



Tobacco control policies and smoking among older adults: a longitudinal analysis of 10 European countries

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ABSTRACT

Background and Aims The impact of tobacco control on European older adults has not been studied, despite evidence that smoking cessation at old age can bring significant life expectancy gains. Our aim was to evaluate the impact of tobacco control policies on smoking among older adults in Europe from 2004 to 2013. **Design** We used longitudinal data from the Survey of Health, Ageing and Retirement in Europe (SHARE, aged 50+ years) from four waves from 2004 to 2013. We used logistic regression models with clustered standard errors to determine whether the implementation of tobacco control policies was associated with changes in smoking status. Furthermore, we studied whether these associations varied by socio-demographic characteristics. Regression coefficients were converted to changes the probability of smoking [marginal effects (ME)]. **Measurements** Smoking status was the dependent variable, and the Tobacco Control Scale (TCS) was the explanatory variable, overall and by its main policy components (pricing and smoke-free policies). Covariates included age, sex, education and country and wave fixed-effects. **Findings** A 10-point increase in TCS was associated with a lower probability of smoking by 1.6 percentage points [95% confidence interval (CI) = -3.208, -0.056] for those aged 50–65, but not for older Europeans. Among those with primary school or no education, the associated drop was of 1.5 percentage points (95% CI = -2.751, -0.253). By contrast, no significant relation between TCS and smoking was observed among those with high education. Higher TCS scores for pricing (ME = -0.636, 95% CI = -0.998, -0.275) and smoke-free policies (ME = -0.243, 95% CI = -0.445, -0.041) were associated with a significantly lower probability of smoking ($P = 0.001$ and $P = 0.018$, respectively). **Conclusion** Increases in tobacco taxes and smoke-free policies are significantly related with a reduction in smoking among European older adults, suggesting potential health gains for this rising share of the population. These policies may be more effective among the lowest educated.

Keywords Older adults, SHARE, smoke-free policies, smoking, TCS, tobacco control policies, tobacco taxes.

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INTRODUCTION

Comprehensive tobacco control policies have been introduced in many European countries during the last 2 decades, especially since the World Health Organization (WHO) Framework Convention on Tobacco Control was signed in 2004 [1,2]. Earlier studies suggested an important impact of these policies on smoking behaviours, both separately [2–5] and as a comprehensive package [6–11]. Furthermore, some policies such as increasing tobacco prices were found to be more effective for low socio-economic status (SES) individuals [12–14], hence potentially reducing socio-economic inequalities in smoking. However, there are still important gaps in the measurement of tobacco control (TC) policies' effectiveness.

First, most research has focused on adolescents and young adults or the overall adult population [6–8,15], while little attention has been paid to the effect on older adults [16]. In fact, doctors are less prone to advise older patients to quit smoking [17], perhaps because they feel that long-term addiction is not reversible, or that benefits are not worth the effort. However, cessation at older ages can still bring significant gains in life expectancy and quality of life [18–21] and a lower risk of disability [22,23]. Also, considering the ageing of the European population [24], it is very important from a public health perspective to study the effectiveness of tobacco control policies among this increasing share of the population.

Secondly, most of the previous evidence is based on cross-sectional [6,8,9,15,25] or repeated cross-sectional

samples [10,11]. Cross-sectional estimates may be affected by unobserved characteristics at country- and individual-level that may influence smoking behaviour. In a cross-sectional design, countries with a stricter TC policy may be those traditionally less tolerant towards tobacco and where tobacco prevalence has been lower before the onset of new policies. While repeated cross-section designs take into account national levels of tobacco consumption prior to the implementation of new policies, the strength of their evidence is limited, because they study changes in smoking behaviour over time at the population-level but not at individual-level [26]. On the contrary, with a longitudinal sample we can include country and individual fixed-effects to control for time-invariant characteristics that may affect the probability of smoking. This enables us to compare the evolution of smoking among 'exposed' individuals [those living in a country where the Tobacco Control Scale (TCS) has increased] with the evolution of smoking among 'non-exposed' or 'control' individuals (those living in a country where TCS did not increase or increased less).

Our aim was to evaluate the impact of TC policies on smoking among older adults in Europe from 2004 to 2013. To do so, we used SHARE (Survey of Health, Ageing and Retirement in Europe), a longitudinal data set that followed Europeans older than 50 years. The data set covers a time-period (2004–13) during which major tobacco control laws were introduced in the countries under study (TCS increased by 50% in our sample during that period). This allowed us to exploit the trends in tobacco control policies within countries and to examine its association with longitudinal changes in smoking status at individual-level. In addition, we tested whether tobacco control policies are associated differently with smoking among socio-demographic groups and which type of tobacco control policies are most strongly associated with changes in smoking prevalence.

