



Original investigation

Economic Evaluation of Five Tobacco Control Policies Across Seven European Countries

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Abstract

Introduction: Economic evaluations of tobacco control policies targeting adolescents are scarce. Few take into account real-world, large-scale implementation costs; few compare cost-effectiveness of different policies across different countries. We assessed the cost-effectiveness of five tobacco control policies (nonschool bans, including bans on sales to minors, bans on smoking in public places, bans on advertising at points-of-sale, school smoke-free bans, and school education programs), implemented in 2016 in Finland, Ireland, the Netherlands, Belgium, Germany, Italy, and Portugal.

Methods: Cost-effectiveness estimates were calculated per country and per policy, from the State perspective. Costs were collected by combining quantitative questionnaires with semi-structured interviews on how policies were implemented in each setting, in real practice. Short-term effectiveness was based on the literature, and long-term effectiveness was modeled using the DYNAMO-HIA tool. Discount rates of 3.5% were used for costs and effectiveness. Sensitivity analyses considered 1%–50% short-term effectiveness estimates, highest cost estimates, and undiscounted effectiveness.

Findings: Nonschool bans cost up to €253.23 per healthy life year, school smoking bans up to €91.87 per healthy life year, and school education programs up to €481.35 per healthy life year. Cost-effectiveness depended on the costs of implementation, short-term effectiveness, initial smoking rates, dimension of the target population, and weight of smoking in overall mortality and morbidity.

Conclusions: All five policies were highly cost-effective in all countries according to the World Health Organization thresholds for public health interventions. Cost-effectiveness was preserved even when using the highest costs and most conservative effectiveness estimates.

Implications: Economic evaluations using real-world data on tobacco control policies implemented at a large scale are scarce, especially considering nonschool bans targeting adolescents. We assessed the cost-effectiveness of five tobacco control policies implemented in 2016 in Finland,

Ireland, the Netherlands, Belgium, Germany, Italy, and Portugal. This study shows that all five policies were highly cost-effective considering the World Health Organization threshold, even when considering the highest costs and most conservative effectiveness estimates.

Introduction

In order to prevent tobacco-related mortality and morbidity, countries have been encouraged to adopt tobacco control policies (TCPs) targeting both adults and adolescents.¹ Preventing smoking among adolescents is of particular interest, as smoking during adolescence is associated with smoking during adulthood. Two of three adolescents who smoke will continue to smoke in adulthood,^{2,3} and the odds of being a smoker are 2.1 times higher for male adults who started smoking before the age of 16, comparing to those who started after age 20.⁴ Raising prices of tobacco products, implementing smoking bans, smoking prevention programs, and cessation support have been recommended by public health institutions to reduce adult and adolescent smoking.^{1,2,5-7}

From an economic perspective, TCPs have proved to be highly cost-effective, or even cost saving.^{5,8,9} Sixteen economic evaluations of TCPs targeting adolescents were identified in a recent systematic review,⁹ but only three evaluated school or nonschool bans (the latter includes bans on smoking in public places, bans on advertising at points-of-sale, or bans on sales to minors). Data were based on simulated scenarios or controlled interventions, which may not reflect the real-world, large-scale, or context-specific outcomes. Up-to-date economic evaluation of policies adopted in the real world are needed to inform decision makers about which policies are more cost-effective, and to what extent these TCPs should be adopted or scaled up. It is fundamental to discuss how cost-effectiveness varies across countries, degree of implementation, and type of design,¹⁰ and what reasons may be behind these variations. Therefore, we evaluated the cost-effectiveness of bans on smoking in public places, bans on sales to minors, bans on advertising at points-of-sale, bans on smoking in school premises, and school education programs. These five policies were selected as evidence suggests that they may reduce adolescents' smoking,^{1,2,5-7} and are implemented, or due to be implemented, in Finland, Ireland, the Netherlands, Germany, Belgium, Italy, and Portugal. These seven countries represent different stages of the tobacco epidemic,¹¹ with prevalence of cigarette use in the last 30 days among 15- to 16-year-old adolescents ranging from 13% in Ireland, 15% in Flanders (Belgium), 21% in Portugal, 22% in Finland, and 37% in Italy.¹²

