Original Investigation

Demand for Factory-Made Cigarettes and Roll-Your-Own Tobacco and Differences Between Age and Socioeconomic Groups: Findings From the International Tobacco Control Netherlands Survey

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Abstract

Introduction: Macroeconomic studies have shown that young individuals who smoke, and have a low socioeconomic status respond more strongly to price increases. Most of this evidence stems from research on factory-made (FM) cigarettes. With the rising popularity of roll-your-own (RYO) tobacco, there is a need for studies on cigarette demand that distinguish between both.

Aims and Methods: This study examined whether individual demand differed for FM and RYO tobacco, and across age, and socioeconomic (income and education) groups. Purchase tasks for FM and RYO cigarettes were included in the 2020 International Tobacco Control (ITC) Netherlands Survey. Adults who smoke daily ($n = 1620$) stated how many cigarettes they would smoke in 24 hours across eight prices. Four demand indices were derived: intensity (consumption at zero costs), alpha (rate of change in elasticity), P_{max} (turning point elasticity), and breakpoint (lowest price where consumption equals zero). The indices were tested for subgroup differences.

Results: Individuals who smoke RYO tobacco indicated higher intensity, and greater alpha than individuals who smoke FM cigarettes. Participants aged 25–39 had lower P_{max}, and 18–24 year olds displayed higher breakpoints. Participants with low income displayed higher intensity, and lower P_{max} than other income groups. No associations were found with education.

Conclusions: Individuals who smoke RYO tobacco indicated higher price sensitivity than those smoking FM cigarettes, supporting the need to harmonize tobacco taxation. Taxation may be especially beneficial to reducing consumption among individuals with a low income or smoke RYO tobacco. Substantially higher prices are needed in the Netherlands to achieve the desired results.

Implications: Individuals who smoke daily were willing to pay substantially higher prices than the current market prices, indicating the room and need for much higher taxation levels. Demand for RYO tobacco was more sensitive to price changes than demand for FM cigarettes. Taxation should be raised at equivalent rates for FM and RYO cigarettes. Taxation appears to be especially effective in reducing consumption among people who smoke RYO tobacco and low-income individuals. It remains important to combine increased taxation with other tobacco control measures.

Introduction

While consumption of factory-made (FM) cigarettes is decreasing, use of roll-your-own (RYO) tobacco is becoming increasingly popular. Worldwide consumption of RYO tobacco rose by 45% between 2000 and 2013, with approximately 86% of it taking place in the European Union.[1] Recent studies in Spain,[2] Italy,[3] and the United Kingdom[4] have indicated that RYO consumption continues to rise. A possible explanation for this rise is that people switched from FM to RYO cigarettes for financial reasons[3]: RYO tobacco is often taxed at lower rates than FM cigarettes, and are thus cheaper to buy. Given the growing proportion of people that smoke RYO tobacco, it is important to gain more knowledge about RYO demand, and whether or how that differs from FM demand.

Increasing prices through excise taxation is an effective strategy for reducing smoking.[5,6] The effect of a change in price on consumption is measured by price elasticity. Price elasticity refers to the relative reduction in consumption resulting from a 1% price increase. A price elasticity of –1 thus implies that consumption decreases proportionally to a price increase, while a price elasticity of 0 implies that consumption is not sensitive to price changes at all. FM cigarettes are estimated to have a price elasticity of –0.4 in high-income countries, meaning that a 10% price increase will lead to a four per cent decrease in consumption. RYO tobacco has been found to have higher price elasticity (–0.64), indicating that individuals who smoke RYO tobacco are more price sensitive than those who smoke FM cigarettes.[6–8] Most studies to date, however, have come from population-level, macroeconomic research. To understand how different groups respond to different prices, individual-level studies are necessary.[9]

Assessing individual demand can be accomplished through behavioral economic analysis, which combines microeconomic theories with psychology to study human behavior.[10,11] Purchase tasks have been proven useful in studying the consumption of addictive products such as alcohol[12] and tobacco.[13–15] Cigarette purchase task (CPT) studies have overwhelmingly focused on FM cigarettes. We found two studies that conducted a separate CPT for RYO tobacco.[9,16] Neither tested for possible differences between RYO and FM tobacco. It remains unclear whether people who smoke RYO or FM cigarettes differ in their sensitivity to price. This is an important question since a well-known policy gap is the historical and current difference between tax rates of RYO versus FM—a difference that diminishes the effectiveness of taxation to reduce demand, since individuals confronting greater costs due to tax increases in FM cigarettes can switch to lower cost RYO tobacco.[17] To the best of our knowledge, the present CPT study is the first behavioral economic study to compare the price sensitivity of RYO and FM cigarettes.

