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Estimation of Own-Price and Expenditure Elasticities of Cigarette Demand by Income Groups

Report

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Introduction

Recent increases in the taxation of tobacco products in Slovakia proved to be relatively successful. The cumulative increase in specific duty for cigarettes between 2018 and 2023 reached more than 36 percent, while during the same period of time consumption of manufactured cigarettes decreased by approximately 16 percent. However, the results of a special Eurobarometer survey *Attitudes of Europeans towards tobacco and electronic cigarettes* (European Commission 2017; 2023) point towards an increasing share of daily hand-rolled cigarette smokers between waves of the survey collected in 2017 and 2023 (increase from 10 percent to 13 percent). Behavioral responses of tobacco smokers to price changes in Slovakia have been underexplored in relevant research. However, a recent study by Lichner and Ostrihoň (2024) indicates a relatively high response of smokers to price increases that is significantly motivated by changes in tobacco taxation rates, amounting to a conditional price elasticity of -0.78. This finding also aligns with results of earlier research by Jamrich and Pokrivčák (2018), who found a conditional price elasticity of -0.92.

The purpose of this study is to utilize available data on household consumption and provide up-to-date evidence about the elasticities of tobacco consumption in Slovak households grouped by income level. Results of the estimations will serve as inputs for research focused on the simulation of impacts of tobacco tax increases in Slovakia. Refined estimations of the elasticities by income groups will enable the assessment of possible social impacts of tobacco taxation.

Recent trends in the public finances of Slovakia have shown worrying signs of potential accumulation of gross government debt at an alarming rate. In part to address this, the government imposed additional increases in the excise duty on tobacco products in late 2023 through law 390/2020 Coll., which was approved by the Slovak Parliament. Since February 2024 all manufactured cigarettes' consumption-related excise duty rates increased, namely the specific rate per 1,000 cigarettes and the ad valorem

components of the mixed tobacco tax structure, as well as the minimal[1] rate per 1,000 cigarettes.

The specific rate increased by almost 8 percent to 91.30 € per 1,000 sticks from the previous 84.60 € per 1,000 sticks. Additionally, the ad valorem rate increased to 25 percent from the previous 23 percent, which had been in effect since 2011. There was an increase of 12 percent in the minimum rate level that increased from 132.10 € per 1,000 sticks to 148 € per 1,000 sticks. In the explanatory report to the law 530/2023 Coll. proposal, the Ministry of Finance anticipated an increase of 106 million euros in tobacco-based revenues in 2024 due to these changes.

One of the main motivations for this research is that these estimates of price and income elasticities of cigarette demand can prove valuable for fine-tuning the ensuing discussion on cigarette taxation in the future. From this perspective the potential reaction of cigarette demand in Slovakia to a hypothetical increase in cigarette specific duty is explored. Additionally, the research also aims to provide further nuance into the understanding of cigarette demand response with regard to different income groups of Slovak households, as policy makers may be particularly interested in the effects of such measures on various income groups. An additional goal, therefore, is to assess the burden carried by individual income groups of Slovak consumers and to identify each group's share of the tax burden of the excise increase.

Literature Review

Only a handful of studies have focused on the price and income elasticities of demand estimation in the context of the Slovak Republic. The majority of papers dealing with the estimation of elasticities in Slovakia focused on food products (for example, Hupkova et al., 2009; Benda Prokeinova & Hanova, 2016; Hupková, 2016; Cupák et al., 2015; Cupák & Tóth, 2017). Nevertheless, for the purposes of our cigarette demand estimations for various income groups, some of these studies may serve as guidance

[1] The minimal rate per 1,000 cigarettes is the minimal amount of duty excised per 1,000 cigarettes, effective when the overall excise rate would be below the minimal amount.

as they focus on the estimation of food expenditures by income groups of households (for example, Kubicová et al., 2011; Rizov et al., 2014)

Additionally, some of the local research has at least partially investigated demand for cigarettes and/or tobacco products. Analysis by Konig and Dovalova (2016) used the quadratic almost-ideal demand system (QUAIDS) to produce elasticities for broader groups of consumer goods, estimated separately for high- and low-income households. One of them was the subgroup of “Alcoholic beverages, tobacco” which pooled together consumption of “addictive” substances and estimated elasticity for the period before the global 2008 crisis, categorizing those products as inferior goods.

Regarding other more detailed examinations of Slovak cigarette demand, Jamrich and Pokrivčák (2018) utilized the Heckman sample-selection model and quantile regression approach to estimate price elasticity of conditional cigarette demand for the period 2006–2012 based Household Budget Survey (HBS) data. The results of the quantile regression indicated that households with light cigarette consumption tend to be more sensitive to price changes than households of moderate and heavy smokers.

Concerning the cigarette price elasticity of countries with similar backgrounds to Slovakia, Vladisavljević et al. (2021) estimated the price and income elasticity of cigarette consumption at the extensive and the intensive margin by low-, middle-, and high-income households in Serbia. Similarly, Cizmovic et al. (2022) and Gligorić et al. (2022) also estimated the price and income elasticity for smoking prevalence and smoking intensity in Montenegro and Bosnia and Herzegovina, respectively, while also disaggregating households into the aforementioned income groups. The authors found the low-income group to be the most responsive, while the high-income group was the least responsive to changes in cigarette prices, at both the intensive and extensive margins. However, from a statistical perspective only the differences between the price elasticity of the high-income group and any of the two remaining income groups were confirmed.

Similar studies were done in other Western Balkan countries, with slightly different estimates obtained. Zubović et al. (2019) found that, in Albania, the prevalence price elasticity of the low-income group is substantially greater in magnitude than the other two income groups, while in Kosovo, they found that the intensity price elasticity of the

high-income group is negligible, and in North Macedonia they found that the prevalence price elasticity of the high-income group and intensity price elasticity of the low-income group are outliers compared to the other income groups.

Regarding the estimation of elasticities for disaggregated cigarette demand geographically further from Slovakia, Austria and Pugadan (2019) estimated the price and income elasticity of cigarette demand in the Philippines for four groups based on income distribution. The authors found the demand to be more price responsive between the years 2009 and 2015, which they hypothesized can be attributed to various factors, such as a permanent increase in cigarette prices, which increased the presence of substitutes.

Other than income groups, analogous elasticities were also distinguished for households with rural and urban residence (John, 2008), demographic characteristics (Zare & Zheng, 2021), and purchase history (Zare & Zheng, 2021; Homaie Rad et al., 2020). John (2008) found the demand for cigarettes in India to be the least price elastic out of the demands examined for various tobacco products. Zare and Zheng (2021) concluded that the demand for e-cigarettes in the United States of America is price elastic and that banning e-cigarettes based on certain features would have a heterogeneous impact on adult demand. Homaie Rad et al. (2020) found that own-price elasticity of cigarette demand in Iran varies from -1.2 for the high end of the household cigarette consumption distribution to -0.91 for the low end of the distribution.

From a theoretical perspective, the regressivity/progressivity of tobacco taxation as a result of varying price elasticity of tobacco demand across income groups was examined by Verguet et al. (2021). The authors provide an extensive review of studies exploring the effects of tobacco taxation on various income groups, as well as theoretical argumentation of conditions under which such taxation is not regressive. As a practical illustration, the authors apply their approach within case studies of five selected European countries, which include Bulgaria as a representative of upper-middle-income countries. The results for the case of Bulgaria suggest that an increase in the relative price of cigarettes by 100 percent would lead to progressivity in net cigarette expenditures—that is, affecting more affluent smokers relatively more than less affluent smokers.

Data and Methodology

Data

To estimate the elasticities of tobacco demand in Slovakia, microdata from the Household Budget Survey (HBS) served as the main source utilized for construction of our data set. The Statistical Office of the Slovak Republic (SOSR) provided us with HBS data published as survey waves in the years 2020–2022. There have been significant changes in the methodology of the collection and creation of microdata waves recently.[2]

Following the recommendations in the *Updated Toolkit on Using Household Expenditure Surveys for Research in the Economics of Tobacco Control* (John et al., 2023), only microdata in constant prices of a single year were used for the estimation of price and income elasticities of cigarette demand. For convenience, constant prices of the year 2021 were selected for these purposes, as such a step allowed us to use the original 2021 HBS wave[3] (featuring observations from 2019, 2020, and 2021 at constant 2021 prices), to which observations for the year 2022 from the 2022 HBS wave, additionally adjusted[4] to be represented at constant prices of 2021, were appended. The total number of households[5] available by combining these two HBS waves was 3,655. However, the number of observations used for estimations was

[2] The SOSR is collecting each released wave across three consecutive years and subsequently adjusting household expenditures for inflation to be represented in the constant prices of the year for which the wave is eventually published.

[3] The SOSR also included in 2021 HBS wave households first interviewed in December 2018. These observations were excluded from the following presentation of the data in graphs. The effect of including/excluding the households surveyed in December 2018 in the model estimation sample is examined as part of the robustness exercises.

[4] The observations from 2022 were additionally adjusted using implicit deflators for each Classification of Individual Consumption by Purpose (COICOP) item at the 4th level computed for observations from 2021 which were featured in both wave 2021 and wave 2022. For items HE09212_p "Aeroplanes microlight aircraft gliders hang-gliders and hot-air balloons," and HE12122_p "Repair of electric appliances for personal care," (Eurostat, 2023) which were not observed in 2021, a deflator provided by the SOSR was used instead.

[5] The households featured in the HBS data were surveyed multiple times, each at different time points within individual waves as well as over the examined years. It was possible to identify this by the Survey on Income and Living Conditions ID variable provided as part of the original HBS data. From these multiple rounds of surveying, only the first appearance of each household was used in the analysis. The number of observations identified this way was 3,288. To these, we added 367 observations of households for which the Survey on Income and Living Conditions ID variable was not reported, under the assumption that these are unique from those for which the ID variable was reported.

slightly reduced by the common sample for which all variables used in the estimation were available.

