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Does policy adoption influence the association between socio-economic differences and smoking prevalence? A longitudinal analysis 2008-2015

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Abstract

Introduction: Smoking is a major public health concern, accounting for nearly 700,000 deaths on an annual basis, globally. The socio-economic differences within smoking are well established, reflected in a social gradient that is estimated to account for half of the socio-economic differences in mortality for men aged 35-69 years in developed settings, such as the European region.

Aim: The study aimed to investigate the association between socio-economic differences and smoking prevalence, and furthermore to explore the influence of policy adoption on the association between socio-economic differences and smoking prevalence.

Methodology: This ecological longitudinal study adopted a quantitative approach to methodology, modelling panel data from 2008-2015. Data for units of analysis (n = 7) were extracted from public data sources including the World Bank, OECD, ESPAD and WHO's Global Observatory. Statistical analysis was conducted using R software, for multivariable linear regression in the form of fixed effects regression models and interaction terms.

Results: Smoking prevalence showed statistical significance in association to education ($p=8.07x10^{-6}$)($p=7.63x10^{-5}$)($p=2.79x10^{-5}$),and employment rate ($p=0.002$)($p=0.003$)($p=0.003$), which were negatively and positively associated, respectively. In isolation, policy adoption of tobacco control strategies showed no statistical significance ($p=0.696$)($p=0.459$) in association to smoking prevalence. However both models, which incorporated a measure for policy adoption, indicated statistical significance ($p=2.80x10^{-9}$) ($p=2.31x10^{-9}$), yet at a slightly decreased significance level when compared to the model that did not ($p=5.99x10^{-10}$).

Conclusions: All three models, with and without incorporated measures for policy adoption influenced the association between smoking prevalence and socio-economic differences, which could be deduced to omitted variable bias. Findings suggest policy regarding tobacco control needs to be stronger and more clearly regulated, with shifted focus on health education, in order to have a truly significant effect, and to overcome the socio-economic differences present within smoking.

Key words: Tobacco, Tobacco control, Tobacco prevention and Socio-economic status

Table of contents

Introduction

Smoking has long been a source of disease, and has in recent decades graduated from being a socially practiced custom to a global endemic, reflected in the 32% smoking prevalence of daily cigarette smokers within the European region (1). Life threatening diseases such as lung cancer and chronic obstructive pulmonary disease are strongly associated with smoking, alongside being the principal risk factor underlying many pathologies – qualifying smoking as a major public health concern (2). It is also well established that there is a strong socio-economic gradient within smoking, represented by the 14% smoking prevalence in managerial and occupational groups, compared to a 29.7% smoking prevalence in routine and manual workers, in the United Kingdom (3). This social gradient existing within smoking is estimated to account for half of the socio-economic differences in mortality for men aged 35-69 years, in high-income settings (4). In order to tackle the growing epidemic, population based tobacco control strategies have been devised to reduce smoking prevalence and encourage smoking cessation, such as smoke free legislation and banning smoking from public places (5). In addition to promoting smoking cessation, population based tobacco control strategies also have the potential to diminish the socio-economic differences present within smoking (6).

The social gradient in health

A social gradient in health may be broadly defined as differences in health status between social groups, as a result of unequal access to healthcare services and/or healthcare facilities (7). The Whitehall studies were longitudinal studies of cardiorespiratory disease and diabetes, and investigated the social determinant of health in the United Kingdom, shifting the concept of 'health disparities' to apparent social gradients (7). The series of experiments linked occupational grade to health, and furthermore observed health improvements with each successive step up occupational grade (7,8). Whilst most of the social gradient is stratified by ethnicity and gender in the USA, in Europe the constituents of the social gradient mostly refer to educational attainment, income and socio-economic status. (8). This social gradient in health has been made noticeably visible within smoking (3,4,6).

Higher educational attainment has been strongly linked with positive health outcomes, due to increased self-efficacy, knowledge and social participation (9). However, more importantly,

education is also a strong predictor of health literacy, a concept concerned with understanding risk and scientific uncertainty, and being able to use this knowledge to make informed decisions and thus ultimately, having control over ones own health (10). Educational differences have most clearly been demonstrated in birth outcomes, where studies have found, that mothers with lower education were more likely to birth infants with intrauterine growth restriction and lower birth weight, and also increased life expectancy for those with higher educational attainment (11).

Income inequality has been named one of the main predictors for health outcomes within the European region, two mechanisms linking the two have been hypothesized, namely the neo-material perspective and psychosocial effects (12). The former mechanism suggests that the unequal distribution in capital, leads to underinvestment in educational and medical services, and allows those in higher strata of society to 'opt-out' and utilize private services, whilst those in the lower strata of society are left with poorly funded public services. On the contrary, the psychosocial mechanism suggests that through social comparison, all strata of society are equally affected, as seeing others better off than oneself, leads to increased stress, which could result in severe implications for both mental and physical health (12). It is important to note that these mechanisms were applied with specific reference to the European region, and do not apply to all health care systems.

Socio-economic status (SES) typically encompasses both education and income, and in most cases also occupation, indicating social, economic and working status, respectively (13, 14). The wide range of variables included, qualify SES as a fitting measure for representing the position a person occupies within society. It has been attributed as one of the major causes underlying the social gradient within health, reflected in two to three times greater risk of incidence of disease and disability, for those with lower SES within the European region (14). Besides the physical limitations associated with lower SES, hypotheses have claimed that SES may also impact biological function. This hypothesis is supported in association with the physical and social environment, with reference to increased exposure to pathogens and reduced access to social resources and support, for those with lower SES (13).

