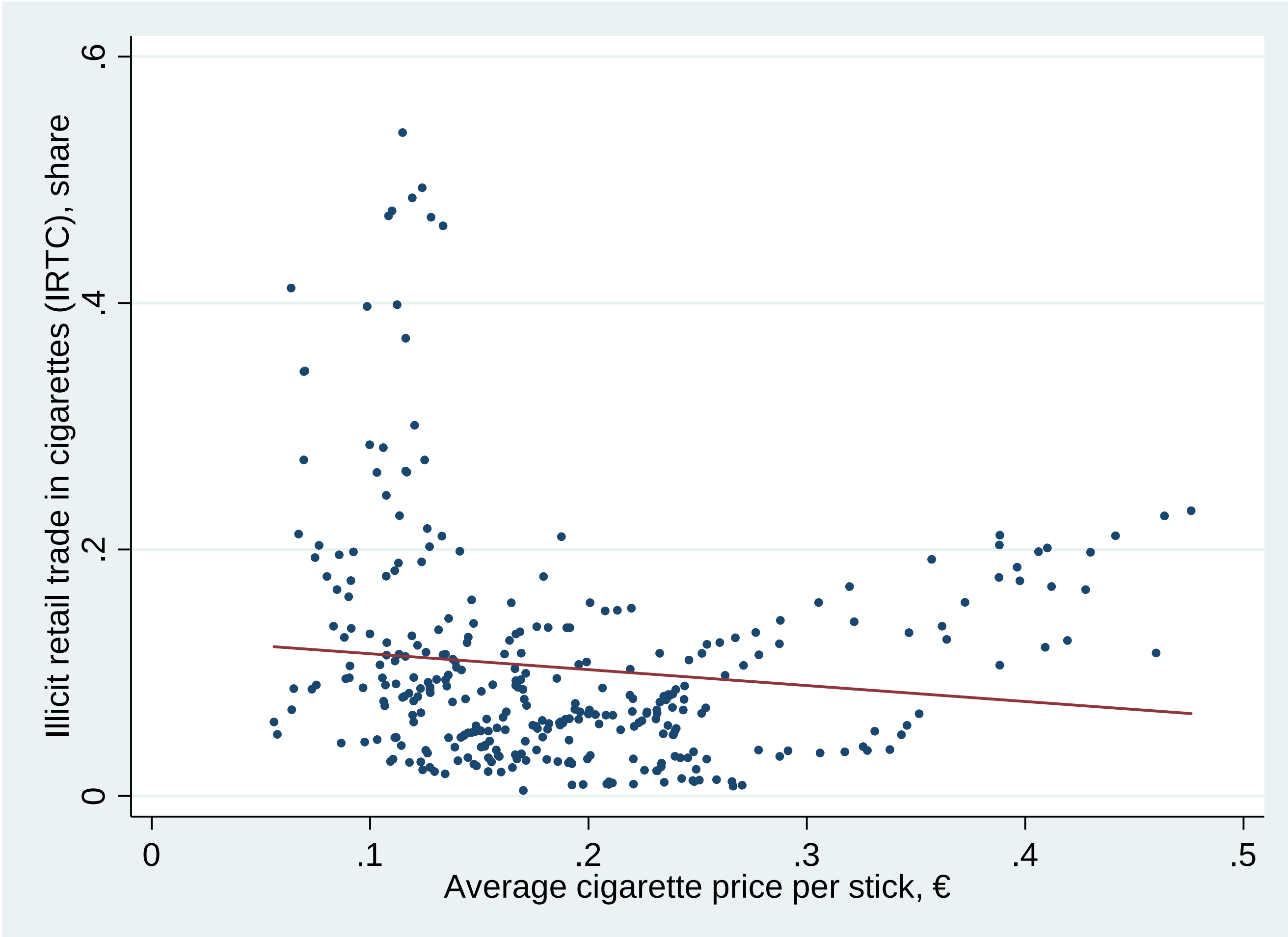
Appendix Figures

Figure A.1. Estimated volume of illicit European trade in cigarettes



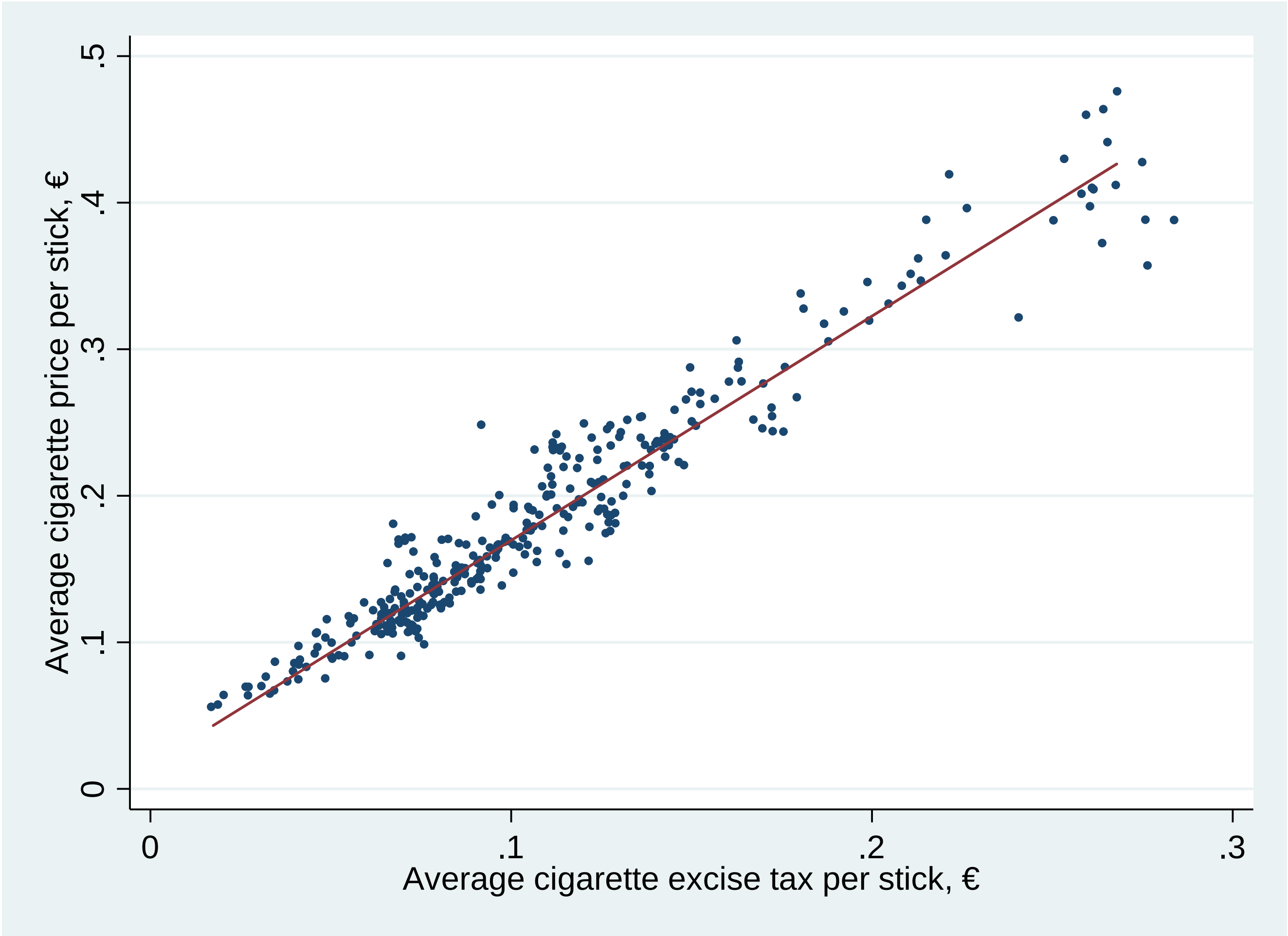
Notes: Data from Euromonitor. Western Europe includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom; Eastern Europe includes Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Macedonia, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, and Ukraine.

Figure A.2: Cigarette prices and IRTC shares in the EU, 1999-2014



Notes: The line of best fit is calculated via OLS regression. See also notes to Figure 2.