Households are split[6] into income groups according to the average income per household member. Based on John et al. (2023), three distinct income groups were subsequently derived as weighted terciles of household distribution based on total income per household member, determining the distribution in each surveyed year separately. This allowed splitting the sample into low-, middle-, and high-income households.[7]

Regarding specific variables used, the HBS data (Eurostat, 2023) contains information about the expenditures on tobacco products (COICOP 02200000) as a main group, cigarettes (02201100), cigars (02201200), and other tobacco products (02201300). The information about the number of cigarettes and cigars is also available. The information regarding expenditures on cigarettes and the number of cigarettes consumed (measured in sticks per year per household) served as the main variables of interest. Furthermore, cigarette unit values were obtained by dividing household expenditures on cigarettes with the amount of cigarettes consumed.

Following the *Updated Toolkit* (John et al., 2023), the annual cluster average of cigarette unit values over the households grouped by HBS primary sampling units were used as proxies for cigarette prices. In cases when an entire primary sampling unit cluster had no cigarette consumption, a annual regional cluster average of cigarette unit values was used instead. The indicator variable of whether a household had any cigarette consumption served as the main variable for modelling smoking prevalence.

Among other variables available in or derived from the HBS data (Eurostat, 2023), the following were used in the analysis: total consumption expenditures of households (which served as a proxy for household total income), household monetary net income, household male ratio (defined as the ratio of number of male household members to household size), household adult ratio (defined as the ratio of number of household members of age 16 and older to household size), child present in household (1 if any member of household is younger than 16 years, 0 otherwise), average age of

[6] The sampling weights of households in the HBS survey were taken into account.
[7] Descriptive statistics for the entire sample of households as well as for the particular income groups are provided in tables A3-A4 in the Appendix.

household members, household size, marital status (1 if at least one household member reports living in consensual union, 0 otherwise), employed ratio (defined as the ratio of employed household members to household size), household economic activity (1 if at least one household member is employed, 2 if no household member is employed and at least one household member is self-employed, 3 if no household member is employed or self-employed and at least one household member is retired, 4 otherwise), highest educational level attained within the household (1 primary education, 2 secondary education, 3 tertiary education), highest educational level attained within the household (ISCED 2011), household type (Eurostat, 2023, defined HB074 variable: 1 one adult person household, 2 two adult person household , 3 more than two adult person household lone parent with ALL children aged 16 or more, 4 one adult with at least one child aged less than 16, 5 two adults with children aged less than 16, 6 more than two adults with children aged less than 16, 9 other), degree of urbanization (1 densely populated, 2 intermediate, 3 sparsely populated, 9 not specified), alcohol consumption prevalence (1 if alcohol consumption is positive, 0 otherwise), and regional dummies (8 NUTS3 Slovak regions).

Data from additional sources were also used to perform the analysis. Specifically, various data on inflation and prices—that is, consumer price index (CPI) and harmonized index of consumer prices (HICP) of groups of products were acquired from the SOSR and Eurostat databases. Information regarding tax returns from tobacco products (which include details on tax rate, quantity of tobacco products taxed, and tax revenues gained) were obtained from the publicly accessible data of the Institute for Financial Policy (IFP) of the Ministry of Finance of the Slovak Republic (MFSR, 2024a).

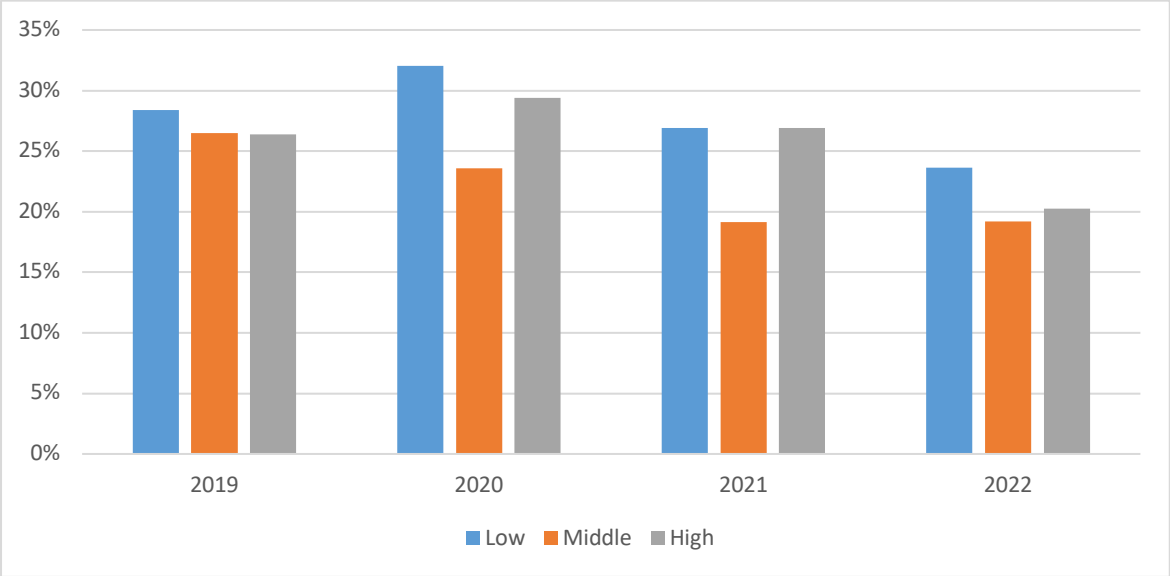
Table 1. Average annual income per HBS sample household member, by income groups (€)

Income group	2019	2020	2021	2022
Low	3,991	4,584	5,030	5,928
Medium	6,008	6,798	7,323	7,013
High	9,654	11,173	12,056	10,558

Source: HBS – waves 2021 and 2022

The underlying database was disaggregated into weighted terciles according to the income per household member. Selection of the three income groups was motivated by the relatively low number of unique observations contained in the data. During the period of interest, low-income households experienced the most significant increase in average income per household member (almost a 50-percent increase, possibly due to the increase in the minimum wage from 520 €/month in 2019 to 646 €/month in 2022). This increase reduced income difference between low- and middle-income households by more than 46 percent—from more than 2,000 € to approximately 1,100 € per household member over the period from 2019 to 2022 (Table 1).

Figure 1. Prevalence of smoking in HBS sample households, by income group



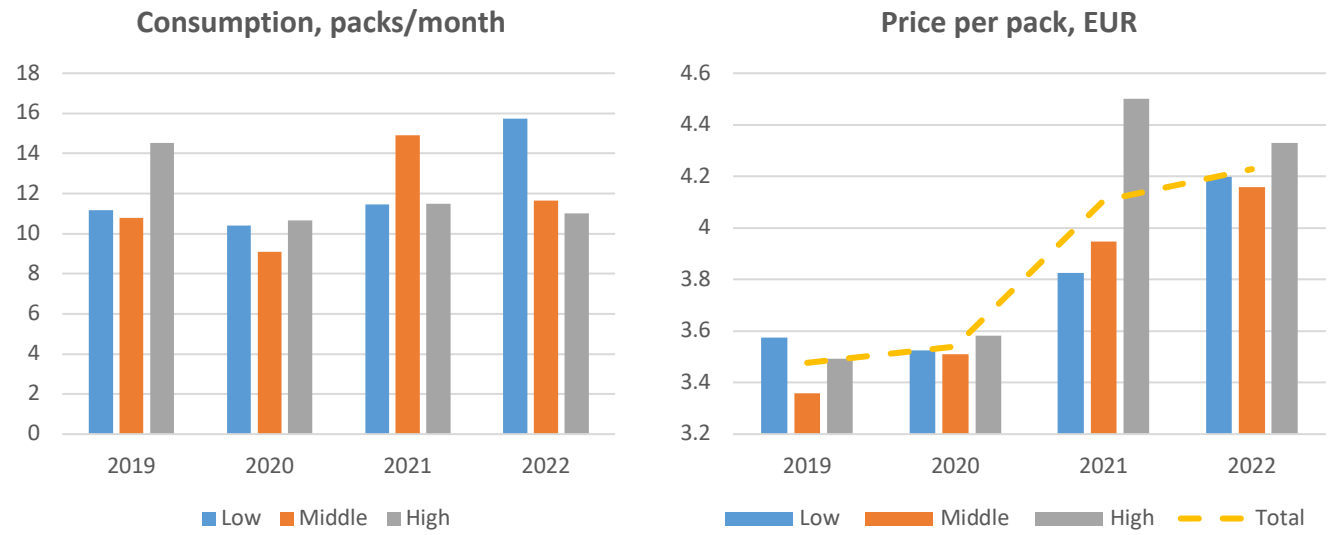
Source: HBS – waves 2021 and 2022

Descriptive statistics in the following paragraphs disaggregated by the year of data collection are based on the HBS sample.[8] However, this detailed presentation of data is not representative of the full population and, thus, should be regarded with caution. Data on the consumption of manufactured cigarettes indicate decreasing prevalence

[8]Descriptive statistics are based on the first appearance of 3,288 households for which Survey on Income and Living Conditions ID variable was available.

for all income groups. Interestingly, the lowest prevalence is found among middle-income households. In this group, approximately 19 percent of households reported non-zero expenditures on cigarettes in 2022. As the sample from which household prevalence across income groups is measured can be considered very limited, this trends need to be verified in the future. Data suggest that the highest prevalence of smoking can be attributed to the low-income group of households, at about 25 percent on average (Figure 1).

Figure 2. Consumption per household (left panel, packs of cigarettes per month) and price per pack of cigarettes (right panel, €, market prices), by income group



Note: Prices presented in the table are based on unit values calculated from HBS data in current prices.
Source: HBS – waves 2021 and 2022

Reductions in smoking prevalence during the observed period (2019–2022) partially result from cigarettes price increases starting in 2021. An additional explanation of the decreasing prevalence across all household income groups is the growing popularity of alternative tobacco and nicotine products, such as heated tobacco products, which was noted by Hudcovský & Morvay (2024). In the case of general non-smoker prevalence, the aforementioned authors hypothesized that its decrease in this period might have been associated with the spread of COVID-19.

