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# Determinants and timing of smoking initiation among adolescents in Central, Eastern and South-Eastern Europe: insights from 10 countries

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**Background:** Youth smoking initiation remains an important public health challenge in Central, Eastern and South-Eastern Europe (CESEE), where early tobacco experimenting increases the risk of long-term nicotine dependence and chronic disease. Understanding the factors that influence smoking initiation is essential for designing effective tobacco control strategies.
**Methods:** This study examined the timing and determinants of smoking initiation among adolescents aged 13–15 years in 10 countries, focusing on differences between European Union and non-European Union member states. Data from the Global Youth Tobacco Survey was processed using survival analysis method to assess the effects of cigarette prices, non-price tobacco control measures, parental smoking, peer influence, risk perception, and gender on smoking initiation.
**Results:** Higher cigarette prices were associated with delayed smoking initiation in non-European Union countries, where adolescents appeared to be more price sensitive as compared to adults. Non-price policies, especially the combined implementation of advertising bans and indoor smoking restrictions, were also associated with later initiation. European Union membership, reflected in the mandatory implementation of the Tobacco Products Directive (TPD), was associated with delayed smoking onset. Nevertheless, social influences remained dominant: peer influence was the significant predictor of earlier initiation, followed by parental smoking, while girls initiated smoking later than boys.
**Conclusion:** The findings highlight the need for comprehensive tobacco control strategies to combine fiscal and regulatory measures with interventions addressing the social drivers of adolescent smoking.

KEYWORDS
**cigarette prices, peer behavior, smoking initiation, survival analysis, tobacco control**

## 1 Introduction

Youth smoking initiation remains a major public health concern due to the early onset of nicotine dependence and its long-term consequences. Nicotine addiction is the key driver of continued tobacco use and contributes to the burden of chronic diseases later in life (1). Studies show that symptoms of nicotine dependence can occur soon after the first few smoking experiences, even before regular or daily use begins (2–4). Adolescents who start smoking early are more likely to become long-term smokers in adulthood, underlining the need for timely

prevention measures (5). Recent international evidence indicates that a substantial proportion of adolescents who have experimented with cigarettes, initiated smoking before the age of 13, while the average age of initiation has remained unchanged or declined in many countries, highlighting persistent limitations in existing prevention efforts (6). From a population-health perspective, effective prevention therefore requires evidence not only on the prevalence of tobacco use, but also on the timing of initiation and the economic, regulatory and social determinants associated with earlier or delayed uptake. These determinants operate across multiple levels, including cigarette affordability, exposure to tobacco promotion, perceived harmfulness, parental and peer behavior, and the strength of national tobacco control policies (7, 8).

The effectiveness of tobacco control strategies also depends on the characteristics of youth behavior. Previous research has shown that young people respond differently to tobacco control measures, especially price and tax increases, than adults (9, 10). Such tailored approaches are crucial for reducing youth tobacco use and smoking initiation as well as for improving public health in general. Understanding youth behavior and the determinants that shape it is important not only to reduce tobacco consumption among youth but also to prevent the initiation of tobacco use (1). Chaloupka and Pacula (9) examined the impact of price on reducing cigarette consumption among adolescents. The results show that adolescents are more sensitive to price changes than adults due to their lower disposable income, weaker addictive behavior, and higher sensitivity to peer influence. They point out that the long-term effects of cigarette price increases are even larger because price-sensitive behavior accumulates over time. These findings are consistent with the conclusions presented in the IARC Handbook on Cancer Prevention (10) that macro-level policies which increase the cost of tobacco consumption are effective tools for reducing the youth smoking prevalence (e.g., tax measures combined with consistent implementation of other tobacco control policies).

There are studies in the literature that estimate the determinants of smoking initiation in adolescents at the national level. Such studies can contribute significantly to understanding the specific behaviors of young smokers, how their decision to start smoking may be influenced, and how tobacco taxation policy can impact smoking prevalence and initiation.

The authors of most single country studies in low- and middle-income countries investigating the effects of price and non-price policies and other factors on smoking prevalence and initiation among youth aged 13–15 have used comparable methodological approaches relying on survival analysis techniques. Survival analysis is a method commonly used in medical research and recently applied in health economics research. Merkaj et al. (11) find that cigarette price is a significant predictor of smoking initiation among youth in Albania, while non-price tobacco control policies also play an important role in reducing initiation. Their results suggest that further increases in excise taxes could lead to a greater decline in smoking rates among adolescents. Mugoša et al. (12) confirm that the indirect effect of price on smoking initiation in Montenegro (operating through various demographic factors) is more pronounced than the direct price effect, indicating that price influences variables such as peer and parental behavior. Using the same methodology, Gligorić et al. (13) show that there is a negative relationship between cigarette prices and smoking initiation among youth in Bosnia and Herzegovina. Jovanović and Zubović (14) find that higher cigarette prices significantly reduce the probability of smoking initiation among students in Serbia. Moreover, non-price measures, such as awareness campaigns and access restrictions, are also effective. Jovanović et al. (15) show that cigarette prices primarily affect adolescents' smoking behavior in North Macedonia through indirect mechanisms, such as influence from peers and parents. In addition to these social factors, smoking initiation is also shaped by personal characteristics and broader societal trends.

