SEMMELWEIS EGYETEM

DOKTORI ISKOLA

Ph.D. értekezések

3516.

BRYS ZOLTÁN

Interdiszciplináris társadalomtudományok
című program

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VOLUNTARY HOUSEHOLD BANS ON TOBACCO AND NICOTINE USE

PhD thesis

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Budapest
2026

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List of Abbreviations

aOR – Adjusted Odds Ratio

AIC – Akaike Information Criterion

AME – Average Marginal Effect

CAPI – Computer Assisted Personal Interviewing

CAWI – Computer Assisted Web Interviewing

CDC – Centers for Disease Control and Prevention

CI – Confidence Interval

COVID-19 – Coronavirus Disease 2019

EDTNAD – Electronic Devices for Tobacco or Nicotine Aerosol Delivery

E-cigarettes – Electronic Cigarettes

EMA – Ecological Momentary Assessment

ETT-TUKEB – Hungarian Medical Research Council (Egészségügyi Tudományos Tanács - Tudományos és Kutatásetikai Bizottság)

EU – European Union

GATS – Global Adult Tobacco Survey

GDP – Gross Domestic Product

GYTS – Global Youth Tobacco Survey

HTP – Heated Tobacco Product

IARC – International Agency for Research on Cancer

IQR – Interquartile Range

KSH – Hungarian Central Statistical Office (Központi Statisztikai Hivatal)

LASSO – Least Absolute Shrinkage and Selection Operator

MICE – Multiple Imputation using Chained Equations

OR – Odds Ratio

PAR – Participatory Action Research

$PM_{2.5}$ – Particulate Matter less than 2.5 μm in diameter

PR-AUC – Precision-Recall Area Under the Curve

RDS – Respondent-Driven Sampling

ROC-AUC – Receiver Operating Characteristic Area Under the Curve

RSS – Residual Sum of Squares

SHA – Secondhand Aerosol

SHAP – Shapley Additive Explanations

SHS – Secondhand Smoke

SIDS – Sudden Infant Death Syndrome

SoHE – Secondary or Higher Education

VIF – Variance Inflation Factor

WHO – World Health Organization

1. Introduction

The major share of secondhand tobacco smoke (SHS) exposure occurs in private homes (Huque & Siddiqi, 2021; Öberg et al., 2011). Following the implementation of smoke-free legislation in workplaces and public indoor environments, private households have become the major remaining source of involuntary exposure to smoke and aerosol (Huque & Siddiqi, 2021). With few exceptions (smoke-free rules in US federally subsidised public housing (Instituting Smoke-Free Public Housing, 2016) and bans on smoking in private vehicles carrying children, introduced in 25 countries (WHO, 2023b)), smoking and the use of aerosol-generating nicotine products in private places remain outside the scope of regulation at present. The Expert Group report to the eleventh WHO FCTC Conference has identified the extension of smoke-free protection to private homes as a forward-looking legal measure (WHO FCTC, 2025). Until these regulations are adopted, in-home exposure reduction remains voluntary. Accordingly, voluntary in-home bans have been regarded as the "final frontier" of smoke-free policies (Huque & Siddiqi, 2021). This dissertation examines voluntary in-home bans on tobacco and nicotine use in Hungary.

In this dissertation, a voluntary in-home ban denotes a self-imposed, interpersonally negotiated household rule that completely prohibits indoor smoking and/or aerosol use. It is non-legislative, and is used in the sense of a “complete home smoking ban” rather than a legal prohibition.

This section reviews the dissertation's background in three parts. First, it covers tobacco and nicotine use, including its forms, prevalence, sociodemographic correlates, and the health consequences of secondhand exposure. Second, it examines voluntary in-home bans, addressing their definition and forms, public health advantages, prevalence and trends, known correlates, and household-level patterns. Finally, it defines the dissertation's scope.

1.1. Tobacco and nicotine use

1.1.1. Brief history and forms

Indigenous peoples of the Americas used tobacco for thousands of years in their ceremonies (Castaldelli-Maia et al., 2016; Godlaski, 2013). European contact with the tobacco plants (genus *Nicotiana*) began in 1492, and the plants spread across Europe during the 16th and 17th centuries, initially as a luxury good, later as a recreational substance (Balázs, 2010; Castaldelli-Maia et al., 2016). In Europe, pipe smoking was dominant until the mid-19th century, when industrialized cigarette manufacturing began. This technological change, along with the disruptions resulting from the two World Wars, led to cigarettes becoming the primary method of tobacco use. During both conflicts, cigarettes were widely included in standard military rations. After the Second World War, women's cigarette smoking became socially acceptable in Europe (Gately, 2003). This expansion continues to be accelerated by the tobacco industry's aggressive marketing activities (Brandt, 2009; Proctor, 2011; Goel et al., 2023).

While combustible cigarettes became the most prevalent form of tobacco use worldwide during the 20th century, consumption patterns have always varied by region and over time. For example, in parts of South Asia, smokeless tobacco products such as chewing tobacco have accounted for a major share of overall tobacco use. (Kendrick et al., 2021). Smokeless tobacco use (snus, chewing tobacco, dry snuff) varies across Europe: a 2010 survey found prevalence was highest in Sweden and Poland (Leon et al., 2016). The EU banned snus in 1992, though Sweden received an exemption; Norway and Switzerland also permit snus sales as non-EU states (Salokannel & Ollila, 2021).

Since the 2000s, the tobacco and nicotine product landscape has diversified rapidly: electronic cigarettes (e-cigarettes) and heated tobacco products (HTPs) have grown markedly, driven by marketing strategies that appeal to young adults (Biyani & Derkay, 2017; Caputi et al., 2017; Couch et al., 2016; Gentzke et al., 2022; Grana et al., 2014). E-cigarettes, often referred to as electronic nicotine delivery systems (ENDS), are battery-powered devices that heat a liquid to produce an aerosol that the user inhales, without burning tobacco (Committee on the Review of the Health Effects of Electronic Nicotine Delivery Systems et al., 2018; Grana et al., 2014). HTPs heat tobacco to temperatures below conventional combustion to generate an aerosol for inhalation (WHO, 2023a). The rapid changes in product design, patterns of use, and aggressive tobacco industry

interference present additional challenges for regulations originally developed for combustible tobacco (Grana et al., 2014; Ling et al., 2022; Pénzes et al., 2024; WHO, 2025a). These successive transformations in tobacco and nicotine products have been accompanied by shifting social norms regarding where, when, and by whom, as well as which products may or may not be used.

This dissertation focuses on combustible cigarette smoking and on e-cigarettes and HTPs, as these forms generate smoke or aerosol that leads to secondhand exposure. In this dissertation, e-cigarettes and HTPs are sometimes collectively referred to as electronic devices for tobacco or nicotine aerosol delivery (EDTNAD). Other combustible products, such as cigars, cigarillos, and waterpipes, are not examined because their prevalence in Hungary is very low (Filippidis et al., 2019). Smokeless and aerosol-free tobacco or nicotine products (e.g. chewing tobacco, nicotine pouches) are also outside the scope of this dissertation, as they do not produce inhalable emissions relevant to indoor secondhand exposure.

1.1.2. Prevalence, trends, and sociodemographic correlates

Globally, the prevalence of smoking has declined since the late 20th century, though reductions have been uneven across countries, genders, and socioeconomic groups (Reitsma et al., 2021). Estimates from the Global Burden of Disease Study 2019 show a decrease in age-standardised smoking prevalence among adults since 1990 (Reitsma et al., 2021). However, these relative declines have been offset by population growth, leading to a continued increase in the absolute number of smokers worldwide (Reitsma et al., 2021). The most recent WHO global monitoring confirms the continuing decline in tobacco use prevalence (WHO, 2025b). However, the prevalence of e-cigarette use has risen over the past decade, particularly among adolescents and young adults (Martins et al., 2022). A recent meta-analysis estimated that 22.7% of students worldwide have ever used e-cigarettes, with substantially higher prevalence among high school students and in high-income countries (Gebeyehu et al., 2025). E-cigarette use is consistently more prevalent among males and is strongly associated with conventional cigarette smoking and alcohol use (Gebeyehu et al., 2025; Martins et al., 2022). HTPs have also become more prevalent since their market introduction, particularly among males, adolescents, and populations in the Western Pacific and European regions (Sun et al., 2023).

In Hungary, the prevalence of tobacco and nicotine use has risen over the past two decades (Brys, Susánszky, et al., 2022). Analyses of repeated cross-sectional health survey (Hungarostudy) data indicate a significant upward trend from 2002 to 2021, with prevalence increasing from 28.2% in 2002 to 34.1% in 2021. (Brys, Susánszky, et al., 2022). Tobacco use is consistently more prevalent among men and shows a pronounced social pattern. Across Hungarian epidemiological studies, educational attainment, economic status, age group, Roma ethnicity, and gender emerge as the most consistently identified correlates, with higher prevalence observed among individuals with lower educational attainment and those living in poorer socioeconomic conditions (Brys, Susánszky, et al., 2022; Brys, Tóth, et al., 2022; Cselkó & Kovács, 2013; Tombor et al., 2010). The influence of education varies by age: among adults aged 18–64 years, individuals without a secondary-school diploma have more than threefold higher odds of tobacco use than those with higher education, whereas educational differences are not observed among adults aged 65 years and older (Brys, Tóth, et al., 2022; Brys, Susánszky, et al., 2022).

Tobacco use disparities persist globally among marginalized populations (Glover et al., 2020). In Europe, Roma population is the largest racialized ethnic minority (McGarry, 2017). Roma population shows persistently elevated tobacco use prevalence. In Spain, smoking disparities between Roma and non-Roma populations have remained unchanged despite overall progress in tobacco control (Usera-Clavero et al., 2019). The Roma people constitute Hungary's largest ethnic minority and the most disadvantaged population in terms of health (Kósa et al., 2007). In Hungary, among the Roma, smoking prevalence is substantially higher than in the general population (Brys, Susánszky, et al., 2022; Paulik et al., 2011). The disparity is pronounced among women: 68.4% of Roma females smoked compared to 33.7% in the general female population (Piko et al., 2021). Beyond prevalence differences, qualitative studies suggest that attitudes toward tobacco control policies diverge fundamentally. Among the Roma population, resistance to tobacco control policies was documented and persisted even after controlling for education and smoking status, with ethnicity remaining a significant independent predictor of opposition to public-place smoking bans and restrictions on tobacco sales to minors. (Paulik et al., 2011). However, these patterns reflect social position rather than ethnic characteristics. Among Roma populations, smoking occurs alongside multiple

health risk factors, including poor living conditions and increased environmental hazards (Cook et al., 2013). Ethnographic research documents how health-endangering behaviors coexist with material deprivation and limited access to healthcare in segregated communities (Belak et al., 2017). While some researchers (Petek et al., 2006; Vokó et al., 2009) argue that there is an ethnic cultural element, it is rather the result of structural exclusion, marginalization, and stigmatization (Belak et al., 2017; Petrova, 2003). Roma households face substantially higher rates of material deprivation, residential segregation, and limited access to healthcare services than non-Roma households (Bernát, 2014; Boros et al., 2021). In 2017, three-quarters of Roma (76%) lived in poverty or social exclusion, compared with one-quarter of non-Roma (Bernát, 2019). Educational attainment among Roma remains far below that of the general population, with 90% lacking qualifications for stable employment (Bernát, 2014).

Although the tobacco and nicotine product landscape has diversified, patterns of use in Hungary remain uneven across products. Combustible cigarettes continue to dominate overall use. While e-cigarette use remains uncommon among the general adult population, it is increasingly prevalent among adolescents and young adults. In 2018, 28.7% of Hungarian adults were current smokers, and only 1.7% reported current e-cigarette use (Brys, Tóth, et al., 2022). However, experimentation with e-cigarettes is substantially more common among younger adults. In a study of Hungarian university students, approximately one-third reported ever trying e-cigarettes (though current use remained low at 0.6%), and experimentation was associated with cigarette smoking and with male gender (Pénzes et al., 2016). Recently, the European School Survey on Alcohol and Other Drugs 2024 found that Hungary has the highest lifetime prevalence of e-cigarette experimentation among adolescents, with 57% of students reporting ever having used e-cigarettes (European Union Drugs Agency, 2025). Data on HTP use in Hungary are sparse. Earlier survey data indicate that among Hungarian adult smokers, HTP awareness remained below 10% and ever use below 1% from 2016 to 2018, placing Hungary among the six surveyed European countries with the lowest rates. (Lotrean et al., 2020). By 2023, current HTP use had increased to 3% and daily use to approximately 2.2% among Hungarian adults (European Commission, 2024).

1.1.3. Initiation and environmental factors

Tobacco and nicotine use typically begin early in the life course. The vast majority of daily users initiate use in young adulthood: 90–95% of smokers start daily use before age 25. (Cselkó & Kovács, 2013; National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012). Initiation and continuation of tobacco and nicotine use during adolescence are shaped by a combination of genetic, psychological, and environmental factors (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; Pénzes et al., 2017; Urbán, 2016). Environmental factors include societal attitudes toward tobacco use, accessibility of tobacco products, smoking-related beliefs, peer influences, and prevailing smoking norms within the family (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; Urbán, 2022). Tobacco industry marketing has been causally linked to the initiation of tobacco use among adolescents by shaping attitudes, risk perceptions, and pro-tobacco social norms (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012).

Peer groups become salient during adolescence and provide the immediate social context for experimenting with tobacco and nicotine products. Their influence operates primarily through the transmission of social norms regarding acceptability and prevalence (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; Simons-Morton & Farhat, 2010; Urbán, 2022). However, peer effects are shaped and moderated by household environments. These include parental smoking behavior and norms, as well as access to tobacco products (Gilman et al., 2009; National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; Wu & Chaffee, 2020).

The family is the central environment for both risk and protection. Supportive parent-child relationships, emotional and instrumental parental support, family stability, and realistically high parental expectations serve as protective factors against initiation, whereas easy household access to tobacco products and parental smoking increase the risk of uptake (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; Pénzes et al., 2017; Urbán, 2022).

Romantic partners also constitute an important intimate, proximal social environment for tobacco and nicotine use. This is particularly relevant from young adulthood onward, when partnership formation often coincides with greater independence from the parental household. Romantic partnerships frequently involve shared households and, for many individuals, a shared child-rearing environment. Within these shared domestic spaces, everyday norms, rules, and health-related behaviors are negotiated between partners (Brys et al., 2023; Christakis & Fowler, 2008; Etcheverry & Agnew, 2008; National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012).

Beyond the family and peer group, school and neighborhood environments also contribute to the initiation of tobacco and nicotine use through mechanisms such as cultural norms, school-level smoking prevalence, socioeconomic disadvantage, and the density and visibility of tobacco retail outlets (Henriksen et al., 2008). In Hungary, the 2013 tightening of tobacco retail regulation, which confined sales to licensed National Tobacco Shops, was followed by substantial decreases in tobacco retailer density and short-term reductions in the prevalence of cigarette smoking among adolescents, although compensatory access strategies also increased (Joó et al., 2025).

1.1.4. Secondhand exposure

Secondhand smoke refers to the involuntary inhalation of tobacco smoke by non-users. It consists primarily of smoke emitted from the smoldering end of combustible tobacco products (sidestream smoke) and smoke exhaled by the user (exhaled smoke). Involuntary exposure to tobacco smoke is a variable mixture of gases and particles generated during tobacco combustion and subsequently transformed through chemical reactions in indoor air (IARC, 2004).

Tobacco smoke contains more than 7,000 chemical compounds, including numerous toxic substances and 70 substances classified as carcinogenic to humans (Soleimani et al., 2022). These include polycyclic aromatic hydrocarbons, tobacco-specific nitrosamines, benzene, formaldehyde, acetaldehyde, carbon monoxide, and ultrafine particulate matter. Involuntary exposure to tobacco smoke is classified by IARC as a Group 1 carcinogen in humans. This classification reflects sufficient evidence of a causal relationship with lung cancer in never-smokers, supported by consistency across

study designs, biological plausibility, and coherence with established mechanisms of tobacco carcinogenesis (IARC, 2004). Epidemiological evidence clearly demonstrates that exposure to SHS increases the risk of lung cancer, heart diseases, stroke, and respiratory diseases among non-smokers (IARC, 2004; WHO, 2023b). Cardiovascular effects are of particular relevance, as even short-term exposure has been shown to impair endothelial function, increase platelet aggregation, and trigger acute coronary events (Bonetti et al., 2011; IARC, 2004). Public health bodies have consistently concluded that there is no safe level of exposure to secondhand tobacco smoke (CDC, 2017; IARC, 2004; WHO, 2023b, 2025a).

The global disease burden attributable to SHS remains substantial despite declines in smoking prevalence. According to the Global Burden of Disease Study 2021, SHS exposure accounted for approximately 1.29 million deaths worldwide in 2021, with a large share attributable to cardiovascular disease and respiratory infections (Su et al., 2025). In WHO European region, SHS was estimated to cause approximately 172,000 deaths and over four million disability-adjusted life years annually (Öberg et al., 2011). Regarding children's exposure, an analysis of the Global Youth Tobacco Survey across 142 countries (2010–2018) found that 33.1% of adolescents aged 12–16 years were exposed to SHS at home, with home exposure declining in most countries since 1999 (Ma et al., 2021). An earlier estimate suggested that 40% of children worldwide were exposed to SHS in 2004 (Öberg et al., 2011). As these sources differ in age bands and country coverage, they provide complementary information.

Children constitute a particularly vulnerable group with respect to SHS. Household tobacco smoke is linked to higher mortality among children under age five and is strongly associated with sudden infant death syndrome (SIDS) (McMartin et al., 2002; Owili et al., 2017). Infants who died from SIDS had higher concentrations of nicotine in lung tissue than control infants who died from other causes (McMartin et al., 2002). Estimates suggest that approximately one-third of all SIDS deaths might have been prevented, if fetuses had not been exposed to maternal smoking before birth (Cnattingius, 2004; Mitchell et al., 1997). Exposure to secondhand smoke during pregnancy is associated with increased health risks (stillbirth, preterm birth, congenital malformations, and low birth weight). During childhood, due to higher respiratory rates and lower body weight, children receive higher doses of inhaled toxicants per unit of body weight than

adults (IARC, 2004; WHO, 2023b). Exposure in early life has been associated with respiratory tract infections, asthma, ear diseases, and impaired lung development (He et al., 2020; Pavić et al., 2024). Children exposed to SHS in early life demonstrated significantly lower scores on measures of cognitive ability compared to unexposed peers (Yolton et al., 2005). Socioeconomic inequalities further shape exposure patterns, as children living in disadvantaged households are more likely to be exposed to SHS within the home (Nazar et al., 2016). Data from the Global Adult Tobacco Survey (GATS), covering 21 countries, showed that children's SHS exposure at home ranged from 4.5% (Panama) to 79.0% (Indonesia). Approximately 508 million children are exposed to SHS globally (Mbulo et al., 2016). In Hungary, survey-based data indicate that a substantial proportion of secondhand smoke exposure occurs in private domestic settings. In 2009, approximately one-fifth of the population reported exposure to tobacco smoke within the home (Paulik et al., 2013). Among children aged 13–15 years (early adolescents), data from the Global Youth Tobacco Survey showed a marked decline in household secondhand smoke exposure in Hungary: in 2003, 84% reported living in homes where others smoked in their presence, and this share decreased to 43% in 2008 (GYTS, 2003, 2009).

Involuntary exposure also arises from secondhand aerosol (SHA): aerosol exhaled by users of e-cigarettes and HTPs and inhaled by bystanders. Although its composition differs from combustible tobacco smoke, SHA delivers nicotine and other toxic substances into indoor air (Fernández et al., 2015). E-cigarette aerosol generally contains nicotine, propylene glycol, glycerin, carbonyl compounds, metal toxins and particulate matter. HTP-aerosol contains nicotine and tobacco-derived constituents generated at temperatures below combustion. Airborne concentrations of some harmful substances may be lower than in cigarette smoke, but emissions are not negligible, and toxic metal emissions are significantly higher in some e-cigarette products (Amalia et al., 2023; Salazar et al., 2025; Uguna & Snape, 2022; WHO, 2023b). Exploratory chemical evidence indicates that HTP emissions, though commonly termed aerosol (including in this thesis), may meet the criteria for smoke formation (Uguna & Snape, 2022). Radon progeny also readily attaches to secondhand tobacco and e-cigarette aerosol particles, adding a radioactive exposure component in radon-exposed areas (Vargas Trassierra et al., 2015; Hámori et al., 2006).

Taken together, the evidence indicates that secondhand exposure from cigarettes, e-cigarettes, and HTPs is harmful to humans. Accordingly, the World Health Organization recommends that all indoor environments be protected from both tobacco smoke and aerosol emissions (WHO, 2023b). (Secondhand tobacco smoke also harms pets, especially cats (Bertone et al., 2002).)

Secondhand exposure is assessed using both environmental and biological markers. Environmental monitoring typically includes measurements of $PM_{2.5}$ as a proxy for secondhand smoke in indoor environments. $PM_{2.5}$ is widely used because tobacco smoke is a major indoor source of fine particles. (Another major source is residential wood and coal heating (WHO 2015)). Smoking indoors produces sharp increases in $PM_{2.5}$ concentrations. $PM_{2.5}$-monitoring allows for continuous, real-time assessment and it is relatively inexpensive (Semple et al., 2015). Airborne nicotine can also serve as an environmental marker of secondhand smoke exposure because it is specific to tobacco emissions, allowing more direct source attribution than $PM_{2.5}$. Other tobacco-specific environmental markers include 3-ethenylpyridine and tobacco-specific nitrosamines. Monitoring these typically relies on passive samplers and off-site laboratory analysis, making it more resource-intensive and less suitable for real-time large-scale household studies (Apelberg et al., 2013). The same applies to surface-level nicotine measurement.

Biomarker-based approaches rely primarily on cotinine. Cotinine is a human metabolite of nicotine and is measurable in blood, saliva, and urine. Cotinine has a half-life of approximately 20 hours and is widely used as an indicator of recent nicotine uptake (Benowitz, 1996; Office on Smoking and Health (US), 2006). Salivary cotinine has been applied in repeated cross-sectional studies in Scotland (Semple, Best, et al., 2026). Hair measurements of nicotine and cotinine provide an integrated measure of long-term exposure to tobacco smoke, reflecting cumulative exposure/uptake over weeks (Kataoka et al., 2021). Urinary polycyclic aromatic hydrocarbon metabolites have also been used as biomarkers of tobacco smoke exposure in population studies, though their specificity is limited by dietary and environmental factors (Smetanová et al., 2026). In large-scale epidemiological studies, SHS exposure is commonly assessed through self-report questionnaire items on exposure in specific settings. Questionnaires are cost-effective and allow assessment of both lifetime and current exposure, though recall accuracy and exposure misclassification are limitations (Avila-Tang et al., 2013).

Legislative measures banning smoking in workplaces and public indoor spaces (health care facilities, schools, public transportation, playgrounds, beaches, etc.) have led to marked reductions in population-level SHS exposure (Callinan et al., 2010). In countries where these bans were introduced, the primary source of SHS shifted to private spaces. Accordingly, by the early 2020s, 25 countries had introduced bans on smoking in private vehicles when children are present (WHO, 2023b). Smoking in cars results in particularly high levels of SHS exposure (Raoof et al., 2015). In Finland, national tobacco legislation extended smoke-free regulations to shared residential environments, including common areas of multi-unit housing (Valvira, 2016). The US has adopted sector-specific smoke-free restrictions in residential settings through federal rules for publicly funded housing, not comprehensive national law (Instituting Smoke-Free Public Housing, 2016). The WHO Framework Convention on Tobacco Control (FCTC) Article 8 obliges Parties to protect people from tobacco smoke in indoor work environments, public transport and (indoor) public places, but it does not extend to the private home. The implementation guidelines address the home only in non-legislative terms, recommending that public education campaigns also target settings for which legislation is not feasible or appropriate, such as private homes (WHO, 2007). However, the Expert Group report to the eleventh WHO FCTC Conference proposes extending smoke-free protection to private homes, vehicles and multi-unit housing, noting that this would build on the Article 8 implementation guidelines (WHO FCTC, 2025). Beyond these sector-specific exceptions and forward-looking proposals, currently, private households generally fall outside the scope of enforceable smoke-free legislation. This reflects legal protections for privacy and autonomy, as well as practical limits on enforcement, although the case for reframing the protection of children from home SHS as a child-rights issue amenable to legislation is growing (Semple, Tigova, et al., 2026).

