Price minimizing behaviours by smokers in Europe (2006–20): evidence from the International Tobacco Control Project

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Background: Effectiveness of tobacco taxation can be undermined through smokers applying price-minimizing behaviours rather than quitting or reducing consumption. Common price-minimizing strategies are buying cheaper tobacco [discount brands or roll-your-own (RYO) tobacco], bulk buying and cross-border purchasing. This study analyses trends in and factors associated with such behaviours in four European countries from 2006 to 2020. Methods: Data came from adult smokers participating in the International Tobacco Control (ITC) Surveys conducted between 2006 and 2020 in England (9 waves, n = 768–4149), France (4 waves, n = 1415–1735), Germany (5 waves, n = 513–1515) and the Netherlands (10 waves, n = 1191–2177). Country-specific generalized estimating equation regression models were fit to assess trends in smoking RYO tobacco, discount brands, bulk buying and cross-border purchasing within the European Union. Results: Buying discount brands or RYO tobacco was the most common strategy in all countries, except France. Except for buying discount brands, estimates of price-minimizing behaviours were highest in France (2019: RYO = 27.2%, discount brands = 17.3%, bulk buying = 34.1%, cross-border purchasing = 34.2%), and lowest in Germany (2018: RYO = 18.6%, discount brands = 43.7%, bulk buying = 8.0%, cross-border purchasing = 9.8%). Direction and magnitude of trends differed by country, and behaviour. Young smokers were less likely to buy in bulk. Low-income and low-education smokers were more likely to purchase RYO tobacco or discount brands. The association with discount brands was not found for French low-income smokers. Conclusions: Smoking cheaper tobacco is the most prevalent price-minimizing strategy in three countries (England, Germany and Netherlands), and more prevalent among low-income individuals. Harmonizing prices across products and countries would reduce switching to cheaper tobacco.

Introduction

Tobacco taxation is an effective measure to reduce smoking prevalence, consumption and initiation. Rather than quitting or reducing consumption when faced with price increases, smokers may engage in price-minimizing behaviours to maintain their smoking habits. In the European Union (EU), common legal price-minimizing behaviours are smoking roll-your-own (RYO) tobacco, discount brands, bulk buying and cross-border purchasing. RYO tobacco use increased by 45% worldwide between 2003 and 2015, most of which occurred in the EU. Bulk buying reduces the impact of taxation since buying larger quantities, such as cartons, often results in a lower price per cigarette than buying single packs. Finally, cross-border purchasing has been the most discussed method of tax avoidance. Cross-border purchasing is more prevalent in regions bordering countries with lower cigarette prices. Sometimes these behaviours are combined to optimize cost-saving, such as buying cigarettes abroad in bulk.

Research indicates that smokers of lower socioeconomic status (SES) are more likely to apply price-minimizing strategies, such as smoking RYO tobacco and bulk buying. Cross-border purchasing has been found to be more common among higher-SES smokers. A study on trends in tax avoidance found associations with income and education in France, the Netherlands and the UK, although they varied in direction and magnitude across countries.

This article examines prevalence and trends of four price-minimizing behaviours (RYO tobacco, discount brands, bulk buying and cross-border purchasing within the EU) in England, France, Germany and the Netherlands between 2006 and 2020. In all four countries prevalence has decreased and taxation was increased over the selected period, albeit to a different extent (figure 1, Supplementary figure S1). Prevalence is lowest of the four countries in England: circa 13.5% of adults smoked in 2020. Taxation in England has been in line with or above inflation levels since 1993, and at least 2% above inflation since 2011. Additional tax increases on RYO tobacco took place in 2011 (10%), 2016 (5%)...
and 2020 (4%). In France, taxation policies were influenced by fiscal rather than public health considerations until 2017, which resulted in stagnating cigarette prices between 2014 and 2017. In 2017, a 15% increase on RYO tobacco was implemented and (bi-annual) tax increases were announced, aiming at reaching an average price of €10 per cigarette pack in November 2020.11–13 While a pack of Marlboro cigarettes cost €10 in 2020, the weighted average price per pack was lower.8 Despite high prices, prevalence of the four countries is highest in France: circa 25.5% in 2020. Similar to France, German taxation policies were influenced by fiscal rather than by public health considerations.14 Cigarette taxes increased annually between 2011 and 2015, but at minimal levels. Simultaneously, the tax differential between cigarettes and RYO was reduced by increasing taxes on RYO to a greater extent. Latest estimates indicate prevalence of 22.4% among Germans above 15 years old (2017). Finally, tax increases in the Netherlands have not been implemented consistently, depending on what parties were in government.15 Taxation increased four times between 2006 and 2016: three included increases on cigarettes and RYO tobacco—but not at similar rates; cigarettes were taxed higher—and one concerned solely RYO tobacco. From 2018 onwards, cigarettes and RYO tobacco taxes increased at least annually, and by the same real amount.16 Between 2006 and 2020 prevalence in the Netherlands decreased from 31.1% to 19.8%.

The present study had two objectives: to estimate prevalence and explore trends in price-minimizing behaviours in the selected countries, and to identify the sociodemographic variables that are associated with each behaviour. We also examined whether the pattern of price-minimizing behaviours differed by country.

Methods

Sample

Data were analysed from the International Tobacco Control (ITC) surveys conducted in the UK, France, Germany and the Netherlands between 2006 and 2020. The UK sample was restricted to England, since Cohort 2 was limited to England. The ITC surveys employ a longitudinal cohort design. Respondents were recruited using probability sampling methods and interviewed using Computer Assisted Telephone Interviews (CATI) (Germany 2007–11; France 2006–12), Personal Interviews (CAPI) (Germany 2016–18), Web Interviews (CAWI) (England 2016–20, France 2019; Netherlands 2008–20) or a mix of CATI and CAWI (UK 2006–14). Respondents lost to attrition were replenished by recruiting new respondents from the same sampling frame. This was not done for Germany wave 2 and 3, and England wave 8 due to funding constraints. More information about sampling designs, methods and the ITC Project is published elsewhere17,18; technical reports of the ITC surveys are available at the ITC Project website: https://itcproject.org/methods/technical-reports/.