METHODS

Data

SHARE is a cohort of individuals aged 50 years and older from 20 European countries. So far, five waves have been collected (the first in 2004 and the last in 2013). We used data from waves 1 (2004–05), 2 (2006–07), 4 (2011) and 5 (2013) for the countries that participated in the four waves: Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Spain, Sweden and Switzerland. Wave 3 was excluded from our analysis because it did not include information about smoking. Individuals were randomly selected from national or regional population registries. In the latter case, two- or multi-stage designs were used, in which regions were sampled first and then individuals randomly selected within regions [27]. The original sample was formed by 25 320 individuals at wave 1, 7923 of them

being followed-up in waves 2, 4 and 5, making a total of 31 692 observations. These individuals who were followed across waves formed the balanced longitudinal sample, which we used in our analysis [28,29]. The difference between 31 692 and the total number of observations in each model is due to missing values in some of the covariates; namely, 960 observations presented missing values in the weights, 540 in education and 60 in smoking status.

Dependent variable

The dependent variable was smoking status, defined as a binary variable based on the question: 'Do you smoke at the present time?', taking the value 1 for 'yes' and 0 for 'no'.

Explanatory variable

The explanatory variable was the TCS, which was first introduced by Joossens & Raw [30]. The TCS is an indicator that evaluates the TC policies at country-level every year. It ranges from 0 to 100. TC policies are categorized as follows: pricing, smoke-free policies, information campaigns, bans on advertising, health warning labels and treatment to smokers. As described in the Supporting information, Table S1, more points are allocated to policies regarded by experts as more effective. The TCS includes policies that were already set at the beginning of each year. For example, if a new policy is introduced in a certain country by May 2008, it is only included in the TCS of 2009. This variable has been used previously in similar research [6,8,11]. We have re-calculated the scores based on the score allocation of 2013, using the underlying data from the earlier reports [31] in order to make it comparable over the years.

When we make use of longitudinal data, we look at whether changes in smoking status are associated with changes in TC policies within countries (as measured by TCS). However, when we observe an individual who changes their smoking status between two waves (e.g. from smoker to non-smoker), we do not know at exactly in which year they did so: it could have been at any year between that wave (e.g. wave 4, 2011) and the previous one (e.g. wave 3, 2007). Therefore, we assigned that person-wave observation the average TCS score of the years between those two waves (e.g. 2008–11). That average TCS score would be measuring the average state of TC policies in the country during the period when they changed their smoking status (e.g. they quit smoking). The years when every wave was carried out as well as its associated TCS score are presented in the Supporting information, Table S3.

We divided the TCS into three categories: pricing policies, smoke-free policies and other TC policies (information campaigns, bans on advertising, health warning labels and

treatment to smokers).¹ We focused mainly on the two types of policies that have contributed the most to the increase in TCS over the period: pricing and smoke-free policies (Supporting information, Table S2). Furthermore, these two policies have been discussed as some of the most effective against tobacco consumption [5].

Socio-demographic characteristics

Age, sex and SES were used as potential confounders. Age was used as continuous variable and as a dummy variable for those older than 65 in the analysis by socio-demographic categories. Furthermore, the SES was measured by the highest level of education completed in three categories: none or primary, secondary and tertiary.

Statistical analysis

As descriptive analysis, we explored the correlation between the variation in TCS and the variation of smoking per country during the period under analysis. We did so by calculating Pearson's correlation coefficients and through scattergraphs. In the multivariate analysis, we used a weighted logistic regression model with smoking status as the outcome and TCS, age (as continuous variable), sex, education, country and time as fixed-effects. Education was included as a categorical variable with three categories: (i) tertiary, (ii) secondary and (iii) primary or non-education (reference category). Male was the reference category for sex. Time fixed-effects (i.e. wave binary variables) were included to control for determinants of smoking that may vary uniformly across European countries over time (e.g. economic cycles). Country fixed-effects (i.e. country binary variables) controlled for those country characteristics that were invariant during the period under analysis, such as culture, institutions or other life-style aspects. By using country and time fixed-effects, we exploited country-specific changes in TCS. 'Cluster-robust' standard errors clustered at individual-level were used to account for the longitudinal structure of the data by using the 'cluster-robust' variance matrix estimator following Wooldridge (2006) [32]. Coefficients were reported as marginal effects, which indicate how much the probability of smoking varies (in percentage points) when the explanatory variable increases by one unit, while setting the rest of the control variables constant at their average values.