Currently, private homes are a major source of secondhand smoke exposure, particularly for females and minors (Huque & Siddiqi, 2021; Semple, Best, et al., 2026). The home is the largest single contributor to nonsmokers' cotinine uptake (Levesque & Mischki, 2021). For nonsmokers living with a smoker, personal-exposure modelling estimates that 84–100% of total daily inhaled $PM_{2.5}$ is received in the home (Semple et al., 2015). Therefore, in-home bans on tobacco and nicotine use are the primary means of further reducing SHS exposure. These in-home rules constitute a distinct layer of

exposure control: as currently, they are not mandated by law but depend on intrahousehold norms, power dynamics, and decision-making. This dissertation focuses on voluntary in-home bans of tobacco and nicotine use.

1.2. Voluntary in-home tobacco and nicotine use bans

1.2.1. Definition and forms

Voluntary household bans on tobacco and nicotine use are informal rules that prohibit the use of tobacco and nicotine products that generate smoke or aerosol within the household. These bans are properties of households. The household is a social unit whose meaning, composition, and boundaries vary across time and culture. The scope of these bans is shaped by the prevailing tobacco and nicotine product landscape. Currently, these bans typically cover combustible tobacco products (such as cigarettes, cigars, and pipes) and/or aerosol-generating nicotine delivery products, such as e-cigarettes and HTPs (CDC, 2017; WHO, 2025a).

The epidemiological literature commonly distinguishes three forms of in-home rules: no ban, partial ban, and complete ban. A no-ban rule means there are no restrictions. A partial ban allows smoking or the use of aerosol-generating products under limited conditions, such as only in designated rooms, at open windows, or at certain times or in specific cases (e.g., absence of children). A complete in-home ban prohibits any indoor use of these products by any person present in the household (including residents, visitors, guests, and household workers) at all times and without any exception (Cartmell et al., 2011; CDC, 2017; Ferketich et al., 2014; Gallus et al., 2016; Haynes et al., 2018; Helgertz et al., 2020; Jankowski et al., 2020; King et al., 2016; Owusu et al., 2020; Pizacani et al., 2003; WHO, 2023b; Zhang, Martinez-Donate, Kuo, & Jones, 2012; Zhang, Martinez-Donate, Kuo, Jones, et al., 2012). Household air-monitoring studies demonstrate that SHS persists in indoor air for prolonged periods after smoking, indicating that only completely smoke-free homes effectively minimize exposure (Semple & Latif, 2014). By contrast, partial restrictions do not reliably prevent exposure, because smoke and aerosol disperse throughout indoor environments (Biener et al., 1997).

Given that the World Health Organization, the Centers for Disease Control and Prevention, and the U.S. Surgeon General have all concluded that there is no safe level of exposure to secondhand smoke or aerosol, complete in-home bans are the only household

rule consistent with effective protection of non-users (CDC, 2017; Office on Smoking and Health (US), 2006; WHO, 2023b, 2025a).

Self-reported information is commonly used in epidemiological studies to estimate household rules. However, it does not always match perfectly with objective exposure measures. In intervention studies designed to reduce household tobacco smoke exposure, homes that report adopting smoke-free rules often still show measurable pollution, indicating that the presence of a rule does not guarantee the absence of exposure (Rosen et al., 2015). Household survey data from Hungary also indicate that some respondents who report smoke-free homes still report secondhand smoke exposure, suggesting incomplete implementation (Paulik et al., 2013). Discrepancies in reporting among household members have also been documented in earlier work, although more recent studies report acceptable level of agreement (Mumford et al., 2004; Zhang, Martinez-Donate, Kuo, & Jones, 2012). Also, asking all household members to participate is not just logistically challenging, but it introduces selection bias: as households in which all members are willing to complete surveys tend to be more health-conscious and socio-economically advantaged, so, it leads to strong under-representation of higher-risk groups (Ranby et al., 2023).

It is also important to acknowledge that some studies (Comiford et al., 2018; Gallus et al., 2016; Helgertz et al., 2020; Shelley et al., 2006) treat the household ban as an attribute tied to the respondent rather than as a characteristic of the household as a social entity. Consequently, these analyses often focus on and report associations between respondent-level characteristics (e.g., gender or smoking status) and reported household rules, while leaving household smoking composition and the attributes of other members unexamined. (For example, in a household where a non-smoking female respondent and a smoking non-respondent male partner are present, but no smoking ban exists, analyzing only respondent characteristics without data on the partner provides incomplete information.)

1.2.2. Advantages of voluntary in-home bans

Voluntary in-home bans on tobacco and nicotine use offer several public health advantages. These benefits extend beyond the reduction of involuntary exposure to

secondhand smoke and aerosol and include effects on smoking-related norms, smoking initiation, and cessation.

The most direct advantage of complete in-home bans is the reduction of secondhand tobacco smoke (SHS) exposure. Studies using environmental measures, including airborne nicotine and fine particulate matter ($PM_{2.5}$), as well as biological markers show markedly lower exposure among household members living in homes with complete smoke-free rules compared with homes without bans (Apelberg et al., 2013). Lower SHS exposure reduces the risk of SHS-related outcomes indicated in Section 1.1.4, such as sudden infant death, respiratory disease in children, and cardiovascular events in adult nonsmokers.

Beyond reducing exposure, voluntary in-home smoking bans are associated with a lower likelihood of tobacco use initiation among early adolescents. A systematic review of observational studies found inverse associations between home smoking restrictions and youth smoking behaviors. Complete bans convey anti-smoking norms that deter early experimentation. (Emory et al., 2010). Consistent with this pattern, longitudinal evidence from a cohort study of U.S. adolescents showed that the absence of a household smoking ban was associated with higher odds of progression from non-smoking to early experimentation among youth living with non-smoking adults (Albers et al., 2008). Prospective cohort analyses also indicate that adolescents living in homes where smoking is prohibited are less likely to initiate smoking over time, particularly when parental behaviour is consistent with the household rule (Luh et al., 2015; Wu & Chaffee, 2020). A similar association was reported for EDTNAD: US adolescents living in households with vaping bans had lower odds of past-month e-cigarette use (Staff et al., 2024).

Among adult smokers, complete in-home bans are associated with higher smoking cessation rates and lower relapse rates. Longitudinal population-based studies indicate that smokers living in smoke-free homes are more likely to make quit attempts, achieve sustained abstinence, and reduce cigarette consumption compared with smokers living in homes where smoking is allowed (Borland et al., 2006; Haardörfer et al., 2018; Messer et al., 2008). The presence of a complete smoke-free home is associated with higher probabilities of subsequent quitting across different national contexts, independent of baseline smoking intensity (Borland et al., 2006). Furthermore, adoption of a smoke-free

home has been linked to cessation among heavier smokers and to lower relapse rates among former smokers (Hyland et al., 2009; Mills et al., 2009).

Household fires are an adverse consequence of indoor smoking. In-home smoking accounts for 6% of all fire incidents in Hungary (Hesz, 2018), and for the majority of fatal fire incidents in Western Europe (European Fire Safety Alliance, 2018).

Besides these immediate benefits, in-home bans also help establish a wider anti-tobacco social norm. Smoke-free household rules are associated with stronger antismoking attitudes among adolescents and greater support for clean indoor air policies (Albers et al., 2008; National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health, 2012; WHO, 2023b). Such bans also function as a mechanism of anti-smoking socialization, conveying to children that tobacco use is unacceptable (Hiemstra et al., 2017; Žaloudíková et al., 2012). Longitudinal research shows that these impacts go beyond adolescence: young adults raised in households with smoking bans are more likely to implement smoke-free policies in their own independent homes (Albers et al., 2009; Mathur et al., 2014).

1.2.3. Prevalence and trends

The prevalence of smoke free homes varies substantially across countries, but generally increased over time. In the United States, nationally representative data from the Tobacco Use Supplement to the Current Population Survey indicate that the proportion of adults reporting smoke-free home rules rose from 43% in 1993 to 91% in 2023, with an annual percent change of 5% between 1993 and 2003, slowing to 1% thereafter (Figure 1.) (National Cancer Institute, 2025, 2026a). Detailed analysis of these data demonstrated increases across all U.S. states (King et al., 2016). An independent state-level survey further corroborates this trend: the Minnesota Adult Tobacco Survey documented smoke-free home prevalence increasing from 64.5% in 1999 to 87.2% in 2010 (St. Claire et al., 2012), and further to 91.5% in 2018 (Helgertz et al., 2020). However, the positive U.S. trend was supported by various public health campaigns (Kegler et al., 2015; National Cancer Institute, 2026b). A similar trend was observed in Scotland: the proportion of smoke-free home changed from 75.2% in 2012 to 90.2% in 2024 (Semple, Best, et al., 2026).

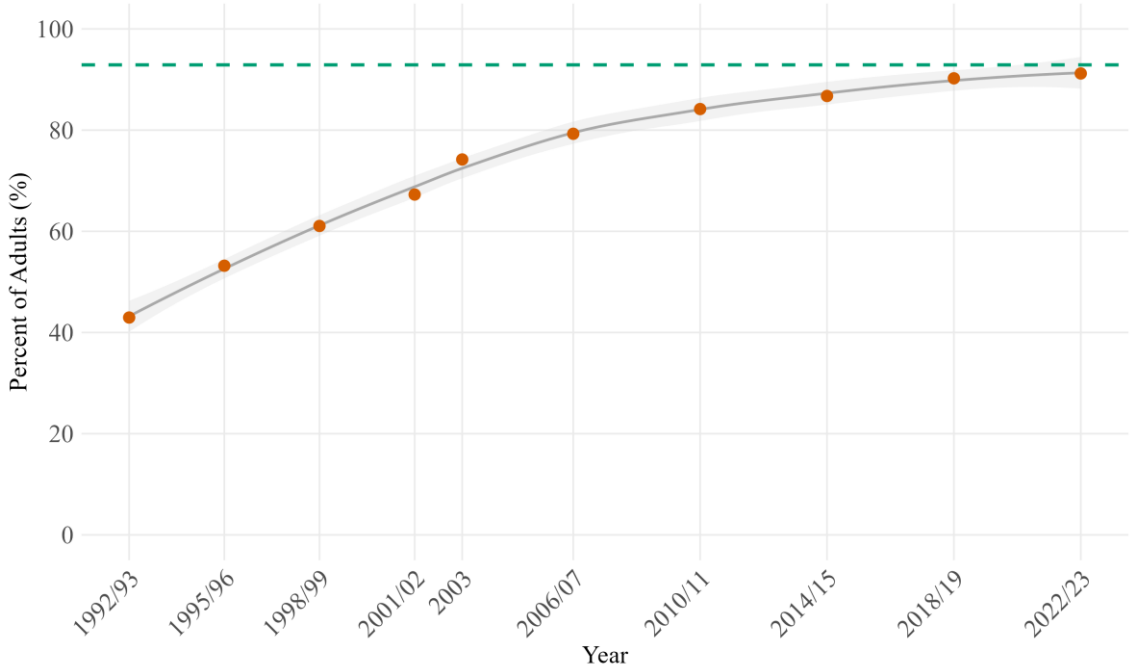


Figure 1. Percentage of US adults living in smoke-free homes, 1992–2023. Orange points represent point estimates from the US Tobacco Use Supplement to the Current Population Survey. The gray line with shaded confidence interval (95% CI) represents a locally weighted smoothing curve. The green dashed line indicates the Healthy People 2030 target (92.9%). Data source: National Cancer Institute, Cancer Trends Progress Report (National Cancer Institute, 2025, 2026a). Figure created by the author.

Outside high-income Western countries, prevalence estimates are generally lower. Data from the Global Adult Tobacco Survey (GATS) conducted in 20 low- and middle-income countries reveal substantial regional variation (Owusu et al., 2020). In Asia, smoke-free home prevalence ranged from 6.4% in Indonesia and 7.6% in Pakistan to 41.4% in India and 46.0% in Kazakhstan (Owusu et al., 2020), while a nationally representative online survey in Japan reported 47.0% in 2015 (Shojima & Tabuchi, 2019). In Africa, GATS estimates ranged from 11.3% in Ethiopia to 36.7% in Kenya, with intermediate values in Nigeria (19.6%), Uganda (24.2%), Cameroon (27.6%), and Senegal (27.9%); in South Africa, 62.5% reported smoke-free home rules (Ayo-Yusuf et al., 2014; Owusu et al., 2020). In Latin America, GATS data showed prevalence of 30.4% in Argentina, 50.3% in Panama, and 52.4% in Mexico (Owusu et al., 2020).

Within the European Union, cross-national data demonstrate pronounced regional differences. The TackSHS survey conducted in 12 European countries in 2017/2018

found that 70.2% of the population lived in smoke-free homes, with substantial variation across countries (Tigova et al., 2025). Prevalence was highest in Northern Europe: England 84.5%, Ireland 79.4%, and Latvia 78.9%. Western European countries showed intermediate levels: Germany 75.0% and France 65.1%. Southern Europe demonstrated greater heterogeneity, ranging from 75.8% in Italy and 74.0% in Portugal to 57.6% in Spain and 44.4% in Greece. Eastern European countries also clustered in the lower range: Poland 69.6%, Bulgaria 56.6%, and Romania 55.2%. Country-specific surveys corroborate this regional pattern. In Poland, a nationally representative survey conducted in 2019 found that 66.1% of individuals reported a complete smoke-free home rule (Jankowski et al., 2020). In Spain, a 2016 survey found 57.3% reported complete smoke-free homes (Díez-Izquierdo et al., 2017). In Italy, voluntary smoke-free home prevalence increased from 59.0% in 2006 to 79.0% in 2014 (Gallus et al., 2016).

Some countries have established national targets for smoke-free home prevalence. Scotland set a target of reducing children's secondhand smoke exposure at home to 6% by 2020 and achieved this level by 2015 (Scottish Government, 2014). As mentioned earlier, in the United States, the Healthy People 2030 initiative targets 92.9% smoke-free home prevalence among adults (U.S. Department of Health and Human Services, 2020). However, most EU countries, including Hungary, have neither established comparable targets nor achieved comparable prevalence levels.

In Hungary, evidence on voluntary smoke-free home rules is limited. A health survey from 1994 found that 75% of respondents aged 15–65 years had lived in a home before age 14 years where someone regularly smoked indoors, suggesting that from the 1930s through the 1980s, indoor smoking was widely accepted (KSH, 1996). More recent cross-sectional data indicate gradual adoption of smoke-free home rules. In 2009, a nationally representative survey of 2,250 adults aged 16–70 years found that 59.3% reported complete smoke-free home rules (Paulik et al., 2013). A subsequent survey in 2010 documented that 54.8% of Hungarian households consistently banned smoking in all rooms (Gallus et al., 2014). However, no nationally representative data on smoke-free home prevalence in Hungary appear to have been published since 2010, representing a relevant research gap.

Data on the prevalence of aerosol-free homes are more limited than for smoke-free homes. Where measured, vape-free household rules are consistently less prevalent

than smoking bans. Multinational data from Canada, the United States, England, and Australia show that allowing vaping inside the home was more common than allowing smoking, particularly among current vapers (Nahhas et al., 2019). Consistent with this pattern, two U.S. studies indicate that vape-free homes were less prevalent than smoke-free rules across housing types and smoking status (Li et al., 2020; Rivard et al., 2021). In Minnesota in 2018, 91.5% of adults reported a complete smoke-free home, whereas 84.0% reported a complete vape-free home (Helgertz et al., 2020). A cross-sectional household survey from England in 2019 further corroborated this pattern, showing that adults were substantially more likely to vape than smoke indoors (Tattan-Birch et al., 2024). No national data on the prevalence of aerosol-free household rules in Hungary were identified. Given the consistent international pattern of lower vape-free than smoke-free home rules, a similar distribution may be plausible in the Hungarian context, but this also remains a research gap.

Various interventions have been developed to promote smoke-free homes, particularly in households with children. These include counselling, motivational interviewing, educational home visits, personalised air quality feedback, and public health campaigns such as Scotland's "Take it Right Outside" (Behbod et al., 2018; Kegler et al., 2015; National Cancer Institute, 2026b; Rosen et al., 2015; Scottish Government, 2014). However, the specific factors that determine intervention effectiveness remain poorly understood. A Cochrane systematic review of 78 controlled trials found that only a minority of interventions reduced successfully children's exposure to environmental tobacco smoke (Behbod et al., 2018). The specific set of features that set effective interventions apart from ineffective is unclear (Behbod et al., 2018). A recent systematic review recommended that family-centred interventions should be explored (Nwosu et al., 2020). While this dissertation does not focus on intervention studies, this unresolved question of what makes smoke-free home interventions effective stresses the need for further research on the patterns of voluntary adoption of in-home bans.

1.2.4. Correlates of voluntary in-home bans

Voluntary in-home smoking bans are empirically associated with household smoking status, presence of children, sociodemographic characteristics (including education and income), ethnicity, knowledge and attitudes toward secondhand smoke harm, and the broader national tobacco control policy environment (Table 1.)

Household smoking status represents the most fundamental predictor across all studies. Households without any smokers demonstrate substantially higher odds of having complete smoking bans compared with households containing at least one smoker (Berg et al., 2023; Intarut, 2021; Jankowski et al., 2020; Pizacani et al., 2003; Tigova et al., 2025; Zhang, Martinez-Donate, Kuo, Jones, et al., 2012). Among households with smokers, mixed-composition households (containing both smokers and non-smokers) show higher likelihood of ban adoption compared with smoker-only households (Pizacani et al., 2003). This association persists throughout diverse geographic contexts. Even those studies which analyze only respondent-level smoking status (rather than full household composition) have documented similar patterns, with non-smoking respondents substantially more likely to report smoke-free home rules (Díez-Izquierdo et al., 2017; Gallus et al., 2016; Helgertz et al., 2020; Li et al., 2020; Owusu et al., 2020; Paulik et al., 2011; Rivard et al., 2021; Szklo et al., 2022).

Presence of children in the household represents a positive predictor of smoke-free home across geographic and cultural contexts. Studies from the United States demonstrate that households with children aged less than 18 years show significantly elevated odds of complete smoking bans (Helgertz et al., 2020; Pizacani et al., 2003; Reyes-Guzman et al., 2023; Rivard et al., 2021; Ulbricht et al., 2014; Zhang, Martinez-Donate, Kuo, Jones, et al., 2012). This association persists in European settings, where living with children aged 14 years or younger associates with higher smoke-free home prevalence (Gallus et al., 2014; Jankowski et al., 2020; Tigova et al., 2025). The protective effect operates even in households containing smokers (Pizacani et al., 2003). However, this relationship is not universal. In Nepal, Armenia and Georgia, the presence of children was not associated with complete smoke-free home adoption in adjusted analyses (Berg et al., 2023; Pandey et al., 2017). This suggests that the influence of child presence may depend on cultural and contextual factors.

Sociodemographic characteristics are also established predictors of smoke-free home adoption. Educational attainment emerges as the most consistent socioeconomic correlate. Higher educational attainment is consistently associated with increased odds of complete smoke-free home rules across national contexts (Borland et al., 2006; Díez-Izquierdo et al., 2017; Helgertz et al., 2020; Intarut, 2021; Jankowski et al., 2020; Li et al., 2020; Mai et al., 2018; Nahhas et al., 2019; Paulik et al., 2013; Pizacani et al., 2003; Reyes-Guzman et al., 2023; Rivard et al., 2021; Shojima & Tabuchi, 2019; Szklo et al., 2022; Tigova et al., 2025; Zhang, Martinez-Donate, Kuo, Jones, et al., 2012). However, in most epidemiological studies, only the respondent's educational attainment was analyzed, and only a small number of analyses incorporated education of other household members, such as partner education (Pandey et al., 2017) or the highest education level of the household (Ulbricht et al., 2014; Wang et al., 2017; Zhang et al., 2015). Education does not operate directly; it operates through enhanced health literacy (Nutbeam & Lloyd, 2021), material resources, cognitive ability, health knowledge and social networks (Cutler & Lleras-Muney, 2010).

Household income demonstrates a similarly consistent gradient. Higher income was significantly associated with increased likelihood of complete smoke-free homes in the majority of studies (Helgertz et al., 2020; Jankowski et al., 2020; Li et al., 2020; Paulik et al., 2013; Pizacani et al., 2003; Rivard et al., 2021; Ulbricht et al., 2014; Wang et al., 2017; Zhang, Martinez-Donate, Kuo, Jones, et al., 2012). In Scotland, the prevalence ratio of non-smoke-free homes between the most and least deprived quintiles widened from 4.7 in 2012 to 10.5 in 2024 (Semple, Best, et al., 2026). Financial hardship often shifts attention toward immediate material concerns, reducing the salience of long-term health protection behaviors. This pattern has been interpreted as a rational adaptive response to constraints (Kóczé, 2010; Mullainathan & Shafir, 2021; Wacquant, 2013; Wilson, 2006). Housing tenure is also an independent predictor: renters show lower prevalence of smoke-free homes (Tattan-Birch et al., 2024) and higher odds of smoking than homeowners (Lim et al., 2010).

Racial and ethnic disparities in smoke-free home adoption are also consistently documented. In several U.S. national analyses, Black households demonstrate lower odds of complete smoke-free home rules compared with non-Hispanic White households (Mai et al., 2018; Reyes-Guzman et al., 2023; Zhang et al., 2013). However, patterns vary

across minority groups. Hispanic households frequently show comparable or higher likelihood of complete bans relative to non-Hispanic Whites (Li et al., 2020; Rivard et al., 2021), and Hispanic single-parent households demonstrate high adoption rates (Mai et al., 2018). Evidence from the United Kingdom similarly indicates ethnic disparities. In an English pregnancy cohort, non-white British mothers were significantly more likely to report smoking occurring in the home three months postpartum compared with White British mothers (Orton et al., 2015). Indigenous children are consistently more likely to be exposed to smoking in the home compared with non-Indigenous children in Australia, New Zealand, Canada, and the United States (Stevenson et al., 2017). No comparable data on smoke-free home adoption among Roma populations were identified, representing an important research gap. It is important to note that, while ethnic disparities in health behaviors exist, ethnicity itself is not the operative mechanism. Ethnic disparities reflect the structural conditions disproportionately concentrated among ethnic minorities, including material deprivation, residential segregation, stigmatization and exclusion from healthcare (Belak et al., 2017; Bernát, 2019; Kóczé, 2010; Petrova, 2003).

Knowledge and attitudes toward secondhand smoke (SHS) are important correlates of smoke-free home adoption. Awareness of SHS harms has been strongly associated with the implementation of complete home smoking bans (Intarut, 2021; Pizacani et al., 2003). Attitudinal factors, including motives to reduce exposure and perceived barriers to establishing restrictions, also predict smoke-free home rules in adjusted analyses (Berg et al., 2023; Borland et al., 2006). Qualitative evidence further indicates that negative perceptions of SHS and concern for family health facilitate adoption, whereas social norms and intra-household negotiation challenges impede implementation (Suteerangkul et al., 2019).