Differences in the prices of cigarettes consumed among the income groups are rather low on average, specifically in the case of low- and middle-income groups (**Figure *2***, right panel). The data for the year 2022 show that the difference between prices of cigarettes smoked by high-income and other income groups was only around 0.10 € per pack.

Data on the intensity of smoking, proxied by the number of packs of manufactured cigarettes consumed at the household level per month (**Figure *2***, left panel), indicate that between 2021 and 2022 middle- and high-income households reduced smoking intensity in reaction to the price increases. On the other hand, in the case of low-income households the intensity increased sharply. There are multiple possible explanations for the sharp increase in consumption among low-income households ranging from increasing affordability, switching to cheaper brands, or quitting by casual smokers (with low intensity of smoking). Importantly, affordability over the period in focus for the low-income group increased the most, as documented in the constant price-per-pack decrease (Figure A1 in the Appendix). However, as the sample size from which the increase in intensity was calculated is rather low, its validity should be tested with future waves of HBS data.

Methods

Estimation of elasticities

To estimate the elasticities of tobacco consumption in Slovakia, we expect to deviate significantly from Deaton's model, suggested by the *Updated Toolkit on Using Household Expenditure Surveys for Research in the Economics of Tobacco Control* (John et al., 2023). This is unfortunately necessary due to Slovak legislation passed in 2004 that prohibits selling a pack of cigarettes to the end user for a price different than the one printed on the seal of the packaging. Since the key assumption of cigarette spatial variation in Deaton's model can, thus, hardly be justified in the conditions of Slovakia, two alternative approaches widely used in the literature are considered instead.

Quadratic Almost-Ideal Demand System (QUAIDS)

The first option which was utilized to estimate own-price and expenditure elasticities involves the QUAIDS. The application presented in this report builds on that of Cupák and Tóth (2017), Lichner and Petríková (2014), and Dybczak et al. (2014), all of which used the QUAIDS to estimate consumption elasticities in similar contexts. From a theoretical point of view, the applied approach employs methods described by Banks et al. (1997), which incorporates quadratic Engel curves into the almost-ideal demand system (AIDS) model proposed by Deaton and Muellbauer (1980).

The QUAIDS model can be specified using an indirect utility function:

$$\ln V^h = \left(\left[\frac{\ln m^h - \ln a\ (\boldsymbol{p}, \boldsymbol{z^h})}{b\ (\boldsymbol{p},\ z^h)} \right]^{-1} + \lambda\ (\boldsymbol{p}, z^h) \right)^{-1} \qquad (1)$$

where p is a vector of prices, z^h are household demographic factors, and m^h are total household expenditures. A more detailed description of the underlying methodology can be found, for example, in the works that are mentioned in the first paragraph of this section.

As a result of mentioned issues with estimating intensity elasticity using the Deaton model, the QUAIDS model was used to estimate total own-price and budget elasticities of cigarette consumption in Slovakia by household income groups.

For the estimation of the QUAIDS demand system, we employed a STATA routine by Lecocq and Robin (2015), which represents an extension of the previous implementation of Poi (2012). The applied routine has several advantages, among which are computation time and possibility to control for endogeneity by the introduction of instrumental variables. An estimator of iterated linear least-squares developed by Blundell and Robin (1999) is used in the presented application.

An additional data limitation regarding QUAIDS was that the quantities consumed were only available for foods, beverages, and tobacco products. For the remaining categories data on quantities are not collected, thus, in the model application, we built on the works of Dybczak et al. (2014) and König and Dovaľová (2016), who faced similar issues. Those authors used price indexes for the consumption groups for which

quantities were not available and, on the basis of unit values, calculated the respective (pseudo-)indexes.

In this application, weighted averages of the price indexes for consumption groups were calculated according to the sub-group expenditure shares and month of surveying. The resulting price indexes reflect the demand structure of households and thus partially cover variability in household tastes, which partly reflect the suggestion of Castellón et al. (2015) to construct household-level prices. However, it is worth noting that Menon et al. (2017) argue against the use of aggregate price indexes as they are generally highly correlated, may suffer from endogeneity, and the estimated elasticities are often not coherent with the theory. Finally, to ground the estimates of the own-price and expenditure elasticities in constant values, the monthly price indexes for all consumption groups were deflated by the overall inflation monthly index.

Simulation of budgetary and consumption effects

To simulate the budget revenues and cigarette demand effects, we employed a simple calculation as described in Lichner and Ostrihoň (2024). The notation of the method used is as follows:

$$Dt{+}1 = Dt{*}(1{+}\xi p{*}\Delta p[\%]{+}\xi i{*}\Delta i[\%]) \qquad (2)$$

where Dt+1 is the new demand, Dt is the demand in year t, ξp and ξi are price and income elasticities, while Δp[%] and Δi[%] represent the percentage increases of prices and income.

To account for the uncertainty of the estimated coefficients of the elasticities, we employed the Monte Carlo simulation approach and added, on top of the elasticity point estimates (price and expenditure), a randomly selected value from the estimated standard deviation. The random draw was repeated 1,000 times, and the low and top quartile[9] values of the demand were selected as the confidence interval, presented in the Results section.

Estimated values of price and expenditure elasticities were used to calculate reactions of different household income groups to a hypothetical increase of the specific excise

[9] Namely, consumption at the 25th and 75th percentiles.

duty rate on cigarettes by 10 percent. Since the utilized stochastic simulation does take into account the uncertainty of individual elasticity estimates, we utilize both statistically significant and statistically insignificant results together with corresponding standard errors. Statistically insignificant elasticities are expected to produce simulation results with higher spreads in expected consumption, which, thus, should be more indistinguishable from the baseline. From this perspective, the simulations should reflect the insignificance observed during the estimation. To obtain further insight into the recent changes in Slovak tobacco taxation, the following baseline scenario assumptions were taken into account:

- Consumption of cigarettes in the baseline, obtained from the data of Tax Returns - Tobacco Products (Ministry of Finance, 2024a) for the months February 2021 – January 2022, is 6.27 billion sticks (313.6 million packs).[10]
- Households' consumption growth rate[11] in 2021 is 2.7 percent, based on macro-economic data from the Ministry of Finance (2024b).
- Weighted average retail price of cigarettes (WAPC) per pack is 3.94 € (2021).
- The policy measure examined is the hypothetical 10-percent growth in the specific duty with the assumption of no change in net-of-tax prices. This translates into 6.3-percent growth in WAPC per pack (4.19 €).

The disaggregation of cigarette consumption by income group is not available based on administrative data from the Ministry of Finance. Therefore, we used the 2021–2022 HBS waves to estimate shares of cigarette consumption by income group. The resulting structure indicates that demand is driven by the high-income group, which comprises approximately 36 percent of cigarettes consumed.

[10] Data for the year 2021 are used to reflect the fact that elasticities are estimated on the constant values of expenditures for the year 2021. The excise calendar affects the tobacco tax rates in February, so 12 months starting in February were opted as the preferred alternative to the calendar year.
[11] As a proxy for household expenditure change.

Results

In this part of the report, the results of the QUAIDS elasticity estimation approach are presented together with simulations of possible consumption and cigarette taxation for the QUAIDS approach. However, the alternative two-part model (2PM results are not that far off from the QUAIDS elasticity estimates, which is why they are reported in the Appendix as supplementary information.

The prices per pack presented in **Figure 2**, based on surveyed cigarette unit values in market prices, rise throughout the observed period for all income groups. On the other hand, cigarette unit values based on constant prices, presented in Figure A1 in the Appendix, on average diminish over time for all-income groups, indicating growing affordability in real terms. As mentioned earlier, the data in constant prices are used for estimation of both approaches. For a more comprehensive understanding of the results obtained and to avoid any confusion, please refer to price and total expenditure developments in constant terms depicted in Figure A1 and Figure A2 in the Appendix.

Quadratic Almost-Ideal Demand System

QUAIDS models the overall consumption as a system of equations describing the complete demand of households, not only the consumption of cigarettes. This also allows the cross-relations with other consumption items to be taken into account.

The consumption data from the Household Budget Survey were disaggregated into 11 commodity/service groups. The division of the categories was mainly in line with the work of Dybczak et al. (2014), and also to reflect the focus of our analysis the “other tobacco products” group was distinguished.[12] The resulting composition of consumption groups is as follows: 1) Food and beverages, (2) Alcohol, (3) Factory-made cigarettes, (4) Other tobacco products, (5) Clothing, (6) Energies, (7) Furniture and home electronics, (8) Health and body care, (9) Education and leisure, (10) Transportation and communication, and (11) Other products and services.

[12] However, almost all elasticity estimates for this category were not significantly differing from zero. The only exception was expenditure elasticity for high-income group (0.581**). It is important to stress that share of expenditures on other tobacco products only formed between 0.1-0.2% of total household expenditures on average.

Estimated elasticities vary across the income levels with more distinct differences present in the case of own-price elasticity. The differences between the expenditure elasticities are not so significant. The most reactive to the price changes seems to be the middle-income group, which also appears to be reflected in the decreasing prevalence among this group of households in the majority of years under analysis.

Table 2. Own-price and expenditures total elasticity estimates by income groups, QUAIDS

	Low-income households	Middle-income households	High-income households	All households
Total own-price elasticity	-0.968**	-1.394***	-0.340	-0.760***
	(0.436)	(0.384)	(0.290)	(0.218)
Total expenditure elasticity	1.051***	1.746***	1.475***	1.329***
	(0.199)	(0.212)	(0.189)	(0.116)
N. of Obs.	1,145	1,221	1,272	3,638

Note: Corresponding standard errors are reported in parentheses, and the statistical significance at the 0.1, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

The results indicate that high-income households are not significantly affected by the level of price changes, which might stem from a decrease in real prices that occurred during the period 2019–2022 (Figure A1 in the Appendix). In other words, the combination of the expenditure (income) development (Figure A2 in the Appendix) with tobacco price changes did not influence the overall level of consumption of this group of households. The impact of price on cigarette consumption is negative and significant in the case of middle- and low-income[13] households.