To investigate whether the association of TCS with smoking was different by socio-demographic group, we interacted the TCS with socio-demographic categorical variables. Sex and education were initially measured by categorical variables, as explained above. Regarding age,

we created a dummy variable for those older than 65 at baseline. As sensitivity analysis, we further carried out two more models: first, a logistic model clustering standard errors at country-level to account for within-country correlation of the error term [33]; and secondly, a linear probability model with individual fixed-effects to account for individual characteristics that are fixed over time [34]. All analyses were carried out using Stata/MP version 13.0. We used the 'Logit' command, with 'VCE cluster' to indicate cluster-robust standard errors, except for the linear probability model, which used 'xtreg'.

Furthermore, we checked for multi-collinearity using the variance inflation factor (VIF) and exploring changes in standard errors [35]. We found a risk of multi-collinearity (VIF for the TCS variables between 9 and 12) when including country dummies, but little variation in standard errors arose, so we kept the model with country dummies as our main model in order to control for non-observable country characteristics.

Due to the hierarchical structure of the data, multi-level appeared as the ideal model to account for time and country data clustering [36]. However, this model presented two limitations [37]: (i) due to the small sample size at the higher unit-level (10 countries), the estimation of the random components and random slopes relied on a low number of degrees of freedom and (ii) the sample of higher unit-level was not random and, therefore, confounding variables at country-level might bias the results. Instead, we opted to cluster standard errors at individual-level and include country fixed-effects, which are applicable to a small number of countries and control for invariable country characteristics.

Treatment of attrition

Longitudinal surveys are affected by attrition due to death, moving away or non-response. If there are systematic differences between those who form the balanced panel and those who were sampled at wave 1, our results may be biased. To test for attrition bias, we carried out the variable addition test [38], which led to a rejection of the null hypothesis of non-attrition bias ($t = -8.35$, P -value < 0.01).

To deal with this bias, we constructed inverse probability weights (IPW), following Jones (2005) [39]. IPWs give more weight to observations that have a higher probability of dropping out. To construct the IPW, we estimated the probability of responding in all waves as a function of observable variables at first wave: age, smoking status, initial TCS, self-reported health status, number of limitations and chronic conditions. IPWs were then formed by the inverse

¹When scores of information campaigns, bans on advertising, health warning labels and treatment to smokers are accounted separately, they remain constant in most of the country-wave observations. However, when we add up these categories into a single aggregated category (other TC policies), the score varies for every country-wave observation. In this way we ensure having enough variability in our explanatory variable of interest.

Table 1 Smoking prevalence of the longitudinal sample per country and wave.

	Smoking prevalence (%)				Absolute variation Wave 5–wave 1
	Wave 1 (2004–2005)	Wave 2 2007	Wave 4 2011	Wave 5 2013	
Austria	21.3 (16.5, 26.0)	19.7 (15.1, 24.2)	21.2 (16.4, 25.8)	15.8 (11.5, 20.1)	–5.5
Germany	18.8 (14.9, 22.6)	16.6 (12.9, 20.2)	16.9 (13.3, 20.4)	16.7 (13.1, 20.1)	–2.1
Sweden	16.6 (13.6, 19.6)	13.4 (10.5, 16.2)	14.7 (11.8, 17.5)	11.2 (8.7, 13.6)	–5.4
Netherlands	26.6 (23.1, 30.0)	24.9 (21.4, 28.3)	20.1 (16.8, 23.2)	18.3 (15.2, 21.4)	–8.2
Spain	20.6 (16.9, 24.2)	16.9 (13.4, 20.3)	13.4 (10.1, 16.5)	11.9 (8.9, 15.0)	–8.6
Italy	20.0 (17.2, 22.8)	17.7 (14.9, 20.3)	17.3 (14.6, 20.1)	13.6 (11.1, 16.1)	–6.4
France	16.2 (13.4, 19.0)	14.8 (12.1, 17.3)	12.1 (9.7, 14.4)	13.2 (10.7, 15.6)	–3.1
Denmark	28.7 (25.1, 32.3)	24.4 (20.9, 27.8)	23.5 (20.1, 26.9)	20.0 (16.8, 23.2)	–8.7
Switzerland	18.4 (14.3, 22.6)	19.3 (15.1, 23.5)	22.0 (17.7, 26.3)	18.7 (14.5, 22.7)	0.2
Belgium	15.1 (13.1, 17.1)	14.6 (12.6, 16.5)	14.1 (12.1, 16.0)	13.4 (11.5, 15.3)	–1.7
Average ^a	20.2	18.2	17.5	15.3	–5.0

Smoking prevalence was calculated using the weighted longitudinal sample; 95 confidence intervals in brackets. ^aUnweighted average of countries' prevalence.

of the predicted probability of responding in the balanced longitudinal sample. Lastly, we multiplied these weights by the cross-sectional weights from the first wave provided by SHARE, which aim to make the sample representative of the 50+ population at wave 1 for each country [40]. The weights were added to the regression as probability weights.