National tobacco control environments appear to be positively associated with voluntary smoke-free home adoption. Cross-national analyses show that stronger national tobacco control policies are associated with higher prevalence of complete home smoking bans (Ferketich et al., 2014). Longitudinal evidence further indicates that implementation of national smoke-free legislation was followed by significant increases in total home smoking bans among smokers (Mons et al., 2013). Trend data from Minnesota similarly demonstrate rising voluntary home bans alongside expansion of workplace smoking

restrictions (St. Claire et al., 2012). Collectively these suggest that stronger public tobacco control policies facilitate diffusion of smoke-free norms into private households.

Evidence on correlates of vape-free home rules is more limited but broadly parallels the correlates of smoke-free homes. Across U.S. national and state-level analyses, current e-cigarette use is the dominant predictor, with vapers and dual users showing substantially lower odds of complete vape-free rules compared with non-users (Helgertz et al., 2020; Reyes-Guzman et al., 2023; Rivard et al., 2021). Living with children is associated with a higher likelihood of vape-free homes, although this protective association is weaker among current e-cigarette users, many of whom continue to permit vaping indoors even in the presence of children (Helgertz et al., 2020; Li et al., 2020). Socioeconomic gradients resemble those observed for smoke-free homes: higher education and higher income are positively associated with vape-free rule adoption, while lower educational attainment and lower income predict permissive policies (Helgertz et al., 2020; Li et al., 2020). Individuals who perceive vaping and secondhand aerosol (SHA) as less harmful than conventional smoking are substantially less likely to implement vape-free home rules (Li et al., 2020; Rivard et al., 2021). Younger adults are consistently less likely to prohibit vaping in the home (Helgertz et al., 2020; Reyes-Guzman et al., 2023).

Table 1. Correlates associated with voluntary in-home smoking bans.

Factor	Direction of association with in-home smoking ban	Example studies (first author and year of publication is indicated)
Absence of smokers in the household (or non-smoking respondent)	↑ Higher likelihood of complete ban	Pizacani et al., 2003; Borland et al., 2006; Jankowski et al., 2020; Tigova et al., 2025; Gallus et al., 2016; Helgertz et al., 2020; Rivard et al., 2021
Presence of children	↑ Higher likelihood in most Western contexts; mixed in some lower and middle income countries	Pizacani et al., 2003; Helgertz et al., 2020; Jankowski et al., 2020; Pandey et al., 2017
Higher educational attainment	↑ Higher likelihood	Borland et al., 2006; Paulik et al., 2013; Li et al., 2020; Tigova et al., 2025
Higher household income	↑ Higher likelihood	Pizacani et al., 2003; Jankowski et al., 2020; Wang et al., 2017
Racialized ethnic minority status	↓ Lower likelihood (varies by group)	Zhang et al., 2013; Mai et al., 2018; Stevenson et al., 2017
Greater perceived harm of second-hand smoke (knowledge)	↑ Higher likelihood of complete ban	Pizacani et al., 2003; Intarut, 2021

Table source: author.

1.2.5. Household-level context and intra-household negotiation

As mentioned earlier, most quantitative epidemiological studies either ignore or just partially consider that voluntary in-home smoking and vaping bans are household-level phenomena. Voluntary bans are informal rules that apply to all household members and govern their behavior within shared domestic space. Households constitute small, repeated-interaction environments in which members routinely observe one another's behaviour, facilitating informal monitoring and the enforcement of shared norms (Ellickson, 2008). Except in one-person households, these bans are not determined by a single individual, but emerge through processes involving multiple household members with divergent preferences, smoking behaviors, health beliefs, and decision-making power. While qualitative research has demonstrated that smoke-free home rules often emerge through negotiation (Kegler et al., 2007; Nichter et al., 2015; Passey et al., 2016), quantitative studies have only partially operationalized this complexity.

An example of how household composition shapes interpretation is provided by Mai et al. (2018), who specifically examined smoke-free home adoption among single-parent families in the United States. By restricting the analytic sample to single-parent households, the authors eliminated negotiation and demonstrated that ethnic disparities and parental smoking status strongly structured rule adoption within this household type. This design underscores that household composition is not merely a background characteristic but a primary context and condition (Mai et al., 2018).

Meanings and forms of households vary across historical and cultural contexts. In the ancient Roman world, the *domus* ranged from nuclear families to extensive patronage-based domestic complexes (often comprising hundreds of residents) (Herlihy, 1985; Wallace-Hadrill, 2010). Among the Mosuo people of southwestern China, matrilineal households remain the stable residential unit (with maternal uncles as primary male authorities) while sexual partnerships occur through *tisese*: a non-cohabiting visiting system between separate households (Shih, 2014). In contemporary Western Europe, *living apart together* relationships constitute an emergent arrangement wherein committed intimate partners maintain separate residences (Liefbroer et al., 2015). Another emerging form in post-divorce settings is *bird-nesting*, where children remain in the family home while separated parents rotate residence on scheduled intervals (Lehtme, 2024). These examples illustrate that household-level decisions are always embedded in

specific socio-cultural contexts, which must be accounted for. Given the diversity of contemporary household forms, one analytically tractable and socially prevalent configuration is the cohabiting two-adult household, which still represents a common child-rearing arrangement (Smock & Schwartz, 2020) and a key context in which in-home tobacco-use norms are negotiated.

Regardless of this complexity and diversity, the vast majority of households are organized along family lines (Sigmund, 1997). While family developmental models exist (e.g. Duvall, 1977), most of these frameworks rely on assumptions of the nuclear family structure and stable household forms specific to post-World War II Western contexts (Clingempeel & Henggeler, 2010). From a systems-theoretical perspective, families function as structured social systems characterized by patterned communication, differentiated roles, internal norms, and power hierarchies (Goldenberg & Goldenberg, 2012; Wampler, 2020). Within family systems, rules arise through norms, negotiation and authority structures. Given that family is a distinct unit, community nursing has long been applying family-level counseling, consultation, and education (Savage et al., 2024).

Housing tenure represents an additional household-level context. Renters show lower prevalence of smoke-free homes than homeowners (Tattan-Birch & Jarvis, 2022) in England. However, this is not solely the decision of the renter: landlords may set tobacco and nicotine-use policies. The relevance of this structural constraint depends on the share of the population in rental housing and on landlord preferences. In subsidized housing, authorities can and do set smoke-free rules (Instituting Smoke-Free Public Housing, 2016). However, only 9.9% of the population lived in rental housing in 2023 in Hungary (Eurostat, 2025), limiting the population-level impact of landlord-imposed restrictions, yet highly relevant when studying decision-making patterns.

Qualitative and quantitative research consistently demonstrates that voluntary smoke-free home rules emerge through intra-household negotiation processes shaped by power relations, gender norms, knowledge, and material conditions. In Western contexts, decisions about smoking in the home are rarely unilateral, but reflect ongoing bargaining among household members (Bottorff et al., 2010; Kegler et al., 2007). These correspond with bargaining models of household decision-making, which view household outcomes as reflecting relative decision-making power and fallback positions of each partner rather than a single shared household utility function (Deb et al., 2024; Manser & Brown, 1980).

In rural United States households, Kegler et al. (2007) document negotiation processes involving conflict, compromise, and children's influence. Similarly, longitudinal qualitative work with Canadian couples shows that adoption of smoke-free homes is shaped by relationship dynamics and shared parenting practices, with more egalitarian arrangements facilitating ban implementation (Bottorff et al., 2010). Evidence from non-Western settings show different negotiation patterns. In Kerala, India, women frequently asked their husbands not to smoke indoors, yet reported limited authority to enforce restrictions due to prevailing gender norms (Nichter et al., 2015). Qualitative evidence from Egypt also shows that the social acceptance of male smoking, masculinity norms, and fear of relationship conflict strongly constrain women's capacity to enforce in-home bans (Hassanein et al., 2024). Similar constraints were reported in Chinese families, where wives most often initiated smoke-free rules but used other relatives as mediators towards senior men (Berg et al., 2015; Mao, 2015), and in Germany and among US multigenerational households, where women's enforcement depended on their household authority (Barrera et al., 2026; Villarreal et al., 2026). In Nepal, secondary analysis indicates that women's decision-making power is associated with lower likelihood of smoking in the home, while husbands' smoking remains a dominant predictor (Pandey et al., 2017). In Malaysia, qualitative interviews with male smokers reveal that indoor smoking is often justified through partial mitigation strategies (Abdul Mutalib et al., 2023). Across Western contexts, concern for children's health emerges as a recurring factor. In Scotland, fathers described smoke-free homes as consistent with their identity as protectors (O'Donnell et al., 2022). In rural U.S. families, children's respiratory health concerns frequently triggered negotiation about restrictions (Kegler et al., 2007). Some families also cited the unpleasant smell of tobacco smoke in household furnishings and clothing as a motivator for adopting restrictions (Kegler et al., 2007). However, these protective intentions coexist with structural and relational barriers, including multiple smokers in the household (Stevenson et al., 2017), clustered alcohol use (Intarut, 2021), and traditional gender norms limiting women's capacity to impose rules (Nichter et al., 2015; Pandey et al., 2017). While qualitative studies document instances where ban adoption was proposed but not implemented (Hassanein et al., 2024; Nichter et al., 2015), no quantitative studies estimating the prevalence of proposed but not yet adopted bans were identified. It also represents a relevant research gap.

1.3. Scope and research gaps

This dissertation aims to study voluntary in-home bans on tobacco and nicotine use that generate smoke or aerosol. The focus is on combustible cigarettes and EDTNAD. Geographically, all empirical analyses are restricted to Hungary, covering the period 2009–2025. Specifically, this dissertation addresses four interrelated dimensions of voluntary in-home smoking bans and EDTNAD-use bans: their prevalence and temporal development; their social and ethnic stratification; their intra-household configuration; and the recalled decision-making patterns underlying their adoption. Corresponding to these four dimensions, four research gaps are identified:

(1) Despite their importance for monitoring tobacco control progress, national estimates on the prevalence and temporal development of voluntary in-home smoking bans in Hungary have been lacking since 2010. Exploratory projections of adoption trajectories are also not available. National estimates on the prevalence of voluntary in-home EDTNAD-use bans are absent.

(2) Despite documented social and ethnic disparities, quantitative evidence on the adoption of voluntary in-home bans among the Roma population is lacking.

(3) Despite the established effects of education and shared decision-making on voluntary ban adoption, quantitative research has not systematically examined how gendered educational disparities between household members or shared household decision-making are associated with household-level adoption of voluntary in-home smoking bans and EDTNAD-use bans, while accounting for household smoking composition and other established determinants.

(4) While qualitative studies document specific decision-making patterns in ban adoption, quantitative evidence on recalled intra-household decision-making patterns underlying the adoption of voluntary in-home smoking bans remains limited, and quantitative evidence on the prevalence of contemplated but not yet adopted bans is absent.

2. Objectives

Translating household-level research gaps into tractable objectives is not trivial. Operationalizing household-level constructs is constrained by data availability and analytical tractability. For population-level prevalence estimation, the individual respondent reporting on their household is the appropriate epidemiological unit: ban prevalence is meaningfully expressed as the proportion of individuals living in households with complete bans. However, for analyses of intra-household configuration and recalled patterns, a household-level unit of analysis is required. Full household composition data are rarely feasible due to non-response and reporting limitations. Given the complexity and diversity of household configurations, unrealistically large samples and surveys would be needed to represent each household composition. The cohabiting couple is therefore used as the unit of analysis for these objectives: it is analytically tractable, demographically prevalent, and represents a key child-rearing context. This restriction means that the identified household-level gaps are partially addressed in this dissertation. Given these considerations, this dissertation has four specific tractable objectives corresponding to the identified four research gaps:

1. To estimate the prevalence of individuals living in homes with smoking bans and EDTNAD-use bans in Hungary, and to explore plausible adoption trajectories under assumptions.
2. To examine the prevalence of voluntary in-home smoking bans and EDTNAD-use bans among the Roma population in Hungary, adjusting for established socioeconomic factors.
3. To examine how gendered educational disparities between cohabiting partners and shared decision making are associated with voluntary in-home smoking bans and in-home EDTNAD-use bans, while adjusting for established factors.
4. To quantify recalled intra-household decision-making patterns underlying the adoption of voluntary in-home smoking bans among cohabiting couples, and to estimate the prevalence of proposed but not yet adopted bans.

3. Methods

All analyses in this dissertation are observational. The dissertation draws on four cross-sectional surveys conducted in Hungary between 2009 and 2025. In all surveys, the unit of observation is the individual respondent. The analyses use three different units of analysis: individual, cohabiting couple, cohabiting homeowner couples. The analyses with different units of analyses are designed to be complementary, not directly comparable. Analyses across datasets within the same objective are not pooled. The correspondence between datasets and objectives is summarised at the end of this section, in Table 2. Two datasets from 2009 are subjected to secondary data analysis. One general online health survey from 2022 is involved, in which a dedicated block was developed and incorporated for the purposes of this research. The latest dataset from 2025 is an online data collection designed for this dissertation.

Data sources and involved measures are described first, then data quality issues are discussed, finally statistical analyses are presented by objectives.

3.1. Surveys and measures

3.1.1. Social Determinants of Smoking Survey, February 2009

The first dataset comes from the first wave of the Social Determinants of Smoking Survey. It is a longitudinal study of Hungarian residents aged 16–70 years (Paulik et al., 2013). Data collection started in February 2009. The sampling design used two stages: settlement and individual levels. The final sample consisted of 48 Hungarian settlements. A self-administered paper-and-pencil questionnaire was completed by 2,286 respondents (response rate: 55.1%). After excluding 36 individuals with missing data on key variables, the final analytic sample comprised 2,250 respondents. The sample was representative of the Hungarian adult population by age, gender, education and region. Only the first wave was used in this dissertation, because the second wave was no longer representative of the general population due to attrition (Brys, Paulik, et al., 2025). The data collection was funded by the Fogarty International Center and the US National Cancer Institute. Data collection was approved by the Regional and Institutional Human Medical Biological Research Ethics Committee of the University of Szeged (No. 2431/2008). The dataset is available upon reasoned request to the University of Szeged, Department of Public Health.

The survey consisted of 93 questions. The following seven measures were involved in this dissertation. The outcome variable (complete ban on in-home smoking) was derived from the question: “Do you allow your friends and acquaintances to light up in your home?” Response options were: “People may smoke anywhere in the home”, “People may smoke only in certain rooms”, and “Smoking is not allowed anywhere in the home”. The latter was operationalised as a complete, voluntary in-home smoking ban, while the first two categories were grouped as no complete ban. “Don’t know” and missing responses were treated as missing. Roma ethnicity was assessed through self-identification with the question: “Which nationality do you consider yourself to belong to?” Predefined response categories included Hungarian, Roma, and other officially recognized national minorities. Respondents identifying as Roma were classified as Roma; all other declared nationalities were classified as non-Roma. Refusals were treated as missing. Educational attainment referred to the respondent’s highest completed level of education and was dichotomised as less than secondary education (less than eight years of schooling, eight years of schooling, or vocational school) versus secondary school or higher (secondary school, college, or university). Settlement type was derived from official population size categories and dichotomised as rural settlement (<2,000 inhabitants) versus larger settlements (≥2,000 inhabitants, including Budapest). Financial deprivation was measured by the question: “Did it happen in the last 12 months that you couldn’t pay the heating/water/gas or lighting charges in time because of financial difficulties?” Responses were coded as yes or no; “Don’t know” responses were treated as missing. Household smoking context was assessed using two items: the respondent’s smoking status and the reported number of other smokers in the household. These were combined to determine whether at least one smoker was present in the household. Belief regarding the harm of secondhand smoke was assessed by agreement with the statement: “Other people’s tobacco smoke increases the risk of lung cancer in non-smokers.” Only respondents who reported “totally agree” were classified as fully endorsing the health risk; all other responses, including uncertainty, were grouped as not fully endorsing the statement.

The survey did not include a direct measure of whether minors lived in the respondent’s household. Housing tenure (owner-occupied vs rented dwelling) was also

not assessed. Missing values on individual variables were handled as specified in the corresponding analytical sections. Weights were not applied.

3.1.2. Eurobarometer 72.3, October 2009

The second dataset derives from the Hungarian subsample of the European Commission Eurobarometer 72.3: Public Health Attitudes, Behaviour and Prevention (European Commission, 2012). Data collection in Hungary took place between 2 and 18 October 2009. The target population comprised residents aged 15 years and older. A stratified multistage (region, household, individual) probability sampling design was applied. Interviews were conducted using computer-assisted personal interviewing (CAPI). Primary sampling units were selected proportionally to population size within regions, followed by random selection of households and individuals within households. In Hungary, fieldwork was carried out by TNS Hungary. The Hungarian sample included 1,044 respondents. The questionnaire and dataset are openly available at the GESIS Data Archive (European Commission, 2012).

The full Eurobarometer 72.3 survey comprised 452 variables across multiple thematic modules, including health check-ups, oral health, alcohol consumption, smoking behaviour, organ donation, blood donation, and physical activity. For the purposes of this dissertation, only one item from the smoking module was used to estimate the crude prevalence of voluntary in-home smoking bans in 2009 (Objective 1). The variable (complete ban on in-home smoking) was derived from question “Which statement best describes the smoking situation in your household?” Response options were: “Not allowed at all”, “Allowed only in certain rooms”, “Allowed everywhere”, and “Don’t know”. “Not allowed at all” was classified as having a complete in-home smoking ban, while all other responses were classified as no complete ban. “Don’t know” responses were treated as missing. To ensure comparability with the 2009 Social Determinants of Smoking Survey, analyses were restricted to respondents aged 18 years and older (n = 1,015). Eurobarometer post-stratification weights were applied in all prevalence estimations to account for sampling design. The questionnaire did not include information on Roma ethnicity, detailed household smoking composition, housing tenure (rented or owned), presence of minors beyond age 18 in the household (only counts of children aged 0–14 were recorded), and on in-home vaping rules.

3.1.3. Online Health Survey, November 2022

The third dataset originates from a nationwide Hungarian online health survey carried out in 2022 during the COVID-19 pandemic. Although the primary objective of the data collection concerned vaccination-related attitudes and health behaviors, the questionnaire contained a block designed for this PhD research. Data were collected between 15 and 26 November, 2022 through Computer Assisted Web Interviewing (CAWI). The target population consisted of Hungarian residents aged 18 years and older. Respondents were recruited from an established online Netpanel (Marketing Resolution). Quota sampling was applied at the individual level to approximate the distribution of the Hungarian adult population by gender, age group, region, settlement type and educational attainment. In total, 1,500 participants completed the survey. Post-stratification weights were calculated. As compensation, respondents received small-value incentive vouchers after completing the survey. The data collection received prior ethical approval from the Hungarian Medical Research Council (ETT-TUKEB: BMEÜ/2422-1/2022/EKU, 4 October 2022) and from the Ethical Review Board of the Centre for Social Sciences (FOIG-1/130-24/2022, 28 October 2022). The full questionnaire and dataset are available at Social Sciences Research Documentation Centre (Albert et al., 2023). The data collection was funded by the Hungarian Academy of Science *High-risk/high yield research on post-COVID phenomena fund* (PC2022 II-5/2022).

The questionnaire included information on partnership status and cohabitation, allowing identification of cohabiting couples for the analyses of intra-household educational configuration. However, in this survey ethnicity was not assessed; housing tenure (owner-occupied vs. rented dwelling) was not measured; and no items captured shared decision-making on financial issues.

For Objective 1, the complete in-home smoking ban was assessed with the question: "Is it allowed to use traditional tobacco smoking products inside your home?" Possible responses were: "Yes, anywhere", "Yes, but not everywhere", and "No, nowhere". Only the third response was classified as a complete ban; the two permissive responses were merged into a single no-ban category. An equivalent question assessed in-home EDTNAD use: "Is it allowed to use electronic tobacco and/or nicotine delivery devices (e-cigarettes and/or heated tobacco products) inside the home?" Identical response options and coding logic were applied. Clean air rules were defined as having

both a complete smoking ban and a complete EDTNAD use ban, simultaneously. The number of minors in the household was recorded as a count and used to estimate the share of minors residing in households without complete bans (Brys, Paulik, et al., 2025).

For Objective 3, inclusion required that the respondent was romantically partnered and sharing a home exclusively with that partner, with no additional adults present. Thirty-one respondents (4.7%) were excluded due to missing data on household rules or on either partner's tobacco or nicotine use status, yielding a final analytic subsample of 623 couples. The cohabiting couple was the unit of analysis. Data on both partners were provided by one respondent. The respondent's gender was directly recorded. The partner's gender was not assessed but assumed to be different from the respondent's, an assumption with negligible impact on measurement given the low prevalence of same-sex couples in Hungary at the time of data collection (IPSOS, 2022). Formal relationship status was not collected (Brys, Pénzes, et al., 2025). Each partner's educational attainment was self-reported on a seven-level ordinal scale. Both responses were dichotomized at secondary school completion, a threshold established in prior epidemiological work (Brys, Susánszky, et al., 2022). Four mutually exclusive couple-level educational composition categories were derived: both partners completing secondary or higher education (dual SoHE); only the female partner reaching this level (female-only SoHE); only the male partner reaching this level (male-only SoHE); and neither partner reaching this level (dual lower-than-secondary; reference category) (Brys, Pénzes, et al., 2025). Couple-level smoking status was categorized into four groups: both partners smoking (dual smoker); only the female partner smoking (female-only smoker); only the male partner smoking (male-only smoker); and neither partner smoking (non-smoker couple; reference). An identical four-category structure was applied to EDTNAD use: dual EDTNAD-user, female-only EDTNAD-user, male-only EDTNAD-user, and non-EDTNAD-user couple (reference). Smoking and EDTNAD-use status were retained as two distinct variables rather than combined, because the two outcomes were analysed in separate models, and the sample size precluded reliable estimation across all possible gendered cross-combinations (Brys, Pénzes, et al., 2025). Sociodemographic covariates included the age of each partner in years, the male-minus-female age difference in years, presence of at least one household member under 18 years of age, residence outside urban settlements, residence in a county where per capita GDP fell below US$31,000 in 2022 (low-GDP

county)(Brys, Pénzes, et al., 2025). Subjective financial deprivation was defined as reporting persistent monthly financial hardship or living conditions characterized by deprivation (Brys, Pénzes, et al., 2025). Listwise deletion was applied for missing outcome data and missing tobacco and nicotine use data (n = 31, 4.7%)(Brys, Pénzes, et al., 2025). Other missing values were handled as described in Section 3.3. No post-stratification weights were applied (Brys, Pénzes, et al., 2025).

3.1.4. Online Cohabiting Couples Survey, September 2025

The fourth dataset derives from a primary data collection conducted specifically for this research in 2025. Accordingly, the questionnaire was designed to capture the factors required for the final study objective, including housing tenure (sample restricted to owners), the presence of children in the household, Roma ethnicity, intra-couple financial decision-making patterns, motives for adopting in-home smoking bans, the existence of prior proposals to introduce bans, and recalled decision-making patterns.

The survey focused on Hungarian adults living in a romantic cohabiting relationship and sharing a household with their partner and without further non-related adults living in the household. Data were collected between 26 August and 16 September, 2025 using CAWI through the research panel of a survey company (Panelstory). The target population consisted of Hungarian citizens aged 18 years and older who were currently in a romantic relationship and residing in the same household as their partner without further non-children adults living with them. Participation was voluntary and anonymous. Respondents received compensation through the panel provider's points-based incentive system, which could be exchanged for vouchers or discounts. The data collection (including the questionnaire and informed consent materials) was reviewed and approved by the Hungarian Medical Research Council (ETT-TUKEB; approval number BM/13665-3/2025, 3 July 2025). An informed consent was also obtained electronically prior to survey completion. The full questionnaire and anonymised dataset are available at OSF (Brys, Deb, et al., 2025). The funding was provided by Semmelweis University.

The questionnaire contained items covering household tobacco and EDTNAD use bans, sociodemographic characteristics and tobacco and nicotine use status of both partners. The number of items completed by each respondent varied due to conditional routing between questions.