Figure A.3: Cigarette prices and taxes in the EU, 1999-2014



Notes: The line of best fit is calculated via OLS regression ($R^2 = 0.934$). Variables constructed using source data from Euromonitor and the European Commission as described in the text. Currency units are 2010 euros.

Figure A.4: Trends in cigarette excise taxes per stick (ExTax)

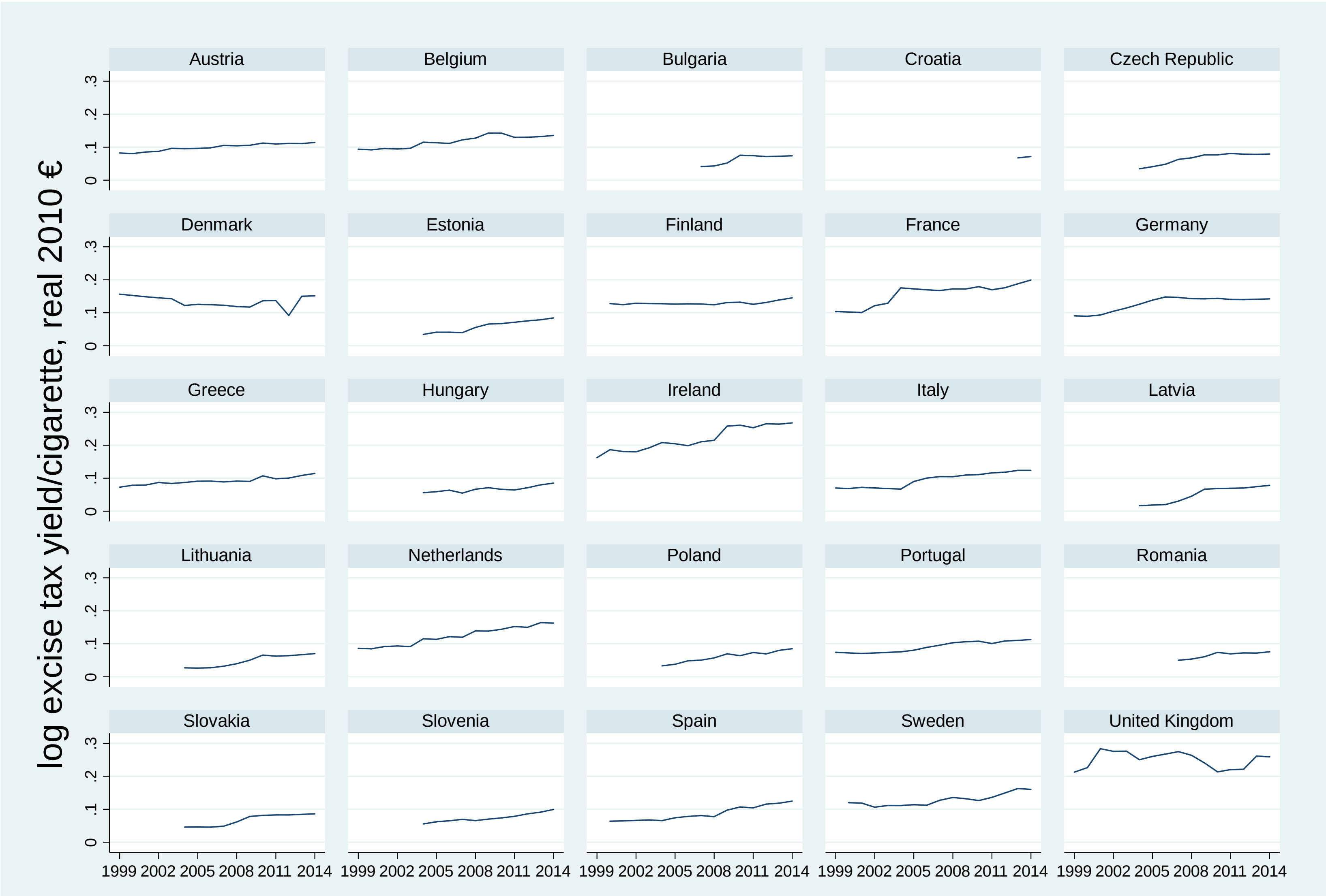


Figure A.5: Relevance and monotonicity of the hypothetical excise tax instrument

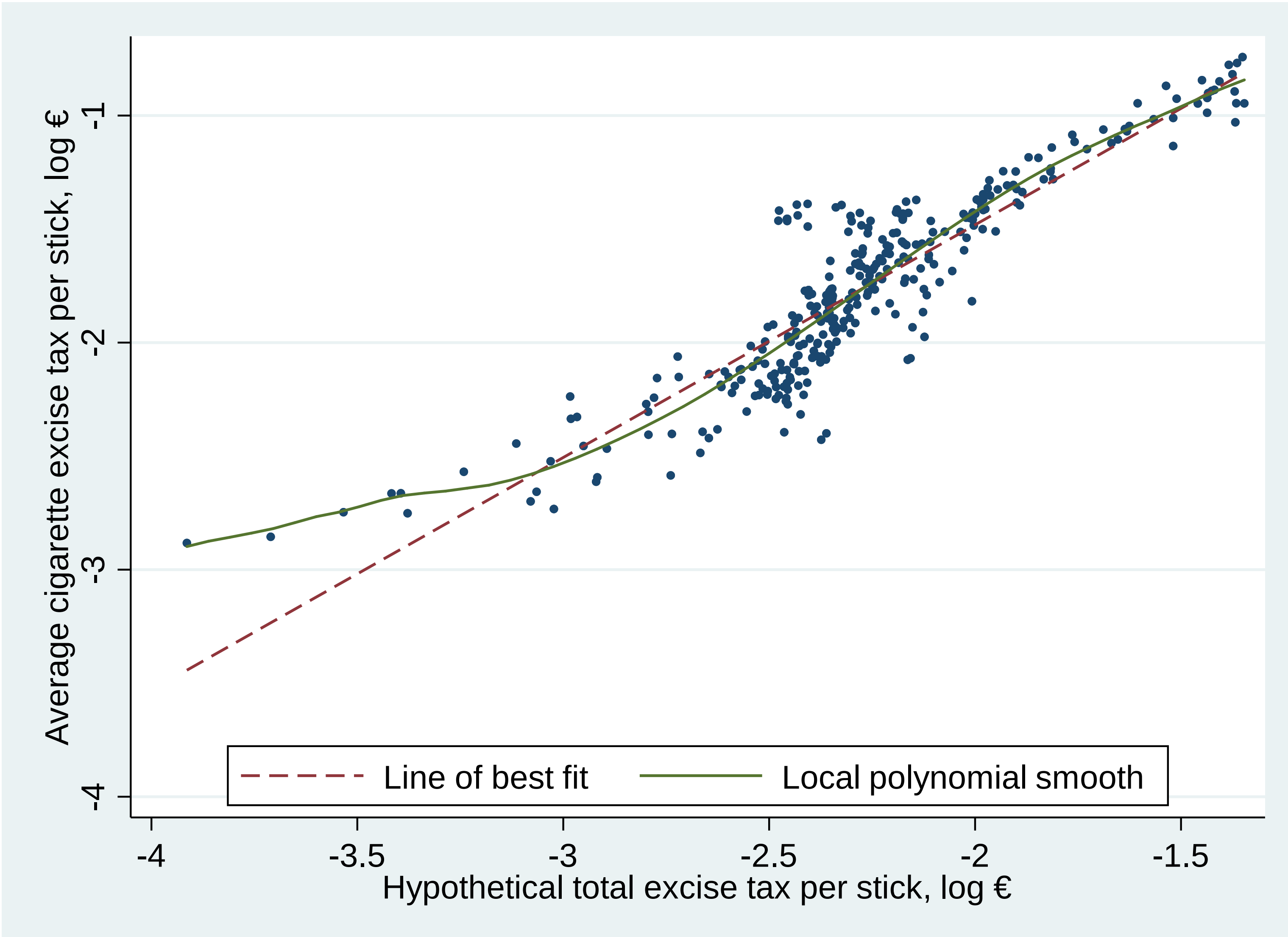