In a CPT, individuals are asked to estimate their daily cigarette consumption over a range of prices. These data are fitted to a demand curve. Four demand indices are usually derived from each demand curve: intensity, alpha (α), P_{max}, and breakpoint. Intensity represents consumption at the lowest price (often zero costs), and is therefore the highest level of demand. High intensity indicates that an individual would, preferably, smoke many cigarettes. α is an index of the rate of change in elasticity.[18] P_{max} is the price per cigarette at which there is maximum spending (number of cigarettes multiplied by the corresponding price). It is the point where demand shifts from inelastic to elastic (>–1), meaning that consumption will decrease more than price increases. Breakpoint is the first price at which consumption equals zero.[19] Except for alpha, higher indices indicate higher demand and therefore a greater willingness to pay higher prices. The indices can be used to inform policymakers how tobacco taxation and pricing policies affect purchasing behavior.[20] For example, breakpoint can inform policymakers what price would result in quitting behavior, rather than merely reducing consumption.

In 2018, the Dutch government announced multiple excise tax increases. The excise tax increases are intended to reduce tobacco consumption especially in two groups: young individuals, and individuals with a low socioeconomic status (SES). Smoking prevalence is highest among young adults: 32.6% of 20–24 year olds smokes, much higher than the population average (22.4%).[21] Similarly, smoking prevalence among people with a low SES (26.2%) is higher than among those with a high SES (15.4%).[21] Macroeconomic studies in high-income countries indicate that these groups are also more sensitive to price changes.[22] There is thus a need for behavioral economic studies that allow for the comparison of the impact of price on demand by different subgroups: type of tobacco, age, and SES.

The aim of the present study is twofold: to compare the impact of price on demand for FM cigarettes and RYO tobacco in the Netherlands, and to assess whether demand differs across age and SES. We hypothesize that individuals that smoke RYO tobacco, people with a low SES, and young individuals have lower demand, and are thus more sensitive to price changes.

Methods

Participants

Data were derived from the International Tobacco Control (ITC) Netherlands Survey, conducted in February and March 2020. Participants were recruited from a probability-based web database administered by Kantar Public. Participants were compensated by this survey firm with "Nipoints," which could be used to acquire gift cards. The sample was designed to represent adults who smoke in the Netherlands: quotas on gender, region, and age were put in place. Inclusion criteria for the ITC survey were that participants had smoked at least 100 cigarettes in their lifetime, and smoked at least monthly ($n = 2128$). For the current study, only individuals who smoked daily and completed the CPTs ($n = 1620$) were included. More information about sampling and weighting can be found elsewhere.[23]

Procedure and Measures

Hypothetical CPT

Two versions of a CPT were embedded in the 40-minute ITC Netherlands Survey: one concerning FM cigarettes (*n* = 1088) and one concerning RYO tobacco (*n* = 532). Individuals were directed to one of two CPTs based on what type of tobacco they indicated to smoke (FM cigarettes only, RYO tobacco only, or both). Dual users were assigned based on the type of tobacco of their usual brand. In the absence of a usual brand they were assigned based on the type of tobacco of the product they currently smoked, restricted to either FM cigarettes or RYO tobacco. Instructions were based on previously validated CPTs and translated from English to Dutch[13,24]:

> Imagine that for the next 24 hours the only cigarettes available to you [are ORDINARY FACTORY-MADE CIGARETTES/is ROLLING TOBACCO]. That is, you have NO ACCESS to any other type of cigarettes or nicotine products for the next 24 hours. The following questions ask how many [ORDINARY FACTORY-MADE CIGARETTES/grams of ROLLING TOBACCO] you would smoke if they cost various amounts of money. [The average number of grams of rolling tobacco per roll-your-own cigarette is 1 gram.] [The average price for an ordinary factory-made cigarette is €0.30, equivalent to €6.00 per 20 sticks./The average price for 1 gram of ordinary roll-your-own tobacco is €0.20 (€10.00 for a 50 gram container of loose tobacco).]
> How many [ordinary factory-made cigarettes/grams of rolling tobacco] would you smoke over the next 24 hours…
> … if they were €X each (equivalent to €Y per 20 sticks)/… if the tobacco cost €X per gram (€Y for a 50 gram container of loose tobacco)