We used a series of cohort samples. All four countries have started a second cohort in the selected timeframe. Due to the difference in sampling design between Germany Cohort 1 (stratified sampling) and 2 (stratified cluster sampling), the two cohorts were treated as separate datasets. The other countries used a similar sampling design across cohorts. The number of included waves ranged from 4 (France) to 10 (Netherlands). Three waves of the Netherlands were excluded from analysis. Wave 2 (2008) and 3 (2009) were excluded due to the small sample of respondents who provided information for the outcome variables, Wave 2 (2020) was excluded since it took place in the same year as the previous wave.

Inclusion criteria were that the participant was at least 18 years old at recruitment and smoked at least monthly at the time of survey completion. Sample sizes differed across countries and waves (England, n = 768–4149; France, n = 1415–1735; Germany, n = 513–1515; and Netherlands, n = 1191–2177).

Outcome measures

Buying roll-your-own tobacco

Respondents were asked whether they smoked factory-made cigarettes, RYO tobacco or both. Dual smokers were asked how many out of ten cigarettes they smoked were RYO tobacco. Those who...
reported smoking RYO exclusively or at least 5 RYO cigarettes out of 10 were coded as RYO tobacco smokers. Sensitivity analyses excluding dual smokers were carried out.

Buying cheap brands

Respondents were asked to report their usual or preferred cigarette brand from a predefined country-specific list, which was updated each wave. Brands were categorized as ‘discount’, ‘non-discount’ or ‘unknown’ (Supplementary table S1), based primarily on industry documents and commercial literature such as trade journals, and secondly on academic classifications. Brands described as ‘value (for money)’, ‘sub-value’, store- or pennysaver brands or other indications of the discount segment were classified as discount brands. Non-discount was assigned for brands indicated as ‘premium’, ‘higher priced’, ‘mid-priced’ or other indications of belonging to the mid- or high-end segment. Brands were ‘unknown’ when no segmentation information was found. Unknown brands were excluded from analyses (England = 1.7%; France = 12.3%; Germany Cohort 1 = 0.6%; Germany Cohort 2 = 5.1%; and Netherlands = 3.1%). Sensitivity analyses including unknown brands in the discount category were carried out.

Buying in bulk

Participants who last purchased FM cigarettes were asked whether they bought them by the pack, carton or as single cigarettes. Respondents who last purchased FM cigarettes by carton were coded as bulk buyers, while those who bought by the pack or as single cigarettes were not.

Cross-border purchasing in the EU

Participants were asked whether they had bought cigarettes or RYO tobacco outside of the country but inside the EU in the last six months, and if so how often (‘only once’, ‘a few times’, ‘many times’, ‘all of the time’ or ‘don’t know’). Respondents who did so at least a few times were coded as participating in cross-border purchasing, similar to Driezen et al.5 Up to 2016, the England surveys did not limit the question to within the EU. Nonetheless, these data (including all cross-border shopping) were included in our analysis.

Covariates

Gender was coded as a man or woman. Age was classified into: 18–24, 25–39, 40–54 and 55 and over. Income was categorized as low, moderate, high or not stated, using country-specific thresholds (England: ≤£15 000, £15 001–£40 000, >£40 000 annually; France: ≤£17 500, £17 501–£29 999, >£30 000 monthly; Germany: ≤£17 500, £17 501–£29 999, >£30 000 monthly; and Netherlands: ≤£20 000, £20 001–£29 999, >£30 000 monthly). Education was categorized as low (no degree, primary and lower secondary education), moderate (middle secondary education and secondary vocational education) and high (upper secondary education, university and post-graduation). The German surveys combined secondary vocational education and upper secondary education in one response option, and were therefore both coded as moderate. Education was measured differently across both Germany cohorts: via educational degree (Cohort 1) or a mixture of educational and vocational degrees (Cohort 2). Nicotine dependence was measured using the Heaviness of Smoking Index, a six-point scale combining the number of cigarettes per day and time to first cigarette after waking up. Intention to quit was categorized as having an intention to quit (next month, within 6 months, or beyond 6 months) versus not (no intention, don’t know). A time-in-sample variable was constructed to adjust for the number of times respondents had previously completed an ITC survey (1, 2, 3 or more surveys).

Statistical analysis

Analysis was performed in SPSS 28. Analyses were weighted using initial cross-sectional sampling weights. A binary variable was set up per outcome variable, indicating participation in the behaviour (1) or not (0). Country-specific generalized estimating equations (GEE) with binomial distributions and logit link were fit to estimate use and trends per price-minimizing behaviour. Models were fit using the unstructured and exchangeable correlation structure. The best fit structure according to the QIC statistic was chosen. Primary analyses treated wave as a categorical variable. Linear trends were explored in separate models. Bonferroni-adjusted significant differences are reported in text. The tables display the original P-values.

Due to the sampling design of Germany cohort 2 (stratified cluster sampling), weighted logistic regression using the SPSS Complex Samples package were carried out in addition to the abovementioned GEE analyses, because SPSS cannot account for clustering among respondents in GEE models. The Complex Sample package accounts for the sampling design, but not for repeated measures. Point estimates were taken from the GEE model, and variance estimates from the complex samples weighted logistic model for Germany Cohort 2. Point estimates from both models were similar.

Results

Sample description

Table 1 displays baseline characteristics per country and cohort. In Cohort 1, France had relatively more young smokers. A greater percentage of German and Dutch smokers did not state their income. Among English, French and German respondents, the most common education level was low, contrary to the Netherlands (moderate). Notable changes between the two cohorts are in income levels in the Netherlands, and education levels in England and Germany.