Despite the works cited above, multi-country studies are scarce in Eastern Europe and in most low- and middle-income countries. This is also the case at the regional level. Schnohr et al. (16) used the Health Behavior in School-aged Children (HBSC) studies and national-level data to examine how contextual factors influence daily smoking among adolescents in 27 European countries. Since national policies are among the factors influencing smoking behavior, the authors decided to include three of them in the analysis: (i) prices (and national tobacco taxes), (ii) the age limit to purchase tobacco products, and (iii) smoking bans in schools. Their results confirm the association between the three mandatory bans and the risk of daily smoking, but they also call for a more detailed analysis of voluntary bans to obtain more robust results. Kostova et al. (17) used data on 349,930 adolescents (mean age 14 years) from 20 low- and middle-income countries obtained from GYTS data between 1999 and 2006. They found that price was an important determinant of both prevalence and intensity of smoking, but they did not analyse smoking initiation.

At the same time, regional studies examining the determinants of smoking initiation among adolescents are even more rare than those looking at the prevalence of smoking. Oh et al. (18) estimate the determinants of smoking initiation among young women in five European countries (mean age 18 years) and conclude that smoking peers are the most important factor influencing smoking initiation. Veeranki et al. (19) identified correlates with the age of smoking initiation among adolescents in Africa and revealed that exposure to parental/peer smoking and industry advertising significantly increase the risk of early smoking initiation among adolescents.

Overall, the findings of the small but growing number of studies from low- and middle-income countries are consistent with studies conducted in high-income countries: price has a negative effect on tobacco use among young people, while the influence on smoking initiation may be a direct or indirect (mostly peer or parental smoking) factor. As youth smoking rates in South-Eastern Europe remain alarmingly high and growing and policies are often inconsistent, there is growing interest in understanding the determinants of smoking initiation across specific regions (20). This study uses a survival analysis approach to fill this gap by examining the determinants of smoking initiation among adolescents aged 13–15 years in both EU and non-EU countries while also identifying similarities/differences between countries with a common historical and geographical background and accounting for contextual factors.

Building on the previously published wiiw HEPA Research Study No. 16 (21), this paper further improves the methodological approach and provides additional analyses to check the robustness of the results. We examine whether the relationship between cigarette prices and smoking initiation differs between EU and non-EU countries. We also estimate three additional Weibull AFT model specifications to examine the robustness of the results to the inclusion of potentially endogenous behavioral variables. In addition, we provide a more detailed interpretation of the results using AFT time ratios and discuss methodological issues related to the timing of the

observed variables, potential endogeneity, and limitations in drawing causal conclusions. Compared to (21), the Limitations section provides a detailed discussion of the methodological limitations, particularly those related to the retrospective nature of the data, potential reverse causality, and the interpretation of the estimated associations.

# 2 Materials and methods

## 2.1 Data

This paper uses data from the Global Youth Tobacco Survey (GYTS) to examine smoking initiation among adolescents aged 13–15 years in selected 10 CESEE countries. GYTS is a nationally representative school-based survey that serves as an international instrument for monitoring tobacco use among youth and assessing key indicators related to tobacco control (22). GYTS employs a globally standardized methodology that includes a two-stage cluster-sampling design. Schools are selected with probability proportional to the number of students during first stage. The classes within the selected schools are selected a systematic equal probability sample with a random start during the second stage (23). All students in the selected classes are eligible to participate in the survey. All data was processed using STATA15 software.

The sample includes young people aged 13–15 and covers both EU and non-EU countries. The GYTS datasets are public and can be used by third parties. The same methodology is applied in all countries and are therefore best suited for this research. To ensure comparability, only countries and GYTS waves with complete information relevant to our analysis were included. Because Serbia has one of the highest prevalence rates of smoking in Europe, an increasing prevalence among adolescents, and an increasing use of new tobacco and nicotine products (24, 25), the need for a comprehensive regional study becomes clear. Rather than being unique to Serbia, high smoking rates among adolescents are a general problem in the Western Balkans, where early initiation and social acceptance of tobacco use remain widespread.

Data on the Global Youth Tobacco Survey (GYTS) waves across the selected countries included in this paper are provided in Supplementary Table S1. In non-EU countries, the GYTS was conducted with wider time gaps between survey waves. Bosnia and Herzegovina has the highest number of conducted waves due to country-specific context, while the latest data available for Serbia are from 2017. In EU countries, the GYTS was conducted more often. Croatia, Romania and Slovenia conducted four waves at relatively regular intervals, while Hungary completed only two waves with no available data beyond 2008. This distribution of survey waves reflects differences in monitoring the continuity of youth tobacco use, potentially indicating varying institutional capacities, public health priorities, and levels of support for international research frameworks.

The final pooled dataset included 121,758 adolescents aged 13–15 years. Table 1 summarizes the main characteristics of the study population. The gender breakdown of the sample shows a slight dominance of female respondents among adolescents aged 13–15 in both the EU and non-EU countries included in the study. On average, girls made up 51.8% of respondents in non-EU countries and 52.7% in EU member states.