It is equally as important to consider that the political climate also plays a major role in shaping health outcomes, as public policy is directly linked to health policy. Findings have suggested that societies with egalitarian values, and also social democrats, have a tendency to

favor redistributive policies, reflected in higher public health expenditure, universal health care and also greater social benefits (15). Studies examining the effects of different political traditions and health outcomes have supported these findings, mirrored by the association in pro redistributive policies and positive health outcomes, indicated by overall reduced infant mortality (15).

Tobacco Control in Europe

The European Union (EU) is a powerful political-economic union, consisting of 28 member states, founded in Maastricht, The Netherlands, in 1993, aiming to strengthen and improve matters including climate change, health, social justice and migration, orchestrated through policy development and international relations. The EU is based on treaties, which are voluntarily and democratically agreed by all members' states, evolving a concept coined 'acquis communautaire' (16). This notion involves mandatory policy diffusion, involving states that want to join, to adopt and implement current EU policy (17). This therefore also involves fostering tobacco control strategies such as the WHO Europe's regional action plans on tobacco, the Framework Convention on Tobacco Control, and the directive on tobacco control.

WHO's three regional action plans on tobacco were established in the European region, the first in 1987, followed up by two publications in 1992 and 1997 (18). The regional action plan of 1987 laid much of the groundwork for the development of tobacco control within Europe, the main objectives of this action plan was to produce country specific comprehensive policy, greater cooperation between intergovernmental and non governmental organizations, place greater emphasis on monitoring and evaluation, and lastly, to ensure dissemination of information to the public (18,19). The regional action plan of 1992 shifted greater focus on tobacco control strategies aimed at adolescents, and the promotion of smoke free environments, after a series of epidemiological studies outlined the risk of second hand exposure, findings estimated a 20-30% increased risk of lung cancer for the spouse of a smoker (18,20). The regional action plan for tobacco of 1997 redirected focus to the functionality of tobacco control strategies, as much of the report revolved around pricing, advertisement, control of smuggling and product regulation. There was also a realization for the need to support smoking cessation services, to address the addictive nature of smoking (20). Alongside the regional action plans, the EU also developed the directive on tobacco

products, established in 2001. The directive set in place laws and regulations regarding the maximum tar and nicotine content of cigarettes, warning labels on tobacco products regarding health implications, ingredients and descriptions of tobacco products (17).

Notably, the EU also displayed the need to confront the issue of tobacco consumption on a global scale, indicated by the political support for World Health Organizations' (WHO) Framework convention on Tobacco control (FCTC). The FCTC was the first evidence based, public health treaty, aiming to respond to the globalization of the tobacco epidemic (21). One of the main articles, Article 5.3, emphasized the necessity to protect tobacco control and public health policies from the vested interests of the tobacco industry, however the main contents of the framework were mainly concerned with tobacco control strategies. Focus of these strategies was namely on the following: price increase and tax measures, protection from exposure to tobacco smoke, regulation of contents of tobacco products, packaging and labeling of tobacco products, tobacco advertising, promotion and sponsorship and restricting sales to and by minors (21).

Population based tobacco control's potential to diminish the social gradient

Tobacco control strategies may be categorized into individual based and population based approaches. Individually based tobacco control strategies mainly focus on smoking cessation, through pharmacological treatments and psychosocial management, referring to strategies such as nicotine replacement therapy and behavioral counseling services, respectively (6). Nicotine replacement therapy is the most widely used, and functions by reducing symptoms of nicotine withdrawal. However, utilization of individually based approaches, has been found to be greater in more educated and affluent smokers, primarily associated to access (22). The out of pocket cost associated with individually based approaches limits access for those with lower SES, although the intention to quit is equal across SES groups (22). A study in the United Kingdom found that, free of charge behavioral support provided by the National Health Service (NHS), reported an increase use of service from smokers from geographically more deprived areas, rather than a hypothesized decrease (6,22).

Population based tobacco control may be defined as 'those applied to populations, groups, areas, jurisdictions or institutions with the aim of changing the social, physical, economic or legislative environments to make them less conducive to smoking' (6). The socio-economic

differences associated with smoking remain a major public health concern, as literature supports a common trend of smoking prevalence being higher among those with lower SES (4-6, 11). Population based tobacco control strategies eliminate the drawback of individual based approaches with reference to the out of pocket payments associated with utilization and access, whilst simultaneously tackling second hand exposure through smoke free legislation. This therefore introduces rationale to research population based tobacco control in relation to socio-economic differences and smoking prevalence, as these strategies come with no direct cost to the individual. As outlined in the tobacco control strategies in Europe, the most common types of population based tobacco control include smoke free legislation in public or work places, tobacco taxation and restriction of sales to and by minors (5). Besides aiming to reduce tobacco consumption, recent studies have also indicated intervention effectiveness of population based tobacco control's ability to diminish the social gradient within smoking (5-6).