For Objective 2, the following 10 measures were used. Two outcome variables were derived: a complete in-home smoking ban and a complete in-home EDTNAD use ban. The in-home smoking ban was assessed by the question: "Is conventional smoking permitted inside your home?" A complete ban was defined as reporting that smoking was not allowed anywhere in the home; the first two response options (allowed anywhere or allowed only in certain rooms) were grouped as non-complete ban. The in-home EDTNAD use ban was operationalised analogously using separate items for e-cigarettes and HTPs; a complete EDTNAD use ban was defined as reporting that neither e-cigarettes nor HTPs were permitted anywhere in the home. Respondents living in rented or otherwise non-owner-occupied dwellings were asked whether the landlord or property owner had prohibited smoking or EDTNAD use; their responses were handled separately and these respondents were excluded from analyses restricted to home-owning couples. Restricting analyses to home-owning couples was a deliberate analytic decision: only home-owners can be assumed to exercise autonomous authority over indoor bans. This restriction significantly improves the interpretability of voluntary ban measurement and produces a more homogeneous analytic sample. However, the subset is more financially stable than the broader cohabiting population, which limits generalisability, yet allows focus on egalitarian household dynamics. Roma household status was defined as a household in which at least one partner was identified as Roma by the respondent, assessed through separate items for the respondent and their partner. This approach reflects that ethnic categorisation in everyday social contexts often operates at the household level and is often based on perceived ethnicity (Kemény & Janky, 2005; Kósa et al., 2007). Highest educational attainment within the couple was derived from the respondent's and partner's reported highest completed level of education, each measured on a seven-point ordinal scale ranging from less than eight years of primary schooling to doctoral degree; and dichotomised as less than secondary graduation versus secondary graduation or higher. The presence of at least one smoker in the household was derived from respondent-reported current use of conventional cigarettes by themselves and their partner. The presence of at least one EDTNAD user was derived analogously from reported current use of e-cigarettes or HTPs by either partner. The presence of minors was defined as at least one child aged 0–17 years residing in the household. Financial deprivation was assessed by a subjective financial situation item; respondents reporting

that the household managed only from month to month, had recurring financial difficulties, or lived in deprivation were classified as financially deprived. Village residence was derived from reported settlement type and defined as residing in a village. Couple mean age was calculated as the arithmetic mean of the respondent's and partner's year of birth, subtracted from the survey year. Weights were not applied.

For Objective 3, the outcome variables were the complete in-home smoking ban and the complete in-home EDTNAD use ban, operationalised as described for Objective 2. Independent variables included Roma household status (operationalised as described above). Income share equality was a binary indicator derived from the respondent's reported share of total household income. Shared home ownership configuration was a binary indicator coded as joint ownership versus sole ownership by either partner (reference). Couple-level educational configuration was operationalised as three binary indicators with both partners below tertiary education as the reference category: male-only tertiary education, female-only tertiary education, and both partners with tertiary education, where tertiary education was defined as bachelor's degree or higher. Couple-level employment configuration was a binary indicator coded as both partners currently employed versus all other configurations (reference). Shared financial decision-making was a binary indicator coded as shared versus male- or female-dominated. Additional covariates were financial deprivation, village residence, presence of minors in the household, presence of at least one smoker in the household, presence of at least one EDTNAD user in the household, and couple mean age, all operationalised as described above. Missing values on explanatory variables were handled by multiple imputation using chained equations, with 20 imputation datasets generated; a single analysis dataset was derived by majority rule, applying the mode for categorical and logical variables and the median for continuous variables.

For Objective 4, the analytic sample was broader than for Objectives 2 and 3: home-owning respondents living in a romantic cohabiting relationship were included regardless of whether further adults residing in the household were children of either partner. The two outcome variables were the complete in-home smoking ban and the complete in-home EDTNAD use ban, operationalised as described above. The EDTNAD use ban required that both e-cigarettes and HTPs were fully prohibited; households banning only one product were not classified as having a complete EDTNAD use ban.

For households without a current complete smoking ban, recalled proposal for introducing a full ban was assessed by asking whether the respondent, their partner, both jointly, or neither had ever proposed that smoking be entirely prohibited in the home. Responses were gender-mapped to produce gender-absolute codes: man only, woman only, jointly, or neither. (For example, when a female respondent reported that the "respondent" proposed the ban, this response was recoded as "female", while "partner" responses were recoded as "male".) For households with a current complete smoking ban, recalled prior permissiveness was assessed by asking whether smoking had previously been permitted anywhere or in certain rooms in the home. Among households reporting ban adoption, the recalled initiator of the ban was assessed using a single-choice item, gender-mapped to distinguish male-initiated, female-initiated, and jointly initiated bans. Recalled conflict during ban adoption was assessed on a three-point scale: no conflict, minor disagreement, or serious conflict; don't-know responses were treated as no conflict. Recalled primary motivation for adopting the ban was assessed by a single-choice item with options covering protection of children, unpleasant smell of tobacco smoke, recommendation by a physician or health professional, and other. Open-text responses to the other category were reviewed and responses referring to smoking cessation were reclassified accordingly. For in-home EDTNAD use bans, identical items were administered separately for e-cigarettes and HTPs. A household was classified as having adopted an EDTNAD use ban if at least one of the two products had previously been permitted and was subsequently banned. For households where both products had been adopted, initiator and primary motivation were classified as concordant if both products yielded the same response, and as mixed or discordant otherwise; conflict level was taken as the maximum across the two products. Weighting was not applied.

3.2. Data quality

In the Online Health Survey (2022) and the Online Cohabiting Couples Survey (2025), one partner per couples provided information on both members of the couple. Requiring participation from both partners was deliberately avoided: studies demonstrate that this design creates systematic underrepresentation of higher-risk households, as couples with greater health concerns are less likely to both consent to and complete surveys (Ranby et al., 2023). Single-respondent reports of household smoking rules have shown satisfactory

concordance with partner-reported data (Zhang, Martinez-Donate, Kuo, & Jones, 2012). Self-reported tobacco use status also demonstrates high accuracy when compared with biochemically verified measures (Stevens et al., 2020).

Online panel-based surveys are subject to limitations of non-probability sampling designs, most notably the potential systematic exclusion of individuals with restricted/limited internet access and/or individuals with low digital literacy (Lehdonvirta et al., 2021). These coverage limitations are partially offset by methodological advantages: the absence of an interviewer reduces interviewer effects and lowers social desirability bias (Kreuter et al., 2008). Self-reported smoking prevalence estimates obtained from online panel surveys have also demonstrated acceptable validity (Klein et al., 2007). However, for the Online Health Survey in 2022, an external validity check was conducted by comparing the online sample prevalence of current tobacco and/or nicotine use against an estimate derived from the Hungarostudy 2021. The Hungarostudy 2021 is a large nationally representative face-to-face health survey of Hungarian adults (n = 7,000) that employed a question with identical wording (Brys, Pénzes, et al., 2025; Brys, Susánszky, et al., 2022). Current tobacco and/or nicotine use prevalence in the 2022 online sample was 37.0% (95% CI: 34.5%–39.5%), while the corresponding Hungarostudy 2021 estimate was 34.1% (95% CI: 33.0%–35.2%). The observed discrepancy of 2.9 percentage points, in the context of a 16-month separation between the two fieldwork periods, was judged to fall within an acceptable range. The 2025 Online Cohabiting Couples Survey was not subject to an equivalent external validation procedure, given the absence of a suitable contemporaneous benchmark dataset.

Some indicators differed slightly across surveys due to differences in questionnaire design and study objectives. For example, financial hardship was measured in the 2009 survey as the inability to pay household utility bills in the previous 12 months, whereas later surveys assessed subjective household financial situation. Minor differences were also present in the wording of household smoking rules and in the availability of certain variables (e.g., presence of minors or EDTNAD use rules). Because each dataset was analysed separately for its respective research objective, no pooled analyses requiring harmonisation of these indicators were performed.

3.3. Data imputation

Missing data handling differed across datasets. For the Social Determinants of Smoking Survey (2009), no imputation was applied. Missing values on individual covariates were handled by listwise deletion.

For the Online Health Survey (2022, Objective 3), missing values were very limited and handled by simple substitution prior to analysis. Missing values on subjective financial status (n = 3, 0.54%) and on the presence of minors (n = 6, 0.96%) were replaced by the median of the observed distribution. When partner age was missing (n = 16, 2.6%), the respondent's own age was substituted; when partner educational attainment was missing (n = 16, 2.6%), the respondent's own educational attainment was substituted. These substitutions were applied under the assumption that within-couple similarity constitutes a reasonable approximation for the missing partner value. Thirty-one respondents (4.7%) with missing outcome or tobacco and nicotine use data were excluded by listwise deletion prior to these substitutions.

For the Online Cohabiting Couples Survey (2025, Objective 3), missing values on explanatory variables were handled by Multiple Imputation using Chained Equations (MICE) (Buuren & Groothuis-Oudshoorn, 2011). Missingness was confined to explanatory variables; both outcome variables and all structural sample inclusion criteria were fully observed in the filtered analytic sample. In total, 61 missing values were distributed across eight explanatory variables, with the largest proportions occurring in variables capturing relative household income contribution and tobacco and nicotine use status of each partner. Both outcome variables and all fully observed explanatory variables were retained as predictors in the imputation model, which is standard practice to preserve associations between variables during imputation. The imputation method was assigned by variable type: logistic regression for binary variables and multinomial logistic regression for factor variables. Convergence was assessed by visual inspection of trace plots of the chain mean and standard deviation of imputed values across iterations, and by density plots comparing the distribution of imputed values against the distribution of observed values. Flat, well-mixed chains with no systematic trend and broadly compatible imputed and observed distributions indicated satisfactory convergence. Diagnostic plots are presented in Figure 2. A single analysis dataset was derived from the 20 imputed datasets by majority rule: for each missing cell, the mode was applied to

categorical and logical variables. This collapsed representation was justified by the very low number of imputed values (0.6%) and was also required because the analytical pipeline involved model fitting on a single design matrix. The resulting dataset comprised 726 cohabiting home-owner couples and was used for all Objective 3 analyses based on the Online Cohabiting Couples 2025 Survey data.

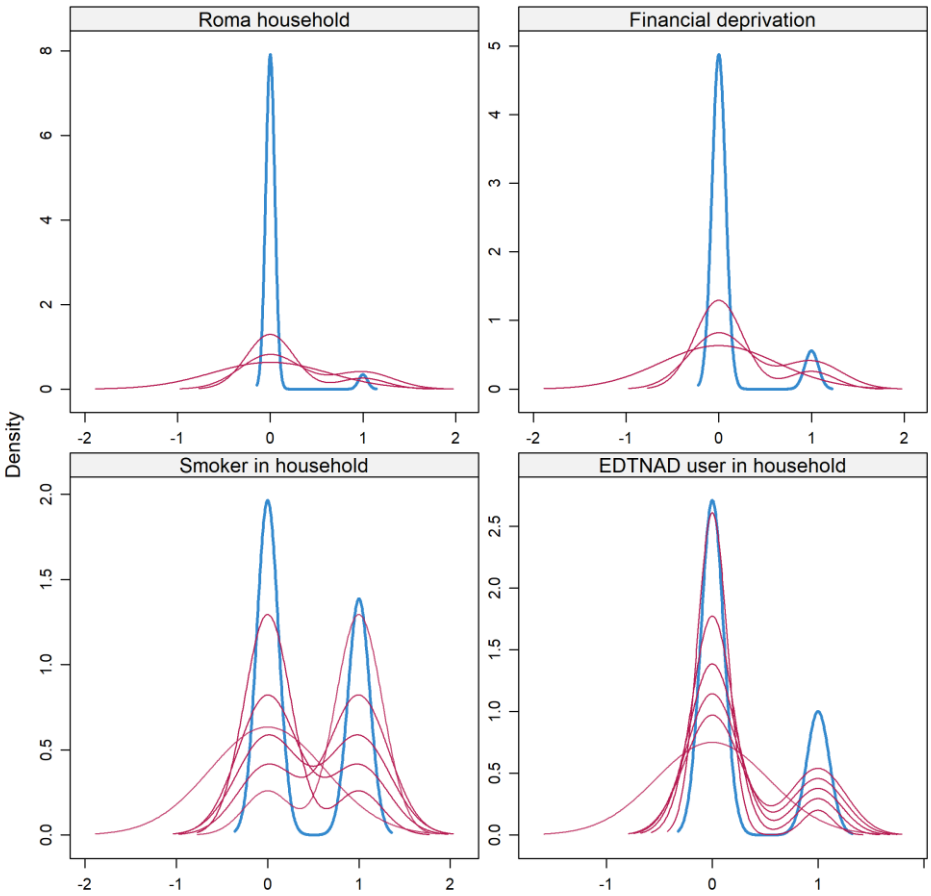


Figure 2. Density plots of observed (blue) and imputed (red) value distributions for binary variables subject to multiple imputation, Online Cohabiting Couples Survey 2025. Each red line represents one of the 20 imputed datasets. Factor variables imputed by polytomous logistic regression are not shown, as kernel density estimation is not applicable to nominal variables. Figure source: author.

3.4. Statistical Analyses

3.4.1. Prevalence and trends

Prevalence estimates were calculated separately for the October 2009 Eurobarometer 72.3 survey (subsetted to respondents aged ≥18 years for comparability) and the 2022 Online Health Survey (conducted in November during the COVID-19 pandemic). In both datasets, a complete in-home smoking ban was defined as reporting that smoking was not allowed anywhere in the home without exception (Brys, Paulik, et al., 2025). (Although the wording of the questions differed, they were conceptually equivalent.) Weighted prevalence estimates and their corresponding 95% CIs were also calculated.

Individual-level sampling is the appropriate unit for prevalence estimation: ban prevalence is meaningfully expressed as the proportion of individuals living in households with complete bans. Under individual-level sampling, larger households are more likely to provide a respondent, aligning with the fact that more individuals are impacted by the household rule.

Temporal differences in the prevalence of complete in-home smoking bans between 2009 and 2022 were assessed using two-sample Z-tests. Effect size was quantified using Cohen's h for proportions (Cohen, 1988). For 2022, within-household differences between smoking bans and EDTNAD use bans were examined using McNemar's test for paired binary outcomes. To estimate the proportion of minors living in households permitting smoking and/or EDTNAD use in 2022, weighted household-level estimates were combined with the reported number of minors per household.

Exploratory logistic growth modelling was applied to explore plausible long-term adoption trajectories of smoke-free homes under defined assumptions. The shape of the diffusion curve may differ across countries; the logistic functional form is an analytic assumption. The logistic growth function was defined as $P_t = K / (1 + exp(-r \times (t - t_0)))$, where P_t is the proportion of adults living in smoke-free homes at time t, K is the carrying capacity, r is the growth rate, and t_0 is the inflection year. K was fixed at 0.929 for all countries, for four reasons. First, identifiability: the logistic function has three free parameters (K, r, t_0), while the Hungarian series contains only two observations; the asymptote therefore cannot be estimated from the data and must be fixed externally. Second, the anchor is policy-defined rather than arbitrary: 0.929 corresponds to the US Healthy People 2030 target for adult smoke-free homes (U.S. Department of Health and

Human Services, 2020), the only published national numeric target of this kind. Third, the ceiling is empirically approachable: Scotland reached 90.2% in 2024 (Semple, Best, et al., 2026) and the United States approximately 91% in 2023 (National Cancer Institute, 2025). Fourth, a ceiling below 100% reflects that universal adoption is implausible while smoker-only households persist. All projections are conditional on this fixed value. The same grid-search procedure was applied to three countries: the United States (10 data points, 1992–2022; National Cancer Institute, 2025), Scotland (11 data points, 2012–2024; Semple, Best, et al., 2026), and Hungary (2 data points, 2009 and 2022). For each country, *r* was swept from 0.01 to 0.50 (step 0.001) and t_0 from 1970 to 2060 (step 0.1). For each (r, t_0) combination, prevalence was predicted at each observed year and the residual sum of squares (RSS) was calculated. Solutions with RSS below 0.001 were retained as acceptable. (The threshold is arbitrary but was informed by the RSS distribution across the grid). Acceptable solutions define trajectory bundles: narrow for the US and Scotland (many observed points constrain the fit tightly), wide for Hungary (two observed points leave more solutions acceptable). As a sanity check, a nonlinear least squares regression was also fitted to the US data; the best-fit grid solution was verified against the nonlinear least squares estimates. The projected year at which smoke-free home prevalence would reach 99% of the assumed ceiling was derived from the acceptable-solution bundle for each country and reported as median with interquartile range.

3.4.2. Social and ethnic stratification

Analyses were conducted separately using the Social Determinants of Smoking Survey (2009) and the Online Cohabiting Couples Survey (2025). In both datasets, bivariate associations between Roma household status and all covariates were assessed using chi-square tests and Cohen's h (for proportion) as effect size measure (Cohen, 1988). For continuous variables, group differences were assessed using Welch's t-test and the Wilcoxon rank-sum test.

For the 2009 data, multivariable analyses were restricted to households reporting at least one smoker, given that only two Roma respondents resided in smoker-free households. Missing values on covariates were handled by listwise deletion. Frequentist binary logistic regression was fitted with the presence of a complete in-home smoking

ban as the dependent variable. Independent variables were: Roma ethnicity, educational attainment below secondary level, total agreement that second-hand smoke causes lung cancer in non-smokers, financial deprivation, and village residence. Multicollinearity was assessed using variance inflation factors. Model fit was evaluated by comparing log-likelihood and Akaike Information Criterion of the full model against the intercept-only null model, with a likelihood ratio test. Discrimination was assessed using the area under the receiver operating characteristic curve (ROC-AUC) with 95% confidence intervals, and the area under the precision-recall curve (PR-AUC) with 95% bootstrap confidence intervals (1,000 resamples). Average marginal effects (AME) with 95% confidence intervals were calculated for all predictors.

For the 2025 data, missing values on explanatory variables were handled by multiple imputation as described in Section 3.3. A joint binary outcome model was fitted, jointly modelling two correlated binary outcomes; complete in-home smoking ban (first outcome) and complete in-home EDTNAD use ban (second outcome). Two simultaneous logistic equations were linked by a conditional log-odds ratio parameter that captures the residual association between the two outcomes after covariate adjustment. This association parameter was constrained to be constant across covariate values, i.e., it did not depend on covariates. Independent variables included Roma household status, highest educational attainment within the couple (secondary or above), financial deprivation, village residence, presence of minors, presence of at least one smoker, presence of at least one EDTNAD user, and mean couple age. Multicollinearity was assessed using variance inflation factors derived from marginal logistic regression models fitted separately for each outcome. Model fit was evaluated by likelihood ratio test comparing the full model against the intercept-only null model. Discrimination was assessed separately for each outcome using ROC-AUC with 95% confidence intervals and PR-AUC with 95% bootstrap confidence intervals (1,000 resamples), derived from marginal logistic model predictions. Average marginal effects with 95% bootstrap confidence intervals (100 resamples) were derived from the joint model for all predictors.

All analyses were conducted in R 4.5.3 (Vienna, Austria). The bivariate binary outcome model was estimated using the VGAM 1.1-14 package (Yee et al., 2015); ROC-AUC and PR-AUC were computed using the pROC 1.19.0.1 (Robin et al., 2011) and

PRROC 1.4 packages (Grau et al., 2015), respectively; average marginal effects were computed using the margins 0.3.26 (Leeper, 2024) package.

3.4.3. Intra-household configuration

Analyses were conducted separately using the Online Health Survey (2022) and the Online Cohabiting Couples Survey (2025). In both datasets, bivariate differences in the prevalence of allowing in-home smoking and in-home EDTNAD use across couple-level educational composition categories were assessed using two-sample z-tests. P-values from pairwise comparisons were adjusted for multiple testing using the Benjamini-Hochberg method (Benjamini & Hochberg, 1995). Within-household differences between the proportion of couples allowing in-home smoking and the proportion allowing in-home EDTNAD use were tested using McNemar's test for paired binary outcomes, with Cohen's h effect size measure. Post-hoc power analyses were conducted for chi-square tests (Brys, Pénzes, et al., 2025).

For the 2022 data, missing values were handled by simple substitution as described in Section 3.3. Two separate binomial logistic LASSO regression models were fitted, one for each outcome: allowing in-home smoking and allowing in-home EDTNAD use. LASSO penalisation applies penalty to the log-likelihood, shrinking coefficients of less informative predictors toward zero (Ranstam & Cook, 2018; Tibshirani, 1996). LASSO was applied because it performs embedded variable selection under multicollinearity, yielding a robust result in the presence of conceptually related predictors (Ranstam & Cook, 2018).

All predictors were standardised to z-scores prior to model fitting, ensuring comparability of penalised coefficients and fulfilling the assumption of standardised inputs. The penalty parameter λ was selected by minimising binomial deviance using fourfold cross-validation. Fourfold rather than fivefold cross-validation was used to ensure a minimum of approximately 150 observations per fold. Because the stochastic nature of cross-validation, each model was estimated across 100 independent iterations. Coefficients and median absolute Shapley values were summarised as medians with 2.5th–97.5th percentile ranges across iterations. Shapley values were approximated using the Strumbelj-Kononenko method with 10 Monte Carlo iterations per observation per model run (Štrumbelj & Kononenko, 2014). A predictor was classified as stable if its

coefficient was non-zero and directionally consistent in at least 95 of 100 iterations and if its median absolute Shapley value exceeded 0.001. Model discrimination was assessed using ROC-AUC and PR-AUC, reported as medians with 2.5th–97.5th percentile ranges across iterations. Independent variables included couple-level educational composition (dual secondary or higher education, female-only secondary or higher education, male-only secondary or higher education, with dual lower-than-secondary as reference category), couple-level smoking composition (dual smoker, female-only smoker, male-only smoker, with non-smoker couple as reference), couple-level EDTNAD use composition (dual user, female-only user, male-only user, with non-user couple as reference), financial deprivation, presence of minors, male partner age, female partner age, male-minus-female age difference, non-urban residence, and residence in counties with per capita GDP below US$31,000 in 2022.

For the 2025 data, missing values on explanatory variables were handled by multiple imputation as described in Section 3.3. Two separate binomial logistic LASSO regression models were fitted, one for each outcome: complete in-home smoking ban and complete in-home EDTNAD use ban. Following the same cross-validation, standardisation, stability assessment, and Shapley-based importance scoring procedure were performed as described for the 2022 analysis. Independent variables included Roma household status, couple-level educational composition (male-only tertiary, female-only tertiary, both partners tertiary, with neither partner holding a tertiary degree as reference), income share equality, joint home ownership, dual employment, shared financial decision-making, financial deprivation, village residence, presence of minors, presence of at least one smoker, presence of at least one EDTNAD user, and mean couple age. (Tertiary education was used as the threshold rather than secondary school completion, as in the 2022 analysis, because the low frequency of couples in which neither partner had completed secondary education precluded reliable estimation.)

All analyses were conducted in R 4.5.3 (Vienna, Austria). LASSO-regression was estimated using the glmnet package 4.1-10 (Friedman et al., 2010); Shapley values were computed using the fastshap package 0.1.1 (Greenwell, 2019).

3.4.4. Recalled motivations and patterns

The analytic sample comprised home-owning respondents in a romantic cohabiting relationship, including households with additional adults where those adults were children of either partner. Recalled proposal for introducing a full ban, recalled initiator, recalled conflict during adoption, and recalled primary motivation were examined using descriptive frequencies and proportions with 95% CI using z-tests.

Survey questions on proposal and initiator used respondent-relative language. These responses were recoded to gender-absolute codes prior to analysis: for male respondents, values were retained as recorded; for female respondents, the respondent and partner codes were swapped. Among households reporting ban adoption, the association between initiator gender and respondent gender was assessed using Fisher's exact test with a simulated p-value (10,000 resamples). Open-text responses to the "other" motivation category were reviewed and responses referring to smoking cessation were reclassified accordingly.