RESULTS

Descriptive analysis

Smoking prevalence at baseline ranged from 15.1% in Belgium to 28.7% in Denmark, with an average of 20.2% (Table 1). Smoking in our sample decreased by 5 percentage points (pp) on average from 2004 to 2013, with Spain showing the highest decrease (–8.6 pp). The data on TCS by country and year reflect a significant effort from most countries in implementing TC policies (Table 2). Overall, the average TCS for these countries has increased by 20 points from 2004 to 2013.

The association between the variation in smoking prevalence and variation in TCS between 2004 and 2013 presents a Pearson's correlation coefficient of $\rho = -0.09$. The negative correlation is higher for variation in TCS of price policies ($\rho = -0.46$), and to a lesser extent for smoke-free

policies ($\rho = -0.21$), whereas other policies are positively correlated ($\rho = 0.25$) (Fig. 1).

Multivariable analysis

We observed a negative association between TCS and smoking likelihood (Table 3, column 3), although not significant at 5%. A 10-point rise in TCS was associated with

Table 2 Evolution of Tobacco Control Scale (TCS) by country.

TCS	Year		Variation	
	2004	2013	Absolute	%
Austria	25	44	19	76
Germany	28	46	18	64
Sweden	51	64	13	25
Netherlands	47	58	11	23
Spain	33	71	38	115
Italy	42	64	22	52
France	54	73	19	35
Denmark	41	59	18	44
Switzerland	31	57	26	85%
Belgium	46	62	16	34
Average ^a	39.7	59.65	20	50

^aUnweighted average of countries' scores.

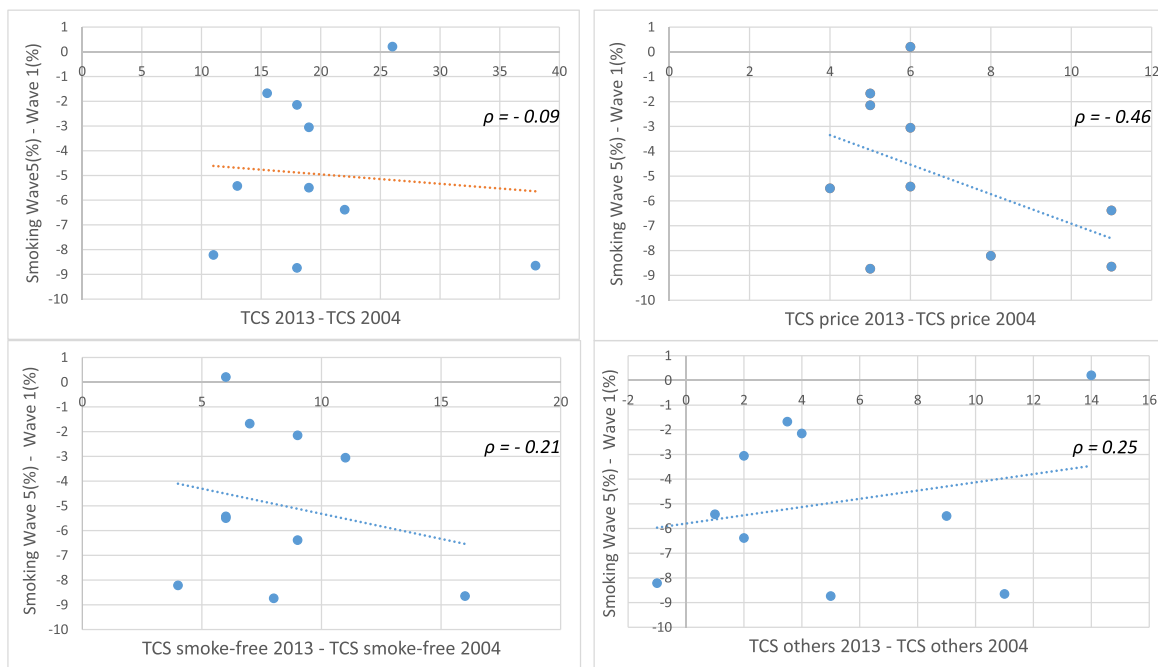


Figure 1 Scattergraph: change (in percentage points) in smoking prevalence (wave 5–wave 1) versus change in Tobacco Control Scale (TCS) (2013–2004). [Colour figure can be viewed at wileyonlinelibrary.com]