Further studies in Australia supported these finding where increased expenditure into tobacco control activities led to reduction in smoking prevalence across all SES groups, mirrored by a 5% smoking prevalence in high SES, comparable to 8% in lower SES, for students aged 12-15 (23). A systematic review focused on tobacco control interventions further supported these findings, and found tobacco taxation measures to be the most effective in reducing smoking prevalence across all socio-economic groups. Additional findings from the USA, reported reduced smoking uptake and tobacco consumption, following the introduction of tobacco taxation, where price sensitivity was more evident in males (5,6). Econometric analysis within the European region also revealed pricing policy to be effective in minors, in which a 10% increase in price, was hypothesized to decrease smoking prevalence by 17% (24).

Policy adoption of population based tobacco control strategies thus has the potential to diminish the socio-economic differences existing within smoking. This study will focus specifically on the policy adoption for tobacco taxation and restriction of sales to and by minors. Tobacco consumption within adolescent group remains a huge problem, as it has been estimated that 58% of new cigarette smokers were aged under 18 in 2008, alongside an estimated 2.4 million aged 12 and older having tried their first cigarette within the last year (25). This therefore highlights the need to re-direct focus on adolescents, following objectives of the regional action plan of 1997, and the FCTC (18,20). Secondly, this study will also examine policy adoption of the tobacco tax, which has shown most promise in reducing the

socio-economic differences within smoking associated with lower income and level of education, according to the literature (5-6,24). As most studies focus on either one specific, or a broad range of population based tobacco control strategies, focusing on only two will provide a more comprehensive overview, whilst still allowing comparison of effectiveness between the two.

Aim

This study aims to investigate the association between socio-economic differences and smoking prevalence, and furthermore aims to explore the influence of policy adoption on the association between socio-economic differences and smoking prevalence, within the European region.

Research question(s)

1) Does policy adoption influence the association between socio-economic differences and smoking prevalence?

2) Has policy adoption of population based tobacco control strategies indicated intervention effectiveness?

Objectives

- To assess the effects of tobacco control interventions on socio-economic differences within smoking.

- To assess policy adoption of tobacco control interventions within the European region.

Null Hypothesis

This study will adopt a hypothesis testing approach (H_o), and thus hypothesize that policy adoption will have no effect on the association between socio-economic differences and smoking prevalence.

Methodology

Study population

The study examined the association between socio-economic differences and smoking prevalence within the European context, namely focusing on the following countries: Czech Republic, Finland, Iceland, Netherlands, Norway, Sweden and the United Kingdom. The specified countries were used as units of analysis (n = 7) (26, 27). Countries were selected based on data availability, following a preliminary search. Additionally, these countries offered a diverse mixture of countries within the European region, with diverse cultural, political and economic histories. The study used ecological data, and thus the study population consisted of aggregate information on individual tobacco smokers or consumers of the countries specified above – with inclusion of all age groups and sexes (6).

Study design

A quantitative approach to methodology was adopted, assessing the association between socio-economic differences and smoking prevalence, and the influence of policy adoption, over the specified time period of 2008-2015. All variables were chosen according to data availability. The specified time period qualified this study as an ecological longitudinal study, modelling panel data (28). A major advantage in using panel data is that it controls for variables, which cannot be observed or measured, such as cultural factors (29). Smoking prevalence was defined as the outcome, and socio-economic differences and policy adoption as the variables.

Data sources

Accessible data sets were extracted from multiple public sources, including the World Bank, the Organization for Economic Co-operation and Development (OECD), The European School Survey Project on Alcohol and other Drugs (ESPAD) and the World Health Organizations Global Observatory (26,27,31,32). Firstly, a summary table was produced for an overview of complete data sets for each country. In the case that all countries had complete data sets from the same source, for the specified time period, data was downloaded in Excel format and copied and pasted into newly created Excel file. Data had to be present from 2008

– 2015, for inclusion into the assembly of the panel (28,29)[1]. Note that for the extraction of employment rate, the last quarter for each year was extrapolated of the specified time period (2008-2015) to ensure homogeneity of data extraction, and similarly, for data for cigarette use among students, data was extracted for all students, including both female and male, for compilation into the data set (27,31).

Measures for outcome and covariates

The measure for the outcome of smoking prevalence was signified by number of daily smokers (total, % of population aged 15 +), as defined by OECD (26). Several predictors were used to indicate socio-economic differences, namely education (tertiary/upper secondary/ below upper secondary, % of 25-64 year olds) and social spending (public % of GDP), as defined by OECD, and household financial consumption expenditure (annual % growth) and employment rate (employment to population ratio, 15+, total %), as defined by the World Bank (26,27). Policy adoption was measured with specific reference to tobacco taxation and restrictive legislation to minors, and was indicated by most sold brand of cigarettes (taxes as a % - specific excise tax), as defined by WHO, and cigarette use among students during the last 30 days (% of students aged 15-16), as defined by ESPAD, respectively (31,32).

It is important to note that only two tobacco control strategies, namely tobacco taxation and restriction of sales to and by minors were assessed within the present study, thus eliminating other tobacco control strategies, which may have been equally or even more effective than the proposed strategies. Additionally, the measures used for policy adoption were proxy measures/indicators, rather than direct policy measures, chosen due to data availability. The most sold brand of cigarettes (taxes as a % - specific excise tax) was linked to tobacco taxation, as the sales would reflect price elasticity and demand of said population, and thus indicate if increasing the tax had an effect on sales. The second proxy measure, cigarette use among students during the last 30 days (% of students aged 15-16) was linked to restriction of sales to and by minors, to indicate their access to tobacco products – reflected in the smoking prevalence. The measures for covariates were selected on the basis of the literature, which hypothesized employment (employment rate (employment to population ratio, 15+, total %)),

[1] *In cases where data was missing for a particular year, data from the previous year was used and substituted when new data became available, to ensure completion of a full data set.*

education (education (tertiary/upper secondary/ below upper secondary, % of 25-64 year olds)) and income (household financial consumption expenditure (annual % growth)), to be strong predictors for smoking outcomes (9,12,14). Therefore these measures were used to indicate the influence of population based tobacco control on the association between smoking prevalence and socio-economic differences.