Roll-your-own tobacco

Prevalence and trends

Estimated use of RYO tobacco, adjusted for covariates, appears highest in England and the Netherlands, and less popular in France and Germany (table 2). In England, estimates increased from 27.4% (2006–07) to 38.3% (2020). Use in the Netherlands remained stable up to 2017, and decreased to 26.8% in 2020. In France, estimated user prevalence remained between 14.0% and 17.0% up to 2012, and increased to 27.2% in 2019 (table 3). RYO use in Germany increased non-significantly from 18.4% to 20.3% in Cohort 1 (2007–11), and decreased from 26.4% to 18.6% in Cohort 2 (2016–18) (table 3). A decreasing linear trend was detected in the Netherlands and Germany Cohort 2, an increasing linear trend in England and France, and no linear trend in Germany Cohort 1.

Sensitivity analyses excluding dual smokers found no linear trends in England and Germany Cohort 2, while an increasing trend was found for Germany Cohort 1. The sensitivity analyses did not reveal trends that differed from the linear trends found in France (increasing) and the Netherlands (decreasing). However, significant increases were found in different years compared with the original analyses (Supplementary table S2).

Characteristics

Significant associations for age, income and education were found for all countries, except for Germany Cohort 2 which only showed associations with income. Smokers younger than 55 years old were more likely to smoke RYO tobacco in England, France and Germany Cohort 1 (except for 18–24 year olds), while in the Netherlands the opposite was found (Supplementary table S3). Greater odds were found among people with a low income (England, France and Germany), moderate income (England, France and Netherlands) and those who did not state their income (England, Germany.
| Country          | Cohort | Sample Size | Gender Distribution | Age Distribution | Income Distribution | Education Distribution | HSI Distribution | Intention to Quit |
|------------------|--------|-------------|---------------------|------------------|--------------------|------------------------|------------------|------------------|
|                  |        |             | Man (%)             | 18–24 years (%)  | Low (%)            | Low (%)                | Low (0–2) (%)     | Yes (%)          |
| England          | Cohort 1 (2006–07) | 1415 | 49.1 | 4.5 | 3.2 | 2.8 | 5.7 | 13.7 | 6.4 |
|                  | Cohort 2 (2016) | 3503 | 54.1 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
| France           | Cohort 1 (2006–07) | 1515 | 44.3 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
| Germany          | Cohort 2 (2019) | 1680 | 52.5 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
|                  | Cohort 1 (2007) | 1735 | 57.7 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
|                  | Cohort 2 (2016) | 1515 | 60.9 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
|                  | Cohort 1 (2008) | 1003 | 54.3 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |
|                  | Cohort 2 (2020) | 2177 | 56.6 | 13.5 | 37.5 | 28.6 | 20.4 | 29.7 | 66.5 |

| Survey wave (year) | n   | RYO tobacco (%) | Discount brands (%) | Bulk buying (%) | Cross-border purchasing (%) |
|--------------------|-----|-----------------|---------------------|---------------|-----------------------------|
| England            |     |                 |                     |               |                             |
| 5 (2006–07)        | 1416| 27.4 (24.9–29.7)| 10.8 (9.0–12.9)     | 25.1 (22.1–28.3)| 25.6 (23.2–28.2)            |
| 6 (2007–08)        | 1330| 30.7 (28.3–33.2)| 11.6 (9.7–13.8)     | 25.3 (22.3–28.5)| 21.5 (19.3–23.9)            |
| 7 (2008–09)        | 1198| 32.8 (30.1–35.5)| 12.4 (10.3–14.8)    | 22.3 (19.6–25.4)| 17.9 (16.7–21.4)            |
| 8 (2010–11)        | 768 | 33.6 (30.7–36.6)| 21.9 (18.4–25.9)    | 20.5 (17.0–24.4)| 18.4 (15.6–21.5)            |
| 9 (2013)           | 866 | 34.1 (31.3–37.1)| 32.7 (28.7–37.0)    | 19.0 (15.8–22.6)| 11.2 (9.2–13.5)             |
| 10 (2014)          | 927 | 28.8 (26.1–31.6)| 34.2 (30.5–38.2)    | 21.6 (18.3–25.3)| 10.1 (8.2–12.3)             |
| 1 C2 (2016)        | 3505| 35.2 (32.8–37.6)| 28.1 (25.0–31.4)    | 19.0 (16.5–21.8)| 16.5 (14.8–18.5)            |
| 2 C2 (2018)        | 4149| 37.5 (35.5–39.5)| 28.8 (26.2–31.6)    | 15.6 (13.8–17.5)| 15.3 (13.9–16.9)            |
| 3 C2 (2020)        | 3246| 38.3 (36.4–40.4)| 28.8 (26.1–31.7)    | 17.5 (15.1–19.3)| 16.0 (14.4–17.7)            |
| France             |     |                 |                     |               |                             |
| 1 C2 (2019)        | 1680| 27.2 (23.6–31.2)| 17.3 (13.9–21.3)    | 34.1 (29.8–38.7)| 34.2 (30.3–38.3)            |
| 1 C2 (2016)        | 3505| 35.2 (32.8–37.6)| 28.1 (25.0–31.4)    | 19.0 (16.5–21.8)| 16.5 (14.8–18.5)            |
| 2 C2 (2018)        | 4149| 37.5 (35.5–39.5)| 28.8 (26.2–31.6)    | 15.6 (13.8–17.5)| 15.3 (13.9–16.9)            |
| Germany            |     |                 |                     |               |                             |
| 1 (2007)           | 1515| 18.4 (16.1–21.1)| 16.3 (13.9–19.1)    | 18.8 (16.2–21.8)| 19.9 (17.5–22.6)            |
| 2 (2009)           | 906 | 19.1 (16.5–22.0)| 30.5 (26.4–34.9)    | 18.8 (15.7–22.3)| 19.6 (16.8–22.7)            |
| The Netherlands    |     |                 |                     |               |                             |
| 1 (2008)           | 2177| 38.8 (36.4–41.3)| 26.4 (23.1–30.1)    | 11.3 (9.3–13.7)| 7.4 (6.3–8.8)               |
| 4 (2010)           | 1662| 38.2 (36.3–40.3)| 24.6 (21.9–27.5)    | NA              | 7.6 (6.5–8.9)               |
| 5 (2011)           | 1601| 37.0 (35.1–39.0)| 24.4 (21.9–27.0)    | NA              | 9.1 (7.9–10.6)              |
| 6 (2012)           | 1527| 37.0 (35.1–39.1)| 25.2 (22.7–27.9)    | 13.6 (11.6–15.9)| 11.5 (10.0–13.1)            |
| 7 (2013)           | 1477| 39.1 (37.1–41.2)| 26.4 (23.7–29.4)    | 13.5 (11.3–16.1)| 14.2 (12.6–16.0)            |
| 8 (2014)           | 1501| 38.0 (35.9–40.1)| 24.7 (22.2–27.4)    | 14.0 (11.9–16.4)| 17.4 (15.5–19.4)            |
| 9 (2015)           | 1523| 37.4 (35.2–39.7)| 23.9 (21.0–27.1)    | 13.7 (11.4–16.4)| 18.7 (16.6–20.9)            |
| 10 (2016)          | 1226| 36.0 (33.7–38.4)| 21.3 (18.4–24.6)    | 13.6 (11.3–16.3)| 18.8 (16.7–21.1)            |
| 11 (2017)          | 1191| 36.1 (33.6–38.6)| 23.3 (19.9–27.1)    | 12.3 (10.1–14.9)| 16.9 (14.8–19.2)            |
| 1 C2 (2020)        | 2067| 26.8 (24.7–29.0)| 21.0 (18.5–23.8)    | 14.7 (12.3–17.4)| 12.3 (10.7–14.1)            |