In order to provide evidence on the cost-effectiveness of (1) real-world, large-scale implementation of TCPs, by (2) using context-specific data, while (3) comparing the cost-effectiveness across policies and (4) countries, this study estimated the cost-effectiveness of implementing the five above mentioned TCPs, from the State perspective. Economic evaluations were performed across seven European settings (Finland-Tampere, Ireland-Dublin, the Netherlands-Amersfoort, Germany-Hanover, Belgium-Namur, Italy-Latina, and Portugal-Coimbra).

Methods

Cost Estimation

Cost data collection followed an "ingredients-based" approach.^{9,13,14} This means that, when available, we identified the resources, quantities, and unit values involved in the implementation of the five

policies. We used the State perspective, which considered costs of implementation at a higher level, as those costs covered by the national state, and those incurred at a lower level by the local authorities (such as municipalities and food safety authorities) or by school administrations. We included costs on personnel, transportation, communication, equipment, material and supplies, and other relevant costs, defined by market prices. These costs did not take into account shadow prices. In some cases, however, we could only obtain total costs without a decomposition of these into quantify of resources and their prices. For example, communication costs were provided as a total, without information on the amount resources and the prices of each communication strategy. [Supplementary Table 1](#) presents these costs measures.

We collected implementation costs for the year of 2016 (2015–2016 school year) in the seven countries represented by one city that participated in the SILNE-R project (Tampere-Finland, Dublin-Ireland, Amersfoort-the Netherlands, Namur-Belgium, Hannover-Germany, Latina-Italy, and Coimbra-Portugal).¹⁵ The SILNE-R project was a project financed by the European Commission, involving seven European countries, and carried out between 2015 and 2018. This project aimed at creating fine grained evidence on how to enhance TCPs' effectiveness and cost-effectiveness in preventing youth smoking. The article resulted from a work package devoted to analyzing the cost and cost-effectiveness of TCPs focusing the youths.

We used a quantitative questionnaire to gather data about the quantity and value for each ingredient, coupled with open questions about how interventions were performed in reality in each setting, and the number of adolescents covered (which informs us about the scale of implementation). Costs were collected at national, regional, local, or school level, depending on the level of implementation in each setting. We collected data from nine institutions for nonschool bans (one national-level institution for Belgium, Ireland, Portugal, and the Netherlands, one local level in Tampere-Finland, two local level in Hannover-Germany, one local level and other regional level in Latina-Italy), 21 for school bans (four schools in Hannover-Germany, three in Amersfoort-the Netherlands, Coimbra-Portugal, Namur-Belgium, Tampere-Finland, and two schools in Dublin-Ireland, as one did not reply), and 19 for school programs (one national, one regional, and one local institution in Hannover-Germany, three schools in Amersfoort-the Netherlands, Coimbra-Portugal, Namur-Belgium and Tampere-Finland, one school- and one local-level institution in Latina-Italy, and two schools in Dublin-Ireland, as one did not reply). TL collected data for Coimbra-Portugal and communicated throughout the whole period of data collection with SILNE-R project data collectors, who shared details about the data, institutions, and contexts. We multiplied the quantity of each ingredient (person-hours, kilometers, equipment, etc.) by its unit cost (in euros), and then calculated its cost per 100 000 persons covered by the policy.

Total costs of nonschool bans were obtained by summing the costs of bans on smoking in public places, bans on sales to minors, and bans on advertising at points-of-sale in each country (except in Italy and Germany, where bans on advertising at points-of-sale were not implemented). We extrapolated the costs collected at school,

local, or regional level for the whole country, in order to provide country-level cost-effectiveness results. In the case of school bans and school education programs, a mean cost was calculated for each country. To obtain the total costs of a multi-strategy approach, we summed the costs of these five policies (or four, in the case of Italy and Germany). Costs had 2016 as reference year. For the sake of international comparison, all costs were adjusted for purchasing power parity.¹⁶ Purchasing power parity is used as a currency conversion rate in order to level the costs according to the purchasing power of different countries.