Statistical analysis

Data clearing and processing was conducted using Microsoft Excel, before being imported into the analytical software. Data analysis was conducted with R software, using the 'plm' package and associated functions: (plm (y~x, data=pdata, model="within", "random")), summary (fixed, random), phtest (random, fixed), for panel econometric analysis. These functions allowed for prediction of fixed effects/within estimators, and random effects estimators, for multivariable linear regression models (29). Results were interpreted at levels of significance, $p<0.05$. The fixed and random effects models can be determined as follows, respectively:

Fixed effects model

$Y_{it} = \beta_1 X_{it} + a_i + u_{it}$

Where:

a_i (i=n) is the unknown intercept for each entity

Y_{it} is the dependent variable, where i=entity and t=time

X_{it} represents one independent variable (IV)

β_1 is the coefficient for that IV

u_{it} is the error terms

Random effects model

$Y_{it} = \beta_1 X_{it} + a + u_{it} + \varepsilon_{it}$

Where:

u_{it} is between the entity error

ε_{it} is within the entity error

Fixed effects models were used to investigate the relationship between predictor and the outcome variable, removing the time – invariant characteristics to assess the net effects of the predictors on the outcome variable (29). Conversely, random effects models assumed

variation across entities, in which the entity term was not correlated with the predictors, allowing time - invariant variables to act as explanatory variables (29). In order to distinguish whether to use fixed or random effects models, the Hausman test was utilized, in which the null hypothesis hypothesizes that there would be no correlation between unique errors and regressors (28,29). If the null hypothesis was accepted, random effects models were used, and if rejected, fixed effects models (28,29).

Results

Smoking prevalence was decreased in all countries, with exception of Czech Republic where a slight increase (2.3%) was reported, whilst the United Kingdom displayed the lowest percentile change (-9.5%) of number of daily smokers (total, % of population aged 15 +) between 2008-15 (see Table 1). Education was increased for all countries, indicated by enrollment or continuation in tertiary/upper secondary/ below upper secondary (% of 25-64 year olds), with the percentile range of 9.8% to 53%, in the Netherlands and Czech Republic, respectively, between 2008-15. Household financial consumption expenditure (annual % growth) was noticeably decreased in the United Kingdom (-470.9%) between 2008-15, and also in Nordic countries Iceland (-143.4%) and Finland (31.5%), whereas contrastingly, Sweden had the biggest percentile change (1091.8%) between 2008-15. Social spending (public % of GDP) was increased in all countries between 2008-15, particularly in Finland (31%). Employment rate (employment to population ratio, 15+, total %) remained relatively unchanged in Czech Republic (0.0%), yet decreased in all other countries between 2008-15. However note all figures were within the percentile range spanning from -1.4% to -7.2%, with reference to the United Kingdom and Netherlands, respectively.

Model 1 estimated the coefficients of the covariates for socio-economic differences, against smoking prevalence (see Table 2). Model 1 rejected the Hausman test, and thus applied fixed effects multivariable regression. The coefficient for education was statistically significant ($p = <0.001$), and most negatively associated with smoking prevalence, assuming that an additional year in tertiary/upper secondary/ below upper secondary education (by the % of 25-64 year olds) would reduce the proportion of daily smokers (total, % of population aged 15 +), by -0.435455 (±0.086). Household financial consumption expenditure indicated a negative trend (-0.315202 (± 0.088)), whilst social spending indicated a positive trend (0.073824 (±0.230)), although both insignificant ($p=0.722$) ($p=0.750$), respectively. The estimated

coefficient for employment rate was statistically significant (p=0.002), and positively associated with smoking prevalence, assuming that an annual increase in employment rate (employment to population ratio, 15+, total %) would increase the proportion of daily smokers (total, % of population aged 15 +) by 0.714550 (±0.217).

Additional analysis was conducted in the form of interaction terms (see Table 2a), and the employment rate-social spending interaction was statistically significant (p=0.002), and revealed a positive association (0.07180(±0.0215)) to smoking prevalence, suggesting that the effect of social spending depends on employment rate and vice versa. The social spending – household financial consumption expenditure interaction was also statistically significant (p=0.031), and revealed a negative association (-0.09133(±0.0419)) to smoking prevalence, suggesting that the effect of social spending depends on household financial consumption, and vice versa. Similar to the social spending – household financial consumption expenditure interaction, the education-employment rate interaction term, was also statistically significant (p=<0.001), and negatively associated (-0.09471(±0.02203)) to smoking prevalence.