a: Estimates are adjusted for gender, age, income, education, heaviness of smoking, intention to quit, survey wave, time-in-sample and weighted.

b: Estimations based on regression models per country, combining both cohorts (except for Germany).

c: NA, not available; type of purchase was not included in wave 4 and wave 5 of the ITC Netherlands survey.
Cohort 2, Netherlands) than people with a high income. Compared to higher education individuals, greater odds were found for lower educated (France, Netherlands) and moderately educated (England, Netherlands) smokers.

Sensitivity analyses revealed lower odds for 18–24 year olds compared to people over 55 in all models except for Germany Cohort 1. Income was no longer significantly associated in the Netherlands and Germany Cohort 1, nor was education in England and Germany Cohort 2.

Greater odds were found for German 18–24 year olds (versus 55 and over), and smaller odds were found for people below 40 years old in England and the Netherlands (Supplementary table S3). Main effects for income and education were found in England, Germany Cohort 1 and the Netherlands. Greater odds were found among those with lower income, moderate income, and those who did not state their income (except for England) compared to higher income individuals. Greater odds were also found for people with a lower or moderate education level compared to people with a high educational level.

### Discount brands

#### Prevalence and trends

Use of discount brands in England, adjusted for covariates, increased significantly from 2006–07 (10.8%) to all years from 2010–11 onwards (>21.9%). Estimates in France ranged from 12.2% (2012) to 20.9% (2008), yet no Bonferroni-adjusted differences were found. In the Netherlands, estimated prevalence decreased from 26.4% (2008) to 21% (2020). In Germany, estimates increased annually from 16.3% to 33.6% in Cohort 1 (2007–11), and then decreased nonsignificantly from 47.3% to 43.7% in Cohort 2 (2016–18). A linear increasing trend was found in England and Germany Cohort 1, a decreasing trend in the Netherlands, and no linear trends for France and Germany Cohort 2.

Sensitivity analyses, including unknown brands as discount brands, showed a decreasing linear trend, but also a significant increase between wave 1 and 2 in France. In the Netherlands, a significant increase in use of discount brands was found between wave 1 and 11, but no linear trend was detected (Supplementary table S4). Sensitivity analyses did not change the results for England and both German cohorts, apart from yielding higher prevalence estimates: circa 1% point per wave for England, and 4 and 3% point per wave for Germany Cohort 1 and 2, respectively (results not displayed).

#### Bulk buying

#### Prevalence and trends

Bulk buying in England, adjusted for covariates, decreased from 25.1% (2006–07) to 17.1% (2020) and was significantly less common from 2016 onwards compared to 2006–07. Bulk buying appears most common, yet stable in France (34.1–38.0%). No Bonferroni-adjusted significant differences in estimated prevalence were found in the Netherlands. In Germany, prevalence within each cohort remained