Effectiveness Estimation: General Approach

We used the DYNAMO-HIA tool to estimate the long-term effectiveness of the different policies in the seven countries. This tool was developed to support the quantification components of health impact assessment projects. It quantifies the long-term impact of short-term changes in the prevalence, morbidity, and mortality of risk factors and related diseases in the whole population. It simulates the evolution of these risk factors, diseases' morbidity, and mortality in a population, through a dynamic Markov-type multistate model that combines stochastic microsimulation to estimate the development of a risk factor exposure, and macrosimulation to project the impact of the risk factor exposure on disease incidence, mortality, and morbidity overtime.^{17,18} This allows us to understand the health gains of an intervention (where the prevalence or transition of a certain risk factor is modified) to a reference scenario (no modification). It thus informs us on how many healthy life years (HLY) would be saved if a certain public health program were implemented.^{19,20} This model is explained in detail in Boshuizen et al.¹⁷ The model requires epidemiological data, elaboration of different scenarios, and validation. We detail these three aspects below.

Effectiveness Estimation: Empirical Data

This tool requires country-specific demographic data, namely population size and future newborns, and epidemiological data on incidence, prevalence, mortality, and relative risks of a given factor leading to a given disease or death, disaggregated by age and sex.²¹

Specifically, it requires country-specific data on prevalence, incidence, disability, and excess mortality related to esophageal, breast, colorectal, oral, and lung cancer, chronic obstructive pulmonary disease, diabetes, ischemic heart disease and stroke, smoking, body mass index, and alcohol consumption. Most of these country-specific data were included on the software and refer to the populations of the early 2000s, which we used as background for these simulations because most TCPs were implemented after that date. For more details on the years of data used regarding the disease and risk factor

parameters for each country, see DYNAMO-HIA data documentation.²¹ We added epidemiological data that were missing on diabetes and ischemic heart disease for Portugal and Belgium. These data were extracted from the Portuguese National Health Survey, Portuguese National Statistics Institute,²² Belgium Standardized Procedures for Mortality Analysis,²³ and Belgium Morbidity Report.²⁴ Data sources and reference years related to smoking are presented in [Supplementary Table 3](#).

Data on relative risks from risk factors and from diseases, for death, disability, or transitions between risk factors were obtained from the literature and extrapolated to all countries.²¹ These data were included in the current version of DYNAMO-HIA software package available at www.dynamo-hia.eu.²¹

Short-term effectiveness data corresponded to the relative reduction in youth smoking prevalence rates in the period after the implementation of the TCPs. The DYNAMO-HIA software defined a smoker as one who smokes at least 1 cigarette/day, or who had smoked at least 100 cigarettes in lifetime and keeps smoking.²⁵ Short-term data were estimated by calculating the mean relative prevalence reduction of current (daily or weekly) smoking as mentioned in peer-reviewed studies and reports, such as Brown et al.'s²⁶ systematic review, the National Cancer Institute Monographs 19²⁷ and 21,⁵ the National Institute for Health and Care Excellence reviews,^{6,28} the Surgeon General report,² and the International Agency for Research on Cancer report²⁹ (more information on effectiveness data is available in [Table 1](#)).