TABLE 1 Characteristics of the analytical sample.

| Characteristic | Overall | Non-EU countries | EU countries |
|---|---|---|---|
| Number of respondents | 121,758 | 73,398 | 48,360 |
| Female (%) | 52.2 | 51.8 | 52.7 |
| Mean age (years) | 14.0 | 14.1 | 13.9 |
| SD | 0.78 | 0.79 | 0.78 |
| Countries included | 10 | 5 | 5 |

Source: Jovanović and Zubović (21), HEPA Study No. 16.

When it comes to the age, respondents in the non-EU countries are slightly older on average at the time of the interview than those in the EU countries (14.1 and 13.9 years, respectively). Overall, age differences across countries were small, and the age distribution was highly comparable across the study sample. The data is shown in Supplementary Table S2.

## 2.2 Research design

In order to understand patterns of tobacco use among youth in the region, the broader regional context must be considered, especially given the historical, cultural and socio-political similarities with neighboring countries. The rationale of this study is to identify similarities and differences in youth tobacco use and the impact of legal frameworks and determinants in countries with a common historical heritage and geographical location. These findings are essential for the development of effective and evidence-based tobacco control strategies. Therefore, the analysis covers Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Hungary, Montenegro, North Macedonia, Serbia, Slovenia and Romania. This country selection allows for a unique regional analysis of youth smoking initiation and provides a valuable basis for increased regional cooperation in tobacco control. Since the regional analysis is also based on EU membership, the process of country selection selects five EU member countries (Bulgaria, Croatia, Hungary, Romania and Slovenia) and five non-EU member countries (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia).

After selecting the countries, variables were identified based on the literature review, their availability and comparability across GYTS datasets, while accounting for country-specific adaptations of the otherwise standardized questionnaire. As a result, certain variables were not available in all survey waves for all countries (e.g., parental education, pocket money, family wealth, experience of smoking in enclosed areas, anti-tobacco messages, pro-tobacco messages and promotions, teachers smoking behavior, urban/rural residence etc). This led to the selection of variables that were comparable across countries and present in all GYTS datasets (peer effects, parental behavior, risk perceptions, gender). The final dataset for this study has more than 120,000 individual records with harmonized variables for all survey waves and countries. All data were cleaned and restructured to allow modeling of time to event, with the outcome of interest being the age at which smoking initiated.

Smoking initiation was defined as the event of interest, with the corresponding time variable measuring the duration, in years, until the respondent first tried a cigarette. Respondents who had initiated smoking contributed an observed event time, whereas those who had

not initiated smoking by the time of the survey were treated as right-censored. Right-censored data refer to individuals for whom the event of interest (e.g., starting to smoke) has not occurred by the end of the observation period. We only know that it has not occurred up to a certain point in time, but we do not know whether or when it might occur later. The inclusion of such data in the survival analysis is essential, as their exclusion can distort the results. All respondents entered the risk set at the beginning of the observation period ($t = 0$), and follow-up continued until smoking initiation or the respondent's age at the time of the survey (maximum $t = 15$), whichever occurred first. This specification allowed adolescents who had not yet initiated smoking to remain in the analysis and contribute information on the timing of smoking onset.

Cigarette prices, EU membership, TPD implementation and non-price tobacco control measures variables are contextual variables, while smoking initiation is measured at the individual level. All of them were assigned to respondents according to their country of residence and the year in which the corresponding GYTS survey was conducted. Thus, all respondents from the same country and survey wave were assigned the same values of these contextual variables. This survey-year matching approach has been applied in previously pooled cross-country analyses of GYTS data, in which country-specific cigarette prices or tobacco control indicators were linked to individual respondents according to the country and year of the survey (26, 27). Thus, the final coefficients are interpreted as contextual associations rather than causal effects.

## 2.3 Variables

To explain variation in the timing of smoking initiation, the analysis considered a set of economic, policy-related, family, peer, and individual-level determinants. The main variables involved in estimating the timing and determinants of smoking initiation in this study are the following: cigarette price in international dollars (adjusted for purchasing power parity), non-price tobacco control measures (i.e., the number of non-price tobacco control measures implemented in the country), parental smoking behavior (with the influence being measured separately for mother, father or both parents), and peer influence (whether best friend offers tobacco). Risk perception is estimated by a variable indicating whether the respondent considers smoking to be harmful. Gender-, time- and country-fixed effects are included in the analysis as well.

Parental smoking behavior is estimated using the GYTS questions: 'How often do you see your father (stepfather or mother's partner) smoking in your home?' or 'How often do you see your mother (stepmother or father's partner) smoking in your home?'. We found that these questions best reflect the parental influence on smoking initiation, as opposed to the question 'Do your parents (caregivers) smoke?', which is not included in all GYTS databases.