Both versions included eight prices: 0×, 0.5×, 1×, 1.5×, 2×, 5×, 10×, and 20× the average market price per cigarette in 2019, rounded to one decimal place (€0.3 for FM, €0.2 for RYO).[25] Prices were presented in preceding order. A maximum allowance of 100 cigarettes per day was accepted per answer. The consumption data generated individual demand curves and four indices: intensity, α, P_{max}, and breakpoint. Intensity and breakpoint were observed values: the amount of cigarettes an individual indicated to smoke at zero price (intensity) and the lowest price at which an individual indicated to not buy tobacco anymore (breakpoint). α and P_{max} were derived (see data analysis). P_{max} and breakpoint were converted to multiples of their respective market price, allowing for comparisons between RYO and FM demand.

Predictor Variables

Participants were classified as smoking FM or RYO cigarettes based on their self-classification. Individuals who indicated to smoke both were coded as smoking either FM or RYO cigarettes based on their current brand and variety. Gender was coded as a dummy variable (man or woman). Age was categorized as: 18–24, 25–39, 40–54, and 55 years and older. Income and education level were used as indicators of SES. Monthly gross household income was categorized into four levels: low (≤2000 euros), moderate (between 2000 and 3000 euros), high income (≥3000 euros) and not stated (refused or don't know). Three levels of education were distinguished: low (primary and lower prevocational secondary education), moderate (middle prevocational secondary education and secondary vocational education), and high (senior general secondary education, (pre-) university education, and higher professional education). The Heaviness of Smoking Index (HSI) was included to adjust for cigarette dependence. Recent literature indicates that dependency is associated with demand indicators.[26] HSI is a validated measure of cigarette dependency in population-based studies,[27] combining two measures: cigarettes per day and time to first cigarette of the day. Respondents were classified as having low (0–2), moderate (3–4), or high (5–6) dependence. Cigarettes per day (CPD) is included in the participant characteristics, but excluded from further analysis since HSI includes CPD.

Data Analysis

First, data were checked for nonsystematic responses using the three-criterion algorithm.[28] This algorithm has been used in several purchase task studies.[25,29,30] Nonsystematic responses are responses that are unaffected, or not affected as expected, by price. The three criteria of the algorithm are: trend (a global reduction in consumption from highest to lowest price), bounce (less than 10% of price increments have resulted in an increase of consumption), and no reversals from zero (consumption remains at zero once prices have exceeded breakpoint). The algorithm identified 94 FM (8.8%) and 97 RYO (18.2%) participants as nonsystematic. Only violation of the trend criterion was found. Twelve of the nonsystematic FM participants were due to zero consumption at all prices. All nonsystematic responses were excluded from further analysis. No sensitivity analyses were carried out including the nonsystematic responders, since they did not respond to the experimental condition. Potential group differences between systematic and nonsystematic responders were tested through binary logistic regressions in SPSS 26 ([Supplementary File](#)). Nonsystematic responders in the FM-CPT were more likely to have a lower-educational level than systematic responders. No significant group differences were found in the RYO-CPT. Participants who did not provide sufficient data points to derive a demand curve were also excluded (FM = 10, RYO = 2). The final unweighted sample consisted of 984 FM and 433 RYO participants, respectively 90.4% and 81.4% of the total responses.

Next, outliers in consumption data, defined as *Z*-scores ≥3.29, were recoded to one unit larger than the next most extreme score in the distribution.[31] About one out of three participants (FM = 29.1%, RYO = 32.1%) were willing to consume at the highest price. Of these participants, 78.1% (FM) and 60.2% (RYO) indicated they would smoke five cigarettes or less a day at this price. We imputed breakpoint at the highest price for participants who did not reach breakpoint in the CPT.