Table 3 Logistic model for the probability of smoking: marginal effects (ME).^a

Variables	(1) ME (95% CI)	(2) ME (95% CI)	(3) ME (95% CI)
TCS	-0.164** (-0.252, -0.070)	-0.043 (-0.165, 0.078)	-0.112 ⁺ (-0.228, 0.003)
Age (years)		-0.926** (-1.050, -0.802)	-0.909** (-1.034, -0.784)
Female		-4.999** (-7.156, -2.842)	-4.880** (-7.036, -2.723)
Educational level			
Base category: none or primary			
Secondary		2.369 ⁺ (-0.292, 5.031)	3.368 ⁺ (0.592, 6.143)
Tertiary		-2.279 ⁺ (-4.857, 0.298)	-1.399 (-4.198, 1.398)
Wave fixed-effects		Included	Included
Country fixed-effects			Included
Observations	30 682	30 176	30 176

95% Confidence intervals (CI) in brackets. TCS = Tobacco Control Scale. ** $P < 0.01$, * $P < 0.05$, ⁺ $P < 0.1$. Clustered standard errors at individual-level.
^aMarginal effects can be interpreted as how much the probability of smoking varies (in percentage points) when the explanatory variable increases by 1 unit.

a 1.1 pp² [marginal effects (ME) = -0.112, 95% confidence interval (CI) = -0.228, 0.003] drop in the risk of smoking (P -value = 0.057). Distinguishing by type of tobacco control policy, increases in prices (ME = -0.636, 95% CI = -0.998, -0.275) and smoke-free policies (ME = -0.243, 95% CI = -0.445, -0.041) were significantly associated with lower probability of smoking. Conversely, the rest of the tobacco control policies showed no clear association (ME = 0.094, 95% CI = -0.099, 0.289, P -value = 0.338) (Table 4). Sensitivity analyses with respect to statistical

²(10-point rise in TCS) \times (-0.11) = -1.1 percentage points.

modelling reported very similar results (Supporting information, Tables S5–S8).

The TCS coefficient was not significantly different by sex (Table 5). On the contrary, a 10-point rise in the TCS significantly decreased the probability of smoking by 1.6 pp (95% CI = -3.208, -0.056) for those younger than 65 years, whereas the association was not significant among those older than 65 (ME = 0.340 pp, 95% CI = -1.475, 2.155, P -value = 0.714). When taking into account prevalence at baseline, relative differences were not significant at 5% [odds ratio (OR) = 1.015, 95% CI = 1.000, 1.030]. A 10-point higher TCS was associated with a 1.5 pp (95% CI = -2.751, -0.253) lower probability of

Table 4 Logistic model of the probability of smoking with type of policies; marginal effects (ME).^a

Variables	(1) ME (95% CI)	(2) ME (95% CI)	(3) ME (95% CI)
TCS price	-0.419** (-0.657, -0.180)	-0.463** (-0.725, -0.201)	-0.636** (-0.998, -0.275)
TCS smoke-free	-0.275** (-0.469, -0.081)	-0.270* (-0.513, -0.026)	-0.243* (-0.445, -0.041)
TCS other	0.057 (-0.212, 0.327)	0.198 ⁺ (-0.029, 0.426)	0.094 (-0.099, 0.289)
Age (years)		-0.914** (-1.038, -0.789)	-0.908** (-1.037, -0.784)
Female		-4.873** (-7.029, -2.716)	-4.878** (-7.033, -2.722)
Educational level			
Base category: none or primary			
Secondary		3.449* (0.742, 6.157)	3.368* (0.593, 6.143)
Tertiary		-1.363 (-4.007, 1.280)	-1.396 (-4.192, 1.400)
Wave fixed-effects		Included	Included
Country fixed-effects			Included
Observations	30 682	30 176	30 176

95% Confidence intervals (CI) in brackets. TCS = Tobacco Control Scale. ** $P < 0.01$, * $P < 0.05$, ⁺ $P < 0.1$. Clustered standard errors at individual-level.
^aMarginal effects can be interpreted as how much the probability of smoking varies (in percentage points) when the explanatory variable increases by 1 unit.