Since the question 'Does one of your closest friends smoke cigarettes?' is not available in all GYTS databases for the selected CESEE countries, we used the question 'If one of your best friends offered you a tobacco product, would you use it?' as the best available approach to estimating the peer influence. This variable was treated as potentially endogenous because of possible reverse causality and unobserved factors. The Wald test of exogeneity rejected the null hypothesis that friend_offered could be treated as exogenous at conventional significance levels. The corresponding Wald test are presented in Supplementary Table S4. Since peer influence is an important predictor of smoking initiation, the variable was retained in the final Weibull models; however, because these models do not directly correct for its potential endogeneity, the coefficient is interpreted as a conditional association rather than a causal effect, and its magnitude should be interpreted with caution (15).

In order to estimate the effects of respondents' perception regarding the dangers of tobacco use, we used the variable (identical in all databases): 'Do you think that tobacco is harmful to your health?'. Perceived harmfulness was also considered potentially endogenous because previous smoking experimentation may influence adolescents' subsequent perceptions of tobacco-related harm. We applied the Wald test and corresponding results are presented in Supplementary Table S5. However, the harmonized GYTS data did not provide a theoretically convincing excluded instrument for this variable. It was therefore retained in the Weibull models and interpreted exclusively as a context-dependent conditional association rather than as a causal effect. The estimated effects should be interpreted with caution (14).

Parental smoking, peer influence, and perceived harmfulness were measured at the time of the survey, whereas age at smoking initiation was reported retrospectively. These variables were therefore not prospectively observed before initiation. Parental smoking was treated as a proxy for household smoking exposure because parental smoking behavior was assumed to be relatively stable over the limited age range covered by the survey. Nevertheless, changes in parental smoking status between the reported age of initiation and the survey date cannot be excluded. Peer influence and perceived harmfulness may be less stable over time and are interpreted as survey-time correlates of retrospectively reported initiation timing rather than as confirmed pre-initiation exposures.

Since tobacco control policies play a significant role in delaying smoking initiation among young people, to examine in depth the effect of various control measures we evaluated Model A, which includes three additional variables:

- EU_TPD—representing the impact of the Tobacco Products Directive (2014/40/EU),
- policy_index—capturing the composite score of individual non-price tobacco control measures (constructed following the approach developed by Ross and Al-Sadat (28), it represents the sum of the number assigned to individual non-price tobacco control measures implemented in a given year), and
- EUacc—EU membership is a dummy variable taking the value 1 if a country is an EU member and 0 otherwise

Since model A demonstrated the impact of EU membership on delaying smoking initiation among young people, we extended the analysis to examine the policies implemented in countries that have not yet joined the EU. A new categorical variable (all_policy) was introduced to capture cross-country differences in tobacco control measures in Model B. This variable encompasses three categories: (i) indoor smoking bans, (ii) advertising bans combined with indoor smoking bans, and (iii) the joint implementation of advertising bans and indoor smoking bans. They are applied in all countries observed

and have been in place long enough to allow an assessment of their impact within the group of countries included in this study.

## 2.4 Statistical analysis

In this study, survival analysis was used to examine the determinants and timing of smoking initiation among adolescents aged 13–15 years in selected CESEE countries. This methodological approach enables a distinction between respondents who had already initiated smoking and those who had not, while explicitly accounting for the timing of this behavioral transition. The analysis first employed non-parametric methods, using Kaplan–Meier and Nelson-Aalen estimators to examine the shape of the survivor and cumulative hazard functions. Based on the observed patterns and comparative model fit across exponential, Weibull, log-normal, and log-logistic specifications, the analysis proceeded with the Weibull parametric model. The Weibull specification was selected because of its flexibility in modeling hazard rates that may vary over time, unlike the exponential model, which assumes a constant hazard. The results of specifications are presented in Supplementary Table S3. Our choice of Weibull parameterization is in line with similar research results available in the literature, such as Chen et al. (29) and Breslau et al. (30).

To estimate how all these determinants affect the timing of smoking initiation, the Weibull model was specified as a function of the selected covariates. The scale parameter for individual $i$ was expressed as:

$$\lambda_i = \exp^{\left(-x_i\beta\right)}$$

where $x_i$ denotes the vector of observed covariates and $\beta$ the corresponding vector of estimated coefficients. The covariate vector included cigarette price, non-price tobacco control measures, parental smoking behavior, peer influence, perceived harmfulness of tobacco use, gender, and the relevant time and country effects. In the accelerated failure-time (AFT) specification, positive coefficients indicate a longer time to smoking initiation, corresponding to delayed onset (positive association), whereas negative coefficients indicate earlier initiation (negative association). Exponentiated coefficients are interpreted as time ratios and they are calculated for interpretation of the results. A time ratio greater than one indicates a longer time to smoking initiation, whereas a time ratio below one indicates earlier initiation.

Country-clustered robust standard errors were used in the analysis to account for potential within-country dependence among respondents and for the assignment of cigarette prices and tobacco-control policies at the country level.