Due to the small number of households reporting EDTNAD ban adoption (n = 34), inferential testing was not conducted for EDTNAD-specific patterns, and these are not reported in detail.

All analyses were conducted in R 4.5.3 (Vienna, Austria).

Table 2. Data sources by dissertation objectives, indicating the unit of analyses.

	Social Determinants of Smoking (2009)	Eurobarometer 72.3 (Age-adjusted Hungarian subsample, 2009)	Online Health Survey (2022)	Online Cohabiting Couples Survey (2025)
Objective 1. Prevalence and temporal trends of voluntary in-home bans†		individual (n = 1,015)	individual (n = 1,500)	
Objective 2. Social and ethnic stratification‡	individual (n = 1,133)§			cohabiting home-owner couple (n = 750/707)§§
Objective 3. Intra-household educational configuration‡			cohabiting couple (n = 623)	cohabiting home-owner couple (n = 726)
Objective 4. Recalled motivations and decision-making patterns				cohabiting home-owner couple (n = 807)§§§

Analyses across datasets within the same objective are not pooled.

†: Exploratory logistic growth modelling for this objective additionally fitted U.S. and Scottish trend data as comparators; these data are not pooled with Hungarian data.

‡: The two datasets for this objective use different units of analysis by design. The analyses are complementary, not directly comparable.

§: Restricted to households with at least one smoker and complete data on all covariates.

§§: n = 750 for descriptive analyses; n = 707 for the multivariate joint outcome model after listwise deletion on all model variables

§§§: Broader analytic sample: home-owning cohabiting respondents including households with additional adults.

Table source: author.

4. Results

This chapter presents the empirical findings corresponding to the four objectives of the dissertation. Analyses are organised in the same order as the objectives. Depending on the objective, different datasets and methods were used as indicated previously in Table 2.

4.1. Prevalence and trends of voluntary in-home smoking and EDTNAD bans

This section presents results on the prevalence and temporal development of voluntary in-home smoking and EDTNAD use bans in Hungary (Objective 1). First, weighted prevalence estimates are reported and differences between 2009 and 2022 are examined. Second, exploratory logistic growth modelling is used to generate plausible long-term adoption trajectories of smoke-free homes in Hungary, alongside US and Scottish trends for comparison.

4.1.1. Observed prevalence

Characteristics of the unweighted Hungarian samples are presented in Table 3. Using the same datasets, but without applying survey weights or age adjustment, point prevalence estimates are 63% for 2009 and 75% for 2022 (Brys, Paulik, et al., 2025). After weighting was applied, the prevalence of in-home smoking bans in 2009 was 61.7% (95% CI 58.5%–64.9%) and in 2022 it was 75.6% (95% CI 73.4%–77.8%). This 13.9 percentage point increase was statistically significant and moderate ($\chi^2 = 46.0$, $p < 0.001$, Cohen's h = 0.28). However, when examining comprehensive clean air rules requiring both smoke-free and EDTNAD-free policies, the increase between 2009 and 2022 was not statistically significant. Clean air rule prevalence was 61.7% (95% CI 58.5%–64.9%) in 2009 and 67.1% (95% CI 64.7%–69.5%) in 2022 ($\chi^2 = 3.3$, $p = 0.07$). (While the 2009 Eurobarometer did not assess vaping and e-cigarette use, from other studies we know that it was still negligible even in 2014 in Hungary (Pénzes et al., 2016)). By 2022, households with smoking bans had not uniformly adopted vaping bans, preventing significant growth in clean air rules despite the significant increase in smoking bans.

Table 3. Descriptive characteristics of the unweighted analytic samples from Eurobarometer 72.3 2009 and the Online Health Survey 2022.

Characteristic	Eurobarometer 72.3 [October 2009]	Online Health Survey [November 2022]
Overall	1,015	1,500
In-home tobacco use ban	642 (63.4%)	1,108 (75.1%)
Missing	2	24
In-home EDTNAD use ban	-	1,054 (72.0%)
Missing	-	36
In-home clean air rules (in-home tobacco use and EDTNAD-use ban)	642 (63.4%)*	969 (66.5%)
Missing	2	42
Number of minors	-	
0	-	969 (64.6%)
1	-	253 (16.9%)
2	-	159 (10.6%)
3	-	61 (4.1%)
4	-	21 (1.4%)
5 or more	-	18 (1.2%)
Missing	-	19

Dates in brackets indicate the survey fieldwork period. Values are presented as n (%). * in 2009 it equals in-home tobacco use ban as EDTNAD use were negligible.

Table source: author, own analysis.

Table 4. Cross-tabulation of household smoking bans and EDTNAD use bans in the Online Health Survey 2022; weighted values (%).

	EDTNAD use allowed	EDTNAD use ban
Smoking allowed	271.3 (18.6%)	79.1 (5.4%)
Smoking banned	130.1 (8.9%)	979.0 (67.1%)

($n = 1459.5$, $\chi^2(1) = 12.0$, $p < 0.001$, McNemar's test)

Table source: author, own analysis.

In 2022, the prevalence of in-home EDTNAD-use ban was 72.5% (95% CI 70.2%–74.8%). McNemar's test confirmed that smoking and EDTNAD use bans differed significantly within households ($\chi^2 = 12.0$, $p < 0.001$), indicating incomplete alignment between the two types of bans (Table 4.). Among individuals living in smoke-free homes, 11.7% (95% CI 9.9%–13.8%) reported that EDTNAD use was nevertheless permitted.

Using weighted estimates of the total number of minors, 25.0% (95% CI 21.3%–30.0%) of minors in 2022 were living in households permitting smoking. This is further stratified by the financial situation of the household (Brys, Paulik, et al., 2025) (Figure 3.) The corresponding proportion was 28.2% (95% CI 24.7%–33.6%) for households permitting EDTNAD use. In total, 33.9% (95% CI 30.4%–39.8%) of minors lived in households without clean air rules (smoking and/or EDTNAD use allowed).

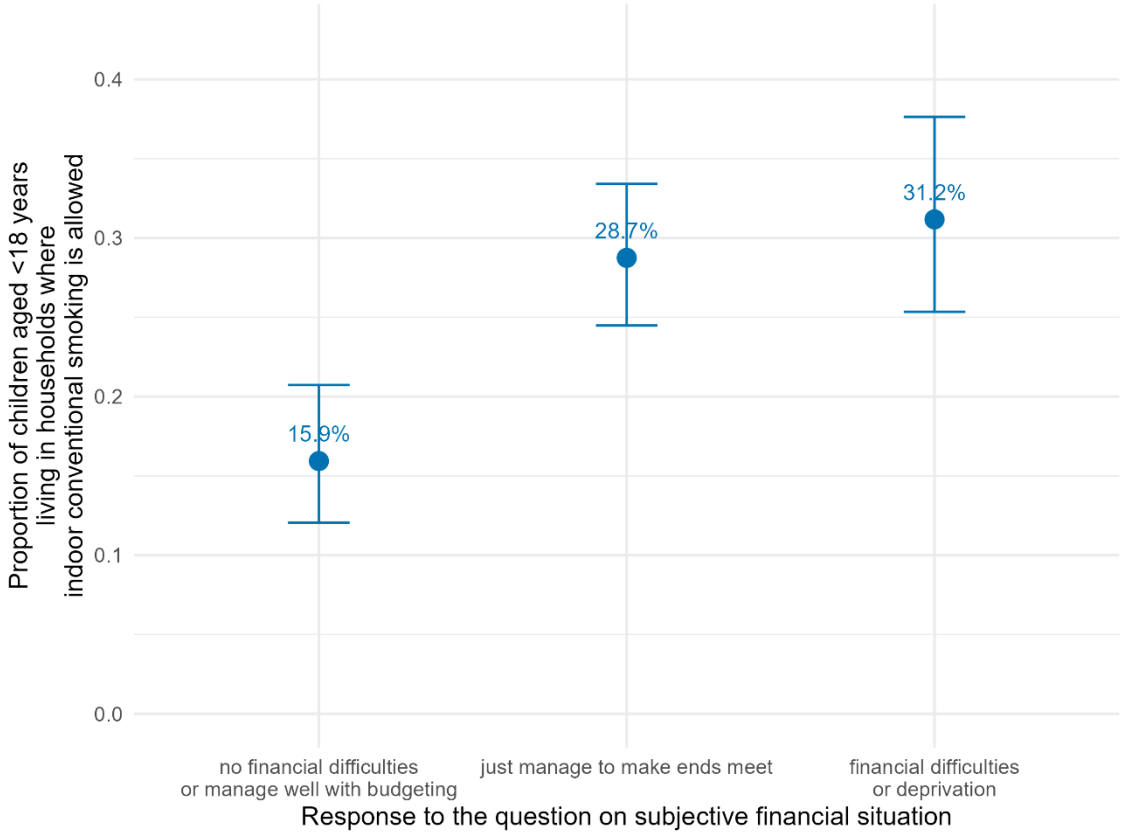


Figure 3. Proportion of children (<18 years) living in households without a complete indoor smoking ban, by household financial situation in the Online Health Survey 2022. Original figure source: Brys, Paulik, et al. (2025). Reproduced under licence from Akadémia Kiadó. Re-use permitted under CC BY 4.0.

4.1.2. Exploratory logistic growth modelling

To explore plausible temporal adoption trajectories of in-home smoking bans under defined assumptions, a simple, exploratory logistic growth modelling was applied to three countries. The same grid-search procedure was applied to the United States (10 data points, 1992–2022), Scotland (11 data points, 2012–2024), and Hungary (2 data points, 2009 and 2022), with the carrying capacity fixed at 0.929 for all countries.

The grid search identified acceptable solutions (RSS < 0.001) that varied by data constraints: 39 for the United States, 523 for Scotland, and 1395 for Hungary. (As validation, nonlinear least squares fitted to US data yielded $r = 0.134$ and $t_0 = 1993.5$, closely matching the grid best fit of $r = 0.135$ and $t_0 = 1993.6$.) Best-fit parameters demonstrated marked cross-national differences. Scotland showed the fastest adoption ($r = 0.19$, $t_0 = 2005$), followed by the United States ($r = 0.14$, $t_0 = 1994$), while Hungary showed substantially slower growth ($r = 0.06$, $t_0 = 1998$) (Figure 4).

Across the 1395 acceptable Hungarian trajectories, the projected year at which smoke-free home prevalence would reach 99% of the assumed ceiling (92.9%) was 2075 (IQR 2067–2085). (However, these projections are conditional on the assumed logistic growth model and fixed ceiling. The Scottish data illustrate that, when observations begin only after the rapid growth phase, the assumed logistic form cannot be validated for the unobserved past and seem unlikely. Nevertheless, once prevalence approaches the ceiling, future projections become less sensitive to the exact historical trajectory. For Hungary, by contrast, the available observations do not yet constrain the trajectory sufficiently, making long-term projections substantially more assumption dependent.)

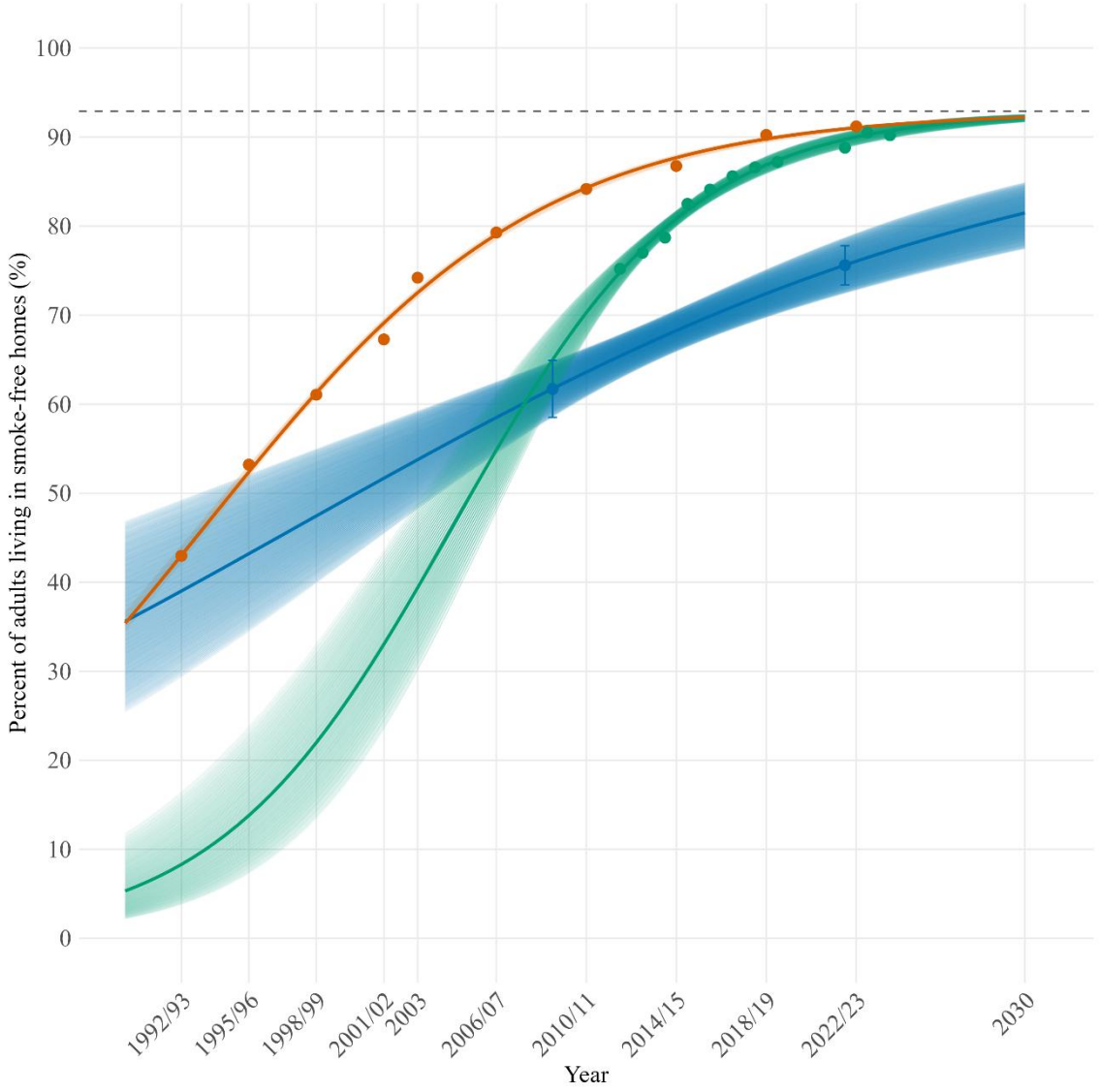


Figure 4. Exploratory logistic growth trajectories of smoke-free home prevalence in the United States, Scotland, and Hungary, 1990–2030.

Logistic growth trajectories fitted to survey data on the proportion of adults living in smoke-free homes. Orange circles represent observed US data (10 data points, 1992–2022), green circles represent Scottish data (11 data points, 2012–2024), blue circles represent Hungarian data (two data points: 2009, 2022). Bold lines show best-fit trajectories (US is orange, Scotland is green, Hungary is blue). Semi-transparent trajectory bundles represent acceptable solutions (RSS < 0.001). The horizontal dashed line indicates the shared ceiling assumption of 92.9%. Hungarian error bars show 95% confidence intervals. Data sources: National Cancer Institute (2025), Semple, Best, et al. (2026), and this dissertation. Figure source: author, own analysis.

4.2. Social and ethnic stratification of voluntary in-home smoking and EDTNAD bans

This section examines the association between self-reported Roma ethnicity and voluntary in-home bans, adjusting for established determinants. Analyses are based on two differently designed datasets: (1) the Social Determinants of Smoking Survey (2009) and (2) the Online Cohabiting Couples Survey (2025).

4.2.1. Social and ethnic stratification: 2009 results

The 2009 sample comprised 2,185 respondents after excluding cases with missing data on the outcome variable and/or on ethnicity (n = 65). Out of the 2,185 respondents, 35 (1.6%) self-identified themselves as Roma. In 2011 based on census data 3.11% self-identified as Roma (KSH, 2013). Bivariate statistics revealed disparities between the two groups. Among Roma respondents, 68.6% had less than secondary education compared with 43.7% of non-Roma respondents ($\chi^2(1) = 7.65$, $p = 0.006$, Cohen's $h = 0.51$). Financial deprivation was reported by 62.9% of Roma respondents versus 31.0% of non-Roma respondents ($\chi^2(1) = 14.77$, $p < 0.001$, Cohen's $h = 0.66$); data on financial deprivation was missing for 23 non-Roma respondents (1.1%). The presence of household smokers was nearly universal among Roma respondents (94.3%) compared with 52.8% among non-Roma respondents ($\chi^2(1) = 22.17$, $p < 0.001$, Cohen's $h = 1.05$); data on smoking presence was missing for 46 respondents. Living in a village status did not differ significantly between groups (40.0% Roma versus 38.5% non-Roma, $\chi^2(1) < 0.001$, $p > 0.9$, Cohen's $h = 0.03$). Total agreement that second-hand smoke causes lung cancer in non-smokers was also less common among Roma (28.6%) than non-Roma respondents (52.7%; $\chi^2(1) = 7.07$, $p = 0.008$, Cohen's $h = 0.50$).

Given the small number of Roma respondents without household smokers (n = 2), all subsequent multivariable analyses were limited to households reporting at least one smoker and with complete data on all covariates (Table 5.).

Among households with at least one smoker, the prevalence of in-home smoking bans was 42.5% (95% CI: 39.6%–45.5%) among respondents who self-identified as non-Roma and 9.1% (95% CI: 0.0%–18.9%) among those who self-identified as Roma (Figure 5). The raw prevalence difference was -33.5 percentage points (95% CI: -43.7 – -23.2), corresponding to an odds ratio of 0.14 (95% CI: 0.04–0.45). This difference was statistically significant and large ($\chi^2(1) = 13.42$, $p < 0.001$, Cohen's $h = -0.81$).

Table 5. Characteristics of respondents living in households with at least one smoker and prevalence of complete in-home smoking bans by respondent characteristics, Social Determinants of Smoking Survey 2009 (n = 1,133).

Characteristic	Overall (N = 1,133)	Smoking ban		p	h
		No (N = 662)	Yes (N = 471)		
Roma ethnicity	33 (2.9%)	30 (4.5%)	3 (0.6%)	<0.001	0.27
Less than secondary education	569 (50.2%)	369 (55.7%)	200 (42.5%)	<0.001	0.27
Total agreement with SHS causes lung cancer	498 (44%)	264 (39.9%)	234 (49.7%)	0.001	0.20
Village residence	463 (40.9%)	264 (39.9%)	199 (42.3%)	0.5	0.05
Financial deprivation	460 (40.6%)	295 (44.6%)	165 (35.0%)	0.002	0.19

Values are presented as n (%). Table source: author, own analysis.

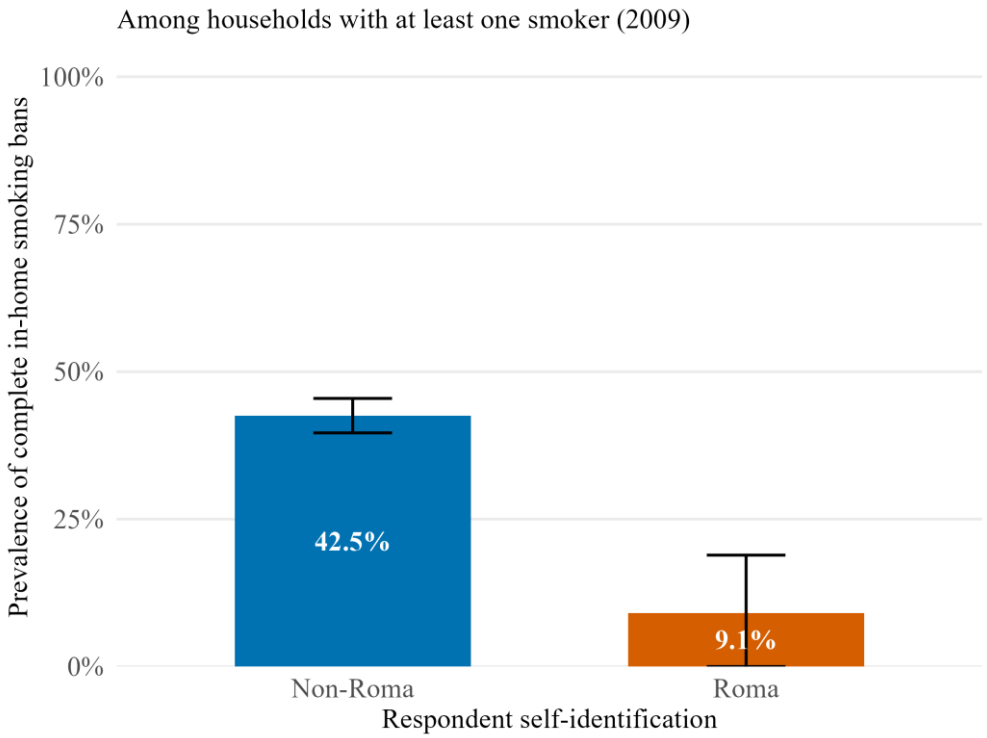


Figure 5. Prevalence of in-home smoking ban among households with at least one smoker by the respondent self-identified ethnicity in the Social Determinants of Smoking Survey 2009 ($n_{Non\text{-}Roma}$ = 1,100; n_{Roma} = 33). Figure source: author, own analysis.

Binary logistic regression was fitted to examine associations between Roma ethnicity and in-home smoking bans, adjusted for established determinants. The dependent variable was the presence of a complete in-home smoking ban. Independent variables included Roma ethnicity, educational attainment below secondary level, total agreement that second-hand smoke causes lung cancer in non-smokers, financial deprivation, and village residence. All independent variables were binary. Variance inflation factors confirmed the absence of multicollinearity (∀VIF < 1.2). Model performance was evaluated using multiple criteria. The full model demonstrated improved fit compared with a null model containing only an intercept. The log-likelihood increased from -769.2 (null model) to -742.6 (full model). The Akaike Information Criterion decreased from 1540.3 to 1497.2. A likelihood ratio test confirmed that the full model fit the data significantly better than the null model ($\chi^2(5) = 53.1$, $p < 0.001$). The area under the receiver operating characteristic curve (ROC-AUC) was 0.62 (95% CI 0.58–0.65). The area under the precision-recall curve (PR-AUC) was 0.51 (95% CI 0.47–0.55), compared with a baseline prevalence of 0.42. Average marginal effects and their 95% confidence intervals were calculated for all predictors to quantify associations on the probability scale (Table 6.).

Table 6. Binary logistic regression results for in-home smoking ban among households with at least one smoker, Social Determinants of Smoking Survey, Hungary, 2009.

Variable	β	SE	p	aOR	AME [95% CI]
Roma ethnicity	-1.804	0.612	0.003	0.16	-0.31 [-0.43, -0.19]
Less than secondary education	-0.513	0.13	<0.001	0.60	-0.12 [-0.18, -0.06]
Total agreement with SHS causes lung cancer	0.365	0.124	0.003	1.44	+0.09 [0.03, 0.14]
Financial deprivation	-0.299	0.129	0.021	0.74	-0.07 [-0.13, -0.01]
Village residence	0.278	0.13	0.033	1.32	+0.06 [0.01, 0.12]
−2LL: full model = 1485.2, null model = 1538.3; $\chi^2(5) = 53.1$, $p < 0.001$ ROC-AUC = 0.62 (95% CI 0.58–0.65) versus 0.50 ; PR-AUC = 0.51 (95% CI 0.47–0.55) versus 0.42					

β = regression coefficient; SE = standard error; aOR = adjusted odds ratio; AME = average marginal effect; CI = confidence interval; SHS = second-hand smoke.

Table source: author, own analysis.