Table 5 Marginal effects of a 10 point-increase in TCS on the probability of smoking (in percentage points), by socio-demographic category.

Marginal effect on the probability of smoking ^a			Absolute difference (ME interaction) ^b	Relative difference (OR interaction) ^c
	(in percentage points)			
Educational level				
(1) None or primary	-1.502* (-2.751, -0.253)			
(2) Secondary	-2.212 ⁺ (-4.441, 0.016)	(2) versus (1)	-7.103 (-2.743, 1.325)	0.996 (0.982, 1.010)
(3) Tertiary	1.826 (-0.461, 4.114)	(3) versus (1)	3.332** (1.147, 5.509)	1.027** (1.009, 1.046)
Age (years)				
(4) 50–65 at baseline	-1.632* (-3.208, -0.056)			
(5) 65+ at baseline	0.340 (-1.475, 2.155)	(5) versus (4)	1.972* (0.152, 3.792)	1.015 ⁺ (1.000, 1.030)
Sex				
(6) Males	-1.227 (-3.028, 0.573)			
(7) Females	-0.891 (-2.444, 0.659)	(7) versus (6)	0.335 (-1.458, 2.130)	1.001 (0.988, 1.015)

95% Confidence Intervals in brackets. ** $P < 0.01$, * $P < 0.05$, ⁺ $P < 0.1$. ^aMarginal Effect indicate how much the probability of smoking change (in percentage points) with a 10-point increase in TCS. They come from the logistic model including simultaneously interactions between TCS and each sociodemographic category (education, age and sex); and were calculated following Karaka-Mandic et al (2011) [49]. ^bMarginal Effects (M.E.) of the interactions represent the absolute difference (in percentage points) of the TCS marginal effect over sociodemographic category (Full results in Table S9, Supporting Information). ^cOdds Ratio (O.R.) of the interactions represent the relative difference (in percentage points) of the TCS marginal effect over sociodemographic category (Full results in Table S9, Supporting Information). TCS = Tobacco Control Scale.

smoking for those with no or primary education, whereas no significant association was found for the highest educated (ME = 1.826 pp, 95% CI = -0.461, 4.114, P -value = 0.118). In this case, both absolute and relative differences were significant.

Pricing policies were related to lower smoking only among those with secondary (ME = -6.480 pp, 95% CI = -10.155, -2.805) or lower levels of education (ME = -6.306 pp, 95% CI = -12.623, -0.010), and not among the more highly educated individuals (ME = 0.908 pp, 95% CI = -6.114, -7.931) (Table 6). They also affected more men than women, although the relative difference was not significant (OR = 1.03, 95% CI = 0.999, 1.063). No significant absolute or relative difference was

observed by age group. Lastly, smoking-free policies also significantly affected the lower-educated more in absolute and relative differences: ME = -3.338 pp, 95% CI = -5.771, -0.906; tertiary: ME = 1.524 pp, 95% CI = -2.237, 5.286), whereas no consistent differences were found among age group and sex (Table 7).

DISCUSSION

Summary of findings

A 10-point increase in TCS was associated with a drop in the probability of smoking by 1.1 pp, although not significant at 5% (P -value = 0.057). By contrast, pricing

Table 6 Marginal effects of a 10 point-increase in TCS price on the probability of smoking (in percentage points) by socio-demographic category.

<i>ME on the probability of smoking^a</i>			<i>Absolute Difference^b</i>	<i>Relative Difference^c</i>
	<i>(in percentage points)</i>		<i>(ME interaction)</i>	<i>(OR interaction)</i>
Educational level				
(1) None or primary	−6.480** (−10.155, −2.805)			
(2) Secondary	−6.306* (−12.623, 0.010)	(2) versus (1)	−0.173 (−4.906, 5.253)	1.008 (0.973, 1.045)
(3) Tertiary	0.908 (−6.114, 7.931)	(3) versus (1)	7.388* (1.128, 13.648)	1.062* (1.005, 1.122)
Age (years)				
(4) 50–65 at baseline	−4.833* (−9.588, −0.079)			
(5) 65+ at baseline	−5.034 ⁺ (−0.0103, 0.0002)	(5) versus (4)	0.200 (−4.698, 4.297)	0.991 (0.955, 1.029)
Sex				
(6) Males	−7.610** (−12.773, −2.448)			
(7) Females	−2.530 (−7.115, 2.054)	(7) versus (6)	5.080* (1.052, 9.107)	1.030 ⁺ (0.999, 1.063)