The statistical analysis presented in this paper extends the methodology used in the wiiw HEPA study (21) by formally examining differences in smoking initiation determinants between EU and non-EU countries and by estimating three additional Weibull AFT model specifications to assess the robustness of policy-related effects. The analysis also considers endogeneity because peer influence and perceived harmfulness due to possible reverse temporality and unobserved confounding. In the absence of a theoretically defensible, excluded instrument in the harmonized GYTS data, no instrumental-variable correction was applied. The Weibull AFT coefficients are therefore interpreted as conditional associations rather than causal effects. To assess the sensitivity of the estimates to the inclusion of these potentially endogenous behavioral variables, we estimated three nested Weibull AFT specifications for Model A: (i) excluding both peer influence and perceived harmfulness; (ii) including peer influence (but excluding perceived harmfulness), and (iii) including perceived harmfulness (but excluding peer influence). We compared the direction, magnitude, and statistical significance of the coefficients for cigarette price, EU_TPD, and policy_index. The results of these alternative specifications are presented in Tables 2–4. The consistency of the estimated associations across these alternative specifications provides an assessment of the robustness of the findings with respect to model specification. This analysis evaluates sensitivity to covariate inclusion and does not resolve endogeneity or establish causal effects.

Both variables were nevertheless retained in the final specifications because of their substantive relevance for smoking initiation; however, given the potential bias associated with endogenous regressors in nonlinear models, the corresponding estimates are interpreted as associations rather than causal effects and their magnitude should be interpreted with caution (14, 15, 31, 32).

# 3 Results

Across the selected CESEE sample, the average age at first cigarette use was 10.8 years, with cross-country variation. Initiation occurred earliest in Montenegro (10.1 years) and latest

TABLE 2 Smoking initiation among youth in CESEE countries—Weibull distribution (sensitivity analysis—i).

| Variable | Model A<br>Coef. |
|---|---|
| Prices in international dollars (PPP adjusted) | 0.029 (0.000)*** |
| EU_Tobacco Product Directive (TPD) | 0.103 (0.000)*** |
| Policy_index | 0.013 (0.000)*** |
| Parental smoking behavior | |
| only father smoke | −0.064 (0.000)*** |
| only mother smoke | −0.096 (0.000)*** |
| both parents smoke | −0.124 (0.000)*** |
| Gender (male = 0) | 0.045 (0.000)*** |
| Time | −0.001 (0.387) |
| EUacc* | 0.021 (0.000)*** |
| _cons | 2.788 (0.000)*** |
| /ln_p | 1.355 (0.000)*** |
| P | 3.878 |
| 1/p | 0.258 |

$n$ = 121,758; Standard errors are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$; EUacc is variable for EU membership status; Country- and time-fixed effects are included in the analysis, but their coefficients are not reported to avoid overcrowding the table, they are available from the corresponding author upon request.
Source: Authors' calculations.

TABLE 3 Smoking initiation among youth in CESEE countries—Weibull distribution (sensitivity analysis—ii).

| Variable | Model A Coef. |
|---|---|
| Prices in international dollars (PPP adjusted) | 0.014 (0.008)*** |
| EU_Tobacco Product Directive (TPD) | 0.060 (0.000)*** |
| Policy_index | 0.008 (0.000)*** |
| Parental smoking behavior | |
| only father smoke | −0.064 (0.000)*** |
| only mother smoke | −0.059 (0.000)*** |
| both parents smoke | −0.071 (0.000)*** |
| Peer influence | −0.154 (0.000)*** |
| Gender (male = 0) | 0.053 (0.000)*** |
| Time | −0.004 (0.001)*** |
| EUacc* | 0.017 (0.588) |
| _cons | 2.996 (0.000)*** |
| /ln_p | 1.421 (0.000)*** |
| P | 4.143 |
| 1/p | 0.241 |

$n$ = 121,758; Standard errors are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$; EUacc is variable for EU membership status; Country- and time-fixed effects are included in the analysis, but their coefficients are not reported to avoid overcrowding the table, they are available from the corresponding author upon request.
Source: Authors' calculations.

TABLE 4 Smoking initiation among youth in CESEE countries—Weibull distribution (sensitivity analysis—iii).

| Variable | Model A Coef. |
|---|---|
| Prices in international dollars (PPP adjusted) | 0.032 (0.000)*** |
| EU_Tobacco Product Directive (TPD) | 0.102 (0.000)*** |
| Policy_index | 0.015 (0.000)*** |
| Parental smoking behavior | |
| only father smoke | −0.064 (0.000)*** |
| only mother smoke | −0.094 (0.000)*** |
| both parents smoke | −0.122 (0.001)*** |
| Risk perception/Perceived harmfulness | 0.036 (0.000)*** |
| Gender (male = 0) | 0.043 (0.000)*** |
| Time | −0.001 (0.160) |
| EUacc* | 0.017 (0.002)*** |
| _cons | 2.655 (0.000)*** |
| /ln_p | 1.357 (0.000)*** |
| P | 3.886(0.003) |
| 1/p | 0.257 (0.001) |

$n$ = 121,758; Standard errors are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$; EUacc is variable for EU membership status; Country- and time-fixed effects are included in the analysis, but their coefficients are not reported to avoid overcrowding the table, they are available from the corresponding author upon request.
Source: Authors' calculations.

in North Macedonia (11.6 years). Among EU countries, the average age ranged from 10.6 years in Croatia and Romania to 11.2 years in Bulgaria. Except for North Macedonia, all other non-EU countries are below the overall average in the sample, suggesting that young people in these countries tend to start smoking earlier than their peers in the EU. Non-EU countries often exhibit weaker enforcement of tobacco regulations, lower public health investment, and greater availability and affordability of tobacco products, all of which may contribute to earlier smoking initiation among youth in these countries (33).