4.2.2. Social and ethnic stratification: 2025 results

The Online Cohabiting Couples (2025) comprised 750 eligible respondents after applying inclusion criteria (cohabiting romantic partnership, home ownership, no further non-child adults in the household, and non-missing ethnicity data). Among these 750 respondents, 35 (4.7%) were classified as Roma households. (It was defined as households in which at least one partner was identified as Roma by the respondent.) Bivariate comparisons revealed disparities between Roma and non-Roma households (Table 7.). At least secondary-level education as the highest attainment within the couple was reported by 83.4% of non-Roma households compared with 31.4% of Roma households ($\chi^2(1) = 51.54$, $p < 0.001$, Cohen's h = -1.09). Financial deprivation was reported by 9.9% of non-Roma households versus 31.4% of Roma households ($\chi^2(1) = 13.49$, $p < 0.001$, Cohen's h = 0.55). Village residence was reported by 24.3% of non-Roma households compared with 62.9% of Roma households ($\chi^2(1) = 23.56$, $p < 0.001$, Cohen's h = 0.80). At least one smoker was present in 40.7% of non-Roma households versus 66.7% of Roma households ($\chi^2(1) = 7.51$, $p = 0.006$, Cohen's h = 0.45). The presence of at least one EDTNAD user did not differ significantly between the two groups (26.3% non-Roma versus 28.6% Roma; $\chi^2(1) = 0.01$, $p > 0.9$). Minors were present in 32.9% of non-Roma households versus 62.9% of Roma households ($\chi^2(1) = 12.03$, $p < 0.001$, Cohen's h = 0.61). Roma households were also significantly younger ($t = 5.0$, $p < 0.001$; $W = 18499$, $p < 0.001$): median of couple mean age: 40 years (IQR: 35–47) compared with non-Roma households median: 52 years (IQR: 40–65).

The prevalence of in-home smoking ban was 80.5% (95% CI: 77.4%–83.2%) among non-Roma households and 54.5% (95% CI: 38.0%–70.2%) among Roma households (Figure 6). The raw prevalence difference was −26.0 percentage points (95% CI: −43.2 to −8.7), corresponding to an odds ratio of 0.29 (95% CI: 0.14–0.59). This difference was statistically significant and moderate ($\chi^2(1) = 13.0$, $p < 0.001$, Cohen's h = −0.57). The prevalence of in-home EDTNAD use ban was 68.8% (95% CI: 65.2%–72.1%) among non-Roma households and 44.1% (95% CI: 28.9%–60.5%) among Roma households (Figure 6). The raw prevalence difference was −24.6 percentage points (95% CI: −41.7 to −7.6), corresponding to an odds ratio of 0.36 (95% CI: 0.18–0.72). This difference was also statistically significant and moderate ($\chi^2(1) = 8.99$, $p = 0.003$, Cohen's h = −0.50).

Table 7. Characteristics of Roma and non-Roma households in the Online Cohabiting Couple sample 2025.

Characteristic	Overall	Roma household		p
		No	Yes	
	N = 750	N = 715	N = 35	
Smoking ban	592 (79%)	574 (81%)	18 (55%)	<0.001
Missing	4	2	2	
EDTNAD-use ban	497 (68%)	482 (69%)	15 (44%)	0.005
Missing	15	14	1	
At least secondary education	601 (80%)	590 (83%)	11 (31%)	<0.001
Financial deprivation	82 (11%)	71 (10%)	11 (31%)	<0.001
Missing	6	6	0	
Village residence	196 (26%)	174 (24%)	22 (63%)	<0.001
Missing	2	2	0	
Minors present	257 (34%)	235 (33%)	22 (63%)	<0.001
At least one smoker	313 (42%)	291 (41%)	22 (67%)	0.006
Missing	7	5	2	
At least one EDTNAD user	197 (27%)	188 (27%)	9 (29%)	>0.9
Missing	15	11	4	
Mean age	52 (40, 65)	52 (40, 65)	40 (35, 47)	<0.001

Table source: author, own analysis.

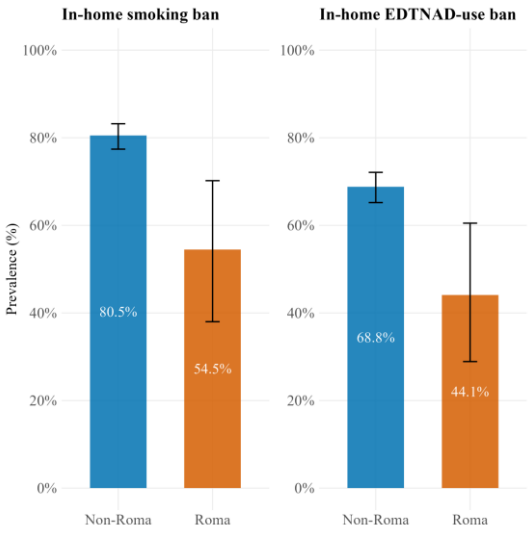


Figure 6. Prevalence of voluntary in-home smoking ban (left panel) and in-home EDTNAD use ban (right panel) among Roma and non-Roma households in the Online Cohabiting Couple Survey 2025. Bars represent crude prevalence estimates; error bars indicate 95% CI. Figure source: author, own analysis.

A multivariate logistic regression with two simultaneous binary outcomes (in-home smoking ban and in-home EDTNAD use ban) was fitted to 707 households with complete data on all variables. Variance inflation factors confirmed the absence of multicollinearity for both outcome equations (∀VIF < 1.60). The full model demonstrated significantly improved fit compared with the null model ($\chi^2(16) = 247.76$, $p < 0.001$). The conditional odds ratio between the two outcomes, after adjustment for all covariates, was 20.36 (95% CI: 11.45–36.20, $p < 0.001$), indicating a strong residual association between the two bans not explained by the included predictors. ROC-AUC was 0.75 (95% CI: 0.70–0.80) for the smoking ban model and 0.79 (95% CI: 0.76–0.83) for the EDTNAD-use ban. PR-AUC was 0.91 (baseline: 0.80) and 0.87 (baseline: 0.67), respectively.

In the multivariate model, Roma household status was associated with significantly lower odds of an in-home smoking ban (aOR = 0.38, 95% CI: 0.15–0.94, $p = 0.04$). The association with in-home EDTNAD use ban was not significant ($p = 0.10$). Presence of at least one smoker in the household was strongly and significantly associated with lower odds of both bans (smoking ban: aOR = 0.23, 95% CI: 0.15–0.34, $p < 0.001$; EDTNAD use ban: aOR = 0.39, 95% CI: 0.27–0.57, $p < 0.001$). The presence of at least one EDTNAD user was similarly associated with lower odds of both bans, with a stronger association for the EDTNAD-use ban (smoking ban: aOR = 0.40, 95% CI: 0.26–0.63, $p < 0.001$; EDTNAD-use ban: aOR = 0.11, 95% CI: 0.07–0.17, $p < 0.001$). Presence of minors in the household was associated with significantly higher odds of both bans (smoking ban: aOR = 2.225, 95% CI: 1.310–3.778, $p = 0.003$; EDTNAD-use ban: aOR = 1.808, 95% CI: 1.134–2.881, $p = 0.013$). Highest educational attainment within the couple at secondary level or above, financial deprivation, village residence, and couple mean age were not significantly associated with either outcome after adjustment (∀ $p > 0.05$) (Table 8.).

Table 8. Logistic regression with two simultaneous dependent variables estimating associations with in-home smoking ban (left) and in-home EDTNAD use ban (right) among cohabiting home-owner couples in the Online Cohabiting Couples Suvery 2025 (N = 707).

	In-home smoking ban (Y_1)					**In-home EDTNAD use ban (Y_2)**				
Variable	**β**	**SE**	**p**	**aOR**	**AME (95% CI)**	**β**	**SE**	**p**	**aOR**	**AME (95% CI)**
Roma household	-0.96	0.46	0.037*	0.38	-0.16 (-0.34 to -0.01)	-0.74	0.46	0.10	0.48	-
Secondary education or above (couple max)	0.27	0.25	0.279	1.31	-	0	0.24	0.99	1	-
Financial deprivation	0.21	0.35	0.56	1.23	-	-0.06	0.31	0.86	0.95	-
Village residence	-0.16	0.23	0.487	0.85	-	-0.13	0.22	0.55	0.88	-
Minors present	0.8	0.27	0.003*	2.22	0.10 (0.04–0.16)	0.59	0.24	0.01*	1.81	0.09 (0.02–0.15)
Smoker in household	-1.49	0.21	<0.001*	0.23	-0.22 (-0.28 to -0.17)	-0.93	0.19	<0.001*	0.39	-0.16 (-0.21 to -0.11)
EDTNAD user in household	-0.91	0.23	<0.001*	0.4	-0.14 (-0.28 to -0.06)	-2.17	0.21	<0.001*	0.11	-0.46 (-0.52 to -0.38)
Mean couple age	-0.01	0.01	0.302	0.99	-	0.01	0.01	0.07	1.01	-

−2LL: full model = 1178.7, null model = 1426.4; $\chi^2(16) = 247.76$, $p < 0.001$; ROC-AUC: $Y_1 = 0.75$ (95% CI: 0.70–0.80), $Y_2 = 0.79$ (95% CI: 0.76–0.83); PR-AUC: $Y_1 = 0.91$ (95% CI: 0.88–0.93) versus baseline 0.80, $Y_2 = 0.87$ (95% CI: 0.84–0.90) versus baseline 0.67

Residual association: conditional OR(Y_1, Y_2) = 20.36 (95% CI: 11.45–36.20).

EDTNAD: electronic devices for tobacco or nicotine aerosol delivery; aOR: adjusted odds ratio; AME: Average Marginal Effect (only significant ones are indicated) ; *: p<0.05

Table source: author, own analysis.

4.3. Intra-household educational configuration of voluntary in-home smoking and EDTNAD use

4.3.1. Intra-household educational configuration: 2022 results

The final analytical sample comprised 623 cohabiting couples with no other adults in the household (Brys, Pénzes, et al., 2025). Overall, 19.6% (95% CI: 16.6%–23.0%) of couples allowed in-home smoking and 25.0% (95% CI: 21.7%–28.7%) allowed in-home EDTNAD use (Brys, Pénzes, et al., 2025). The difference between the two proportions was statistically significant (McNemar's $\chi^2 = 13.61$, $p < 0.001$, Cohen's $h = -0.13$) (Brys, Pénzes, et al., 2025).

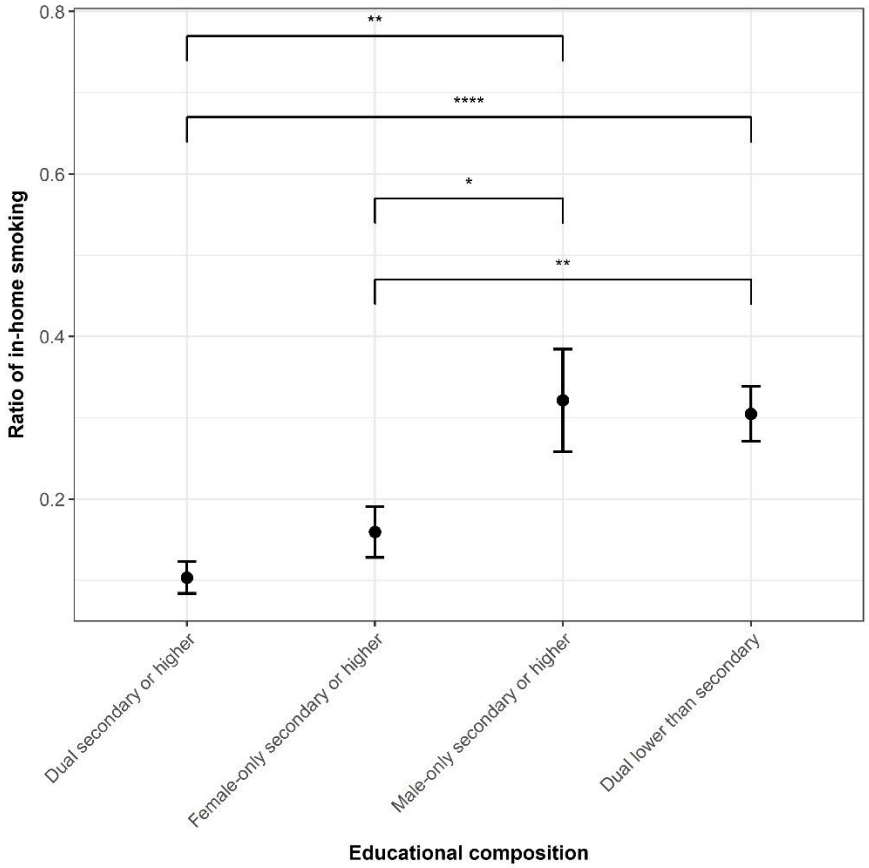


Figure 7. Prevalence estimates of allowing in-home smoking by partners' educational attainment compositions (n = 623) in the Online Health Survey 2022. P values of the two-sample z-tests were adjusted using the Benjamini-Hochberg method. Intervals express SE. (*p<0.05, **p<0.01, *****p<1×10−5). Figure source: Brys, Pénzes, et al. (2025). Reproduced under licence from BMJ Publishing Group Ltd. Re-use permitted under CC BY-NC.

Bivariate tests showed that the proportion of couples allowing in-home smoking was 10.3% (95% CI: 6.9%–15.0%) in dual SoHE couples, 15.9% (95% CI: 10.5%–23.4%) in female-only SoHE couples, 32.1% (95% CI: 20.6%–46.1%) in male-only SoHE couples, and 30.5% (95% CI: 24.1%–37.7%) in dual lower-than-secondary couples. Pairwise comparisons with Benjamini-Hochberg correction revealed that allowing in-home smoking was significantly less prevalent in dual SoHE couples compared with both male-only SoHE ($p < 0.001$) and dual lower-than-secondary couples ($p < 0.001$), and in female-only SoHE couples compared with both male-only SoHE ($p = 0.030$) and dual lower-than-secondary couples ($p = 0.008$). Dual SoHE and female-only SoHE couples did not differ significantly from each other ($p = 0.181$), and male-only SoHE couples did not differ significantly from dual lower-than-secondary couples ($p = 0.943$) (Figure 7.) (Brys, Pénzes, et al., 2025).

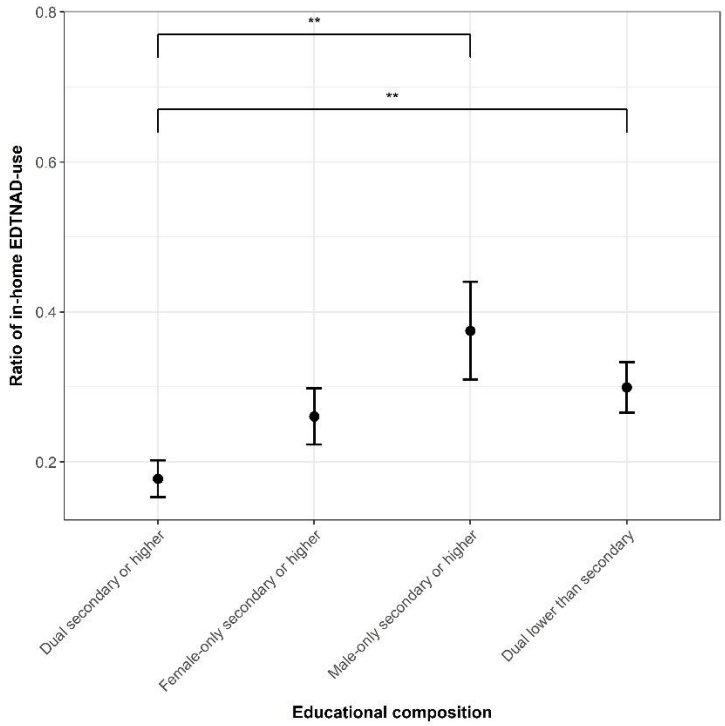


Figure 8. Prevalence estimates of allowing in-home EDTNAD use by partners' educational attainment compositions in the Online Health Survey 2022 (n = 623). p-values of the two-sample-tests. were adjusted using the Benjamini-Hochberg method. Intervals express SE. (*p<0.05). EDTNAD refers to electronic devices for tobacco or nicotine aerosol delivery (including e-cigarettes and heated tobacco products). Figure source: Brys, Pénzes, et al. (2025). Reproduced under licence from BMJ Publishing Group Ltd. Re-use permitted under CC BY-NC.

The proportion of couples allowing in-home EDTNAD use was 17.8% (95% CI: 13.3%–23.3%) in dual SoHE couples, 26.1% (95% CI: 19.2%–34.4%) in female-only SoHE couples, 37.5% (95% CI: 25.2%–51.5%) in male-only SoHE couples, and 29.9% (95% CI: 23.6%–37.1%) in dual lower-than-secondary couples. For allowing in-home EDTNAD use, fewer pairwise differences reached statistical significance after correction: dual SoHE couples differed significantly from both male-only SoHE ($p = 0.013$) and dual lower-than-secondary couples ($p = 0.013$), while no other pairwise comparisons reached statistical significance (Figure 8.) (Brys, Pénzes, et al., 2025).

Two separate binomial LASSO regression models were fitted (one for each outcome) using 4-fold cross-validation repeated across 100 iterations to select the optimal penalty (minimal, best performing) lambda (shrinking) parameter. The shrinkage trajectories of all penalised coefficients across the full range of $\ln(\lambda)$ are presented for both models in Figure 9. The median optimal $\ln(\lambda)$ was −4.92 (2.5th–97.5th percentile: −5.67 to −4.45) for the in-home smoking model and −4.93 (−5.31 to −4.56) for the in-home EDTNAD use model (Figure 9., Table 9.) (Brys, Pénzes, et al., 2025). Model performance was acceptable for both outcomes: ROC-AUC was 0.84 (0.83–0.84) and PR-AUC was 0.60 (0.60–0.60) for the smoking model; ROC-AUC was 0.83 (0.83–0.84) and PR-AUC was 0.65 (0.64–0.65) for the EDTNAD use model. Coefficients and SHAP-based variable importance scores are reported as medians across 100 iterations; variables are considered stable if their coefficient was non-zero and directionally consistent in at least 95% of iterations (Table 9.)(Brys, Pénzes, et al., 2025).

Financial deprivation was positively associated with allowing both in-home smoking ($\beta = 0.18$, 2.5th–97.5th percentile: 0.17–0.19) and in-home EDTNAD use ($\beta = 0.06$, 0.05–0.07). Presence of minors in the household was negatively associated with allowing both outcomes (smoking: $\beta = -0.23$, −0.29 to −0.16; EDTNAD use: $\beta = -0.26$, −0.31 to −0.20). Regarding educational composition, dual SoHE ($\beta = -0.14$, −0.17 to −0.11) and female-only SoHE ($\beta = -0.16$, −0.21 to −0.11) were negatively associated with allowing in-home smoking, while male-only SoHE showed no stable association with this outcome ($\beta = 0$, 0.0–0.01). For allowing in-home EDTNAD use, male-only SoHE was positively associated ($\beta = 0.11$, 0.09–0.12), whereas dual SoHE and female-only SoHE showed no stable association. Among smoking composition variables, all three non-reference categories were associated with allowing in-home smoking: dual smoker couples showed

the largest effect (β = 1.09, 1.03–1.14), followed by male-only smoker couples (β = 0.56, 0.50–0.62) and female-only smoker couples (β = 0.40, 0.36–0.45). The same ordering was observed for allowing in-home EDTNAD use (dual: β = 0.59, 0.55–0.61; male-only: β = 0.37, 0.34–0.40; female-only: β = 0.30, 0.27–0.32). For EDTNAD use composition, all three non-reference categories were associated with allowing in-home EDTNAD use (dual: β = 0.49, 0.46–0.51; female-only: β = 0.48, 0.45–0.49; male-only: β = 0.43, 0.42–0.44), while none showed a stable association with allowing in-home smoking. SHAP-based variable importance scores were consistent with the pattern of stable coefficients across both models (Table 9.).

Table 9. Results from 100 iterations of binomial logistic LASSO regression (values in brackets show 2.5th–97.5th percentile range) of the Online Health Survey 2022 data.

Table 3 Results from 100 iterations of binomial logistic LASSO regression (values in brackets show 2.5th–97.5th percentile range)

	Allowing in-home smoking		Allowing in-home EDTNAD use	
Characteristic	Beta values median (p2.5–p97.5)	Median absolute Shapley	Beta values median (p2.5–p97.5)	Median absolute Shapley
Model parameters and performance metrics				
Lowest binomial deviance	0.78 (0.76 to 0.80)	–	0.90 (0.89 to 0.93)	–
Optimal penalty parameter ln(λ)	−4.92(−5.67 to −4.45)	–	−4.93 (−5.31 to −4.56)	–
ROC-AUC at optimal ln(λ)	0.84 (0.83 to 0.84)	–	0.83 (0.83 to 0.84)	–
PR-AUC at optimal ln(λ)	0.6 (0.60 to 0.6)	–	0.65 (0.64 to 0.65)	–
Sociodemographic variables				
Male age (in years)	0 (0 to 0.01)	<0.001	−0.05 (−0.05 to −0.05)*	0.001*
Female age (in years)	0 (0 to 0)	<0.001	−0.13 (−0.16 to −0.09)*	0.001*
Age difference (male–female in years)	0 (0 to 0.04)	<0.001	0 (0 to 0)	<0.001
Living with minors	−0.23 (−0.29– to −0.16)*	0.002*	−0.26 (−0.31 to −0.2)*	0.002*
Residing in non-urban settlement	0.06 (0.02 to 0.09)	<0.001	0.02 (0.01 to 0.03)	<0.001
Residing in low-GDP counties	0.08 (0.05 to 0.11)	0.001*	0.1 (0.07 to 0.11)*	0.001*
Financially deprived	0.18 (0.17 to 0.19)*	0.002*	0.06 (0.05 to 0.07)*	0.001*
Educational composition				
Dual secondary or higher	−0.14 (−0.17 to −0.11)*	0.001*	0 (0 to 0)	<0.001
Female-only secondary or higher	−0.16 (−0.21 to −0.11)*	0.001*	0 (0 to 0)	<0.001
Male-only secondary or higher	0 (0.0 to 0.01)	<0.001	0.11 (0.09 to 0.12)*	0.001*
Dual lower than secondary (Reference)	–		–	
Smoking composition				
Dual smoker couple	1.09 (1.03 to 1.14)*	0.009*	0.59 (0.55 to 0.61)*	0.006*
Female-only smoker couple	0.40 (0.36 to 0.45)*	0.004*	0.3 (0.27 to 0.32)*	0.003*
Male-only smoker couple	0.56 (0.50 to 0.62)*	0.005*	0.37 (0.34 to 0.40)*	0.003*
Non-smoker couple (Reference)	–		–	
EDTNAD-use composition				
Dual EDTNAD-user couple	0.02 (0 to 0.04)	<0.001	0.49 (0.46 to 0.51)*	0.005*
Female-only EDTNAD-user couple	0.08 (0.05 to 0.10)	<0.001	0.48 (0.45 to 0.49)*	0.003*
Male-only EDTNAD-use couple	0.02 (0 to 0.06)	<0.001	0.43 (0.42 to 0.44)*	0.004*
Non-EDTNAD-user couple (Reference)	–		–	

Penalised beta coefficients and absolute Shapley values are model-specific; compare magnitudes within a model, not between models.
*marks variables whose coefficients were non-zero and directionally stable in ≥ 95 % of 100 bootstrapped LASSO models (a robustness indicator, not *a* p-value star).
EDTNAD, electronic devices for tobacco or nicotine aerosol delivery; GDP, gross domestic product; LASSO, Least Absolute Shrinkage and Selection Operator; PR-AUC, precision-recall-AUC; ROC-AUC, receiver operating characteristic–area under the curve.