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**Table 3. Associations of time (wave) and each price-minimizing behaviour, per country**

| Wave | RYO tobacco (%) (95% CI) | Discount brands (%) (95% CI) | Bulk buying (%) (95% CI) | Cross-border purchasing (%) (95% CI) |
|------|-------------------------|-----------------------------|-------------------------|----------------------------------|
| England | | | | |
| 5 | 1.18 (1.09–1.27)** | 1.08 (0.89–1.32) | 1.01 (0.85–1.20) | 0.80 (0.68–0.93)** |
| 6 | 1.30 (1.17–1.45)** | 1.17 (0.94–1.44) | 0.86 (0.71–1.05) | 0.68 (0.57–0.81)** |
| 7 | 1.35 (1.19–1.60)** | 2.32 (1.79–3.00)*** | 0.77 (0.60–0.98)* | 0.66 (0.53–0.81)** |
| 8 | 1.38 (1.19–1.60)** | 4.02 (3.07–5.27)** | 0.70 (0.54–0.91)** | 0.37 (0.29–0.47)** |
| 9 | 1.08 (0.92–1.26) | 4.31 (332–5.58)** | 0.82 (0.64–1.05) | 0.33 (0.25–0.42)** |
| 10 | 1.45 (1.25–1.68)** | 3.23 (2.53–4.14)** | 0.70 (0.57–0.87)** | 0.58 (0.49–0.69)** |
| 11 | 1.60 (1.39–1.84)** | 3.34 (2.65–4.23)** | 0.55 (0.45–0.67)** | 0.53 (0.45–0.62)** |
| 12 | 1.66 (1.44–1.91)** | 3.35 (2.63–4.26)** | 0.62 (0.50–0.76)** | 0.54 (0.47–0.66)** |
| France | | | | |
| 1 | 1.16 (0.96–1.41) | 1.34 (0.99–1.89) | 1.08 (0.90–1.30) | 1.13 (0.94–1.36) |
| 2 | 1.05 (0.83–1.34) | 0.70 (0.51–0.96)* | 1.06 (0.85–1.33) | 0.97 (0.80–1.24) |
| 3 | 2.17 (1.85–2.54)** | 1.06 (0.86–1.31) | 0.91 (0.77–1.09) | 1.77 (1.52–2.07)** |
| 4 | 1.28 (1.22–1.35)** | 0.99 (0.92–1.06) | 0.97 (0.92–1.03) | 1.19 (1.13–1.25)** |
| Germany | | | | |
| 1 | 1.04 (0.91–1.20) | 2.24 (1.88–2.68)** | 0.99 (0.83–1.20) | 0.98 (0.83–1.15) |
| 2 | 1.13 (0.96–1.32) | 2.60 (2.08–3.25)** | 0.86 (0.66–1.11) | 1.17 (0.96–1.41) |
| 3 | 1.06 (0.98–1.15) | 1.60 (1.44–1.78)** | 0.95 (0.84–1.07) | 1.13 (1.05–1.20) |
| 12 | 0.63 (0.39–0.99)* | 0.86 (0.59–1.29) | 0.96 (0.50–1.52) | 0.89 (0.44–1.63) |
| The Netherlands | | | | |
| 1 | 0.98 (0.89–1.07) | 0.91 (0.76–1.09) | NA c | 1.03 (0.82–1.28) |
| 2 | 0.93 (0.84–1.03) | 0.90 (0.74–0.99) | NA c | 1.25 (0.99–1.57) |
| 3 | 0.93 (0.83–1.04) | 0.94 (0.76–1.16) | 1.23 (0.96–1.59) | 1.61 (1.30–2.01)** |
| 4 | 1.01 (0.90–1.14) | 1.00 (0.80–1.26) | 1.23 (0.94–1.61) | 2.07 (1.67–2.56)** |
| 5 | 0.97 (0.85–1.09) | 0.91 (0.73–1.14) | 1.28 (0.98–1.67) | 2.62 (2.10–3.25)** |
| 6 | 0.94 (0.83–1.08) | 0.87 (0.68–1.12) | 1.25 (0.92–1.69) | 2.86 (2.26–3.62)** |
| 7 | 0.89 (0.76–1.02) | 0.75 (0.58–0.98)* | 1.23 (0.92–1.66) | 2.89 (2.30–3.64)** |
| 8 | 0.89 (0.77–1.04) | 0.85 (0.64–1.11) | 1.10 (0.80–1.50) | 2.54 (1.99–3.24)** |
| 9 | 0.58 (0.50–0.75)*** | 0.74 (0.61–0.90)** | 1.35 (1.07–1.70)** | 1.75 (1.43–2.14)** |
| 10 | 0.97 (0.96–0.98)*** | 0.98 (0.96–1.00)* | 1.02 (1.00–1.04)* | 1.08 (1.07–1.10)** |

a: **C2** – Cohort 2.
b: Linear trends were explored through separate models. All analyses adjusted for gender, age, education, income, heaviness of smoking index (continuous), intention to quit and time-in-sample.
c: NA, not available; type of purchase was not included in wave 4 and wave 5 of the ITC Netherlands survey.

*: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001.
stable, but dropped from 16.5% in Cohort 1 (2011) to 8.3% in Cohort 2 (2016). A decreasing linear trend was found in England, an increasing trend in the Netherlands, and no linear trends in France and Germany.

Characteristics
Age and income were significantly associated with bulk buying in all countries. Lower odds were found for all age groups below 55 compared to those over 55 years old, except for 40–54 year olds in Germany Cohort 1 (Supplementary table S3). Bonferroni-adjusted age differences in Germany Cohort 2 were non-significant. People with a lower income (England, France, Netherlands), moderate income (England, France, Germany Cohort 1), and who did not state their income (England) were less likely to buy in bulk than people with high income. Education was only associated with bulk buying in France: lower-educated individuals displayed smaller odds than high-educated individuals.

Cross-border purchasing within the EU
Prevalence and trends
In England, adjusted estimates of cross-border purchasing were significantly lower each wave compared to 2006–07 (25.6%), and lowest in 2014 (10.1%). In France, estimates remained stable up to 2012, and then increased significantly to 34.2% in 2019. In the Netherlands, estimates increased annually to 18.8% in 2016, and then decreased in the subsequent years. No differences within a cohort were found in Germany, albeit differences between cohorts were noted. Estimates ranged between 19% and 22% in Cohort 1 (2007–11), and between 9% and 11% in Cohort 2 (2016–18). A decreasing linear trend was detected in England, and increasing trends in France, Germany and the Netherlands were found.