95% Confidence Intervals in brackets. ** $P < 0.01$, * $P < 0.05$, ⁺ $P < 0.1$. ^aMarginal Effect indicate how much the probability of smoking change (in percentage points) with a 10-point increase in TCS price. They come from the logistic model including simultaneously interactions between TCS price and each sociodemographic category (education, age and sex); and were calculated following Karaka-Mandic et al (2011) [49]. ^bMarginal Effects (M.E.) of the interactions represent the absolute difference (in percentage points) of the TCS price marginal effect over sociodemographic category (Full results in Table S10, Supporting Information). ^cOdds Ratio (O.R.) of the interactions represent the relative difference (in percentage points) of the TCS price marginal effect over sociodemographic category (Full results in Table S10, Supporting Information). TCS = Tobacco Control Scale.

Table 7 Marginal effects (ME) of a 10 point-increase in Tobacco Control Scale (TCS) smoke-free on the probability of smoking (in percentage points) by socio-demographic category.

<i>ME on the probability of smoking^a</i>			<i>Absolute difference</i>	<i>Relative difference</i>
	<i>(in percentage points)</i>		<i>(ME interaction)^b</i>	<i>(OR interaction)^c</i>
Educational level				
(1) None or primary	−3.338** (−5.771, −0.906)			
(2) Secondary	−4.274* (−8.017, 0.528)	(2) versus (1)	−0.935 (−4.935, 3.064)	0.996 (0.968, 1.025)
(3) Tertiary	1.524 (−2.237, 5.286)	(3) versus (1)	4.863** (0.815, 8.911)	1.040** (1.006, 1.075)
Age (years)				
(4) 50–65 at baseline	−3.550* (−6.153, −0.947)			
(5) 65+ at baseline	−0.480 (−3.534, 2.573)	(5) versus (4)	3.069 ⁺ (−0.402, 6.542)	1.022 (0.994, 1.051)
Sex				
(6) Males	−3.151* (−6.305, 0.001)			
(7) Females	−2.179 ⁺ (−4.644, 0.307)	(7) versus (6)	0.972 (−2.494, 4.439)	1.003 (0.978, 1.030)

95% Confidence Intervals in brackets. ** $P < 0.01$, * $P < 0.05$, ⁺ $P < 0.1$. ^aMarginal Effect indicate how much the probability of smoking change (in percentage points) with a 10-point increase in TCS smoke-free. They come from the logistic model including simultaneously interactions between TCS price and each sociodemographic category (education, age and sex); and were calculated following Karaka-Mandic et al (2011) [49]. ^bMarginal Effects (M.E.) of the interactions represent the absolute difference (in percentage points) of the TCS smoke-free marginal effect over sociodemographic category (Full results in Table S11, Supporting Information). ^cOdds Ratio (O.R.) of the interactions represent the relative difference (in percentage points) of the TCS smoke-free marginal effect over sociodemographic category (Full results in Table S11, Supporting Information). TCS = Tobacco Control Scale.

(P -value = 0.001) and smoke-free policies (P -value = 0.018) were significantly and negatively associated with smoking. The negative association between TCS and smoking was observed especially among those aged between 50 and 65 years and among those with lower levels of education (none, primary or secondary). By contrast, no relationship between TCS and smoking was found among those older than 65 and among those with higher education. Furthermore, the association of TCS with smoking was not found to be different between men and women.

Interpretation of the results

Increases in prices and smoke-free policies were significantly associated with a reduction in smoking, in line with previous evidence [5]. In particular, our research is among the first to verify this association for a population aged 50 years and older.

An increase in TCS diminished the probability of smoking for those aged younger than 65 years but not for those aged 65 or more. We suggest two explanations

for this differential effect. First, the lack of effect of TCS on those older than 65 is possibly explained by them having a larger share of the so-called 'hardcore' smokers, compared to those younger than 65 years. Hardcore smokers, defined as those unwilling or unable to quit [41], may be less responsive to current tobacco control policies. Studies in different countries found that hardcore smokers are more prevalent among older-aged smokers [42–44]. Causes behind the increased number of hardcore smokers include increased nicotine dependence and lower motivation to quit [45].

Secondly, the absolute difference in the TCS effect might be due to differences in initial smoking prevalence between age groups. Smoking prevalence among those aged 65+ years was already low at baseline (9.1%), and after 10 years it decreased by less than 2 pp, to 7.4%. In contrast, prevalence among those younger than 65 fell by more than 6 pp, from 27 to 20.2% over the same period. When we take into account the baseline odds of smoking, the relative difference in TCS effect between age groups was not significant at 5%.