Model 2, estimated the coefficients of the covariates for socio-economic differences, against smoking prevalence, adding a measure for policy adoption - namely the most sold brand of cigarettes (taxes as a % - specific excise tax) to the model (see Table 3). Model 2 also rejected the Hausman test, and thus applied fixed effects multivariable regression. The goodness of fit (R^2), between model 1 (66.4%) and model 2 (66.5%), remained relatively unchanged, suggesting that the added measure did not reduce or increase the models ability in predicting estimates for coefficients. Similar to model 1, household financial consumption expenditure indicated a negative trend (-0.381138 (± 0.905)) and social spending a positive one (0.0638690 (±0.234)), although both insignificant (p=0.676) (p=0.786), respectively. The estimated coefficients for education (p=<0.001) and employment rate (p=0.003) remained statistically associated to smoking prevalence, assuming that an additional year in tertiary/upper secondary/ below upper secondary education (by the % of 25-64 year olds) would reduce the proportion of daily smokers (total, % of population aged 15 +), by -0.4195459 (±0.096), and that an annual increase in employment rate (employment to population ratio, 15+, total %) would increase the proportion of daily smokers (total, % of population aged 15 +), by 0.7063175 (±0.220). The added measure for policy adoption had no association to smoking prevalence (p=0.696). However it is important to note that overall, model 2 ($p= 2.80x10^{-9}$) was statistically significant, yet the significance level was slightly

decreased when compared to model 1 ($p=5.99x10^{-10}$), suggesting that the addition of the proxy for policy adoption into the model did not greatly influence the association between smoking prevalence and socio-economic differences.

Model 3 estimated the coefficients of the covariates for socio-economic differences, against smoking prevalence, adding a measure for policy adoption, namely the cigarette use among students during the last 30 days (aged 15-16,%) (see Table 4). Model 3 also rejected the Hausman test, and thus applied fixed effects multivariable regression. The goodness of fit (R^2), between model 1 (66.4%) and model 3 (66.8%), also remained relatively unchanged, suggesting that the added measure did not reduce or increase the models ability in predicting estimates for coefficients. Similar to model 1, household financial consumption expenditure indicated a negative trend (-0.014645 (± 0.914)), whilst social spending indicated a positive one (0.057621 (±0.233)), although both insignificant (p=0.873) (p=0.806), respectively. The estimated coefficients for education (p=<0.001) and employment rate (p=0.003) remained statistically associated to smoking prevalence, assuming that an additional year in tertiary/upper secondary/ below upper secondary education (by the % of 25-64 year olds) would reduce the proportion of daily smokers (total, % of population aged 15 +), by -0.418946 (±0.089), and that an annual increase in employment rate (employment to population ratio, 15+, total %) would increase the proportion of daily smokers (total, % of population aged 15 +), by 0.691539 (±0.221). Cigarette use among students had no association with overall smoking prevalence (p=0.459). As with model 2, overall model 3 ($p=2.31x10^{-9}$), was statistically significant, yet the significance level was slightly decreased when compared to model 1 ($p=5.99x10^{-10}$), suggesting that the addition of the proxy for policy adoption into the model did not greatly influence the association between smoking prevalence and socio-economic differences. Note that the fit of the model remained relatively unchanged, regardless of which policy measure was included in the model.

Discussion

The two measures for policy adoption of tobacco control measures showed no statistically significant association between smoking prevalence and socio-economic differences, within the European region. An overall trend illustrated that education remained negatively associated with smoking prevalence, whilst employment rate remained positively associated with smoking prevalence, both at levels of statistical significance. Consistent with other

findings, educations' negative association to smoking prevalence has proven to be a strong predictor for smoking, supported by the education – employment interaction term, which indicated a negative association (9,11). As the proxy indicators for policy adoption of tobacco control measures - with specific reference to tobacco taxation and restriction of sales to minors, had no statistically significant effect on the association between smoking prevalence and socio-economic differences, the present study accepts the null hypothesis (H_o).

Educations' negative association between socio-economic differences and smoking prevalence remains consistent with other findings, in which those with higher educational attainment (specifically above high school education) have reported reduced smoking prevalence, mirrored by lower figures in smoking initiation, and increases in number of quit attempts and smoking cessation (9,11,33). Recent studies have linked lower education to place of residence i.e. more deprived neighborhoods in which the use of tobacco may be more acceptable, whilst also having increased accessibility to tobacco products (11, 34). The perceived acceptability of tobacco use has also been postulated to create a sense of normality, and thus reducing the likelihood of quit attempts, for those with lower educational backgrounds (34). Alternative reasoning supporting present findings can also be linked to resources which aid quit attempts or smoking abstinence, which are not confined to financial resources – in terms of affording individually based cessation services, but also psychological resources such as self –efficacy, which aid the effectiveness of population based tobacco control strategies (34).

In contrast to education, the results for employment rate were positively associated to socio-economic differences and smoking prevalence, suggesting an increase in employment would result in a rather counter-intuitive increase in smoking prevalence, consistent with other studies (3,36,37). The positive association may be deduced to employment leading to increased disposable income, and therefore overcoming price sensitivity, due to the addictive nature of nicotine. Supporting studies have also hypothesized that those in higher occupational grades (mainly in supervisory or managerial roles) may be more susceptible to stress and thus use smoking as a coping mechanism (3,35). However, when analyzing smoking patterns throughout the economic recession of 2007 – which corresponds to the timeline of the present study, smoking patterns across countries remain conflicting. For instance in the USA, smoking prevalence was at 32.6%, post-crisis among the unemployed, whereas in Iceland, a decline in smoking prevalence was noted, dropping from 17.4% to

14.8% between 2007 and 2009 (36,37). The latter observation has been linked to the procyclical relationship between macroeconomics and smoking behaviour, with reference to affordability – as there was a noted increase in relapse for individuals with increased income between 2007 and 2009 in Iceland (37). Findings from the present study thus suggest, that increased employment equals increased income, which may be used to overcome the barrier of price sensitivity, supported by the positive association mirrored in the employment – social spending interaction term.