To test the robustness of the estimated elasticities resulting from the QUAIDS estimation procedure two alternative samples were utilized: a sample excluding the observations from the year 2018 and a sample without outliers (top and bottom percentile) of income per household member and quantity of cigarettes purchased.[14]

[13] Only at 5% level of significance.
[14] Bottom and top percentiles of non-zero cigarette consumption households were eliminated.

The results indicate rather stable estimates for total population and medium- and high-income groups of households (**Table *3***).

Table 3. Robustness of own-price and expenditures total elasticity estimates, QUAIDS

		Low-income households	Middle-income households	High-income households	All households
without outliers	Price	-0.559	-1.347***	-0.359	-0.648***
	Expenditure	0.998***	1.467***	1.503***	1.185***
	n. of obs.	1,097	1,193	1,225	3,515
without 2018	Price	-0.893**	-1.418***	-0.378	-0.740***
	Expenditure	1.027***	1.803***	1.488***	1.336***
	n. of obs.	1,102	1,178	1,228	3,508

The results presented in **Table *2***, above, entered the formula (2) used for the conducted simulation exercise. In terms of total expenditure elasticities (**Figure *3***), the middle-income households seem to react most profoundly to changes in their incomes and increase their consumption of cigarettes.

Figure 3. Total cigarette consumption elasticities by income groups, QUAIDS

Note: Element highlighted with intermittent pattern is insignificant at 5% level.

Source: Authors' estimates based on 2021–2022 waves of Slovak HBS data.

The most significant reaction to price in consumption is seen in the case of the middle-income group. This means that, for example, a one-percent increase of cigarette prices would result in an almost 1.4-percent decrease in cigarette consumption among middle-income households. However, this result should be interpreted with caution, as it may very likely partially reflect recent trends among smokers to transition towards alternative tobacco products rather than quit smoking. For example, in 2017 the share of current e-cigarette users according to Eurobarometer data was virtually non-existent (0 percent), while in 2023 this proportion rose to 3 percent and an additional 4 percent of Slovak respondents claimed that they are daily users of heated tobacco products.

The distribution of estimated expenditure elasticities across selected income groups is relatively similar for both methodologies. The lowest reaction to an increase in income (in this research, proxied by household expenditures) should be expected in the case of low-income households.

Simulations of demand and tax revenue impacts

Projections of the changes in consumption and revenues are based on the elasticities estimated above. Results indicate that the most evident decrease in consumption occurs in the case of the middle-income group of households as a reaction to the

growing price. However, the simulated interval of consumption for the middle-income group is not distinctly different from the baseline value. Total cigarette consumption is expected to decrease by 1.7 percent as a consequence of assumed growth of total household consumption (proxy for income level) and estimated total expenditure elasticities from 313.6 million packs. This change would be accompanied by a 6.8-percent increase in tobacco tax revenues.

Table 4. Simulation of increase in specific duty by 10%, by income groups

		Consumption			Tax revenue			
Income group	**Share in total consumption**	Baseline^{mp}	Scenario^{mp}	Change$^{\%}$	Baseline^{me}	Scenario^{me}	Change$^{\%}$	Change^{me}
Low	34.7%	108.8	105.3	-3.3%	260.6	273.7	5.0%	13.1
			[99.4; 111.3]			[258.4; 289.5]		
Middle	29.7%	93.3	89.5	-4.1%	223.4	232.8	4.2%	9.4
			[84.9; 94]			[221.9; 245.7]		
High	35.6%	111.5	113.6	1.9%	268.4	296.8	10.6%	28.4
			[109.6; 117.7]			[286.4; 307.5]		
Total		**313.6**	**308.3**	**-1.7%**	**752.4**	**803.3**	**6.8%**	**50.9**
			[299.9; 316.8]			[782.3; 826.5]		

Note: Superscript *mp* refers to millions of packs and *me* refers to millions of €. Values in brackets represent lower and upper quartiles of the estimates distribution.

Additionally, the policy measure would also have a slight restructuring effect in terms of the representation of income groups among the households of smokers. The share of low- and middle-income households among smokers would decrease. On the other hand, the position of high-income households would become more prominent, with 36.8 percent of total consumption.

Conclusions and Discussion

The main contribution of this report is that the estimated reaction in cigarette consumption to the price changes for high-income households is rather limited. This suggests that price has no impact on the high-income group and that affordability increased significantly during the period studied. To account for the uncertainty of the elasticity estimates in the fiscal simulation part, an ancillary contribution is the incorporation of the standard errors of estimates into Monte Carlo simulations.

The simulation of the 10-percent increase in the specific duty indicates that this change would affect all household income groups in a significant way, as the majority[15] of them would lower their consumption of cigarettes, on average. According to obtained elasticity estimates, the total number of cigarettes consumed would decrease, while at the same time total tobacco tax revenues would increase. However, when accounting for the uncertainty of elasticity estimates, simulations indicate a possible slight increase in total consumption (316.8 million packs for the 75th percentile of the results distribution). This might indicate that affordability for certain groups of households would outweigh the expected decreases from the simulated changes in price. The analysis regarding price formation assumes that a hypothetical increase of the specific duty by 10 percent would translate into a 6.3-percent growth in price, while the corresponding tax burden would remain on the low-income and high-income households with slight restructuring towards high-income households.

To foster behaviors of decreasing consumption among Slovak households across all income groups, an increase in taxes of at least 10 percent is needed to motivate households to decrease their consumption in the following year. It is possible that the effect of a one-time change would diminish over time due to potential living standards growth. Therefore, it is important to introduce other measures as well to improve the effectiveness of tobacco duty increases, as the growing affordability of cigarettes might limit the impact of an isolated tax increase. Such measures should include focusing on youth awareness about potential addictiveness and harmfulness of smoking as well as important risk factors of smoking initiation (Atem et al., 2024).

[15] With the only exception of high-income households for which simulations suggest possible increases at a higher margin.

The results of this study support a recommendation to public authorities to foster both fiscal and non-fiscal policies to address tobacco use. The additional funds earned through increased government revenue from the tobacco product duties (both specific and ad-valorem rate) can be used to stabilize public finances and create resources for implementation of non-fiscal tobacco control measures, including education and promotion of healthy lifestyles. The results obtained in this report suggest that the change in the overall excise rate should be at least 10 percent to stimulate households to decrease their consumption across all income groups in the following period. However, it should be kept in mind that sharp increases in the availability of alternative products should limit the scope of the consumption reduction, thus authorities should also impose taxation on such products to complement taxes on traditional tobacco and nicotine products.

Among the main limitations of this study, the relevant data availability stands out. The results are significantly shifted by the inclusion of a limited number of outliers. An additional limitation of the results presented in this study is the lack of data covering new smoking products such as heated tobacco products, e-cigarettes, and nicotine pouches. Tobacco users could be shifting away from cigarettes to other tobacco products. Inclusion of future rounds of surveyed households and utilization of scanner data in future research in this area should provide deeper insights into these topics.

References

Act No. 530/2023 Coll. on amending certain laws in connection with the improvement of the state of public finances. Available on: https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2023/530/20231231.html

Atem, F.D., Bluestein, M.A., Chen, B., Harrell, M.B., Messiah, S.E., Kuk, A.E., & Pérez, A. (2024). Application of inverse weighting analysis to assess the association of youth perceptions with the age of initiation of tobacco products. *Frontiers in Public Health*, 12:1203631. doi: 10.3389/fpubh.2024.1203631

Austria, M. S., & Pagaduan, J. A. (2019). Are Filipino smokers more sensitive to cigarette prices due to the sin tax reform law?: A difference-in-difference analysis. *DLSU Business and Economics Review, 28*(2), 10-25.

Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Review of Economics and Statistics, 79*(4), 527-539.

Benda Prokeinova, R., & Hanova, M. (2016). Modelling consumer's behaviour of the meat consumption in Slovakia. *Agricultural Economics, 62*(5), 235-245.

Blundell, R. & J.-M. Robin. (1999). Estimation in large and disaggregated demand systems: An estimator for conditionally linear systems. Journal of Applied Econometrics, 14, 209–232.

Castellón, C. E., Boonsaeng, T., & Carpio, C. E. (2015). Demand system estimation in the absence of price data: An application of Stone-Lewbel price indices. *Applied Economics*, 47, 553–568.

Cizmovic, M., Mugosa, A., Kovacevic, M., & Lakovic, T. (2022). Effectiveness of tax policy changes in Montenegro: Smoking behaviour by socio-economic status. *Tobacco Control, 31*(Suppl 2), s124-s132.

Cheng, K. J. G., & Estrada, M. A. G. (2020). Price elasticity of cigarette smoking demand in the Philippines after the 2012 Sin Tax Reform Act. *Preventive Medicine*, 134, 106042.

Cupák, A., Pokrivčák, J., & Rizov, M. (2015). Food demand and consumption patterns in the new EU member states: The case of Slovakia. *Ekonomický časopis, 63*(4), 339-358.

Cupák, A., & Tóth, P. (2017). Measuring the efficiency of VAT reforms: Evidence from Slovakia (No. WP 6/2017). Research Department, National Bank of Slovakia.

Deaton, A. (1997). *The analysis of household surveys: A microeconometric approach to development policy.* Johns Hopkins University Press, Baltimore

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review, 70*(3), 312-326.

Dybczak, K., Tóth, P., & Vonka, D. (2014). Effects of price shocks on consumer demand: Estimating the QUAIDS demand system on Czech household budget survey data. *Czech Journal of Economics and Finance, 64*(6), 476-500.