A 10-point increase in TCS decreased the probability of smoking by 1.5 pp for those with none or primary education, whereas no association was found for those with higher education. This suggests that the increase in TCS altered the socio-economic pattern of smoking. It is expectable that low-SES people reacted more to increases in prices, as they have a lower disposable income. In fact, pricing policies have been consistently identified as more effective for low SES groups [12,14]. For example, Hu *et al.* [46] found that TC policies during the period 1990–2007, and in particular increases in prices, were related to smoking more among low-SES groups. However, another study by Bosdriesz *et al.* [11], using more recent data (from 2006 to 2012) did not find that raising taxes was more effective among the lower-educated. It is worth noting that we focused on people older than 50 years, whereas these European studies address the entire adult population (20 years and older). Smoke-free policies were also associated with lower smoking prevalence only among the lower-educated, unlike previous studies which found no differential effect over SES [1,2].

Limitations

Although our study design can be considered as a 'quasi-random' experiment, TC policies are not randomly implemented across countries. The implementation of policies responds to a political process that may be influenced by changes in societal attitudes towards tobacco. A country-specific short-term decrease in societal tolerance towards smoking could simultaneously lead to the implementation of TC policies and to a drop in smoking [47].

Nevertheless, for national societal attitudes towards smoking being the driver of the implementation of TC policies, the political process should have followed a 'bottom-up' path, with citizens encouraging national governments to take action against tobacco. Societal preferences for TC policies are expected to be channelled through voting for parties with different ideologies and policy proposals, at least to a certain extent. However, previous research found that the implementation of TC policies in Europe did not vary with the ideology of the political party in power [48]. Nevertheless, politicians may follow public opinion on TC once they are in power, regardless of their ideological background. In such a case, implementation of TC policies could still derive from changes in societal attitudes towards smoking.

Therefore, our data did not permit us to draw definite conclusions about causal relationships. However, we consider that causality is likely, because the longitudinal nature of the data allowed us to relate country-specific changes of TC policies with longitudinal changes in smoking behaviour.

Our results may be affected by attrition and non-response bias. Our sample represents 31.3% of the initial sample at wave 1. We aimed to reduce the potential bias by using survey weights. Furthermore, contrary to the longitudinal weights supplied by SHARE, our IPWs are designed for the outcome of interest, smoking; and they also account for other relevant variables not included in the SHARE weights such as health conditions or TCS. There may also be other factors related with non-response that may affect smoking behaviour, which are excluded from our weighting procedure.

Conclusions and policy implications

Our results show that tobacco control policies in general, and more specifically price increases and smoke-free policies, are significantly related to a reduced smoking prevalence among European older adults from 2004, suggesting potential health gains among this rising share of the population. The greater relationship observed among lower-educated people suggests that tobacco control policies may also contribute to decreasing socio-economic inequalities.

Declaration of interests

None.

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SHARE.w2.610 10.6103/SHARE.w4.610, 10.6103/SHARE.w5.610, 10.6103/SHARE.w6.610), see Börsch-Supan *et al.* (2013) for methodological details. The SHARE data collection has been primarily funded by the European Commission through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812) and FP7 (SHARE-PREP: no. 211909, SHARE-LEAP: no. 227822, SHARE M4: no. 261982). Additional funding from the German Ministry of Education and Research, the Max Planck Society for the Advancement of Science, the US National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064, HHSN271201300071C) and from various national funding sources is gratefully acknowledged (see www.share-project.org). The first author was supported by a PhD research Grant from Fundação para a Ciência e Tecnologia. This work was also supported by the SILNE-R project, financed by the European Union's Horizon 2020 research and innovation programme (Grant Agreement number 635056).

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 Description of Tobacco Control Scale (TCS).

Table S2 Evolution of Tobacco Control Scale by policy dimension.

Table S3 Waves information and corresponding TCS score of the longitudinal sample.

Table S4 Descriptive characteristics of the longitudinal balanced sample at baseline.

Table S5 Sensitivity analysis of Table 3 (I): Linear model with individual fixed effects.

Table S6 Sensitivity analysis of Table 3 (II): Logistic model with errors clustered at country level, Marginal Effects.

Table S7 Sensitivity analysis of Table 4 (I): Coefficients from linear model with individual fixed effects.

Table S8 Sensitivity analysis of Table 4 (II): Logistic model with errors clustered at country level, Marginal effects.

Table S9 Logistic model with interactions of TCS per socioeconomic group.

Table S10 Logistic model with interactions of TCS price per socioeconomic group.

Table S11 Logistic model with interactions of TCS smoke-free per socioeconomic group.