Long-Term Effectiveness Estimation: Computing Different Scenarios

The simulation model estimated how short-term effects on smoking rates would in the long-term result in an increase in the number of HLY lived by the target population. It followed the whole population alive at year 0, including all age groups from zero to 95 years old, until the last person of the cohort died. That is, the model adopted a lifelong time horizon, and followed the complete country populations alive at year 0 without the introduction of newborns in future years, to allow control over the total countries' population size. Although the cohort included and followed the complete population, the reduction in smoking prevalence was applied only to minors (17 years old or younger), who were the focus of our study. We computed several scenarios, specifying several short-term effectiveness results, against a baseline nonintervention scenario. We based our scenario on the assumption that the risks of initiation, reinitiation, or cessation in these cohorts did not change, that is, that the probability of transition between nonsmoker to smoker, smoker to former smoker, or former smoker to smoker did not change.

Table 1. Short-Term Effectiveness Estimates Reported in the Literature for Bans on Smoking in Public Places, Sales to Minors, Advertising at Point-of-Sale, Smoking in School Premises, School Education Programs (Minimum, Maximum, and Mean of All Values Reported)

	Minimum effectiveness	Maximum effectiveness	Mean	References
Bans on smoking in public places ^a	0%	31.9%	11.35%	5,2,30-32
Bans on sales to minors ^b	0%	50%	25.6%	5,28
Bans on advertising at points-of-sale ^b	0%	16%	8%	5,2,33
Bans on smoking in school premises ^b	0%	11%	3.7%	5,29,32,34,35
School education programs ^b	0%	41.9%	9.99%	[4,2,36]

These percentages correspond to the relative reduction in smoking prevalence rates after the implementation of the abovementioned policies.

^aThese estimates were only measured among adults, as no data on adolescents were available.

^bEstimates were measured among adolescents.

Further assumptions from the DYNAMO-HIA software, unrelated to these scenarios, are documented elsewhere.³⁷

Validity

Internal validity has been previously evaluated by the DYNAMO-HIA team.^{17,18} External validity was assessed by discussing the extent to which the findings from the countries' sample would be generalizable to the whole countries populations, and to other countries.¹³

Cost-Effectiveness Analysis

Long-term effectiveness was calculated for the complete country population at year 0, but resulted from the reduction in smoking prevalence in those younger than 18, because we were only interested in assessing how the policies targeting adolescents smoking could affect the whole population in the long run.

Long-term cost estimates were calculated for a time horizon of 18 years, until those aged 0 at year 0 reached 18 years old (excluding). This time horizon reflects the total number of years of implementation of these policies in the cohorts' minors. We considered that these annual costs would not vary from year to year and discounted them at 3.5% annual rate.^{9,13} Long-term effectiveness estimates were also discounted at a 3.5% annual rate.

Cost estimates were then divided by the total number of HLY saved by the cohort, for nonschool bans, school bans, school programs, and all TCPs together.

Deterministic sensitivity analyses were performed to observe how cost-effectiveness estimates would change in face of variations in several parameters as by (1) widening short-term effectiveness scenarios (with 1%, 2%, 3%, 5%, 20%, 30%, 40%, and 50% prevalence reduction), (2) using the highest costs reported for each policy instead of its mean estimates (Supplementary Table 4), (3) 3.5% discount rate on effectiveness (Supplementary Table 5), and (4) 3.5% and 5% discount rates on costs⁹ (Supplementary Tables 6 and 7).

Results

Costs

Costs were mostly dependent on the number of person-hours devoted to the implementation of these policies, and to the value per hour of personnel.

The three nonschool bans (bans on smoking at public places, bans on sales to minors, and bans on advertising at points-of-sale) were monitored and enforced simultaneously in Belgium, Finland, Ireland, and Portugal. For that reason, their costs are presented in an aggregated form. Smoke monitoring was performed together with other areas (such as food safety or occupational health). Bans were implemented at the local level in Finland, Germany, and Italy, and at the national level in the remaining countries. Costs varied between €2,612 (Germany) and €74,107 (Finland) per 100 000 persons covered.