The proxy indicator for tobacco taxation reported to have no statistically significant effect on the association between socio-economic differences and smoking prevalence, inconsistent with findings from the literature (6, 40). The functionality of tobacco taxation is based on the fundamental economic principle of the downward sloping demand curve, and estimates have predicted that an increase of 10% on a pack of cigarettes, would reduce demand by about 4% of the general adult population within the European region (38). However, a few studies also accounted for the addictive nature of tobacco consumption, which the present study did not – by grouping participants into nicotine dependence levels. The Fageström test of cigarette dependence is a tool commonly used to establish dependence levels; it is a questionnaire, which although focused on nicotine – the most addictive component of smoking, also aims to encompass other factors that may be associated with cigarette dependence (41). Findings from theses studies found that heavier and more persistent smokers were far less sensitive to pricing policy than mild smokers, mirrored by 37.9% decreasing usage, but only 5.2% making cessation attempts (39-42). The latter studies also suggested additional cessation policy or education campaigns were required, to further strengthen existing pricing policy on more heavier smokers (40). Interestingly, there was also an overall trend across the literature that found taxation to be more effective in younger age groups such as 20-29, associated to a time of tobacco consumption initiation and lower nicotine dependence (6,40). As the tobacco tax is regressive, it also supports the positive equity impact, by showing a greater decrease in tobacco consumption, in those with a lower SES (6). However, within the present study, policy adoption for tobacco taxation reported no statistically significant association, supporting the breadth of the literature, advocating for the need for incremental AVT increases within tobacco taxation, in order to be a more effective policy measure for tobacco control (6,38,40).

Findings of the present study with regards to restriction of sales to minors were inconsistent with the literature – which reported restrictions to have an effect. A study in Finland found a 20% decrease in smoking of 14 years olds in the year of 2003, after implementation of the legislation (43). However, the study also reported implementation to be less effective than predicted, as ¾ children still reported easy access to products from shops, kiosks and service stations nearby their homes (43). Legislation affects commercial sources, and implementation may have triggered a switch, from purchasing from commercial sources to non-commercial sources, such as buying of older friends or family members. Therefore, restriction of sales may impact tobacco purchase from commercial sources, but not tobacco use – as other channels to access have been made available. Additionally, it could also be argued that this particular legislation more so effects smoking initiation, rather than cessation. Despite this, a decrease in daily smoking was observed in younger age groups, whilst smoking prevalence remained unchanged by older age groups not targeted by the ban (43). This suggests that the policy may be effective to some extent, just not as effective as predicted due to the non-commercial sources available for tobacco purchase.

Interestingly, interventions association with restrictions of sales to and by minors outside the European region had a much stronger focus on differential accessibility and density of tobacco retailers, for the different units of analysis. A past study in California, USA identified geographic distribution of tobacco retailers to be a major predictor for smoking, in which a school identified as having a 'high' smoking prevalence, found 62% of all tobacco sales to be within a one mile radius of the school (42). The study further went on to identify racial targeting – as most tobacco retailers were located within Hispanic majority neighborhoods (42). Similarly with density of tobacco retailers, supporting research has found the prevalence of smoking to be 32% higher among students in schools with a high density of tobacco retailers, compared to students in school without any tobacco retailers – within the proximity of school (44). The international comparison thus highlights the needs for tailored tobacco control interventions, opposed to the 'one size fits all' approach.

Policy implications

The broad nature of the present study does not allow for specific recommendations for population based tobacco control strategies to be made. The data for this study was collected with specific reference to the European region, which has shown strong support for population based tobacco control, mirrored in policy and European specific legislation, such

as the series of regional action plans on tobacco, and the directive on tobacco products (17-19). It is important to consider that such political support may not be present in many other countries. As there were no statistically significant associations, results indicate the need for stricter regulation, in order to achieve successful policy adoption. The findings of the present study thus support majority of findings of the published literature, and therefore may recommend on a broader sense, advocating for incremental increases in tobacco taxation to increase effectiveness, and reducing access (especially of non-commercial sources) to hinder sale of tobacco products to minors (6,9,14).

The negative association between education on smoking prevalence and socio-economic differences perhaps highlight an area of weakness with regard to policy. The notion is based on the assumption that increased educational attainment correlates to increased knowledge about the health consequences associated with smoking, and also wanting to invest in one self. Therefore redirecting focus on health education could potentially strengthen the effectiveness of existing population based tobacco control strategies. Health education programs already exist, and a recent meta-analysis found that 73% of 11 school–based prevention programs, increased participants knowledge on the health effects of smoking (46). The school setting also transcends to preventative efforts regarding minors. Therefore promotion of health education with specific regard to the implications of smoking on health may strengthen existing pricing policy. However to iterate, the implications for policy should be taken as suggestions, opposed to concrete recommendations for policy, due to the breadth of this study.