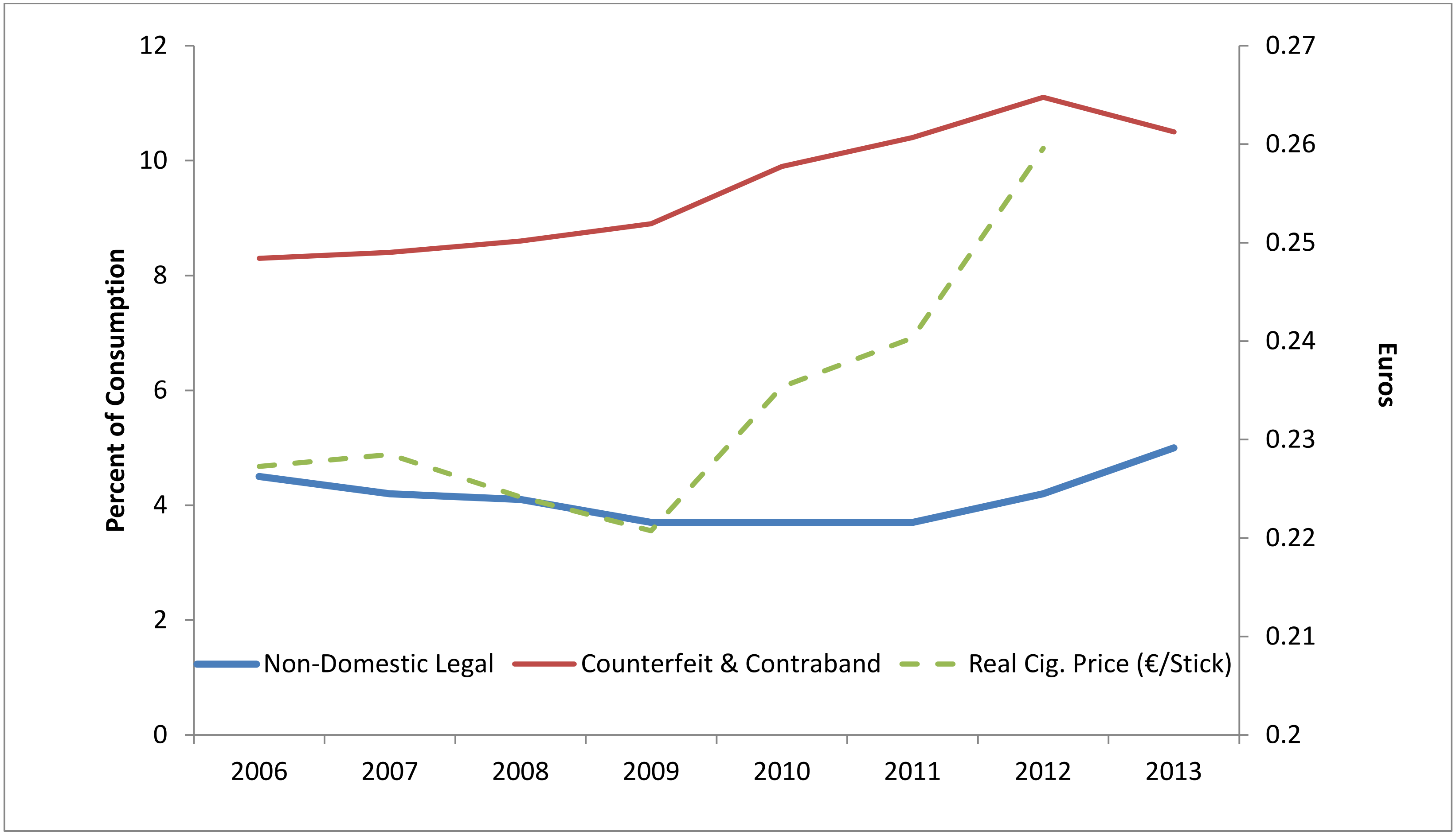


Figure A.6: Data from KPMG Project Star for cigarette consumption and prices in the EU



Note: Price are national averages weighted by population. The data source is KPMG Project Star reports, various years.