Characteristics
Greater odds were found among French 18–24 and 25–39 year olds, and Dutch 40–54 year olds compared to those over 55 years old (Supplementary table S3). Smaller odds were found for low-income (England, France, Netherlands), moderate-income (England, France) and not-stated income (England, France, Netherlands) smokers compared to high-income smokers. In England, people with a lower or moderate education level displayed smaller odds than people with a higher educational level.

Discussion
This study explored trends in and factors associated with four price-minimizing behaviours in England, France, Germany and the Netherlands. No country displayed the same trend across all behaviours, nor did we find similar trends for one behaviour across countries. Decreasing trends in bulk buying and cross-border purchasing were found in England and Germany, while in the Netherlands smoking RYO tobacco or discount brands decreased. No decreasing trends were found in France. In Germany only one increasing trend (use of discount brands) was found, while the other countries displayed two increasing trends. The most recent data indicates that price-minimising behaviours, except for smoking discount brands, are least common in Germany. Germany has implemented the least stringent tobacco control measures of the four countries: taxation did not keep pace with inflation which resulted in more affordable tobacco over time. Thus, there may have been little need for German smokers to increase efforts to reduce their costs of smoking.

In England, Germany and the Netherlands buying cheaper tobacco—RYO tobacco or discount brands—was the most popular behaviour. This could be because cheaper tobacco is readily available, while bulk buying and cross-border purchasing require more upfront costs. In France, bulk buying and cross-border purchasing were most used. Cross-border purchasing might be more popular in France since all neighbouring countries have lower prices, and cross-border purchasing appears to be more prevalent in regions bordering lower-priced countries.4,5,26,27 While this also holds for the Netherlands, the price difference with surrounding countries is much greater in France.

The secondary aim of our article was to explore characteristics associated with price-minimizing behaviours. Younger individuals were less likely to buy in bulk, smoke discount brands (England, Germany Cohort 1, Netherlands), and more likely to smoke RYO tobacco (England, France, Germany Cohort 1). Cross-border purchasing and bulk buying were less common among low-income smokers (except for Germany), which could be explained due to the required upfront costs.7 Consistent with past studies,6 low-income smokers were more likely to smoke RYO tobacco (England, France, Germany) or buy discount brands (England, Germany Cohort 1, Netherlands). Low-educated smokers bought more RYO tobacco (France, Netherlands) and discount brands (England, Germany Cohort 1, Netherlands).

The results have several implications. The availability of affordable alternatives reduces the impact of tobacco taxation.26,29 Three possible strategies could be employed to counteract these price-minimizing behaviours: taxing cigarettes and RYO tobacco at equivalent rates, setting minimum prices and having a tax structure that minimizes price variability. A simple tax structure, preferably a specific uniform tax rate, is the most effective tax structure for reducing price variability.30,31 Setting higher minimum prices can help prevent undershifting of taxation, whereby tax increases are not fully passed on to consumers but partially absorbed by the industry to keep prices cheap.32 Furthermore, by raising the price of the cheapest brands, minimum prices may reduce large price discrepancies between premium and non-premium brands. While cross-border purchasing was one of the least applied behaviours, this strategy is dominant in the public debate about increasing taxation and often used as an argument by the tobacco industry.33 The focus on cross-border purchasing has detracted from the benefits of applying stronger national-level measures to reduce the other three price-minimization strategies, especially since pertinent EU legislation (i.e. Directive 2011/64/EU) only sets harmonized minimum rates. Policymakers should be vigilant of cross-border purchasing derailing the focus from implementing tax increases or adjusting the tax structure within countries, which, as this study shows, would be more beneficial.

The results should be interpreted with some caution. First, our study is limited to four price-minimizing strategies. Other price-minimizing strategies might include using discounts or coupons, buying single-cigarettes rather than packs, or switching to other affordable substitutes, such as cigarillos or cigars. Use of discounts or coupons and buying single-cigarettes were not examined in our study because they are not legal in the four countries; discounts, coupons or other price-promotions have been prohibited by law in the UK and the Netherlands since 2002, in Germany since 2010 and in France since 2014.34–38 Switching to other affordable products than RYO tobacco, such as cigarillos or cigars, were excluded since not all countries collected this information. For similar reasons, purchases per container or more cigarettes per pack were not categorized as bulk buying. Furthermore, some behaviours might not have been deliberate price-minimizing strategies, such as smoking RYO tobacco or cross-border purchasing. Studies have found smokers to prefer RYO tobacco for the taste or the misperception that RYO cigarettes are healthier than manufactured ones,6,39,40 or buy cigarettes abroad because they are on holidays. By omitting single-time cross-border purchases we tried to limit the inclusion of convenience purchases abroad in our measure. Finally, all countries’ prevalence estimates show a difference between the cohorts. This could also be the result of tobacco control measures implemented in between.
In conclusion, smoking cheaper tobacco was the most common price-minimizing behaviour in three countries and more commonly used by low-income smokers. Our findings suggest that governments should increase efforts to reduce price variability between tobacco products to discourage individuals to switch to a cheaper brand or variety of tobacco instead of quitting.

Supplementary data
Supplementary data are available at EURPUB online.

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Conflicts of interest: G.T.F. has served as an expert witness or consultant for governments defending their country’s policies or regulations in litigation. All other authors have no conflicts of interest to declare.