Strengths and weaknesses

Methodological weaknesses in the study included: the use of ecological data, the quality of the data in relation to data availability and contextual factors. The use of ecological data is often associated to ecological bias or 'ecological fallacy', which infers that associations observed between variables on an aggregate level, tends to not accurately represent the associations that exist on an individual level (30). This may hold true to a certain degree, as the study objective was to examine policy adoption of population based tobacco control, rather than the effects of individual based tobacco control strategies. However, it is important to note, that inclusion of individual based tobacco control strategies could have greatly impacted the association between socio-economic differences and smoking prevalence. It is

equally as important to consider that ecological data does not account for specific health outcomes (30). A methodological limitation was data quality, which can be deduced to the lack of data availability for units of analysis, meaning that in some cases data for the previous year had to be used to balance the unbalanced data set. This held true for measures for policy adoption, in which proxy measures/indicators had to be used, instead of actual policy measures, due to data availability. This held particularity true for inclusion of the household financial consumption expenditure (annual % growth) covariate, in light of the economic recession. The economic recession had varying impacts on the different countries included in units for analysis, which may have weakened the analysis. Additionally, the rate of rate result – may have not adequately captured changes over time. However, it still remained necessary to include an indicator linked to income, as it was reported to be a strong predictor for smoking (12-14). Use of this specific proxy indicator can again be linked to poor data availability. Furthermore, using countries based on data availability, opposed to random selection may have created bias, and thus also reduce the overall generalizability and reliability of the study. It is also important to note that, contextual factors such as religious and cultural factors for each unit of analysis were not feed into the regression model. Lastly, relying purely on quantitative analysis did not provide comprehensive explanations within the discussion, and lacked breadth and reflexivity gained from qualitative analysis.

Despite the widely published success of tobacco taxation, there have been concerns regarding the measure used for tobacco taxation, with debate surrounding whether to use the specific rate or the ad valorem rate (AVT). The specific rate refers to the fixed amount per quantity, whereas the AVT refers to the fixed percentage of the product. For instance, using the specific rate, a pack of cigarettes of twenty in the United Kingdom, had the retailing price of €5.88, of which the specific rate accounted for €3.01, whereas in Spain a pack of cigarettes could be purchased for as low as €1.76, of which the specific rate only accounted for €0.61 (42). This example highlights the huge harmonization gap between northern and southern EU member states, and for this reason use of the AVT is generally favored. In addition to better harmonization, the use of AVT also affects the manufacturers decision to invest in product quality, increasing price whilst the specific rate does not (42). It is important to note that within the present study, the measure for most sold brand of cigarettes was indeed taxes as a percentage of the specific excise tax rate, which may have accounted for the insignificant result of the proxy for policy adoption in isolation, and could be considered a study weakness. This may be deduced to the different numbers of countries utilized for units of analysis,

which span across all of Europe, in which Nordic countries (Finland and Sweden), had a far lower percentage of the specific excise tax rate, when compared to the remaining units of analysis.

Nonetheless, the study also had its strengths, such as the utilization of R software, longitudinal study design, and the use of panel data. The use of R software combated one of the study limitations, by warranting statistical analysis of unbalanced panel data sets (29). By taking into account the error terms (u_{it}), which include remainder of disturbances (ε_{ijt}), commands can be applied without causing inconsistency of fixed/within or random estimators (28). Additionally, the use of longitudinal study design, warranted analysis over a seven-year time period from 2008 – 2015, improving causality inference (29,30). This is supported by the use of the fixed effects regression model, in which the time variant and number of observations over time, increase the models ability to predict estimate coefficients, reflected in the goodness of fit (R^2). Lastly, the use of panel data was another major strength of the study, as panel data accounts for individual heterogeneity by controlling for factors, which cannot be observed, or measured over time, such as religious, cultural or historical factors, eliminating yet another study weakness (29).

However, with all the results it is important to consider that, despite there being differences in the levels of significance between model 1 ($p=5.99x10^{-10}$), model 2 ($p= 2.80x10^{-9}$) and model 3 ($p=2.31x10^{-9}$), note that the differences are extremely small, which could suggest that the results of this study were vulnerable to omitted variable bias, thus reducing validity of the results. This is a type of bias that compensates for missing factors, by at times under or overestimating the effect of one variable (29). The presence of omitted variable bias may be further supported by relatively unchanged R^2 (66.4% - 66.8%), in which adding policy measures did not increase the models ability to predict estimates.

Conclusion

Proxy indicators for policy adoption of tobacco taxation and restriction of sales to and by minors, showed to have no significant effect on the association between socio-economic differences and smoking prevalence, within the European region. Findings of the present study thus suggest policy measures for tobacco control need be stricter and more clearly regulated, in order to have a truly significant effect on the association between socio-

economic differences and smoking prevalence. Tobacco taxation is still hypothesized to be the most effective population based tobacco control strategy for reducing the social gradient within smoking, whilst also signposting education as the strongest predictor for smoking, across socio-economic groups. Therefore to conclude, policy adoption of population based tobacco control strategies shows potential in reducing smoking prevalence across all socio-economic groups, with redirected focus on health education, stricter regulation and more successful policy diffusion across the European region.