The bans on smoking at school premises were mostly implemented at the local or school level by schools' staff, by monitoring school breaks and providing educational talks with noncompliant students and their parents. As monitoring was performed simultaneously to the monitoring of misconduct, with no time or staff exclusively allocated to smoking prevention, opportunity costs for personnel were near zero, and we considered only costs with sanctioning, or costs with material or equipment. Finnish informants reported that as their students were usually compliant with the ban, no costs were allocated to enforce it. In the remaining countries mean costs varied between €7,839 (Germany) and €47,802 (Italy) per 100 000 students covered.

Costs with school education programs included the number of person-hours, materials, and equipment needed to prepare and implement the educational activities. Mean costs varied between €64,546 and €512,175 per 100 000 students, in Ireland and Italy, respectively. These programs were implemented at national or regional level in Germany, national and school level in the Netherlands, and regional and school level in Italy, covering a larger number of adolescents (larger scale). In the remaining countries these programs were implemented at school level, at a smaller scale.

Effectiveness

Table 2 shows the number of HLY saved after the implementation of TCPs. The estimates varied between 291 HLY saved per 100 000 persons covered in Portugal, for a 1% relative smoking prevalence reduction among adolescents, and 38 000 HLY saved per 100 000 persons covered in Ireland, for a 50% relative reduction. Supplementary Figure 9 exemplifies the 50-year modification of smoking prevalence in each country for three short-term effectiveness scenarios (4%, 10%, and 26% relative prevalence reduction).

Cost-Effectiveness

Estimates of cost-effectiveness varied depending on the implementation costs in each setting, and on the values of long-term effectiveness (Figure 1).

The implementation of nonschool smoking bans would cost, assuming 26%^{5,28} and 8%^{5,2,33} mean prevalence reductions, from €3.65 to €11.86 per HLY saved in Germany, €17.82 to €57.80 per HLY in Ireland, €14.13 to €45.93 per HLY in Italy, €21.17 to €68.78 per HLY in Belgium, €26.02 to €84.63 per HLY in Portugal, €33.31 to €108.18 per HLY in the Netherlands, and €77.92 to €253.23 per HLY in Finland, respectively (Table 3).

The implementation of school smoking bans cost €12.67 per HLY in Germany, €13.79 per HLY in Ireland, €29.59 per HLY in the Netherlands, €35.46 per HLY in Belgium, €45.04 per HLY in Portugal, and €91.87 per HLY in Italy, assuming a 4% prevalence reduction.^{23,38-40} In Finland, as explained earlier, the implementation of the school smoking bans had no extra costs for the schools.

Table 2. PPP-Adjusted Costs Per 100 000 Persons Covered, for Year 0, for Each Type of Policy, and Long-Term Effectiveness for 1% Prevalence Reduction (HLY Saved Per 100 000 Inhabitants)

	Netherlands	Germany	Portugal	Finland	Belgium	Italy	Ireland
Costs nonschool bans	36 659.84	2612.28	10 936.99	74 107.83	16 975.01	9940.24	19 883.12
Costs school bans	22 623.56	7839.86	15 484.54	0.00	21 153.11	47 802.22	9 127.30
Costs school education programs	433 213.38	199 822.21	410 303.33	187 610.12	237 517.13	512 175.81	64 546.39
Long-term effectiveness for 1% prevalence reduction	761.55	495.78	291.25	659.19	552.83	398.43	771.85

HLY = healthy life years; PPP = purchasing power parity.