Table source: Brys, Pénzes, et al. (2025). Reproduced under licence from BMJ Publishing Group Ltd. Re-use permitted under CC BY-NC. On the top left corner, the table retains its original numbering as Table 3 in Brys, Pénzes, et al. (2025).

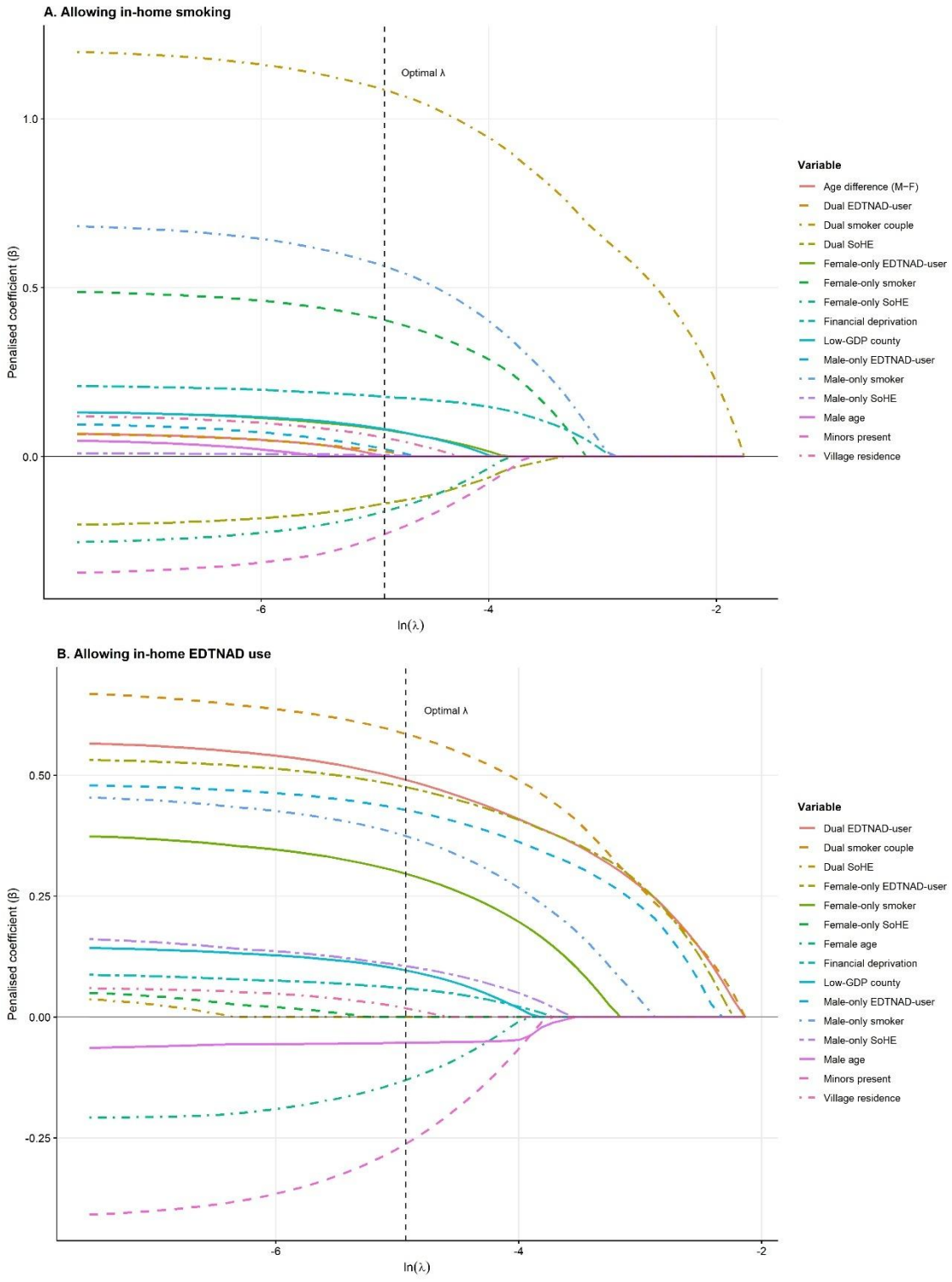


Figure 9. Penalised coefficient paths from binomial LASSO regression models estimating the probability of allowing in-home smoking (Panel A) and allowing in-home use of electronic devices for tobacco or nicotine aerosol delivery (EDTNAD; Panel B) among cohabiting couples, Online Health Survey 2022. (n = 623). Figure source: author, own analysis.

4.3.2. Intra-household educational configuration: 2025 results

The final analytical sample comprised 726 cohabiting home-owner couples with no additional non-child adults, after multiple imputation of missing values of explanatory variables. Overall, 81.1% (95% CI: 78.0%–83.9%) of couples reported a complete in-home smoking ban and 68.9% (95% CI: 65.3%–72.2%) reported a complete in-home EDTNAD use ban. The difference between the two proportions was statistically significant (McNemar's $\chi^2 = 50.61$, $p < 0.001$, Cohen's $h = 0.29$).

In this analysis also two separate binomial LASSO regression models were fitted (one for each outcome) using 4-fold cross-validation repeated across 100 iterations to select the optimal penalty (minimal, best performing) lambda (shrinking) parameter. The median optimal ln(λ) was −4.38 (2.5th–97.5th percentile: −4.75 to −4.10) for the in-home smoking ban model and −4.49 (−5.01 to −3.79) for the in-home EDTNAD use ban model. Model performance was acceptable for both outcomes: ROC-AUC was 0.75 (0.75–0.75) and PR-AUC was 0.91 (0.91–0.91) for the smoking ban model; ROC-AUC was 0.81 (0.80–0.81) and PR-AUC was 0.89 (0.88–0.89) for the EDTNAD use ban model. The shrinkage trajectories of all penalised coefficients across the full range of ln(λ) are presented for both models in Figure 10. Coefficients and SHAP-based variable importance scores are reported as medians across 100 iterations; variables are considered stable if their coefficient was non-zero and directionally consistent in at least 95% of iterations (Table 10.).

Roma household status was negatively associated with both outcomes: in-home smoking ban (β = −0.14, 2.5th–97.5th percentile: −0.16 to −0.12) and in-home EDTNAD use ban (β = −0.15, −0.17 to −0.11). Shared financial decision-making was positively associated with both outcomes (smoking ban: β = 0.10, 0.07–0.12; EDTNAD use ban: β = 0.08, 0.02–0.10). Presence of minors in the household was positively associated with the in-home smoking ban (β = 0.24, 0.18–0.27), but showed no stable association with the in-home EDTNAD use ban (β = 0.1, 0.00–0.15). Presence of at least one smoker in the household was negatively associated with both outcomes (smoking ban: β = −0.68, −0.70 to −0.64; EDTNAD use ban: β = −0.34, −0.35 to −0.28), as was presence of at least one EDTNAD user (smoking ban: β = −0.19, −0.22 to −0.16; EDTNAD use ban: β = −0.90, −0.92 to −0.84). Mean couple age was positively associated with the in-home EDTNAD use ban (β = 0.10, 0.02–0.16) but showed no stable association with the in-

home smoking ban (β = 0, −0.01 to 0.00). Both tertiary education was positively associated with the in-home EDTNAD use ban (β = 0.11, 0.03–0.13) but showed no stable association with the in-home smoking ban. Female-only tertiary education, male-only tertiary education, female income share equality, joint home ownership, dual employment, financial deprivation, and village residence showed no stable association with either outcome. SHAP-based variable importance scores were consistent with the pattern of stable coefficients across both models (Table 10).

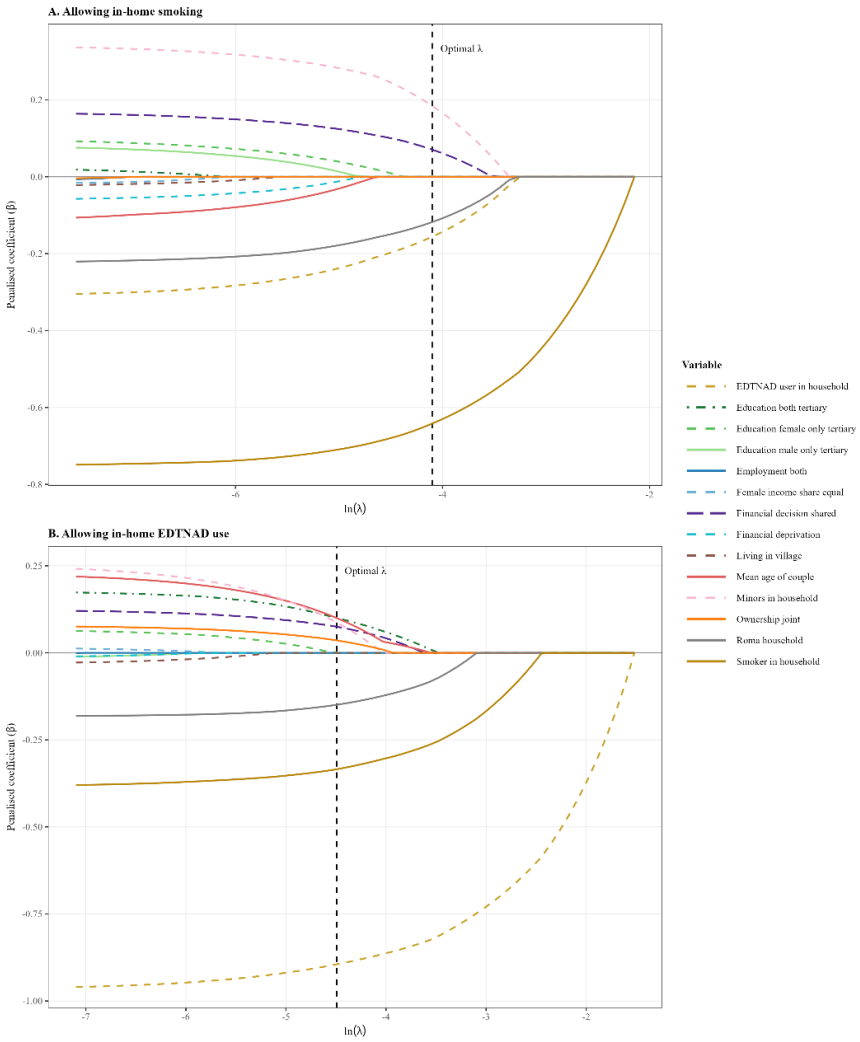


Figure 10. Coefficient paths from binomial LASSO regression models estimating the probability of a complete in-home smoking ban (Panel A) and a complete in-home use ban on electronic devices for tobacco or nicotine aerosol delivery (EDTNAD) (Panel B) among cohabiting homeowner couples in the Online Cohabiting Couples Survey 2025 (n = 726). Figure source: author, own analysis.

Table 10. Results from 100 iterations of binomial logistic LASSO regression estimating the probability of a complete in-home smoking ban and EDTNAD use ban among cohabiting home-owner couples in the Online Cohabiting Couples Survey 2025.

	Complete in-home smoking ban		Complete in-home EDTNAD use ban	
Characteristic	**Beta values median (p2.5–p97.5)**	**Median absolute Shapley**	**Beta values median (p2.5–p97.5)**	**Median absolute Shapley**
Lowest binomial deviance	0.87 [0.86–0.89]		1 [0.99–1.02]	
Optimal penalty parameter ln(λ)	-4.38 [-4.75 to -4.1]		-4.49 [-5.01 to -3.79]	
ROC-AUC at optimal ln(λ)	0.75 [0.75–0.75]		0.81 [0.8–0.81]	
PR-AUC at optimal ln(λ)	0.91 [0.91–0.91]		0.89 [0.88–0.89]	
Mean couple age	0 [-0.01–0]	0	0.10 [0.02–0.16]*	0.001
Roma household (at least one member is self-identified as Roma)	-0.14 [-0.16 to -0.12]*	0.001	-0.15 [-0.17 to -0.11]*	0.001
Equal income share	0 [0–0]	0	0 [0–0]	0
Equal home ownership	0 [0–0]	0	0.04 [0–0.05]	0
Educational composition				
None tertiary (reference)				
Male-only tertiary	0 [0–0]	0	0 [0–0]	0
Female-only tertiary	0.01 [0–0.03]	0	0.01 [0–0.03]	0
Dual tertiary	0 [0–0]	0	0.11 [0.03–0.13]*	0.001
Both employed	0 [0-0]	0	0 [0–0]	0
Shared financial decision	0.1 [0.07-0.12]*	0.001	0.08 [0.02–0.10]*	0.001
Financial deprivation	0 [0–0]	0	0 [0–0]	0
Village residence	0 [0–0]	0	0 [0–0]	0
Minors in household	0.24 [0.18–0.27]*	0.002	0.1 [0–0.15]	0.001
Smoker in household	-0.68 [-0.7 to -0.64]*	0.005	-0.34 [-0.35 to -0.28]*	0.002
EDTNAD user in household	-0.19 [-0.22 to -0.16]*	0.001	-0.9 [-0.92 to -0.84]*	0.007

* indicate stability. Table source: author, own analysis.

4.4. Recalled motivations and household decision patterns

The final analytical sample from 2025 comprised 807 home-owning respondents living in a romantic relationship with their partner. (In this analysis further adults living in the household were included). Recalled proposal for introducing a full ban, recalled motivations, and intra-household decision-making patterns underlying voluntary in-home bans were examined using descriptive frequencies and proportions (Figure 11).

Among households without a full in-home smoking ban (n = 168), 53.3% (95% CI: 45.7%–60.8%) reported that a complete smoking ban had previously been proposed. Proposals for introducing a full ban were most frequently reported as joint (23.6%, 95% CI: 17.8%–30.7%), followed by proposals initiated by women (17.6%, 95% CI: 12.5%–24.1%) and men (12.1%, 95% CI: 8.0%–18.0%).

Among households with a full smoking ban (n = 639), 23.0% (95% CI: 19.9%–26.4%) reported that the ban had been adopted after smoking had previously been allowed in the home, while 77.0% (95% CI 73.6%–80.1%) reported that smoking had never been permitted indoors. Among households reporting ban adoption (n = 147), bans were most frequently initiated jointly by household members (65.0%, 95% CI: 56.9%–72.4%), whereas unilateral initiation by women (24.5%, 95% CI: 18.2%–32.1%) was more common than unilateral initiation by men (10.5%, 95% CI: 6.5%–16.6%). Reported conflict during the adoption process was uncommon: 89.1% (95% CI: 83.1%–93.2%) reported no conflict, 9.5% (95% CI: 5.8%–15.4%) reported minor disagreement, and 1.4% (95% CI: 0.4%–4.8%) reported serious conflict. Regarding motivations, the most frequently recalled reason for adopting a smoking ban was the unpleasant smell of tobacco smoke (57.9%, 95% CI: 49.8%–65.7%), followed by protection of children (25.5%, 95% CI: 19.1%–33.2%). Review of open-text responses indicated that several responses originally recorded under “other” referred to smoking cessation; these were therefore classified as quitting smoking (9.7%, 95% CI: 5.8%–15.8%). Doctor’s recommendation was reported by 4.8% (95% CI: 2.4%–9.6%), while the remaining other reasons accounted for 2.1% (95% CI: 0.7%–6.0%). (Patterns underlying voluntary in-home EDTNAD bans were not analysed in detail because the number of households reporting ban adoption was small (n = 34), precluding reliable estimation of proportions and inferential testing.)

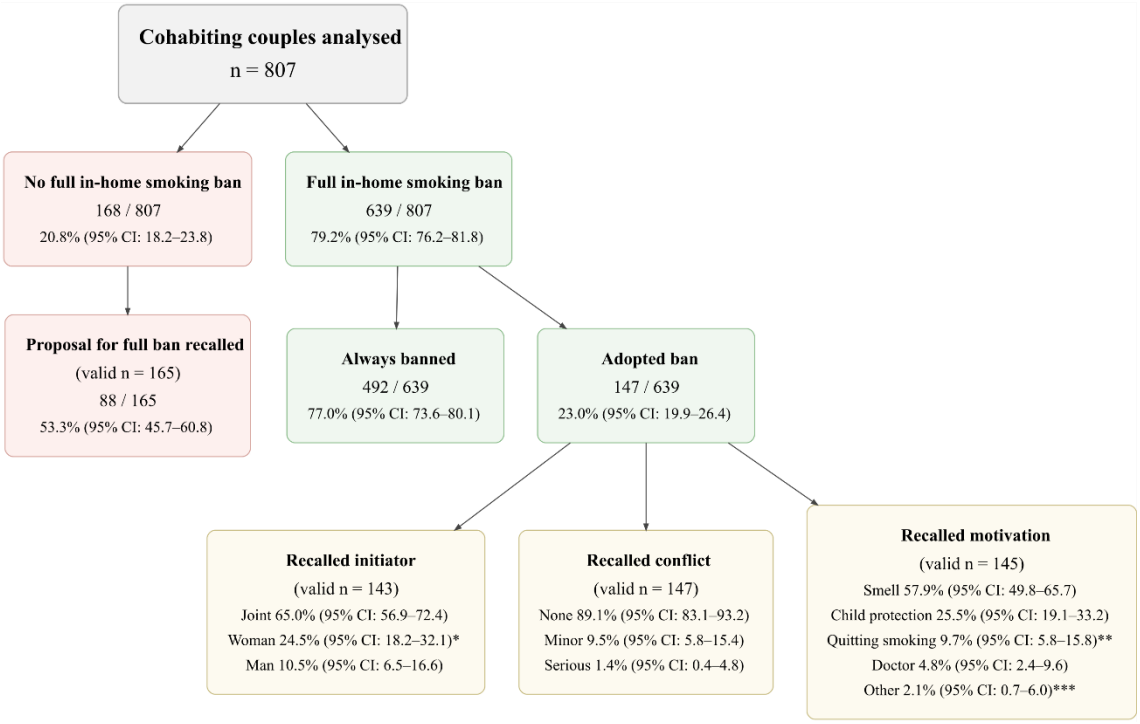


Figure 11. Cohabiting couples' smoking-ban status and recalled patterns of ban suggestion and adoption among cohabiting home-owning respondents in the Online Cohabiting Couples Survey 2025 (n = 807). Percentages represent proportions within the analytic denominator indicated for each stage. Figure source: author, own analysis.

* represents that female partners were more likely to initiate than male

** represents that Quitting category was generated from open-text *Other* category.

*** other (excluding quitting) were mostly home renovation

5. Discussion

This dissertation analyzed the prevalence and temporal trends, social and ethnic stratification, intra-household configuration and recalled decision-making patterns of voluntary in-home bans on smoking and EDTNAD use in Hungary. All analyses are observational and non-pooled, analyses are based on four cross-sectional surveys conducted between 2009 and 2025.

In this section, the results are summarized and interpreted in order of the study objectives. First, prevalence estimates and temporal trends are discussed. Second, social and ethnic disparities are examined. Third, intra-household configuration within couples (educational disparities and shared decision-making) is considered. Fourth, recalled motivations and decision-making patterns within couples are described, including whether complete bans had previously been proposed. Finally, the strengths and limitations of the analyses are addressed.

5.1. Prevalence and trends

The prevalence findings show that the proportion of respondents reporting that smoking was completely banned inside their home increased from 61.7% in 2009 to 75.6% in 2022 in Hungary. However, the estimated prevalence in Hungary remains below levels reported in several Western European countries, for example 84.5% in England in 2018 (Tigova et al., 2025) and 91.2% in the United States in 2022 (National Cancer Institute, 2025, 2026a). Exposure of children to SHS at home also remains substantial: in 2022 about 25% of Hungarian children lived in homes permitting smoking, whereas Scotland reduced children's exposure at home to 3% in 2022 (Scottish Government, 2024). Under a logistic growth functional form and a fixed ceiling of 92.9%, the two Hungarian data points are consistent with a substantially slower adoption trajectory ($r = 0.06$) than Scotland ($r = 0.19$) or the United States ($r = 0.14$). Conditional on these assumptions, the assumed ceiling would be approached around 2075 in Hungary. This projection is exploratory and sensitive to the choice of form and ceiling.

Complete in-home EDTNAD-use bans were less prevalent than smoking bans in 2022 in Hungary. This pattern is consistent with international evidence showing that vaping is more frequently permitted indoors than smoking (Li et al., 2020; Nahhas et al., 2019; Rivard et al., 2021). Individuals who perceive SHA as less harmful than tobacco

smoke are substantially less likely to implement vape-free household rules (Li et al., 2020; Rivard et al., 2021).

The results further indicate that increases in smoking bans do not necessarily correspond to increases in clean-air rules (comprehensive indoor bans covering both smoking and EDTNAD use). While the proportion of individuals living in homes with complete in-home smoking bans increased markedly between 2009 and 2022, the rapid spread of e-cigarettes and HTPs introduced a new source of indoor aerosol exposure. About 12% of Hungarian individuals living in smoke-free homes report that EDTNAD use remains permitted indoors, indicating that indoor clean-air rules have not fully adapted to the changing tobacco and nicotine product landscape. When smoking bans and EDTNAD use bans were considered jointly, the increase in comprehensive clean-air rules between 2009 and 2022 was not statistically significant.

5.2. Social and ethnic stratification

The association between Roma status and voluntary in-home bans was examined in three complementary analyses with different units of analysis and covariate structures: individual respondents in smoker-only households (2009), cohabiting homeowner couples in a multivariate outcome model (2025), and cohabiting homeowner couples in multivariable penalised regression additionally adjusting for intra-couple educational, financial, and decision-making configurations (2025). All three analyses indicate that Roma status is independently associated with lower likelihood of complete in-home smoking bans. For the EDTNAD use ban, Roma status was studied only at the couple level in the 2025 data. The association with lower odds of a complete EDTNAD use ban was stable in the penalised regression and marginally significant in the multivariate outcome model ($p = 0.10$). The direction was consistent across both analyses. However, the strong residual association between the smoking ban and the EDTNAD use ban after covariate adjustment (conditional OR = 20.36) suggests a shared household-level propensity to adopt clean air rules, beyond the measured determinants.

No prior quantitative evidence on smoke-free home adoption among Roma populations was identified. The observed Roma–non-Roma disparity is consistent with ethnic disparities in smoke-free home adoption documented among other racialized minority populations: Black households in the United States (Mai et al., 2018; Reyes-

Guzman et al., 2023; Zhang et al., 2013) and Indigenous populations in Australia, New Zealand, Canada, and the United States (Stevenson et al., 2017). The disparity is also consistent with previously documented Roma–non-Roma differences in smoking prevalence and attitudes toward tobacco control policies in Hungary (Paulik et al., 2011; Piko et al., 2021).

Ethnicity itself is not the operative mechanism (Williams et al., 2019). The present analyses show that Roma households are disproportionately characterised by the very factors that most strongly predict absence of in-home bans across all models in this dissertation: high smoking prevalence, low educational attainment, and financial deprivation. In the 2009 data, 94.3% of Roma households contained at least one smoker; in the 2025 data, Roma households reported substantially lower education, higher financial deprivation, and higher smoking prevalence than non-Roma households. These are established structural determinants of ban adoption, not ethnic attributes. The structural interpretation is further supported by broader evidence that Roma health disadvantages are produced by material deprivation, residential segregation, stigmatisation, and exclusion from services rather than by cultural or ethnic characteristics (Belak et al., 2017; Bernát, 2014, 2019; Cook et al., 2013; Kóczé, 2010; Petrova, 2003). The residual association of Roma status after adjustment likely reflects unmeasured structural factors (institutional racism, segregation and stigmatization) rather than an independent ethnic effect (Williams et al., 2019).

Beyond Roma status, the social patterning of in-home ban adoption observed in the 2009 individual-level analysis was broadly consistent with the international literature. Lower educational attainment, financial deprivation, and lack of belief in SHS harm were all independently associated with lower odds of a complete smoking ban. However, in the 2025 couple-level analyses, lower education and financial deprivation were not significantly associated with either outcome after adjustment. This is likely attributable to the restriction of the 2025 sample to homeowner couples, who represent a more socioeconomically homogeneous subpopulation.