Patterns of cigarette experimentation differed between EU and non-EU countries. Although the average age at initiation tended to be somewhat lower in several non-EU countries, a higher proportion of adolescents in EU countries reported having ever tried cigarettes (52.0%). The same pattern was observed for smoking in the past 30 days, reported by 20.2% of adolescents in EU countries and 9.1% in non-EU countries. These findings suggest that the timing of initiation and the overall prevalence of experimentation capture distinct dimensions of adolescent smoking behavior.

The non-parametric survival analysis, based on Kaplan–Meier (KM) survival estimates and Nelson–Aalen (NA) cumulative hazard estimates, showed that the probability of remaining a non-smoker decreased with age, with a more pronounced decline after approximately age 10. In line with this pattern, the cumulative hazard of smoking initiation increased more rapidly during early adolescence. When the sample was stratified by EU membership, adolescents in EU countries had a lower probability of remaining non-smokers and a higher cumulative hazard of initiation than those in non-EU countries, particularly after ages 10–11. This pattern is consistent with the higher prevalence of cigarette experimentation observed in the EU group.

As described in the Methods section, alternative parametric survival specifications were compared following the non-parametric analysis. Based on the Akaike and Bayesian information criteria (AIC and BIC), the Weibull model provided the best fit to the data and was therefore selected for the subsequent analysis of smoking initiation determinants (Supplementary Table S3).

The research results showed that both policy-related and social factors were significantly associated with the timing of smoking initiation. Across all three specifications presented in Tables 2–4, higher cigarette prices were positively associated with delaying smoking initiation, with time ratios ranging from 1.04 to 1.08. The tobacco control environment showed a similar pattern: implementation of the EU Tobacco Products Directive (TPD) was associated with delayed smoking initiation with time ratios ranging between 1.12 and 1.17. Similarly, the index of non-price tobacco control measures and EU membership were all positively and statistically significantly associated with later initiation in all three specifications. These results suggest that both fiscal and regulatory tobacco control measures are related to postponement of smoking initiation among adolescents.

Parental smoking was significantly associated with earlier smoking initiation, with a slightly stronger association observed when both parents smoked (time ratios ranging from 0.81 to 0.84 across model specifications). Female adolescents tended to initiate smoking later than males. The behavioral variables included in the models were also significantly associated with the timing of smoking initiation. In

Table 3, peer-related susceptibility was associated with earlier initiation (time ratio = 0.67), suggesting that adolescents who reported willingness to accept tobacco offered by a friend tended to initiate smoking earlier. In Table 4, perceived harmfulness of smoking was positively associated with the time to smoking initiation (time ratio = 1.06), suggesting that greater awareness of smoking-related health risks was associated with delayed initiation. These findings should be interpreted as associations rather than causal effects, given that the behavioral variables were measured at the time of the survey.

To assess the practical significance of the results presented in Table 3, the AFT coefficients were exponentiated and interpreted as time ratios. The coefficient for cigarette price ($\beta = 0.014$) corresponds to a time ratio of 1.014, indicating that a one-international-dollar increase in cigarette price is associated with approximately 1.4% longer time to smoking initiation, holding other variables constant. The coefficient for peer influence ($\beta = -0.154$) was associated with earlier smoking initiation, with a time ratio of 0.857, indicating approximately 14.3% shorter time to initiation among adolescents who reported willingness to accept tobacco offered by a friend. Parental smoking was also associated with earlier initiation, particularly when both parents smoked ($\beta = -0.071$), corresponding to approximately 6.9% shorter time to initiation. Finally, the coefficient for girls ($\beta = 0.053$) corresponds to a time ratio of 1.054, indicating approximately 5.4% longer time to smoking initiation compared to boys.

Among non-EU countries (Model B in Supplementary Table S10), higher cigarette prices were also positively associated with smoking initiation. To examine whether the price coefficients differ significantly between subsamples, we re-estimated the survival model using the pooled sample and included an interaction term between cigarette price and EU status. A Wald test indicates that the price coefficient differs significantly between EU and non-EU adolescents ($\chi^2(1) = 4.11$, $p = 0.043$). Non-price tobacco control measures showed statistically significant and positive associations, while the largest effect was observed when advertising bans and indoor smoking restrictions were implemented jointly. This suggests that combined regulatory measures may be more strongly associated with postponing smoking onset than individual measures implemented separately.