α was derived by fitting the consumption data to the exponentiated demand [equation (1)](#) in GraphPad Prism 8 (La Jolla, California) using the exponentiated demand analyses template.[32,33] The equation states:

$$Q = Q_0 \times 10^{k(e^{-\alpha Q_0 C} - 1)} \tag{1}$$

in which *Q* is the consumption of the good at price (*C*), *k* is a constant that denotes the range of consumption in logarithmic units, and α signifies the rate of decline of consumption across the demand curve. Q_0, consumption at free price, was constraint to the observed values. *k* was set at a constant among all curves (*k* = 1.78) based the range of data for FM cigarettes. P_{max}, the price at which demand turns elastic, was derived using the equation for analytical P_{max} by Gilroy et al.[18]

All subsequent analyses were executed in SPSS version 26 using individual demand data. Mann–Whitney *U* tests were conducted to compare demand indices from the FM and RYO purchase task. Associations between sociodemographic subgroups and indices were assessed through factorial analyses of variance (intensity, α, and P_{max})

and an ordinal logistic regression (breakpoint). Due to violation of the assumption of homogeneity, bootstrapping was used for intensity, and α was log-transformed. All variables were entered simultaneously. For each significant association, pairwise comparisons with Bonferroni adjustments, correcting for other variables in the model, were carried out (tables not displayed).

Results

Participant Characteristics

Table 1 shows the participants characteristics by type of tobacco. The percentage of participants by type of tobacco differed for gender ($\chi^2(1, N = 1417) = 45.12, p \leq .001$), age ($\chi^2(3, N = 1420) = 125.04, p \leq .001$), income ($\chi^2(1, N = 1420) = 11.32, p = .010$), education ($\chi^2(1, N = 1407) = 19.63, p \leq .001$), cigarette dependence ($\chi^2(2, N = 1415) = 38.54, p \leq .001$), and cigarettes smoked per day ($t(1414) = -6.072, p \leq .001$). Individuals who smoke RYO tobacco were more often men, older, low-income, low-educational level, more nicotine dependent and smoked more cigarettes per day than individuals who smoke FM cigarettes.

Demand Indices

Figure 1 displays the group demand curves for FM cigarettes and RYO tobacco. The group curve shows higher intensity and a steeper decline (α) for RYO tobacco than FM cigarettes. The model provided a good fit to the individual data of both purchase tasks (mean

Table 1. Participant Characteristics per Type of Tobacco Smoked (Weighted Data)

	Smokes FM cigarettes (N = 962)	Smokes RYO tobacco (N = 461)	p
Gender			.001***
Men	458 (47.7%)	305 (66.7%)	
Women	502 (52.2%)	152 (33.3%)	
Age			.001***
18–24 years	164 (17.0%)	21 (4.5%)	
25–39 years	299 (31.1%)	74 (16.1%)	
40–54 years	267 (27.8%)	137 (29.9%)	
55+ years	232 (24.2%)	226 (49.4%)	
Income			.010*
Not stated	225 (23.4%)	92 (20.0%)	
Low	289 (30.0%)	166 (36.4%)	
Moderate	332 (34.5%)	164 (35.8%)	
High	117 (12.1%)	35 (7.7%)	
Education			.001***
Low	342 (35.8%)	216 (47.9%)	
Middle	413 (43.2%)	166 (36.8%)	
High	201 (21.0%)	69 (15.4%)	
HSI			.001***
Low	477 (49.7%)	152 (33.3%)	
Moderate	428 (44.6%)	254 (55.7%)	
High	54 (5.7%)	50 (11.0%)	
Cigarettes per day (M (SD))	13.59 (7.34)	16.17 (7.73)	.001***

p values were based on chi-square tests (gender, age, income, education, HSI) and independent samples *t*-test (cigarettes per day). FM = factory-made cigarettes; RYO = roll-your-own tobacco; HSI = Heaviness of Smoking Index; *M* = mean.
*$p \leq .05$.
***$p \leq .001$.

$R^2 = .83$ [FM], .82 [RYO]). Participants who gave responses that were low fitting ($R^2 \leq .30$) were excluded from the individual-level analysis (3 RYO participants, <1% of RYO participants), similar to previous CPT studies.[26,34] Sensitivity analysis indicated that in- or exclusion of these individuals did not change the results.