5.3. Intra-household configuration

Two complementary couple-level analyses examined how gendered educational disparities between cohabiting partners and shared decision-making are associated with voluntary in-home smoking bans and EDTNAD use bans. Both analyses used LASSO regression with Shapley-based variable importance. The analysis of the Online Health Survey 2022 included 623 cohabiting couples with educational configuration operationalised at the secondary education threshold. The analysis of the Online Cohabiting Couples Survey 2025 included 726 cohabiting homeowner couples with educational configuration operationalised at the tertiary education threshold. The analysis of the Online Cohabiting Couples Survey additionally adjusted for Roma household status and four couple-level equality indicators: equal income share, equal home ownership, both partners employed, and shared financial decision-making.

In the 2022 data, gendered educational disparities were detected. Dual secondary-or-higher education and female-only secondary-or-higher education were negatively associated with allowing in-home smoking. Male-only secondary-or-higher education showed no stable association with this outcome. For allowing in-home EDTNAD use, male-only secondary-or-higher education was stably associated with allowing use, whereas dual and female-only configurations showed no stable association.

In the 2025 data, only dual tertiary education was stably associated with the EDTNAD use ban. No educational configuration reached stability for the smoking ban. However, the direction of female education coefficients was consistent with the 2022 findings. The difference might reflect the more socioeconomically homogeneous homeowner sample and the inclusion of shared financial decision-making. The finding that female partner's education is more consequential for in-home smoking ban adoption than male partner's education is novel in the quantitative literature. Most prior studies used only respondent-level education; few incorporated partner education (Pandey et al., 2017; Ulbricht et al., 2014; Wang et al., 2017; Zhang et al., 2015). The observed gendered asymmetry is consistent with qualitative evidence documenting women's role in initiating and negotiating in-home bans (Bottorff et al., 2010; Kegler et al., 2007; Nichter et al., 2015). It is also consistent with evidence from Nepal showing that women's decision-

making power is associated with lower likelihood of smoking in the home (Pandey et al., 2017). From a theoretical perspective, the finding aligns with bargaining models of household decision-making, in which higher education enhances bargaining power (Deb et al., 2024; Manser & Brown, 1980).

In the 2025 analysis, four couple-level equality indicators were included. Of these, only shared financial decision-making was stably associated with both in-home smoking bans and EDTNAD-use bans. Equal income share, equal home ownership, and dual employment showed no stable association with either outcome. This pattern suggests that the process of joint decision-making matters more for ban adoption than structural equality indicators per se. The finding is consistent with qualitative evidence that more egalitarian couple arrangements facilitate ban implementation (Bottorff et al., 2010).

As expected, household smoking and EDTNAD-use composition remained the dominant predictor of both outcomes across both analyses, consistent with the established primacy of household smoking status in the international literature (Berg et al., 2023; Jankowski et al., 2020; Pizacani et al., 2003; Tigova et al., 2025). Presence of minors was stably protective for smoking bans in both datasets, in line with findings from diverse Western contexts (Gallus et al., 2014; Helgertz et al., 2020; Pizacani et al., 2003). Financial deprivation was stably associated with allowing both smoking and EDTNAD use in Online Health Survey 2022. However, it showed no stable association in Online Cohabiting Couples Survey 2025, likely attributable to the homeowner restriction producing a more socioeconomically homogeneous sample.

The couple-level analytical approach operationalising gendered educational configuration and shared decision-making as couple-level predictors produced interpretable and largely consistent results across two independent datasets with different sample compositions, educational thresholds, and covariate structures. This supports the analytical value of treating voluntary in-home bans as household-level phenomena and examining intra-couple configurations rather than relying solely on respondent-level characteristics. The approach is consistent with theoretical frameworks emphasising that household outcomes emerge through negotiation among members with divergent characteristics and decision-making power (Deb et al., 2024; Kegler et al., 2007; Manser & Brown, 1980).

5.4. Recalled motivations and patterns

Recalled decision-making patterns underlying the adoption of voluntary in-home smoking bans and the prevalence of proposed but not yet adopted bans were examined among cohabiting homeowner couples in Hungary (n = 807). EDTNAD-specific patterns were not analysed due to the small number of households reporting ban adoption (n = 34).

Among households without a complete in-home smoking ban, 53.3% reported that a complete ban had previously been proposed. This appears to be the first quantitative estimate of proposed-but-not-adopted in-home smoking bans. This quantitative finding that approximately half of households without bans have previously engaged with the possibility closely corresponds to the qualitative observation by Kegler et al. (2007), who reported that (in a highly different sample) roughly half of families without smoking restrictions had at least discussed the possibility of limiting smoking in the home. The present results provide a quantitative estimate of this proportion in a different national context and population. From an intervention perspective, these households represent an easily addressable population where motivation has been expressed but implementation has not occurred. (This finding is robust to recall bias, as the expressed motive itself is the intervention-relevant signal.)

Among households with a complete smoking ban, the majority (77%) reported that smoking had never been permitted indoors. This pattern is consistent with qualitative findings where several families reported that a smoke-free home had always been understood as the default (Kegler et al., 2007). Only 23.0% reported that the ban was adopted after smoking had previously been allowed in the home. Among households reporting ban adoption, bans were most frequently initiated jointly by both partners (65%). Among unilateral initiators, women were significantly more likely to initiate than men (24.5% versus 10.5%). While this finding is strongly limited by recall bias, it is consistent with qualitative evidence that most often women raised the topic of household smoking restrictions (Barrera et al., 2026; Kegler et al., 2007; Nichter et al., 2015). Recalled reported conflict during ban adoption was uncommon: 89.1% reported no conflict, 9.5% minor disagreement, and 1.4% serious conflict. This is also consistent with Kegler et al. (2007), who documented that the vast majority of families reported no serious disagreement. However, both findings should be interpreted cautiously, as

retrospective reports may be affected by rosy retrospection, whereby past experiences are remembered as more positive and less conflictual than they were.

The most frequently recalled motivation for adopting a smoking ban was the unpleasant smell of tobacco smoke (57.9%), followed by protection of children (25.5%), quitting smoking (9.7%), and doctor's recommendation (4.8%). The prominence of smell as a motivation is consistent with qualitative evidence documenting that the permeating odour of tobacco smoke in household furnishings and clothing motivated families to adopt restrictions (Kegler et al., 2007). However, the relative ranking differs from the qualitative literature, where protection of children emerged as the dominant theme (Kegler et al., 2007). This discrepancy may reflect methodological differences between open-ended qualitative interviews and single-choice survey items, sample composition differences (the present sample was not restricted to households with children), or stronger social desirability effects in face-to-face qualitative settings. Doctor's recommendation was reported by only 4.8% of households, despite qualitative evidence that physician advice can serve as a trigger for ban adoption (Kegler et al., 2007). Quitting smoking was identified as a motivation through review and reclassification of open-text responses, consistent with Kegler et al. (2007) documenting smoking cessation as one of several life events triggering adoption of household smoking restrictions.

5.5. Strengths

This dissertation provides what appears to be the first temporal comparison of voluntary in-home smoking ban prevalence in Hungary, addressing a research gap that had persisted since 2010. It also provides the first national estimates of in-home EDTNAD use ban prevalence and comprehensive clean air rules in Hungary. The analyses appear to provide the first quantitative evidence on smoking bans among Roma populations in Europe. The couple-level analyses produced two findings: 1) the female partner's education is more strongly associated with smoking ban adoption than the male partner's education, and 2) shared financial decision-making is associated with ban adoption while structural equality indicators are not. The quantitative estimation of proposed-but-not-adopted bans (~53% of households without complete bans) and of recalled initiator, conflict, and motivation patterns provides population-level estimates for phenomena previously documented only in qualitative research.

Methodologically, this appears to be the first study to deliberately use the cohabiting couple as the unit of analysis for examining voluntary in-home smoking bans. This approach enabled the detection of gendered educational asymmetries and the role of shared decision-making; associations that are invisible in respondent-level analyses. Four independent datasets were analysed separately with complementary designs. It allowed replication of patterns across different samples, analytical units, time periods, and covariate structures. LASSO regression is not a standard method, but its strength lies in its sensitivity to identify which predictors are the most relevant in the presence of correlated or structurally dependent covariates (avoiding optimism bias). Shapley values complement this by providing a model-agnostic measure of each predictor's contribution.

5.6. Limitations

The theoretical framework draws on bargaining models of household decision-making (Manser & Brown, 1980; Deb et al., 2024) and family systems theory (Wampler, 2020). However, the dissertation does not directly test them. The empirical measures (couple-level educational configuration, a binary shared financial decision-making item, and structural equality indicators) are just observable proxies, not direct operationalisations of negotiation processes, fallback positions, or relative bargaining power.

Methodologically, several design-level limitations apply across all objectives. All analyses are cross-sectional; causal inference is not possible. Observed associations may reflect unmeasured confounding. All data are self-reported. Self-reported household bans do not perfectly correspond to actual SHS or SHA exposure (Paulik et al., 2013; Rosen et al., 2015). Online panel surveys systematically exclude individuals with limited internet access and/or low digital literacy (Lehdonvirta et al., 2021). This coverage limitation is particularly relevant because digitally excluded and socially marginalised populations are precisely the groups where smoking ban prevalence is lowest and where Roma households are concentrated. The single-respondent design means the partner's perspective is not directly captured, and respondent gender may influence recalled attributions such as the initiator role. Different question wordings and data-collection modes across datasets for the same constructs (ban definition, financial deprivation; CAPI in 2009 versus CAWI in 2022) limit strict comparability of prevalence estimates across

time points, although datasets were analysed separately and not pooled. The 2009–2022 mode difference is expected to bias against, not toward, the observed increase, and the +13.9 percentage-point change ($\chi^2 = 46.0$, $p < 0.001$, Cohen's $h = 0.28$) is large relative to plausible mode or wording effects; it is presented as the best available evidence of direction and approximate magnitude, not as a precise trend estimate.

Sample restrictions limit generalisability in several ways. Roma sample sizes are small in both datasets (n = 33–35), resulting in wide confidence intervals and limited statistical power. Roma self-identification underestimates Roma population size, which is typically estimated at approximately ~7% of the total population (Romaversitas, 2025). However, the association between Roma household status and lower ban adoption was observed consistently across three complementary analyses using different units of analysis, covariate structures, and time periods. In the penalised regression, Roma status was stably selected with a non-zero coefficient magnitude despite the inclusion of correlated structural variables. This convergence across analyses supports the presence of a real disparity, although the precise magnitude of the adjusted association remains uncertain.

Restriction to homeowner couples in 2025 improves interpretability of voluntary ban measurement but produces a more socioeconomically advantaged sample than the broader cohabiting population. Results of this dataset are not generalisable to renter households, single-parent households, or multi-generational households, where different negotiation dynamics and power structures may apply (Villarreal et al., 2026).

The 2022 survey was conducted during the COVID-19 pandemic, which may have affected household norms or tobacco use patterns. The focus of the survey (COVID-19 vaccination) might also have filtered participants. The 2025 survey lacks external validation. Furthermore, several variables relevant to ban adoption were not available in all datasets.

Analytical and modelling choices introduce further limitations. The exploratory logistic growth modelling relies on only two Hungarian data points and imposes three assumptions: a logistic functional form, a fixed ceiling shared with the United States (K = 92.9%) and continuation of the 2009–2022 adoption pace. The heterogeneity already observed between the US (r = 0.14) and Scotland (r = 0.19) demonstrates that countries differ in pace, and potentially also in shape and ceiling. Accordingly, the projected timing

should be interpreted as conditional on these modelling assumptions, not as an empirical estimate. In particular, the ceiling was fixed externally for identifiability reasons (two national data points cannot identify three parameters), and the projected timing depends directly on this choice. The 2022 data point was collected during the COVID-19 pandemic, which may additionally affect the trajectory estimates.

LASSO regression is more sensitive to sample composition than standard logistic regression. Accordingly, its results may not replicate in samples with different distributions. In the 2025 dataset, majority-rule collapsing of the 20 multiply imputed datasets into a single analysis dataset is not part of the standard multiple-imputation workflow. Rubin's pooling rules were not applied because they assume a fixed model specification, whereas penalised regression procedures such as LASSO perform data-driven variable selection. When different predictors are selected across imputed datasets, Rubin's rules cannot be straightforwardly applied to combine coefficients. Therefore, a single collapsed dataset was used for the penalised regression analyses, which departs from the standard multiple-imputation workflow and should be considered a methodological limitation. However, the low number of imputed values (0.6%) limits the impact of this limitation.

EDTNAD-specific decision-making patterns could not be analysed due to the small number of reported ban adoptions (n = 34). Recalled decision-making patterns are subject to recall bias, rosy retrospection bias, and social desirability. Respondents may overstate their own role in initiating bans.

Finally, no biomarker or environmental validation of self-reported ban status was conducted. Analyses did not account for housing characteristics (e.g., apartment vs. house, presence of a balcony) that may influence the feasibility of indoor smoking restrictions. Temporal comparisons between 2009 and 2022 may be confounded by broader tobacco control policy changes in Hungary during this period, including the 2012 smoke-free legislation and the 2013 tobacco retail restrictions (Joó et al., 2025).

6. Conclusions

This section summarises the main findings, identifies public health and policy implications, outlines recommendations for future research.

6.1. Main findings

The prevalence of complete voluntary in-home smoking bans in Hungary increased from 61.7% in 2009 to 75.6% in 2022. This level remains below several Western European countries and the United States. Exploratory logistic growth modelling suggests Hungary follows a slower adoption trajectory than Scotland or the United States.

Complete in-home EDTNAD use bans were less prevalent than smoking bans in 2022. Approximately 12% of individuals living in smoke-free homes reported that EDTNAD use remained permitted indoors. Consequently, the increase in comprehensive clean air rules between 2009 and 2022 was not statistically significant. In 2022, approximately 25% of minors lived in households permitting smoking and approximately 34% lived in households without clean air rules.

Roma households had significantly lower prevalence of complete in-home smoking bans than non-Roma households in both the Social Determinants of Smoking Survey (2009) and the Online Cohabiting Couples Survey (2025), even after adjustment for established determinants.

Among cohabiting couples, the female's partner educational advantage was associated with voluntary smoke-free bans. Shared financial decision-making was also associated with both in-home smoking and EDTNAD use ban, while structural equality indicators (equal income share, equal home ownership, dual employment) were not.

Among households without a complete smoking ban, 53.3% reported that a ban had previously been proposed. Women were significantly more likely to initiate a ban than men. The most frequently recalled motivation for ban adoption was unpleasant smell of tobacco smoke (57.9%), followed by protection of children (25.5%).

Among households with a complete ban, 77.0% reported that smoking had never been permitted indoors. Together with the increase in ban prevalence between 2009 and 2022, this might indicate that the smoke-free home is increasingly becoming the default: an emerging societal norm in Hungary.

6.2. Public health and policy implications

Regular surveillance of both in-home smoking and EDTNAD use ban prevalence should be instated in Hungary. Monitoring smoking bans alone overestimates indoor air protection. A national target for smoke-free and aerosol-free home prevalence should be established to guide surveillance, with particular attention to households with children. It would be consistent with broader calls to explicitly protect children from home SHS exposure (Semple, Tigova, et al., 2026). Self-reported household rules should not be regarded as direct measures of secondhand smoke exposure. Periodic incorporation of exposure biomarkers, particularly salivary cotinine, would strengthen surveillance.

The proportion of smoke-free homes that permit EDTNAD use indoors represents a communication gap. Public health messaging should address SHA harm explicitly. Interventions that address both smoking and EDTNAD use are necessary to promote comprehensive indoor air protection. Health marketing approaches should consider audience segmentation by smoking status, household composition and socioeconomic status.

Roma households are a high-priority subpopulation. Interventions should address the structural determinants concentrated in these households: smoking prevalence, financial deprivation, segregation and low educational attainment.

The finding that approximately half of cohabiting couples without bans have previously proposed one identifies a population segment where motivation exists but implementation has not occurred. Interventions targeting the contemplation-to-adoption transition should be developed and implemented for this subpopulation.

Health promotion programmes advocating voluntary smoke-free and aerosol-free households should be developed with consideration of gender power imbalances within households. Interventions should strengthen the decision-making power of women who often initiate bans while simultaneously engaging resistant male partners. Methods emphasising fathers' protective role may facilitate ban adoption in households with gender-power imbalance (O’Donnell et al., 2022). The association between shared financial decision-making and ban adoption suggests that the process of joint decision-making matters for household-level health outcomes. This is consistent with family-centred intervention approaches.

The prominence of unpleasant smell as a recalled motivation and the low recall of doctor's recommendation suggest two specific opportunities. Sensory discomfort may represent an underutilised communication frame. Medical counselling (particularly by paediatricians) for smoke-free home promotion appears to be underutilised and should be strengthened. Particular attention is warranted for socially disadvantaged households with children and at least one smoker. Health promotion messages should address both smoking and EDTNAD use within the home, emphasize that secondhand aerosol is not harmless, and build on the motivations identified in this study, particularly protecting children and maintaining a clean indoor environment.

Beyond voluntary adoption, the very slow progress documented in this dissertation suggests that health interventions alone may not be sufficient to achieve comprehensive protection of adults and children from SHS/SHA in the home in Hungary. A broader debate has recently been initiated on whether protecting children from home SHS/SHA should be reframed as a children's right to clean air and placed on the tobacco control legislative agenda (Semple, Tigova, et al., 2026). This suggestion is consistent with the forward-looking measures proposed to the eleventh WHO FCTC Conference, which include extending smoke-free protection to private homes, vehicles and multi-unit housing (WHO FCTC, 2025); FCTC Article 8 currently does not extend to the private home (WHO, 2007). In the Hungarian context, approximately 25% of minors lived in households permitting smoking in 2022, and exploratory projections (conditional on the assumed functional form, fixed ceiling, and continuation of the 2009–2022 pace) suggest that near-universal smoke-free homes would be reached only several decades from now. Given these findings, a complementary legislative framework warrants consideration.

Promotion of voluntary in-home tobacco and nicotine use bans should be integrated into comprehensive tobacco control programmes, including public health campaigns, educational activities, interventions, rather than implemented as a stand-alone programme.

6.3. Recommendations for future research

Several directions for future research emerge from this dissertation.

First, given the emerging discussion on legislative approaches to protecting children from home SHS exposure (Semple, Tigova, et al., 2026), future research should assess public support in Hungary for such policy measures (including the still-absent ban on smoking in cars with children).

Second, the cross-sectional design of all analyses in this dissertation does not allow causal inference. Longitudinal studies are needed to establish the temporal ordering between couple-level predictors and ban adoption.

Third, future studies should examine the implementation and maintenance of household bans rather than their mere presence. Ecological momentary assessment (EMA), for example through smartphone-based reporting of smoking or vaping episodes, could quantify the frequency and context of ban violations and temporary lapses. Findings could be validated using in-home devices and/or biomarkers of tobacco-smoke exposure, such as cotinine and, potentially, DNA methylation at the CpG locus cg05575921 in the aryl-hydrocarbon receptor repressor (AHRR) gene.

Fourth, underrepresented populations and household types require dedicated attention. More robust epidemiological evidence on voluntary household bans among the Roma population is needed. Ethnicity should not be treated as the operative mechanism: the disparity reflects structural conditions (residential segregation, material deprivation, exclusion from healthcare, and insular social networks) concentrated among Roma households (Belak et al., 2017; Petrova, 2003). Framing racism as an aspect of the social context rather than an attribute of minority groups (Baciu et al., 2017), and inequities as products of social hierarchy rather than difference (WHO CSDH, 2008), is both statistically stronger and non-stigmatising. Methodologically, this calls for oversampling Roma households through respondent-driven sampling (RDS) embedded within general-population studies rather than stand-alone “Roma studies”; direct measurement of segregation and deprivation (geocoded indices, social-network data) to convert unmeasured confounders into measured exposures; and periodic specialised data collection for this small, geographically concentrated population (Baciu et al., 2017). Non-stigmatising practice further requires community co-design of instruments and

interpretation, anti-deficit framing, and careful handling of self-identification, consistent with participatory action research (PAR).

Fifth, the couple-level analytical approach should also be extended to single-parent, multi-generational, and renter households, where different negotiation dynamics and power structures may apply. For renter households in particular, the ban decision is not purely intra-household, as landlords may set or forbid tobacco and aerosol rules (Instituting Smoke-Free Public Housing, 2016).

Finally, further research should focus on translating these findings into effective interventions. Qualitative investigation of proposed-but-not-adopted bans could identify barriers preventing implementation. Intervention research on norm formation around emerging nicotine products is needed, to shape indoor aerosol norms before permissive patterns become entrenched. Marital conflict research on health decisions could also clarify why some proposals lead to adoption while others do not.

7. Summary

A major share of second-hand smoke and aerosol exposure occurs in private homes. Because smoking and aerosol-generating tobacco and nicotine product use within private households currently fall outside the enforceable scope of tobacco control legislation in Hungary, reductions in indoor exposure depend mainly on voluntary household rules. Evidence on the prevalence, distribution, and couple-level patterns of voluntary in-home bans in Hungary has been limited.

This dissertation examines voluntary in-home smoking bans and bans on the use of electronic devices for tobacco or nicotine aerosol delivery (EDTNAD) in Hungary across four dimensions: prevalence and temporal trends, social and ethnic stratification, intra-household configuration, and recalled decision-making patterns. Analyses draw on four cross-sectional surveys conducted between 2009 and 2025. For analyses of intra-household patterns, the unit of analysis was the cohabiting couple.

The prevalence of complete in-home smoking bans increased from 61.7% in 2009 to 75.6% in 2022. However, complete EDTNAD use bans were less prevalent than smoking bans: approximately 12% of individuals living in smoke-free homes reported that EDTNAD use was permitted indoors. Consequently, the increase in comprehensive clean air rules between 2009 and 2022 was not statistically significant. In 2022, approximately 25% of minors lived in households permitting smoking. Roma households had significantly lower prevalence of complete smoking bans than non-Roma households, even after adjustment, for household smoking composition and socioeconomic factors. In couple-level analyses, the female partner's educational advantage was associated with smoking ban adoption. Shared financial decision-making was also associated with both smoking and EDTNAD use ban adoption. Among households without a complete smoking ban, 53.3% reported that a ban had previously been proposed but not adopted.

Voluntary in-home smoking bans in Hungary have increased but remain incomplete and socially stratified. Reducing secondhand smoke and aerosol exposure in private homes requires surveillance, interventions and consideration of legal approaches. Public health efforts should address both indoor smoking and EDTNAD use, with particular attention to socially disadvantaged populations, including the Roma population. Household interventions should also take into account the decision-making processes and intra-household gendered power dynamics.

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10. Acknowledgements

I am grateful to my supervisor, Prof. Dr. Fruzsina Albert, for her professional and emotional support throughout this work. I thank my co-supervisor, Dr. Melinda Pénzes for her methodological rigour and support. I also thank Dr. Ildikó Danis (Semmelweis University) for her valuable inputs during my PhD-studies. I am also grateful to dr. Vitrai József (Hungary Academy of Sciences, Preventive Medicine Committee), whose guidance was invaluable in several critical decisions during this research. I would also like to acknowledge the late Prof. Dr. Béla Buda, whose mentorship and intellectual curiosity first sparked my interest in interdisciplinary research. I am also grateful to my employers and colleagues at the Centre for Social Sciences (Hungary) and the University of Potsdam (Germany) for their support throughout my doctoral studies. I am also grateful to the Department of Cognitive Science at Central European University (Austria-Hungary) for allowing me to attend their lectures and workshops. (As English is not my first language, I used Anthropic Claude Opus 4.8 for English language grammar correction.)

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