Ethics statement
The survey protocols and all materials, including the survey questionnaires for the United Kingdom/England Surveys were cleared for ethics by King’s College London IRB (IRB PNM/13/14-151 and IRB RESCM-17/18-2240), the Office of Research Ethics, University of Waterloo, Canada (ORE#10556, ORE#13978, ORE#17469 and ORE#20803/30570). The survey protocols and all materials, including the survey questionnaires for the Germany Surveys were cleared for ethics by Medizinische Fakultät Heidelberg (IRB S-138/2007 and IRB 196/2016), the Office of Research Ethics, University of Waterloo, Canada (ORE#13858 and ORE#21262/30709). The survey protocols and all materials, including the survey questionnaires for the France Surveys were cleared for ethics by the Office of Research Ethics, University of Waterloo, Canada (ORE#13005, ORE#18346/30190 and ORE#40720); ethics clearance in France was waived due to minimal risk. The survey protocols and all materials, including the survey questionnaires for the Netherlands Surveys were cleared for ethics by the Office of Research Ethics, University of Waterloo, Canada (ORE#14666, ORE#18920/30242 and ORE#41704); ethics clearance in the Netherlands was waived due to minimal risk.

Data availability
In each country participating in the International Tobacco Control Policy Evaluation (ITC) Project, the data are jointly owned by the lead researcher(s) in that country and the ITC Project at the University of Waterloo. Data from the ITC Project are available to approved researchers 2 years after the date of issuance of cleaned data sets by the ITC Data Management Centre. Researchers interested in using ITC data are required to apply for approval by submitting an International Tobacco Control Data Repository (ITCDR) request application and subsequently to sign an ITCDR Data Usage Agreement. The criteria for data usage approval and the contents of the Data Usage Agreement are described online (http://www.itcproject.org).

Key points
- Smokers reduce the impact of tobacco taxation through applying price-minimizing behaviours, such as buying cheaper tobacco [roll-your-own (RYO) or discount brands], bulk buying and cross-border purchasing, rather than quitting or reducing consumption.
- Smoking cheaper tobacco (RYO or discount brands) was the most used strategy, and cross-border purchasing the least used strategy in England, Germany and the Netherlands between 2006 and 2020.
- No country displayed the same trend across all behaviours, nor did we find similar trends for one behaviour across countries.
- In Germany, one increasing trend (use of discount brands) was found, while the other countries displayed increasing trends in two price-minimizing behaviours (England: RYO tobacco, discount brands; France: RYO tobacco, cross-border purchasing; and Netherlands: bulk buying, cross-border purchasing).
- Governments should increase efforts to reduce price variability between tobacco products to discourage individuals to switch to a cheaper brand or variety of tobacco instead of quitting.

References
1 Wilson LM, Avila Tang E, Chander G, et al. Impact of tobacco control interventions on smoking initiation, cessation, and prevalence: a systematic review. J Environ Public Health 2012;2012:961724.
2 Islami F, Stoklosa M, Drope J, Jemal A. Global and regional patterns of tobacco smoking and tobacco control policies. Eur Urol Focus 2015;1:3–16.
3 Guindon GE, Driezen P, Chaloupka FJ, Fong GT. Cigarette tax avoidance and evasion: findings from the International Tobacco Control Policy Evaluation (ITC) Project. Tob Control 2014;23(Suppl 1):i13–22.
4 Nagelhout GE, van den Putte B, Allwright S, et al. Socioeconomic and country variations in cross-border cigarette purchasing as tobacco tax avoidance strategy. Findings from the ITC Europe Surveys. Tob Control 2014;23(Suppl 1):10–8.

5 Driezen P, Thompson ME, Fong GT, et al. Cross-border purchasing of cigarettes among smokers in six countries of the EUREST-PLUS ITC Europe Surveys. Tob Induc Dis 2018;16:A13.

6 Brown AK, Nagelhout GE, van den Putte B, et al. Trends and socioeconomic differences in roll-your-own tobacco use: findings from the ITC Europe Surveys. Tob Control 2015;24:i11–16.

7 Licht AS, Hyland AJ, O’Connor RJ, et al. Socio-economic variation in price minimizing behaviors: findings from the International Tobacco Control (ITC) Four Country Survey. Int J Environ Res Public Health 2011;8:234–52.

8 European Commission. Excise duty tables (archive). 2022. Available at: https://circabc.europa.eu/ui/group/4e1c8a15-d45e-440e-8fec-f5d121e40755/library/e42f85d-cf41-4580-ada0-2d40-faa6dce1 (31 October 2021, date last accessed).

9 Government.UK. Tobacco Products Duty Rates for 2020. 2020. Available at: https://www.gov.uk/government/publications/changes-to-tobacco-duty-rates-from-11-march-2020/tobacco-products-duty-rates-for-2020 (25 July 2021, date last accessed).

10 Action on Smoking and Health [ASH]. Timeline of Changes in Tobacco Taxation in the UK From 1993 to the Present 2017. Available at: https://ash.org.uk/information-and-resources/taxation-illicit-trade/taxation/ash-analysis-of-tobacco-tax-increases-in-the-uk/ (25 July 2021, date last accessed).

11 Assemblee Nationale. Project de loi de financement de la sécurité sociale pour 2017. 2016. Available at: https://www.assemblee-nationale.fr/14/projets/pl0472.asp (25 February 2022, date last accessed).

12 Observatoire Français des drogues et des toxicomanies. Tabagisme et arrêt du tabac en 2020. 2021. Available at: https://www.ofdt.fr/ofdt/fr/tt_20bd.pdf (16 September 2021, date last accessed).

13 Ministre des Solidarités et de la Santé. PROGRAMME NATIONAL DE LUTTE CONTRE LE TABAC 2018-2022. Available at: https://solidarites-sante.gouv.fr/IMG/pdf/180702-pnlt_def.pdf (25 March 2022, date last accessed).

14 Steidl F, Wigger BU. Tabaksteuer in Griechenland: steuerpolitische Fehlentscheidungen. Wirtschaftsdienst 2017;97:584–7.

15 Willemsen M. Tobacco Control Policy in the Netherlands. Between Economy, Public Health, and Ideology. Basingstoke: Springer International Publishing, 2018.