Table 2 lists the individual unadjusted means for each demand by type of tobacco. On average, individuals who smoke RYO would consume more when tobacco would be free of cost (intensity), and displayed a steeper decline in consumption (α) than individuals who smoke FM cigarettes. Demand for FM and RYO tobacco would turn elastic (P_{max}) at more than 9× the respective market prices, and would reach breakpoint at a twelvefold price increase. Excluding participants that did not reach breakpoint (29.1%), estimations for P_{max} and breakpoint would be €2.33 and €2.97 (FM), and €1.75 and €1.84 (RYO) per cigarette.

Intensity
Intensity refers to how many cigarettes someone would smoke if they were available free of cost. The analysis of variance indicated main effects for gender, income, and cigarette dependence (Table 3).
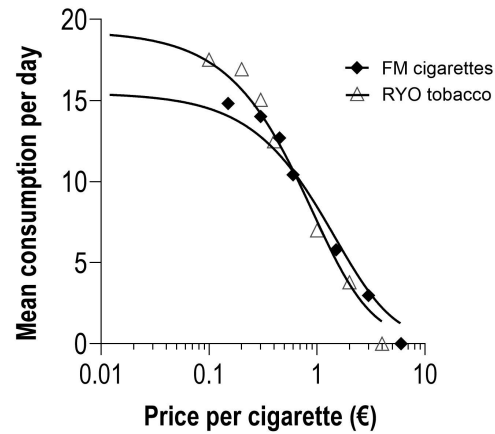

Figure 1. Group demand curves for factory-made (FM) cigarettes and roll-your-own (RYO) tobacco.

Table 2. Demand Indices for FM Cigarettes and RYO Tobacco

	FM cigarettes	RYO tobacco	
	Mean (SD)	Mean (SD)	p
Intensity	15.47 (8.99)	19.20 (11.53)	.001***
Alpha (log)	−1.93 (.41)	−1.82 (.41)	.001***
P_{max}			
Euros	2.93 (2.16)	1.92 (1.42)	—
Multiplication of 2019 market price	9.79 (7.20)	9.59 (7.09)	.540
Breakpoint			
Euros	3.85 (2.12)	2.53 (1.44)	—
Multiplication of 2019 market price	12.84 (7.06)	12.67 (7.20)	.508

FM = factory-made; RYO = roll-your-own. Intensity = number of indicated cigarettes to be smoked at free price; Alpha = rate of change in elasticity; P_{max} = price at which elasticity turns elastic; Breakpoint = price at which individual stops to buy cigarettes; Multiplication of 2019 market price = price for P_{max} or breakpoint relative to the 2019 market price for FM cigarettes and RYO tobacco.
***$p \leq .001$.

Table 3. Group Differences Across Intensity, Alpha, and P_{max}

	Intensity		Alpha (log)		P_{max}	
	F	p	F	p	F	p
Gender	8.143	.004*	.001	.997	.123	.726*
Age	1.859	.135	.684	.562	5.576	.001***
Income	2.950	.032*	3.059	.027*	8.905	.001***
Education	1.484	.227	.474	.622	1.003	.367
HSI	298.418	.001***	150.458	.001***	1.232	.292

*$p \leq .05$.

***$p \leq .001$.

Females indicated to have lower intensity than males (adjusted difference, *d*, is 1.266, *p* = .004). Pairwise comparisons with Bonferroni adjustments, correcting for other variables, indicated that individuals with low income were in the direction of having higher intensity than those with a moderate income (*d* = 1.527, *p* = .052). Significant differences were found between all groups of cigarette dependency, with more dependent respondents showing higher intensity.

Alpha (*α*)

α reflects the rate of change across the curve. A greater *α* indicates that consumption will decrease more sharply as prices increase, indicating lower demand. Significant main effects were found for income and cigarette dependence (Table 3). Pairwise comparisons with Bonferroni adjustments, correcting for other variables, only indicated significant differences for cigarette dependence between all groups. Individuals with higher dependence displayed a smaller *α*, indicating a smaller change in consumption as prices increase.

P_{max}

P_{max} represents the price at which there is maximum spending, and demand shift from inelastic to elastic. A low P_{max} indicates low demand. The model indicated group differences for age and income (Table 3). Pairwise comparisons with Bonferroni adjustments, correcting for other variables, indicated that spending by individuals aged 25–39 peaked at a lower price than those aged 40–54 (*d* = 1.449, *p* = .024) and over 55 (*d* = 1.920, *p* = .001). Spending by individuals with low income peaked at lower prices than those with moderate (*d* = 2.266, *p* = .001) or high income (*d* = 2.325, *p* = .004).