European Commission. (2017). Special Eurobarometer 458. *Attitudes of Europeans towards tobacco and electronic cigarettes.*

European Commission. (2023). Special Eurobarometer 539. *Attitudes of Europeans towards tobacco and electronic cigarettes.*

Eurostat. (2023). *Household Budget Survey 2020 Scientific-use files User Manual*. Version 1, 12 July 2023. https://ec.europa.eu/eurostat/documents/203647/7610424/HBS_2020_User+manual_22+countries.pdf/e7e13803-03d6-292d-07bd-432b48a358b3?t=1692628728272

Gligorić, D., Kulovac, D. P., Mićić, L., & Pepić, A. (2022). Price and income elasticity of cigarette demand in Bosnia and Herzegovina by different socioeconomic groups. *Tobacco Control, 31*(Suppl 2), s101-s109.

Homaie Rad, E., Pulok, M. H., Rezaei, S., & Reihanian, A. (2021). Quality and quantity of price elasticity of cigarette in Iran. *The International Journal of Health Planning and Management, 36*(1), 60-70.

Hudcovský, M., & Morvay, K. (2024). *Landscape view of the tobacco market in Slovakia*. Report.

Hupková, D. (2016). *Estimating interaction between income and expenditures for food and non-alcoholic beverages in Slovakia*. Proceedings of the International Scientific Days 2016 The Agri Food Value Chain—Challenges for Natural Resources Management Society.

Hupkova, D., Bielik, P., & Turčeková, N. (2009). Structural changes in the beef meat demand in Slovakia and demand elasticity estimation. *Agricultural Economics, 55*(8), 361-367.

Jamrich, M., & Pokrivčák, J. (2018) Sensitivity of Slovak demand for cigarettes to price change. International Scientific Days 2018: Towards Productive, Sustainable and Resilient Global Agriculture and Food Systems: Proceedings.

John, R.M. (2008). Price elasticity estimates for tobacco products in India. *Health Policy and Planning*, 23, 200–209. doi:10.1093/heapol/czn007

John, R.M., Vulovic, V., Chelwa, G., & Chaloupka, F.J. (2023). *Updated toolkit on using household expenditure surveys for research in the economics of tobacco control.* A Tobacconomics Toolkit. Chicago, IL: Tobacconomics, Institute for Health Research and Policy, University of Illinois Chicago. www.tobacconomics.org

König, B., & Dovaľová, G. (2016). Trends in household consumption inequalities in Slovakia: Empirical evidence. *Ekonomický časopis, 64*(3), 238-259.

Kubicová, Ľ., Kádeková, Z., Nagyová, Ľ., & Stávková, J. (2011). The income situation of the private households and its impact on the food consumption in the Slovak Republic. Acta Univ. Agric. Silvic. *Mendelianae Brun, 59*(7), 217-224.

Lecocq, S. & Robin, J. M. (2015). Estimating almost-ideal demand systems with endogenous regressors. The Stata Journal, 15(2), 554-573.

Lichner, I., & Ostrihoň, F. (2024). *Estimation of price and income elasticity of demand for tobacco cigarettes in Slovakia* (Tobacconomics Working Paper No. 24/4/1). Tobacconomics. www.tobacconomics.org/research/estimation-of-price-and-income-elasticity-of-demand-for-tobacco-cigarettes-in-slovakia-working-paper-series

Lichner, I., & Petríková, K. (2014). Odhad výdavkových elasticít pomocou modelu QUAIDS–prípad Slovenska. In *Forum Statisticum Slovacum*, 10, 150-156.

Menon, M., Perali, F., & Tommasi, N. (2017). Estimation of unit values in household expenditure surveys without quantity information. *Stata Journal*, 17, 222–239.

Ministry of Finance. (2024a). *Tax returns - Tobacco products*. https://www.mfsr.sk/files/archiv/53/Tax_returns_tobacco_products_EN_2024_10_15.xml

Ministry of Finance. (2024b). Makroekonomická prognóza (september 2024)/Macroeconomic forecast (September 2024). https://www.mfsr.sk/files/archiv/16/Makro_tabulka_MV_13sep2024.xlsx

Poi, B. P. (2012). Easy demand-system estimation with QUAIDS. The Stata Journal, 12(3), 433-446.

Rizov, M., Cupak, A., & Pokrivcak, J. (2014). *Food security and household consumption patterns in Slovakia.*

Roodman, D. (2008). cmp: Stata module to implement conditional (recursive) mixed process estimator. Statistical Software Components S456882, Department of Economics, Boston College. http://ideas.repec.org/c/boc/bocode/s456882.html

Verguet, S., Kearns, P.K.A., & Rees, V.W. (2021). Questioning the regressivity of tobacco taxes: A distributional accounting impact model of increased tobacco taxation. *Tobacco Control*, 30, 245–257. doi:10.1136/tobaccocontrol-2019-055315

Vladisavljević, M., Zubović, J., Đukić, M., & Jovanović, O. (2021). Inequality-reducing effects of tobacco tax increase: Accounting for behavioral response of low-, middle-, and high-income households in Serbia. *International Journal of Environmental Research and Public Health, 18*(18), 9494.

Zubović, J., Vladisavljević, M., Gjika, A., Zhllima, E., Imami, D., Gligorić, D., Mićić, L., Preradović Kulovac, D., Pepić, A., Prekazi, B., Pula, E., Trajkova Najdovska, N., Mugoša, A., Čizmović, M., Laković, T., Popović, M., Đukić, M. & Jovanović, O. (2019). *Impacts of tobacco excise increases on cigarette consumption and government revenues in Southeastern European countries* [Report]. IES. https://www.tobacconomics.org/files/research/561/Regional-report-2019.pdf

Zare, S., & Zheng, Y. (2021). Consumer preferences for e-cigarette flavor, nicotine strength, and type: Evidence from Nielsen Scanner data. *Nicotine & Tobacco Research*, 823–828. doi:10.1093/ntr/ntaa238

Zhai, Z., Zhang, L., Hou, X., Yang, Q., & Huang, Z. (2023). Price elasticity of electricity demand in China: A new instrument variable based on marketization policy. *Energy for Sustainable Development*, 76, 101275.

Appendix

Two-part model

The two-part model (2PM), suggested by the *Updated Toolkit* (John et al., 2023), is the general framework for the second of the alternative approaches applied to Slovak data. Specifically, the *Updated Toolkit* (John et al., 2023) advises that a standard binary-choice model is used in the first part for estimating smoking prevalence and, separately, Deaton's model (1997) is used in the second part for cigarette demand, conditional on the individual being a smoker. Because of the violation of key assumptions of Deaton's model (1997), mentioned above, the second part of the approach is filled with the standard linear regression model. Although our methodology largely follows the guidance of the *Updated Toolkit* (John et al., 2023), the exposition deviates from it to accommodate this change. We also draw from the presentation of methodology by Cizmovic et al. (2022) and Wooldridge (2010).

Hence, the first part of the 2PM in our application takes the form:

$$\begin{aligned} \mathrm{P}(y_i > 0|p_i, i_i, \boldsymbol{x}_i, \boldsymbol{z}_{1i}) &= \mathrm{P}(Y_i = 1|p_i, i_i, \boldsymbol{x}_i, \boldsymbol{z}_{1i}) \\ &= \mathrm{P}(Y_i^* > 0|p_i, i_i, \boldsymbol{x}_i, \boldsymbol{z}_{1i}) \\ &= \mathrm{P}(e_i > -\theta_1 p_i - \vartheta_1 i_i - \boldsymbol{x}_i\boldsymbol{\beta}_1 - \boldsymbol{z}_{1i}\boldsymbol{\gamma}_{11}|p_i, i_i, \boldsymbol{x}_i, \boldsymbol{z}_{1i}) \\ &= \Phi(\theta_1 p_i + \vartheta_1 i_i + \boldsymbol{x}_i\boldsymbol{\beta}_1 + \boldsymbol{z}_{1i}\boldsymbol{\gamma}_{11}) \end{aligned} \quad \text{(A1)}$$

where, in equation (A1) y_i stands for cigarette consumption of the household *i*; Y_i is an indicator variable taking the value of 1 if cigarette consumption of household *i* is positive; Y_i^* is the latent variable obtaining positive values if we observe cigarette consumption of household *i*; e_i is a normally distributed variable; p_i and i_i are prices and total household expenditures, respectively; $\mathbf{x}_i$ represents the vector of additional covariates used in the analysis and $\mathbf{z}_{1i}$ the vector of potential additional explanatory variables identifying the selection equation. Following Austria and Pugadan (2019), urbanization dummies were used for this purpose. Jamrich and Pokrivčák (2018) utilized the prevalence of alcohol consumption in a similar manner, which inspired us to consider it also in our case.

Given the assumption that the random variable e_i in (A1) has a normal distribution, the binary choice model of probability that the household *i* has positive cigarette consumption is estimated as a probit model. However, since many of the households are surveyed multiple times over the examined period (see Data section, footnote 6),

the crucial assumption of observation independence is very likely violated. Because of this, all the results of the 2PM are relegated to a role of supplementary information to the previously described QUAIDS approach.

The second part of the 2PM takes the form:

$$y_i = \theta_2 p_i + \vartheta_2 i_i + \boldsymbol{x}_i \boldsymbol{\beta}_2 + u_i \quad \text{if } y_i > 0 \tag{A2}$$

In equation (A2), u_i represents the error term. The parameters θ_2, ϑ_2, $\boldsymbol{\beta}_2$, and $\boldsymbol{\gamma}_2$ estimated by ordinary least squares (OLS) are allowed to differ from parameters θ_1, ϑ_1, $\boldsymbol{\beta}_1$, and $\boldsymbol{\gamma}_1$ in equation (A1) estimated as the first part of the approach.