To estimate the practical significance of the results presented in Supplementary Table S10, we translated AFT coefficients into time ratios, as previously described. The coefficient for cigarette price ($\beta = 0.029$) corresponds to a time ratio of 1.029, indicating that a one-international-dollar increase in cigarette price was associated with an approximately 2.9% longer time to smoking initiation. The coefficient for peer influence ($\beta = -0.133$) corresponds to a time ratio of 0.875, indicating an approximately 12.5% shorter time to smoking initiation. Parental smoking behavior was also associated with earlier initiation, although the magnitude varied according to parental smoking status. When both parents smoke, the time ratio was 0.935, indicating an approximately 6.5% shorter time to initiation. Among the policy measures, the joint implementation of advertising bans and indoor-smoking restrictions showed the largest association with smoking initiation. The coefficient of 0.141 corresponds to a time ratio of 1.151, indicating an approximately 15.1% longer time to initiation relative to the reference policy category. Overall, the results suggest that the combined policy measure had greater substantive magnitude than cigarette price, while peer and parental smoking were strongly associated with earlier initiation. These conversions are illustrative, and the estimates should be interpreted as associations rather than causal effects.

This paper provides a more detailed analysis of the inconsistencies observed in the association between perceived harmfulness and smoking initiation compared to the previously published wiiw HEPA study (21). In the original models, now presented in Supplementary Tables S9, S10, the coefficient of perceived harmfulness changed from negative (−0.005) to positive (0.005), indicating that the association was not stable across specifications. To further examine this issue, additional Weibull AFT specifications were introduced in this paper, allowing us to assess the sensitivity of the results to the inclusion of potentially endogenous behavioral variables.

Overall, building on findings first reported in the wiiw HEPA study (21), the formal testing of differences in the association between cigarette prices and smoking initiation across EU and non-EU countries, together with three additional sensitivity analyses assessing the robustness of policy estimates to the inclusion of potentially endogenous behavioral variables, represents a significant contribution of this paper to the understanding of factors influencing youth smoking initiation. The overall results show that the direction of the associations between smoking initiation and cigarette prices, EU TPD implementation, and non-price tobacco control measures remains consistent across model specifications, although the magnitude of the coefficients varies. In addition to the study, in this paper all results and coefficients are analysed with more caution, without drawing causal conclusions.

## 4 Discussion and policy implications

This study examines the determinants and timing of smoking initiation among adolescents aged 13–15 years in 10 CESEE countries. By comparing EU and non-EU environments, it extends existing evidence on youth smoking initiation and highlights the combined importance of economic, regulatory, and social factors.

The findings indicate that higher cigarette prices are positively associated with smoking initiation, particularly in non-EU countries, suggesting greater sensitivity to tobacco affordability. At the same time, peer influence showed a statistically significant association of earlier smoking uptake (negative association with smoking initiation), followed by parental smoking behavior. Female adolescents generally initiated smoking later than males. These results underline that while tobacco control policies matter, the social environment remains a critical factor shaping adolescent smoking behavior.

The temporal interpretation of the individual- and household-level variables requires caution. Parental smoking behavior, peer influence, and perceived harmfulness were measured at the time of the survey, while smoking-initiation age was reported retrospectively. Parental smoking may be a comparatively stable household characteristic, particularly given the respondents' restricted age range of 13–15 years. It is therefore plausible that current parental smoking reflects exposure during at least part of the period preceding initiation. However, the data does not provide parental smoking histories, and changes in parental smoking status cannot be ruled out. Greater temporal ambiguity applies to peer influence and perceived harmfulness. Current peer relationships may not correspond to those present at the reported age of initiation. In addition, smoking experimentation may affect subsequent friendship patterns and perceptions of smoking-related harm. These associations may therefore reflect

reverse temporality, exposure misclassification, or both. Consequently, the coefficients are interpreted as associations between survey-time characteristics and retrospectively reported initiation timing, rather than causal effects on smoking initiation.

The association between perceived harmfulness and smoking initiation was not consistent across specifications. Perceived harmfulness was associated with a slightly shorter time to initiate in Table 3 and a slightly longer time to initiation in Table 4. However, both coefficients were very small and almost identical in absolute magnitude. The reversal should therefore not be interpreted as evidence that awareness of smoking-related harm meaningfully encourages initiation in one group while preventing it in another. Several factors could explain the difference. The meaning and formation of perceived harmfulness may vary across countries because of differences in tobacco-control communication, social norms, family and peer environments, and previous exposure to smoking-prevention campaigns. In addition, perceived harmfulness was measured at the time of the survey rather than before smoking initiation. Adolescents who have already experimented with cigarettes may subsequently have changed their assessment of smoking-related harm. This creates the possibility of reverse temporality and may partly explain the instability of the coefficient across specifications. Consequently, the perceived harmfulness coefficients are interpreted as small, context-dependent associations between current risk perception and retrospectively reported initiation timing. No causal conclusion is drawn from either estimate.

A key contribution of the study is the assessment of the broader policy environment. The results suggest that EU membership and implementation of the TPD are positively associated with smoking initiation. Moreover, the combination of tobacco advertising bans and indoor smoking restrictions showed stronger associations with initiation than individual measures implemented separately. This finding supports the value of comprehensive and mutually reinforcing tobacco control policies.