Breakpoint

Breakpoint reflects the first (thus lowest) price an individual is not willing to pay for cigarettes, resulting in zero consumption. The ordinal logistic regression indicated that individuals aged 18–24 were significantly more likely to reach breakpoint at a higher price than any other age group, tested with a Bonferroni-adjusted alpha-level of.008 (25–39: $\chi^2(1)$ = 9.365, *p* = .002; 40–54: $\chi^2(1)$ = 6.979, *p* = .008; 55 and over: $\chi^2(1)$ = 10.458, *p* = .001). Individuals with moderate cigarette dependence were significantly more likely to reach breakpoint at a higher price than those with a low dependence ($\chi^2(1)$ = 31.784, $p \leq$ .001), tested with a Bonferroni-adjusted alpha-level of.0167.

Discussion

The first aim of our study was to determine the impact of price on demand for FM and RYO tobacco in the Netherlands. The main finding is that individuals who smoke RYO tobacco seem more price sensitive than individuals who smoke FM cigarettes. This is

consistent with the results of macroeconomic studies.[7] A second important finding was that both types of tobacco required substantial price increases for demand to turn elastic (P_{max}) or not to be willing to buy tobacco anymore (breakpoint). On average, Dutch adults who smoke daily required an eightfold price increase for consumption to decrease more than proportionally to the price increase, and a twelvefold increase to quit buying tobacco. Our estimations of *α* for FM cigarettes are comparable with the estimations for people who smoke daily by Heckman et al. in their four-country comparison.[14] Our estimations for P_{max} and breakpoint for FM cigarettes are much higher. For the United States, England, and Canada they concluded an approximately five- (P_{max}) or tenfold (breakpoint) increase from market prices, while in Australia a four- (P_{max}) or eightfold (breakpoint) increase would suffice. This could be explained by the inclusion of individuals who smoke nondaily (19.6%) in the Heckman study: participants who did not smoke daily reported significantly lower demand for all indices than those who did. Our estimations for P_{max} and breakpoint are also higher than a previous estimation of FM demand in the Netherlands.[25] This might be the result of the greater number of participants not reaching breakpoint in our study (29.1% vs. 16.1%), resulting in higher estimations for P_{max} and breakpoint. The higher breakpoint in our study could also be explained due to higher levels of dependency in our sample, which is significantly associated with a higher breakpoint. A 2014 study found that people that smoked daily in New Zealand would reach breakpoint at a price of NZ\$1.45 per cigarette; just over double the market price of that year (NZ\$0.70). While this estimation is much lower than our findings, it is also much lower than findings from other studies.

The second aim of our study was to determine age and SES differences in tobacco demand. Except for 25–39 year olds whose spending peaked at lower prices, no indications were found that young individuals had lower demand than older individuals. It could be that the effect of age is mediated by cigarette dependency. A common explanation for young individuals being more price sensitive is that they are less dependent and have a shorter smoking history than older individuals.[35] Inspection of our data showed that older respondents were more often highly or moderately dependent than younger respondents. By omitting dependency from our models, age becomes significantly associated with all indices. It thus appears that less cigarette dependent people, who are often younger, have lower cigarette demand. Another surprising finding was that young adults (18–24 years old) displayed a higher breakpoint than any other age group. A possible explanation for the higher breakpoint could be that the youngest group is less attentive of the financial repercussions of tobacco consumption at high prices. Young adults often have lower financial capabilities, meaning that they are less able to maintain and control personal finances.[36]

Regarding SES, we found several associations between demand and income. Low-income individuals displayed higher intensity, yet spending would peak at a lower price per cigarette (P_{max}) than any other income group. This indicates that individuals with low income might be more sensitive to higher prices. No evidence for lower demand was found for individuals with low education. It could be that the effect of education is reduced in multivariable analyses, as this effect is mediated by the variable income. Nonetheless, our findings about SES differences in demand for tobacco suggest that increased taxation might be more effective among individuals with low income.