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Tables

Table. 1 - Descriptive statistics and percentile changes for outcome variable and indicators for socio-economic differences (n=7): 2008-15

Indicator (outcome variable)	**Country**	**2008**	**2015**	**Change (%)**
Smoking prevalence (total, % of population aged 15 +)	Czech Republic	21.8	22.3	2.3
	Finland	20.4	15.4	-24.5
	Iceland	17.6	10.5	-40.3
	Netherlands	23.3	19.1	-18.0
	Norway	21	13	-38.1
	Sweden	14.6	11.9	-18.5
	United Kingdom	21	19	-9.5
Indicator	**Country**	**2008**	**2015**	**Change (%)**
Education (tertiary/upper secondary/ below upper secondary, % of 25-64 year olds)	Czech Republic	14.49	22.18	53.0
	Finland	36.58	42.74	16.8
	Iceland	31.59	38.84	22.9
	Netherlands	32.16	35.33	9.8
	Norway	36.00	42.70	18.6
	Sweden	32.02	39.78	24.2
	United Kingdom	35.21	43.49	23.5
Indicator	**Country**	**2008**	**2015**	**Change (%)**
Household financial consumption expenditure (annual % growth)	Czech Republic	2.90	3.04	5.0
	Finland	2.11	1.45	-31.5
	Iceland	-7.037	3.05	-143.4
	Netherlands	0.90	1.75	93.6
	Norway	1.67	2.06	23.5
	Sweden	0.22	2.71	1091.8
	United Kingdom	-0.67	2.50	-470.9
Indicator	**Country**	**2008**	**2015**	**Change (%)**
Social Spending (public % of GDP)	Czech Republic	17.84	19.47	9.2
	Finland	23.34	30.57	31.0
	Iceland	15.17	15.67	3.3
	Netherlands	19.58	22.31	13.9
	Norway	19.15	23.90	24.8
	Sweden	25.57	26.67	4.3
	United Kingdom	20.88	21.50	3.0
Indicator	**Country**	**2008**	**2015**	**Change (%)**
Employment Rate (employment to population ratio, 15+, total %)	Czech Republic	55.90	55.90	0.0
	Finland	58	54.29	-6.4
	Iceland	73.5	70.09	-4.6
	Netherlands	64.30	59.70	-7.2
	Norway	65.5	62.59	-4.4

	Sweden	60	58.90	-1.8
	United Kingdom	59	58.20	-1.4

Table. 2 - Model 1: Fixed effects regression model of smoking prevalence and socio-economic differences in Europe (n=7): 2008-2015

Coefficients	Estimate	Std. Error	t-value	P-value
Education	-0.435455	0.086168	-5.0535	8.078e-06
Household financial consumption expenditure	-0.031502	0.088105	-0.3576	0.722386
Social spending of GDP	0.073824	0.230667	0.3200	0.750448
Employment rate	0.714550	0.217305	3.2882	0.001988

F statistic: **p-value: 5.9943e-10**

Table. 2a – Interaction terms for covariates of socio-economic differences and smoking prevalence in Europe (n=7): 2008-2015

Coefficient	Estimate	Std. Error	t-value	p-value
Employment x Social	0.07180	0.02147	3.344	0.00165
Social x House	-0.09133	0.04108	-2.223	0.03116
Social x Education	0.02643	0.02331	1.134	0.26274
Household x Education	0.06941	0.03611	1.922	0.06077
Education x Employment	-0.09471	0.02203	-4.298	8.84e-05

Table. 3 - Model 2: Fixed effects regression model of smoking prevalence, socio-economic differences and policy adoption of tobacco taxation in Europe (n=7): 2008-2015

Coefficient	Estimate	Std. Error	t-value	p-value
Education	-0.4195459	0.0959246	-4.3737	7.631e-05
Household financial consumption expenditure	-0.0381138	0.905323	-0.4210	0.675854
Social spending of GDP	0.0638690	0.2342814	0.2726	0.786453
Employment rate	0.7063175	0.2204147	3.2045	0.002551
Most sold brand of cigarettes	-0.0079005	0.0200563	-0.3939	0.695590

F-statistic: **p-value: 2.8061e-09**

Table. 4 - Model 3: Fixed effects regression model of smoking prevalence, socio-economic differences and policy adoption of restriction of sales to and by minors in Europe (n=7): 2008-2015

Coefficient	Estimate	Std. Error	t-value	p-value
Education	-0.418945	0.089380	-4.6873	2.799e-05
Household financial consumption expenditure	-0.014645	0.091380	-0.1603	0.873422
Social spending of GDP	0.057621	0.232847	0.2475	0.805729
Employment rate	0.691539	0.220566	3.1353	0.003092
Cigarette use amongst students	0.45655	0.061111	0.7471	0.459084

F statistic: **p-value: 2.3129e-09**

Appendices

Appendix 1: Popular science summary

Is the fight against smoking a losing battle?

Despite knowing the devastating consequences associated with smoking, it remains a major problem within society, upping its death poll (which is noticeably higher in more disadvantaged segments of the population), year by year. The public health sphere has devised tobacco control strategies as a response to tackle the growing epidemic. These strategies may range from banning smoking in work places, placing shocking images on your cigarette packet or simply increasing the price of cigarettes. Not only do these strategies aim to reduce smoking as a whole, they also hope to even out the disparities present within smoking. What is perhaps most remarkable about these strategies, is that hey come with no direct, financial cost to the individual.

But on the contrary, recent findings have shown that better education was more likely in lowering your chances of smoking, and increasing the probability of quitting, than the proposed strategies. Therefore, for these strategies to be successful the EU would need to reinforce stricter and more clearly regulated policies. However, increasing the tax on tobacco has proven extremely successful in the past, and NGO's alongside many health boards, are advocating for further increases in the price of tobacco– to increase its effectiveness.