Although the primary guideline of the *Updated Toolkit* (John et al., 2023), Deaton's model, is hardly applicable in the conditions of Slovakia, outlined procedures for validation of econometric models were all used during the phase of model selection and verification. Namely, all models were tested for joint statistical significance of all estimated parameters compared to an alternative model featuring only a constant, which was the F-test in the case of the OLS models and the likelihood ratio test for probit models. The specification link test and the variance inflation factor (VIF) were used for models estimated by both the OLS and probit techniques.

Following the *Updated Toolkit* (John et al., 2023), the Hosmer-Lemeshow goodness-of-fit test with 10 groups was used for the verification of probit models. Depending on the nature of the model, a suitable analogue for the coefficient of determination was computed to assess the goodness of fit, specifically, common R^2 in case of OLS and McFadden's pseudo R^2 for probit models. Additionally, the statistics for Akaike information criterion (AIC) and Bayesian information criterion (BIC) computed for all estimated models were crucial during the model selection.

The process of model selection was performed by fitting all potential specification variants from the additional explanatory variables listed in the previous section using the entire sample of households. Subsequently, the statistical tests used for the verification of models (that is, Hosmer-Lemeshow goodness-of-fit test, specification link test, and VIF) were computed along with the aforementioned information criteria (AIC and BIC). Models which satisfied the Hosmer-Lemeshow goodness-of-fit test and

the specification link test were ranked according to the information criteria and subsequently evaluated by income groups.

In the end, the specification with the lowest BIC for smoking prevalence was selected as the main specification. Corresponding models were able to pass the Hosmer-Lemeshow goodness-of-fit test and the specification link test for all income groups, although the mean VIF was considerably high for high-income households.

Furthermore, the suggested 2PM framework was extended to allow the verification of the assumption of independence between the first and second part of the approach. This was empirically verified by expanding the framework into a Heckman sample-selection model, which was obtained using Roodman's (2008) conditional recursive mixed-process estimator. This step allowed for the correlation between e_i from equation (A1) and u_i from equation (A2) to be empirically tested by a standard Wald test.

An additional extension of the 2PM framework was in the direction of verifying the exogeneity of cluster average unit values (serving as proxies for cigarette prices) and of total household consumption expenditures (serving as proxies for household income). To accommodate this option, the 2PM framework was expanded to allow an instrumental-variable (IV) approach compatible with the already mentioned Roodman's (2008) conditional recursive mixed-process estimator. Specifically, the following first-stage equation for cigarette price was considered:

$$p_i = \boldsymbol{x}_i\boldsymbol{\beta}_3 + \boldsymbol{z}_{1i}\boldsymbol{\gamma}_{31} + \boldsymbol{z}_{3i}\boldsymbol{\gamma}_{33} + \varepsilon_i \tag{A3}$$

and household incomes were considered:

$$i_i = \boldsymbol{x}_i\boldsymbol{\beta}_4 + \boldsymbol{z}_{1i}\boldsymbol{\gamma}_{41} + \boldsymbol{z}_{4i}\boldsymbol{\gamma}_{44} + \epsilon_i \tag{A4}$$

In equations (A3) and (A4), the ε_i and ϵ_i represent random errors, $\mathbf{z}_{3i}$ a vector of instruments for cigarette price, $\mathbf{z}_{3i}$ a vector of instruments for household income, with both of these sets being different from variables identifying the selection equation—that is, $\mathbf{z}_{1i}$ in equation (A1). Drawing inspiration from Cheng & Estrada (2020), we used monthly data for the log of the nationwide excise duty floor for a cigarette (adjusted to 2021 constant prices) as a potential instrument. The instrument for total household consumption expenditures was household monetary net income. As with the sample

selection bias, the exogeneity of prices can be empirically tested by assessing the statistical significance of correlation between the error terms e_i from equation (A1) and ε_i, ϵ_i from equations (A3)-(A4), or u_i equation (A2) and ε_i, ϵ_i from equation (A3)-(A4) using standard Wald tests.

Finally, the Heckman sample-selection extension and the IV extension of the 2PM can be combined into an IV-Heckman sample-selection approach, within which it is possible to simultaneously account for endogeneity and sample selection biases. As before, correlations of respective error terms were tested using Wald tests.

Two-Part Model results

From all the specifications examined, a relatively broad model was selected for the main results. This decision was driven by the results of the specification link test and the Hosmer-Lemeshow goodness-of-fit test, as the model presented in Table A1 was able to pass both tests at the 5-percent significance level for all income groups as well as for the entire sample composed of all households when used to explain smoking prevalence. Additionally, the selected set of explanatory variables also satisfied the specification link test at the 5-percent significance level when applied to smoking intensity (see Table A2), regardless of whether the entire sample or particular income groups was examined. Nevertheless, McFadden's pseudo-R^2 appears to be rather low. However, the joint statistical significance test confirms that the specification is a statistically significant improvement to a model with an intercept only.

Despite satisfying the abovementioned criteria, the obtained mean VIF for the presented specification is rather high, with individual VIFs reaching at most a value slightly above 30 when the high-income group was examined.

Table A1. Smoking prevalence elasticity estimates by income groups

	Low-income households	Middle-income households	High-income households	All households
El. (Price)	-0.905**	-0.252	-0.112	-0.274**

	(0.394)	(0.227)	(0.200)	(0.134)
El. (Exp)	0.433***	0.664***	0.608***	0.530***
	(0.163)	(0.169)	(0.136)	(0.085)
Estimated parameters				
Log of cluster average of cigarette unit values	-0.735**	-0.179	-0.087	-0.209**
	(0.315)	(0.161)	(0.154)	(0.102)
Log of total household expenditures	0.352***	0.472***	0.470***	0.405***
	(0.131)	(0.118)	(0.104)	(0.064)
Male ratio	0.491**	0.493***	0.045	0.299***
	(0.211)	(0.174)	(0.135)	(0.093)
Adult ratio	1.161**	1.654*	-0.170	0.917**
	(0.573)	(1.004)	(1.345)	(0.445)
Household economic activity: at least one household member is employed				
at least one household member is self-employed	0.043	-0.724**	0.039	-0.119
	(0.223)	(0.305)	(0.169)	(0.119)
at least one household member is retired	-0.284*	-0.299**	-0.246**	-0.236***
	(0.158)	(0.124)	(0.122)	(0.066)
otherwise	0.038	0.128	-0.308	0.159
	(0.214)	(0.299)	(0.656)	(0.155)
Highest education attained within household: ISCED1				
ISCED2	-0.084	0.048	0.387	0.033
	(0.196)	(0.208)	(0.475)	(0.132)
ISCED3	-0.374*	-0.282	0.063	-0.284**
	(0.201)	(0.200)	(0.466)	(0.128)

ISCED4	-0.620	-0.436		-0.675**
	(0.442)	(0.418)		(0.277)
ISCED5			0.346	-0.494
			(0.856)	(0.636)
ISCED6	-0.611**	-0.741**	-0.130	-0.553***
	(0.284)	(0.299)	(0.493)	(0.168)
ISCED7	-0.683***	-0.671***	-0.201	-0.586***
	(0.225)	(0.219)	(0.469)	(0.136)
ISCED8		-0.598	-0.151	-0.600**
		(0.515)	(0.518)	(0.235)
Region: Bratislavský kraj				
Trnavský kraj	0.101	0.071	0.366**	0.268***
	(0.225)	(0.172)	(0.144)	(0.094)
Trenčiansky kraj	0.059	-0.235	0.271*	0.098
	(0.220)	(0.161)	(0.143)	(0.090)
Nitriansky kraj	0.134	0.224	0.394***	0.340***
	(0.233)	(0.153)	(0.140)	(0.090)
Žilinský kraj	-0.083	-0.099	0.381**	0.152
	(0.228)	(0.174)	(0.159)	(0.097)
Banskobystrický kraj	0.149	0.034	0.212	0.241***
	(0.216)	(0.156)	(0.134)	(0.086)
Prešovský kraj	-0.056	0.224	0.329**	0.252***
	(0.220)	(0.156)	(0.144)	(0.089)
Košický kraj	0.231	0.131	0.472***	0.356***
	(0.225)	(0.162)	(0.136)	(0.090)
Marital status	-0.155	-0.267**	-0.122	-0.164**

	(0.124)	(0.121)	(0.107)	(0.066)
Children present	0.518*	0.487	0.026	0.356*
	(0.269)	(0.371)	(0.512)	(0.189)
Residence type: one adult				
two adults	0.320*	0.342**	0.016	0.210***
	(0.191)	(0.157)	(0.123)	(0.082)
more than two adults	0.183	0.189	0.124	0.204*
	(0.246)	(0.228)	(0.163)	(0.109)
one adult with at least one child	0.111	-0.183	-0.542	-0.106
	(0.291)	(0.310)	(0.349)	(0.159)
two adults with children	-0.046	0.116	-0.158	0.009
	(0.270)	(0.267)	(0.221)	(0.128)
more than two adults with children	0.250	0.577**	0.521*	0.419***
	(0.287)	(0.275)	(0.283)	(0.140)
Constant	-5.989***	-6.810***	-5.173***	-5.602***
	(1.391)	(1.505)	(1.654)	(0.741)
N. of Obs.	946	1342	1348	3654
ll	-531.421	-646.986	-723.418	-1931.142
Pseudo R^2	0.064	0.107	0.062	0.068
VIF (Mean)	9.232	12.175	29.143	11.312
LR test	72.211	154.268	95.020	283.120
	0.000	0.000	0.000	0.000
Link test	1.150	0.395	1.071	1.794
	0.250	0.693	0.284	0.073
HL test	9.471	4.322	10.846	12.709
	0.304	0.827	0.211	0.122

Note: Table A1 presents the smoking prevalence price [El. (Price)] and income/total expenditure [El. (Exp)] elasticity estimates for low-, middle-, and high-income households as well as all available households reported in 2021 and 2022 Slovakia HBS data, using the two-part model—specifically, the probit model in the case of smoking prevalence. Corresponding standard errors are reported in parentheses, and the statistical significance at the 0.1, 0.05, and 0.01 level is indicated by "*", "**", and "***", respectively. Additionally, corresponding number of observations (N. of Obs.), values of the log-likelihood function (ll), McFadden's pseudo coefficient of determination (Pseudo-R^2), mean of obtained variance inflation factors (VIF), model joint statistical significance likelihood ratio test (LR), specification link test (Link test), and Hosmer-Lemeshow goodness-of-fit (HL) test are reported. Corresponding p-values of all the aforementioned tests are reported below each statistic.