16 Rijksoverheid. Nationaal Preventie Akkoord. 2018. Available at: https://www.rijksoverheid.nl/beregen/doc/2018/04/11/nl-nl.minzvw/docs/nl-nl.minzvw.IMG/pdf/7290594-NP-Akoord-en-helpen-om-te-stopten.pdf (25 March 2022, date last accessed).

17 Bailar BA. The effects of rotation group bias on estimates from panel surveys. Br J Addict 1975;70:23–30.

18 Lucht AS, Hyland AJ, O’Connor RJ, et al. How do price minimizing behaviors impact smoking cessation? Findings from the International Tobacco Control (ITC) Four Country Survey. Int J Environ Res Public Health 2011;8:1671–91.

19 Chai K, Hemminki D, Forster J, St Claire AW. Use of price-minimizing strategies by smokers and their effects on subsequent smoking behaviors. Nicotine Tob Res 2012;14:864–70.

20 Shang C, Chaloupka FJ, Fong GT, et al. The association between tax structure and cigarette price variability: findings from the ITC Project. Tob Control 2015;24:ii88–93.

21 Shang C, Lee HM, Chaloupka FJ, et al. Association between tax structure and cigarette consumption: findings from the International Tobacco Control Policy Evaluation (ITC) Project. Tob Control 2019:28:316–1.

22 Partos TR, Hiscock R, Gilmore AB, et al. Public Health Research. Impact of Tobacco Tax Increases and Industry Pricing on Smoking Behaviours and Inequalities: A Mixed-Methods Study. Southampton [UK]: NIHR Journals Library, 2020.

23 Heatherton TF, Kozlowski LT, Frecker RC, et al. Measuring the heaviness of smoking: using self-reported time to the first cigarette of the day and number of cigarettes smoked per day. Br J Addict 1989;84:791–9.

24 Thompson ME, Boudreau C, Driezen P. Incorporating Time-in-Sample in Longitudinal Survey Models. Ottawa, Canada: Statistics Canada, 2008.

25 Balar BA. The effects of rotation group bias on estimates from panel surveys. J Am Stat Assoc 1975;70:23–30.

26 Andler R, Guignard R, Lermanier-Jeannet A, et al. Evading the price: do French smokers go abroad to buy cheaper tobacco? Eur J Public Health 2019;29:186.

27 Gomarje R, Torregrossa H, Bolze C, et al. Decrease in cross-border tobacco purchases despite intensification of antitobacco policies in France. Tob Control 2021;30:428–33.

28 Licht AS, Hyland AJ, O’Connor RJ, et al. How do price minimizing behaviors impact smoking cessation? Findings from the International Tobacco Control (ITC) Four Country Survey. Int J Environ Res Public Health 2011;8:1671–91.

29 Choi K, Henrichus D, Forster J, St Claire AW. Use of price-minimizing strategies by smokers and their effects on subsequent smoking behaviors. Nicotine Tob Res 2012;14:864–70.

30 Shang C, Chaloupka FJ, Fong GT, et al. The association between tax structure and cigarette price variability: findings from the ITC Project. Tob Control 2015;24:ii88–93.

31 Smith KE, Savell E, Gilmore AB. What is known about tobacco industry efforts to influence tobacco tax? A systematic review of empirical studies. Tob Control 2013;22:144–53.

32 Parrot SR, Gilmore AB, Hitchman SC, et al. Availability and use of cheap tobacco in the United Kingdom 2002-2014: findings From the International Tobacco Control Project. Nicotine Tob Res 2018;20:714–24.

33 Partos TR, Gilmore AB, Hitchman SC, et al. Availability and use of cheap tobacco in the United Kingdom 2002-2014: findings From the International Tobacco Control Project. Nicotine Tob Res 2018;20:714–24.

34 EU. European Tobacco Directive. 2014. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32014L0040 (4 May 2022, date last accessed).

35 Parliament of the United Kingdom. Tobacco Advertising and Promotion Act 2002. Available at: https://www.legislation.gov.uk/ukpga/2002/36/section/9#section-9-6 (4 May 2022, date last accessed).

36 Code de la santé publique. Article L3512-4 2016. Available at: https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000032550568/ (4 May 2022, date last accessed).

37 Tabak-en rookwaren.wet. 1988. Available at: https://wetten.overheid.nl/BWBR004 4302/2021-07-01 (2 May 2022, date last accessed).

38 Tabaksteuergesetz (TabStG). Abschnitt 5. 2009. Available at: https://www.gesetze-im-internet.de/tabstg_2009/BJNR187010009.html#BJNR187010009BJNG0005000 (15 March 2022, date last accessed).

39 Minardi V, Ferrante G, D’Argenio P, et al. Roll-your-own cigarette use in Italy: sales variations in cross-border cigarette purchasing as tobacco tax avoidance strategy. Tob Control 2021;30:iii4–9.

40 Bailar BA. The effects of rotation group bias on estimates from panel surveys. J Am Stat Assoc 1975;70:23–30.

41 Partos TR, Hiscock R, Gilmore AB, et al. Public Health Research. Impact of Tobacco Tax Increases and Industry Pricing on Smoking Behaviours and Inequalities: A Mixed-Methods Study. Southampton [UK]: NIHR Journals Library, 2020.

42 Heatherton TF, Kozlowski LT, Frecker RC, et al. Measuring the heaviness of smoking: using self-reported time to the first cigarette of the day and number of cigarettes smoked per day. Br J Addict 1989;84:791–9.

43 Thompson ME, Boudreau C, Driezen P. Incorporating Time-in-Sample in Longitudinal Survey Models. Ottowa, Canada: Statistics Canada, 2008.

44 Balar BA. The effects of rotation group bias on estimates from panel surveys. J Am Stat Assoc 1975;70:23–30.

45 Hoek J, Ferguson S, Court E, Gallopel-Morvan K. Qualitative exploration of young adult RYO smokers’ practices. Tob Control 2016;26:563–8.