The findings of this study have important implications for tobacco pricing and taxation policy in the Netherlands and countries

with a similar tobacco landscape. This study indicates the need to raise tobacco taxation substantially, and at equivalent rates, for FM cigarettes and RYO tobacco. The availability of cheaper (RYO) tobacco reduces the impact of taxation in both tobacco consumption and prevalence.[37] Instead of quitting, price sensitive individuals who smoke might be inclined to substitute their tobacco for a cheaper (RYO) brand to reduce costs. Almost a third of participants indicated their willingness to consume at all prices, signifying both the power of tobacco addiction and the affordability of tobacco in the Netherlands.[38] Only around 10% indicated to stop buying tobacco at a 200% increase. Tax increases are often much smaller: the most recent tax increase (April 2020) raised tariffs by circa 15% for FM cigarettes (€1 per pack) and 26% for RYO tobacco (€2.50 per 50 g). This was the largest increase in specific excise taxation on RYO tobacco in the Netherlands since the early 1990s.[39] Our findings regarding SES suggest that taxation is more effective among individuals with low income. While tobacco taxation remains an effective method of reducing tobacco consumption in general, it remains crucial to combine this with other tobacco control measures.

These results need to be interpreted with caution for several reasons. Data collection was limited to individuals who smoke daily. Less than 30% of the Dutch people who smoke do so less than daily, and many of these have a high SES.[21] Research suggests that individuals who do not smoke daily may respond more strongly to price changes than those who do.[14,40] Many participants were willing to continue to consume tobacco at the highest price that we presented them with (€200 per pack of FM cigarettes) in our CPT, suggesting that our price range used may have been too small. The previously mentioned Heckman et al. study was the only study we found which also reported that not all respondents (16.1%) reach breakpoint.[25] Their range of prices was €0–€30 per cigarette. Furthermore, our CPTs estimated cigarette demand for FM and RYO tobacco independently. Price-minimizing behaviors, such as cross-border purchasing, were not taken into account in our purchase task. Our findings could therefore be an underrepresentation of the influence of price on low SES groups, who are more likely to apply these behaviors.[41,42] The nonstandardized nature of RYO could also impact our findings. The instructions of the CPT referred to cigarettes containing 1 g of RYO tobacco. It could be that individuals already used less than 1 g per cigarette, or would decrease the grams of tobacco per cigarette as prices increase. This was not accounted for in our purchase task or models. Additionally, we have not controlled for type of tobacco in our analyses of variance or ordinal logistic regression, which could be seen as a limitation. It is not unlikely that price sensitivity is a causal predictor of type of tobacco one smokes, since switching to RYO tobacco is a price-minimizing strategy applied by individuals who smoke.[42,43] Inclusion of type of tobacco could therefore have led to overcorrection of the models.

This study adds to the growing literature on individual demand for tobacco products, and application of behavioral economic analyses such as CPT in tobacco control. Our results complement previous studies on individual tobacco demand, which were typically limited to FM cigarettes. We found individuals who have low income and those who smoke RYO tobacco to be more sensitive to price increases. While consumption will likely decrease with each price increase, substantially higher prices are required to achieve the sizeable reductions in tobacco consumption and prevalence. Participants of both purchase tasks indicated that prices would have to increase substantially for them to decrease their consumption at least proportionally to the price increase. This reinforces the need to increase both FM cigarettes and RYO tobacco by a significant margin, and at equivalent rates.

Declaration of Interests

GTF has served as an expert witness or consultant for governments defending their country's policies and regulations in litigation. All other authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Ethical Approval

The survey protocols and all materials, including the survey questionnaires, were cleared for ethics (ORE#41704) by Office of Research Ethics, University of Waterloo, Canada. Ethics clearance in the Netherlands was waived due to minimal risk.

Data Availability

The data are jointly owned by a third party in each country that collaborates with the International Tobacco Control Policy Evaluation (ITC) Project. 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. To avoid any real, potential, or perceived conflict of interest between researchers using ITC data and tobacco-related entities, no ITCDR data will be provided directly or indirectly to any researcher, institution, or consultant that is in current receipt of any grant monies or in-kind contribution from any tobacco manufacturer, distributor, or other tobacco-related entity. The criteria for data usage approval and the contents of the Data Usage Agreement are described online (http://www.itcproject.org). The authors of this paper obtained the data following this procedure. This is to confirm that others would be able to access these data in the same manner as the authors. The authors did not have any special access privileges that others would not have.

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