The highest price elasticity of Slovak cigarette demand at the extensive margin was recorded for the income group of low-income households, which surpassed -0.9. Additionally, this estimate was statistically significant at the 5-percent level. Price elasticity estimates for the other income groups presented in Table A1 were statistically insignificant at the 5-percent level, as well as at the 10-percent level. However, the price elasticity of cigarette demand in Slovakia at the extensive margins based on the entire sample composed of all income groups was -0.274 and statistically significant at the 5-percent level.

On the other hand, all the estimates of the total expenditure elasticity of Slovak cigarette demand at the extensive margins are statistically significant at the 5-percent level. Of those, the highest estimate was recorded for the group of middle-income households at a value of 0.664 and the lowest for the low-income households at a value of 0.433.

Regarding the estimated parameters for other control variables used, the results appear to support the notion that men are more prone to being smokers than women, except for the case of high-income households. Another exception among high-income households is that the share of adults in the household (members older than 16 years) also generally increases the probability of the household containing smokers. All these increases are statistically significant for all examined income groups.

On the other hand, if the highest economic activity status of the household is driven by retired individuals, the probability of the household containing smokers is lower than for households whose economic status is driven by an employed individual for all individual income groups. However, this result is statistically insignificant for low-income households and the opposite and statistically significant result is achieved for the entire sample. Attainment of a higher educational level within a household appears to decrease the incidence of smokers being present in the household, with such an

effect being highly stable and statistically significant at the 5-percent level (particularly for the tertiary level of education - ISCED6 and ISCED7, except for the high-income group).

Table A2 presents the estimates for smoking intensity elasticity. The R^2 statistic indicates that the variability of the conditional cigarette demand explained by the model is rather modest, explaining almost 18 percent of the variation in the case of the group of middle-income households. Nevertheless, the F-test for the joint significance of all explanatory variables compared to an intercept model is statistically significant at the 5-percent level for all income groups.

Table A2. Smoking intensity (conditional consumption) elasticity estimates by income groups

	Low-income households	Middle-income households	High-income households	All households
El. (Price)	-0.724	-0.142	-0.417*	-0.325**
	(0.553)	(0.247)	(0.242)	(0.159)
El. (Exp)	0.434**	0.848***	0.676***	0.655***
	(0.199)	(0.199)	(0.154)	(0.099)
Estimated parameters				
Log of cluster average of cigarette unit values	-0.724	-0.142	-0.417*	-0.325**
	(0.553)	(0.247)	(0.242)	(0.159)
Log of total household expenditures	0.434**	0.848***	0.676***	0.655***
	(0.199)	(0.199)	(0.154)	(0.099)
Male ratio	0.421	-0.118	0.115	0.093
	(0.305)	(0.291)	(0.211)	(0.145)
Adult ratio	-0.092	-1.059	2.795	-0.060
	(0.785)	(1.710)	(2.199)	(0.656)

Household economic activity: at least one household member is employed				
at least one household member is self-employed	-0.487	-0.525	0.053	-0.251
	(0.302)	(0.556)	(0.247)	(0.178)
at least one household member is retired	0.265	-0.028	-0.120	0.072
	(0.205)	(0.185)	(0.198)	(0.099)
otherwise	-0.050	-0.019	-0.952	-0.067
	(0.290)	(0.445)	(1.069)	(0.221)
Highest education attained within household: ISCED1				
ISCED2	-0.065	0.668*	1.684**	0.308
	(0.263)	(0.346)	(0.779)	(0.197)
ISCED3	0.353	0.733**	1.546**	0.387**
	(0.269)	(0.337)	(0.771)	(0.193)
ISCED4	-0.259	0.932		0.307
	(0.640)	(0.728)		(0.469)
ISCED5			0.703	-0.432
			(1.341)	(1.074)
ISCED6	-0.038	0.832*	1.531*	0.308
	(0.390)	(0.495)	(0.806)	(0.251)
ISCED7	0.060	0.509	1.304*	0.117
	(0.313)	(0.368)	(0.777)	(0.204)
ISCED8		-1.918**	1.108	-0.575
		(0.885)	(0.853)	(0.375)
Region: Bratislavský kraj				

Trnavský kraj	-0.304	-0.017	0.198	0.006
	(0.366)	(0.284)	(0.222)	(0.147)
Trenčiansky kraj	-0.100	0.040	0.149	0.032
	(0.349)	(0.284)	(0.220)	(0.145)
Nitriansky kraj	-0.174	-0.217	0.068	-0.060
	(0.374)	(0.250)	(0.208)	(0.138)
Žilinský kraj	-0.145	-0.432	-0.347	-0.261*
	(0.366)	(0.294)	(0.233)	(0.153)
Banskobystrický kraj	-0.480	-0.048	-0.022	-0.163
	(0.353)	(0.263)	(0.207)	(0.137)
Prešovský kraj	-0.303	-0.218	0.090	-0.112
	(0.367)	(0.260)	(0.221)	(0.140)
Košický kraj	-0.097	-0.053	-0.280	-0.165
	(0.360)	(0.269)	(0.205)	(0.139)
Marital status	0.110	0.158	0.025	0.081
	(0.166)	(0.168)	(0.151)	(0.091)
Children present	0.243	-0.376	0.656	-0.056
	(0.362)	(0.580)	(0.771)	(0.265)
Residence type: one adult				
two adults	-0.352	-0.250	0.021	-0.038
	(0.291)	(0.241)	(0.185)	(0.123)
more than two adults	-0.053	-0.552	-0.242	-0.160
	(0.383)	(0.339)	(0.236)	(0.162)
one adult with at least one child	-0.751*	0.481	0.265	0.011
	(0.443)	(0.508)	(0.646)	(0.264)
	-0.457	-0.101	-0.047	-0.058

two adults with children	(0.384)	(0.399)	(0.352)	(0.187)
more than two adults with children	-0.581	-0.860**	-0.211	-0.341*
	(0.407)	(0.393)	(0.357)	(0.197)
Constant	2.435	0.239	-3.750	0.740
	(2.154)	(2.688)	(2.686)	(1.156)
N. of Obs.	272	309	349	930
ll	-371.245	-446.434	-493.925	-1346.394
R^2	0.155	0.177	0.166	0.105
VIF (Mean)	8.792	13.340	47.619	10.468
F test	1.722	2.231	2.368	3.756
	0.019	0.001	0.000	0.000
Link test	0.093	0.025	-0.984	0.114
	0.926	0.980	0.326	0.910

Note: Table A2 presents the smoking intensity price [El. (Price)] and income [El. (Exp)] elasticity estimates for low-, middle-, and high-income households as well as all available households reported in 2021 and 2022 Slovakia HBS data, using the two-part model. Specifically linear regression is estimated by ordinary least squares (OLS). Corresponding standard errors are reported in parentheses, and the statistical significance at the 0.1, 0.05, and 0.01 level is indicated by "*", "**", and "***", respectively. Additionally, corresponding number of observations (N. of Obs.), and values of the log-likelihood function (ll), coefficient of determination (R^2), maximal obtained variance inflation factor (VIF), model joint-statistical significance F-test, and performed specification link test (Link test) are reported. Corresponding p-values of all the aforementioned tests are reported below each statistic.

The price elasticity of cigarette demand at the intensive margin is (in absolute value) highest for the group of low-income households, which exceeds -0.7, and lowest for the group of middle-income households, at about -0.14. The average, based on the entire sample of observations is approximately -0.33. However, only the estimates for high-income households and the entire sample of households are statistically significant at the 10-percent level, and only the entire sample estimates are significant at the 5-percent level.

In contrast, the total expenditure elasticity of cigarette demand at the intensive margin is stably statistically significant at the 5-percent level, regardless of whether the entire sample or any of the income groups is examined. The highest value is found in the

case of the middle-income group, which almost reaches the value of 0.85, while the lowest is in the case of low-income households, at about 0.43. The estimate for the entire sample of households is quite close to the one for high-income households, as both elasticities are above 0.65. The increase in income would, therefore, strongly impact the middle- and high-income households in the sense of increased relative affordability of cigarettes and ensuing additional cigarette consumption.

Regarding the effects of other control variables, we may notice that the highest education attained appears to be the most distinguishing factor across income groups. While this tendency is consistent across all income groups, it is statistically significant at the 5-percent level only for middle- and high-income households. If the lower secondary education (ISCED3) is the highest attained education within middle- and high-income households, then the consumption of such households would be statistically significantly higher than of other comparable middle- and high-income households which have primary education (ISCED1) as their highest attained education.

Robustness of the 2PM results

Overall, the obtained results are fairly stable towards omitting surveys recorded during the year 2018 for both price and total expenditure elasticity of cigarette demand at both the intensive and the extensive margin. Compared to the main results, removing the top one percent of all households and the bottom one percent of households with nonzero cigarette consumption based on the amount of cigarettes consumed in each examined year, and subsequently the top and bottom one percent of households based on total consumption expenditures per household member in each examined year, leads to a considerable decrease (in absolute value) in the prevalence price elasticity estimates based on the whole sample of households and for the low-income households. Furthermore, these prevalence price elasticities estimated are statistically insignificant at the 5-percent level for the low-income group as well as when all households are examined. However, the prevalence total expenditure elasticity does not dramatically change with the removal of outliers.