The findings presented in this paper are based on the results previously published in wiiw HEPA Research Study No. 16 (21). To further confirm these findings, additional analyses were conducted, including a formal comparison between EU and non-EU countries and new sensitivity specifications. The results remained consistent in terms of the direction of the main policy-related associations, providing further support for the importance of comprehensive tobacco control policies in delaying smoking initiation among adolescents.

The policy implications are straightforward (21). Continued increases in tobacco excise taxes should remain a central element of tobacco control, particularly in non-EU countries where tobacco products remain relatively affordable. Governments should also strengthen the implementation and enforcement of advertising bans and smoke-free environment regulations, while non-EU countries may benefit from further alignment with EU tobacco control standards. However, regulatory and fiscal measures alone are unlikely to be sufficient. School-based prevention programs, family-oriented initiatives, and public awareness campaigns are needed to address the statistically significant influence of peers and parents on smoking behavior.

Future research should examine the growing role of novel tobacco products and assess whether the determinants of initiation differ across product categories and regulatory contexts.

Overall, the findings suggest that delaying smoking initiation requires an integrated approach that combines taxation, regulation, and interventions targeting the social drivers of tobacco use. Such a strategy offers the greatest potential to reduce youth smoking uptake and the long-term burden of tobacco-related disease across the CESEE region.

## 5 Limitations

Although this study provides useful information for preventing young people from tobacco smoke, there are some limitations to be acknowledged. For instance, the study relied on individuals' own memory regarding past smoking behavior. As such, the dependent variable could be subject to measurement error with an unknown bias. Considering that our sample was composed of young people with relatively short smoking histories, we believe that our findings are robust. The final GYTS sampling weights and country-clustered robust standard errors were incorporated into the estimated models. However, the complete original survey design could not be reconstructed because consistently harmonized school-level PSU and stratum identifiers were unavailable across all country-year surveys included in the pooled dataset. Consequently, although the variance estimates account for unequal selection probabilities and within-country dependence, they may not fully capture clustering and stratification at the school and classroom levels.

Previous studies using GYTS data to estimate the timing of smoking initiation/experimentation have applied conventional duration and split-population survival models without explicitly incorporating the full complex survey design (sampling weights, clustering, and stratification) in the survival-model estimation. We acknowledge that failure to account fully for the complex sampling structure may affect statistical inference, the estimated standard errors and confidence intervals because observations within sampling clusters may not be independent. In addition, some potentially important information, including parental education, pocket money, family wealth, exposure to smoking in enclosed spaces, exposure to anti-tobacco and pro-tobacco messages and promotions, teachers' smoking behavior, and urban or rural residence, was either unavailable or not measured consistently across the included countries and survey waves. Had these variables been available and comparable, they could have been incorporated into the survival analysis. Their omission may have resulted in residual confounding, and the estimated relationships should be interpreted as associations.

Since we used risk perception in our analysis as determinant of smoking initiation among youth, variable perceived harmfulness was measured at the time of the survey and may have been influenced by previous smoking experimentation, prevention messages, and the respondent's current social environment. The reversal in the sign of the perceived harmfulness coefficient across specifications illustrates the instability of this association. Although alternative specifications were considered, the available data does not provide a credible instrument or retrospective history of perceived harmfulness at the time of initiation. The estimates should therefore be interpreted as context-dependent associations rather than causal effects.

This study combines retrospectively reported age at smoking initiation with parental, peer, and perception variables measured at the time of the survey. The analysis therefore cannot establish whether these characteristics preceded smoking initiation. Current parental smoking was used as a proxy for earlier household exposure because parental smoking is plausibly more stable than peer relationships or risk perceptions over the relatively short period covered by respondents aged 13–15 years. Nevertheless, the absence

of retrospective exposure histories may result in exposure misclassification. Reverse temporality is a particular concern for peer influence and perceived harmfulness because smoking experimentation may affect subsequent peer relationships and perceptions of harm.

## Data availability statement

The datasets analyzed in this study are publicly available through the Global Youth Tobacco Survey (GYTS) database maintained by the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO). The original GYTS datasets can be accessed through the CDC Tobacco Control Data Repository: https://www.cdc.gov/tobacco/global/gtss/gtssdata/index.html. The harmonized analytical dataset generated for the present study is available from the corresponding author upon reasonable request.

## Ethics statement

This study involved a secondary analysis of publicly available, de-identified data from the Global Youth Tobacco Survey (GYTS). The authors were not involved in the original data collection, had no direct contact with the participants, and had no access to personally identifiable information. The original surveys were conducted by the responsible national implementing institutions in accordance with the standardized GYTS protocol and applicable national requirements. The GYTS procedures provide for voluntary and anonymous participation, protection of students' privacy, parent or guardian notification, and approval by the relevant national authority. Any required consent or assent procedures for the original data collection were administered by the respective national implementing institutions. No additional ethical approval or informed consent was required for the present secondary analysis of publicly available, de-identified data.

## Author contributions

OJ: Conceptualization, Writing – original draft, Writing – review & editing, Investigation, Formal analysis, Methodology, Data curation, Visualization. JZ: Project administration, Writing – review & editing, Validation, Methodology, Supervision, Conceptualization.

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## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2026.1976932/full#supplementary-material

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