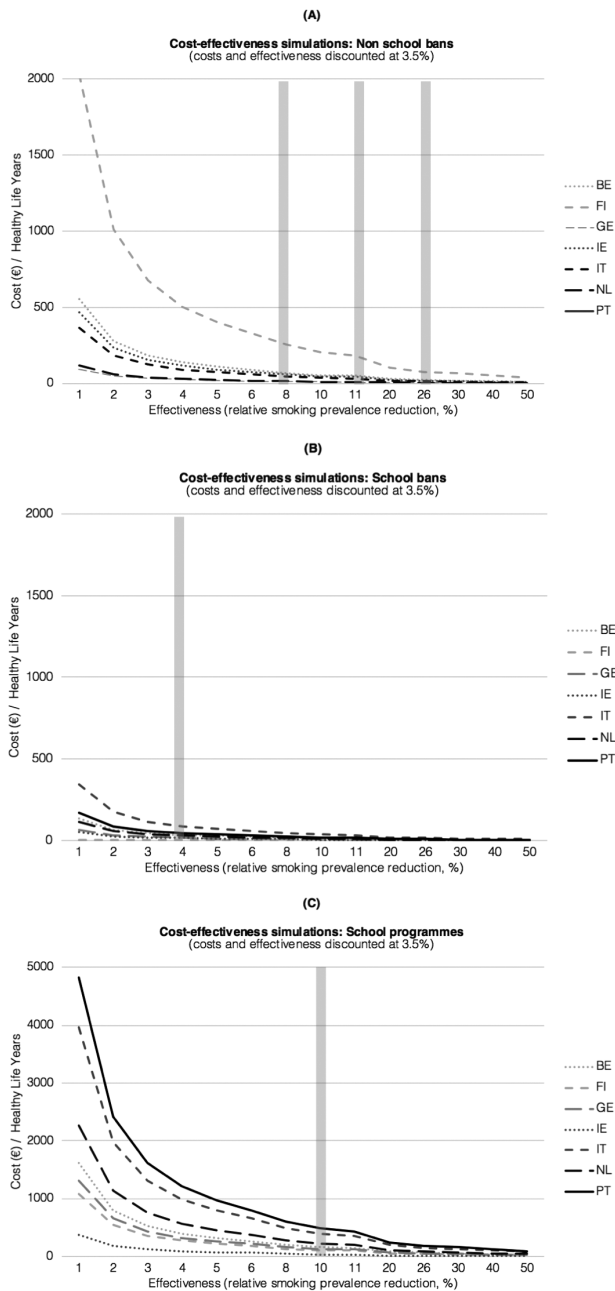


Figure 1. Cost-effectiveness of nonschool bans (A), school bans (B), school education programs (C) for 3.5% discount rate (purchasing power parity-adjusted euros per healthy life years saved). The vertical bars mark the mean of all effectiveness results reported by the literature for each policy.

The implementation of school education programs cost €37.55 per HLY saved in Ireland, €108.24 per HLY in Finland, €130.63 per HLY in Germany, €160.78 per HLY in Belgium, €226.06 per HLY in the Netherlands, €394.84 per HLY in Italy, and €481.35 per HLY in Portugal, assuming a 10% prevalence reduction.^{2,4,36}

The cost-effectiveness for lower effectiveness scenarios, as 1% prevalence reduction scenario, is less favorable, but still below €4,813 per HLY (value for Portugal, 1% relative prevalence reduction, costs school education programs, 3.5% discount rate for costs and effectiveness). Threshold analysis demonstrated that the minimum short-term effectiveness for highly cost-effective interventions is

situated between 0.12% in Ireland for school bans and 0.0003% in Italy for school programs (3.5% discount rate for costs and effectiveness) (Supplementary Table 8). Other deterministic sensitivity analyses were performed applying 3.5% discount rates only to effectiveness. In this case the costs per HLY became larger reaching €6568.98 per HLY for school education programs implemented in Portugal, for 1% prevalence reduction (Supplementary Table 5). The same occurred when using the highest cost estimates reported in each country for school bans and school education programs, instead of their mean cost value: the costs per HLY became larger, but still less than €8371.47 per HLY for Portugal, for school education programs, for a 1% prevalence reduction and 3.5% discount rate for costs and effectiveness (Supplementary Table 4). Applying 3.5% and 5% discount rate on costs was associated with better cost-effectiveness values (Supplementary Tables 6 and 7), as we do not discount the benefits that mostly occur in the long run.