In the case of the intensity price elasticity, the results for low-income households and high-income households appear to be not very dramatically affected by the removal of outliers. On the other hand, intensity price elasticity for the sample of all income groups almost doubled in magnitude, while analogous elasticity for middle-income households is more than six times what it was before the outliers were removed. Furthermore, these dramatically shifted intensity price elasticity estimates for middle-income households, and all income groups are statistically significant at the 5-percent level. In the case of low-income households and the sample of all households, the intensity total expenditure elasticity is lower when the outliers are removed from the estimation sample. The most dramatic expenditure elasticity shift is observed for the low-income households, which is almost a quarter of what it was before the removal of outliers and ceases to be statistically significant at the 5-percent level.

Lastly, additional specification assumptions were tested. After jointly estimating smoking prevalence and smoking intensity via Roodman's (2008) conditional recursive mixed-process estimator to capture potential Heckman sample-selection bias, the correlation between the error terms of the two equations was tested for the whole sample as well as for low-, middle-, and high-income household sub-samples. Similarly, the correlation between the error terms of IV equations, explaining the variation in cigarette unit values and total consumption expenditures, in either the smoking prevalence and smoking intensity equations was also examined for the whole sample and all the income group sub-samples.

To complement these tests, the two extensions of the 2PM approach (Heckman sample-selection approach and IV approach) were combined and the correlation of individual error terms was examined in an IV-Heckman sample-selection framework. The majority of these tests yielded statistically insignificant results. However, there were indications of total expenditures being endogenous for the sample of all households, decisions on the extensive and intensive margins being correlated for low-income households, and the cigarette price being endogenous when the extensive margin for high-income households was examined. Furthermore, the estimated parameters were in many cases unstable (elasticities obtaining opposing signs and values in multiples of 2PM estimates presented in Table A1 and A2). Taking into consideration potential indications of weak instruments, these results were deemed unreliable for forming any policy recommendations.

Based on the performed robustness exercises, the main results presented in Table A1 and A2 appear to be rather sensitive to described changes in the settings of the analysis. One may only hypothesize the causes for such an outcome, although the smaller sample sizes of cigarette-consuming households available for individual income groups certainly do not leave much room for experimentation. At the moment, the results in Table A1 and A2, in some respects, present the extent of insight into the issue of cigarette demand response that was possible to attain given the selected methodology and available data. Nevertheless, relatively low robustness of the results should be kept in mind when considering the outcomes of the analysis for practical policy making.

Table A3. Descriptive statistics for low-income and middle-income households

Income group (sample)	Low-income households					Middle-income households				
Variable / Statistic	Obs.	Mean	SD	Min	Max	Obs.	Mean	SD	Min	Max
Cluster average cigarette unit value (€)	953	0.22	0.30	0.12	9.22	1,344	0.24	0.55	0.12	9.22
Total expenditures on cigarettes (€)	953	153.39	371.37	0	3657.24	1,344	129.12	353.94	0	3503.81
Total quantity of cigarettes consumed (sticks)	953	777.55	1958.91	0	23040	1,344	679.65	1895.50	0	19932
Total consumption expenditures (€)	953	10419.13	6055.97	2163.12	51990.99	1,344	9798.78	5688.69	1643.72	47683.41
Household monetary net	953	13125.40	6864.12	0	43080	1,344	14262.81	7405.05	5040	54786

income (€)										
Male ratio	953	0.43	0.25	0	1	1,344	0.38	0.28	0	1
Adult ratio	952	0.84	0.21	0.25	1	1,344	0.94	0.14	0.33	1
Child present in household (dummy)	953	0.40	0.49	0	1	1,344	0.16	0.36	0	1
Average age (years)	953	46.12	20.50	12	90	1,344	57.57	17.78	16	93
Household size (person)	953	3.11	1.63	1	10	1,344	2.24	1.16	1	7
Marital status (dummy)	953	0.63	0.48	0	1	1,344	0.55	0.50	0	1
Employed ratio	953	0.23	0.24	0	1	1,344	0.26	0.32	0	1
Household economic activity (categorical)	953	1.99	1.06	1	4	1,344	2.14	1.01	1	4
Highest educational level attained within the household (categorical)	953	2.19	0.54	1	3	1,344	2.21	0.53	1	3
Highest educational level attained within the household - ISCED (categorical)	953	3.63	1.99	1	8	1,344	3.77	1.99	1	8

Household type (categorical)	953	3.54	1.77	1	6	1,344	2.54	1.58	1	6
Minimal excise duty on cigarette (€/stick)	953	0.12	0.00	0.12	0.13	1,344	0.12	0.00	0.12	0.13
Alcohol consumption prevalence (dummy)	953	0.65	0.48	0	1	1,344	0.59	0.49	0	1
Degree of urbanization (categorical)	953	1.90	0.97	1	3	1,344	1.73	0.93	1	3
Region (categorical)	953	4.81	2.18	1	8	1,344	4.42	2.33	1	8

Table A4. Descriptive statistics for high-income and all available households

Income group (sample)	High-income households					All households				
Variable / Statistic	Obs.	Mean	SD	Min	Max	Obs.	Mean	SD	Min	Max
Cluster average cigarette unit value (€)	1,358	0.23	0.43	0.14	9.22	3,655	0.23	0.45	0.12	9.22
Total expenditures on cigarettes (€)	1,358	156.30	397.37	0	4989.70	3,655	145.55	375.20	0	4989.70
Total quantity of cigarettes	1,358	762.47	1934.30	0	20555	3,655	735.95	1926.57	0	23040

consumed (sticks)										
Total consumption expenditures (€)	1,358	12363.61	7103.04	2442.89	93529.22	3,655	10913.48	6441.16	1643.72	93529.22
Household monetary net income (€)	1,358	20688.22	11169.34	6864	182628	3,655	16353.57	9490.45	0	182628
Male ratio	1,358	0.42	0.31	0	1	3,655	0.41	0.28	0	1
Adult ratio	1,358	0.97	0.11	0.4	1	3,654	0.93	0.16	0.25	1
Child present in household (dummy)	1,358	0.09	0.29	0	1	3,655	0.20	0.40	0	1
Average age (years)	1,358	50.41	15.08	15	92	3,655	51.92	18.21	12	93
Household size (person)	1,358	2.05	0.99	1	6	3,655	2.39	1.32	1	10
Marital status (dummy)	1,358	0.46	0.50	0	1	3,655	0.54	0.50	0	1
Employed ratio	1,358	0.66	0.38	0	1	3,655	0.40	0.38	0	1
Household economic activity (categorical)	1,358	1.42	0.78	1	4	3,655	1.83	1.00	1	4
Highest educational level attained within the household (categorical)	1,358	2.45	0.52	1	3	3,655	2.30	0.54	1	3
Highest educational level attained within the household - ISCED (categorical)	1,358	4.73	2.11	1	8	3,655	4.09	2.09	1	8
Household type (categorical)	1,358	2.28	1.38	1	6	3,655	2.70	1.64	1	6

Minimal excise duty on cigarette (€/stick)	1,358	0.12	0.00	0.12	0.13	3,655	0.12	0.00	0.12	0.13
Alcohol consumption prevalence (dummy)	1,358	0.64	0.48	0	1	3,655	0.62	0.48	0	1
Degree of urbanization (categorical)	1,358	1.48	0.82	1	3	3,655	1.68	0.92	1	3
Region (categorical)	1,358	3.80	2.53	1	8	3,655	4.29	2.40	1	8

Figure A1. Average price per pack, constant prices, sample used for model estimation

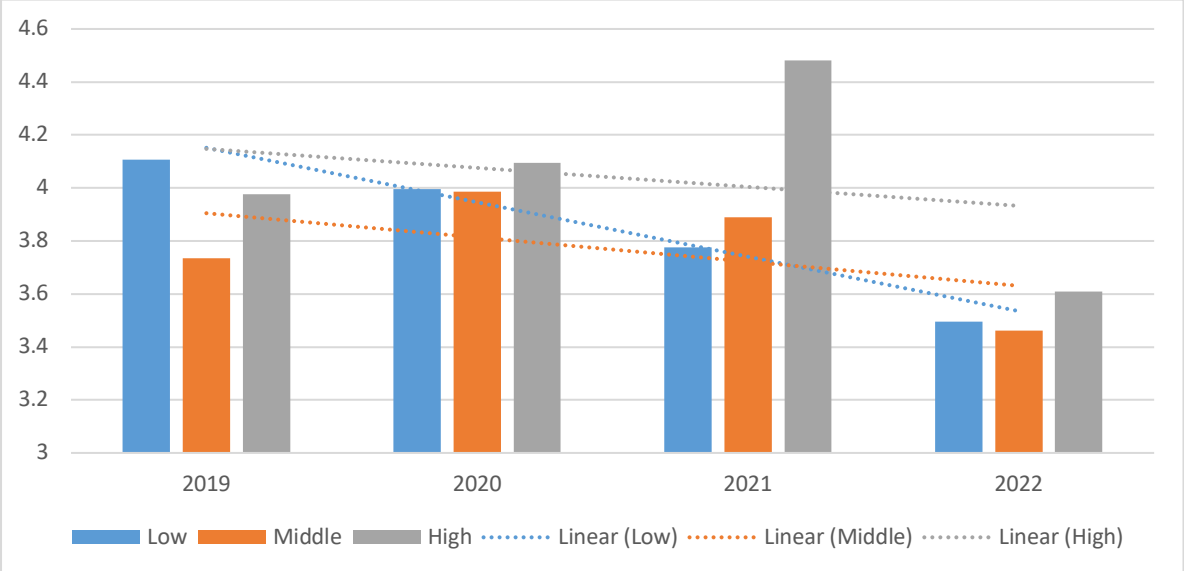


Figure A2. Average total expenditures per household, constant prices, sample used for model estimation