Figure A.7: Stated cigarette consumption vs. estimated actual consumption

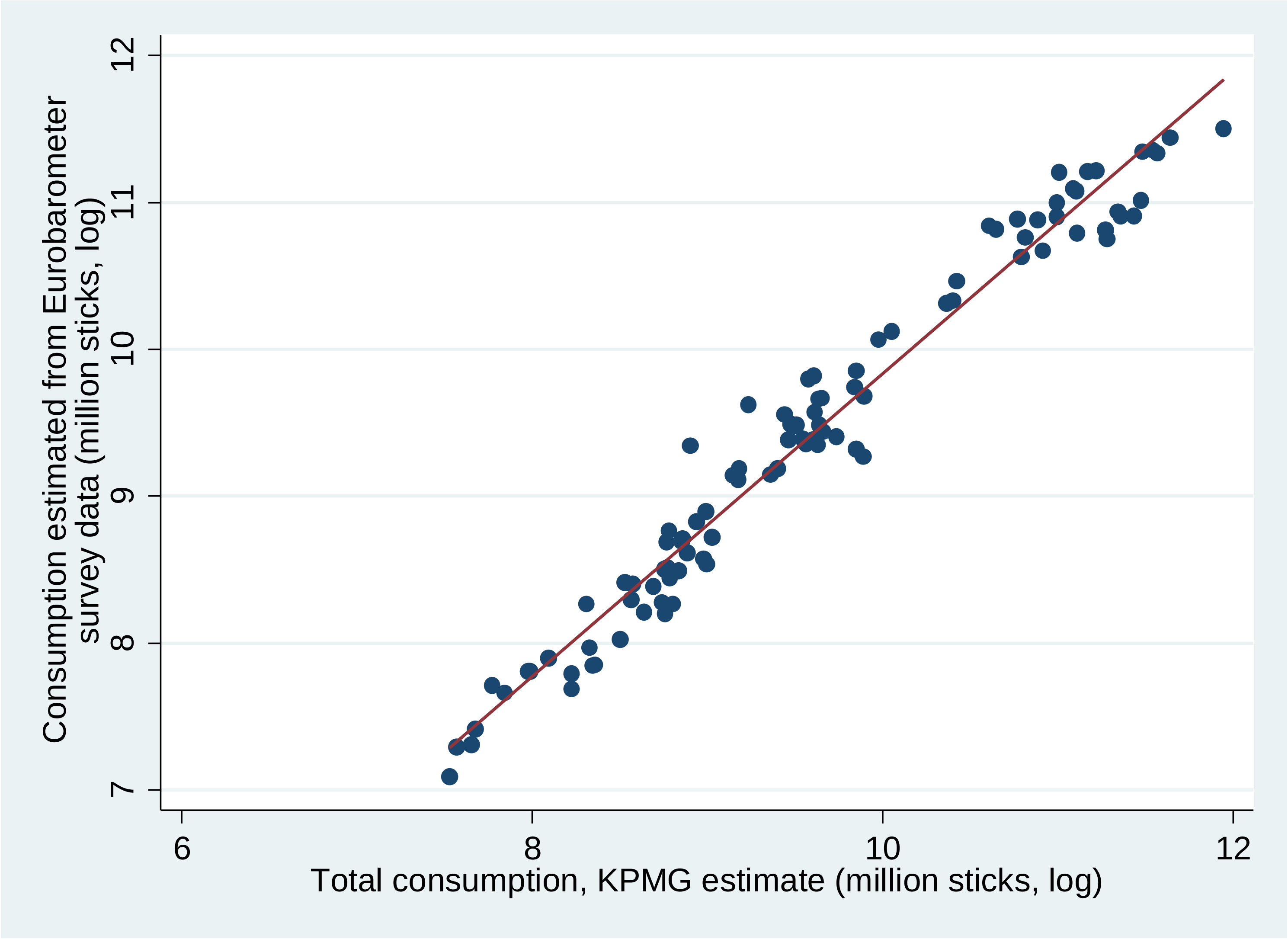


Figure A.8: Components of cigarette excise taxes