Discussion

Main Findings

The costs of all policies varied between €93,556 and €569,918 per 100 000 persons covered, for Ireland and Italy, respectively, and varied according to the number of person-hours devoted to the policies' implementation. Long-term effectiveness estimates varied according to the variability of short-term effectiveness and ranged from about 1200 HLY saved per 100 000 persons covered in Portugal for the implementation of bans on smoking in school premises (considering a short-term 4% prevalence reduction), to about 20 000 HLY in Ireland for the implementation of nonschool bans (26% prevalence reduction).

Cost-effectiveness values were quite low in all countries (see Table 3). Compared to the nonintervention scenario, the incremental cost-effectiveness ratio would be below €2500 per HLY for nonschool bans, below €500 per HLY for school bans, and below €5000 for school education programs, even assuming the worst effectiveness scenarios. Cost-effectiveness estimates varied across countries, with the largest discrepancy for nonschool bans, but threshold analysis demonstrated that the minimum short-term effectiveness for highly cost-effective interventions is situated below 1% in all countries and policies.

Interpretation of Results

For all policies, cost-effectiveness ratios were situated much below the World Health Organization thresholds for public health interventions to be regarded as highly cost-effective.⁴¹ These thresholds correspond to the gross domestic product *per capita* for each country, and varied between €22 500 in Portugal (lowest value) and €53 300 in Ireland (highest value) in 2016, according to the Organisation for Economic Co-operation and Development figures.⁴² Cost-effectiveness estimates were based on 1%–50% relative prevalence reduction scenarios, and even in the most conservative scenarios (1% relative prevalence reduction, highest costs, and 3.5% and 5% discount rates), the implementation of these policies remained highly cost-effective.

Nevertheless, incremental cost-effectiveness results varied across policies. Bans were more cost-effective than school education programs because they covered a larger scale, requiring smaller marginal costs, that is, minor additional costs of implementation for one additional person covered, for similar effectiveness estimates.³⁸ Cost-effectiveness results also varied across countries, depending on

Table 3. Cost-Effectiveness of Nonschool Bans, School Bans, and School Programs, Per Country (PPP-Adjusted Euros Per HLY)

	Prevalence reduction (%)	Netherlands	Germany	Portugal	Finland	Belgium	Italy	Ireland
Nonschool bans	8	108.18	11.86	84.63	253.23	68.78	45.93	57.80
	11	78.72	8.62	61.59	183.72	50.04	33.41	42.12
	26	33.31	3.65	26.02	77.92	21.17	14.13	17.82
School bans	4	29.59	12.67	45.04	(No costs)	35.46	91.87	13.79
School programs	10	226.06	130.63	481.35	108.24	160.78	394.84	37.55

To estimate the cost-effectiveness ratio, we divided the costs of implementation in each country by the number of HLY saved for the national population. These estimates are given for each assumed prevalence reduction value. As an example, the total costs of implementation of nonschool bans for the whole 18-year period in the Netherlands were €483 531.67 per 100 000 inhabitants, and the total number of HLY saved per 100 000 inhabitants by these bans (assuming a smoking prevalence reduction of 8%) would be 4469.65 HLY (both values were discounted at 3.5%); yielding a cost-effectiveness ratio of €108.18/HLY. HLY = healthy life years; PPP = purchasing power parity.

the implementation costs, and long-term health gains. First, implementation costs depend on the intensity of implementation in each country, which depends on the staff devoted to monitoring and enforcing the policy, for example, in the case of nonschool bans.³⁹ Second, long-term effectiveness depends on the short-term effectiveness, and on each country population characteristics (ie, smoking rates, population-target size, and weight of smoking on morbidity and mortality). Thus, the higher costs of implementation in Portugal, Italy, and the Netherlands may be due to high monitoring and sanctioning efforts, but as long-term health gains were smaller in the first two countries than in the Netherlands, due to lower youth smoking rates at year 0,⁴⁰ their cost-effectiveness ratios were much higher.

We defined the same short-term effectiveness estimates in all countries, as detailed data per country were absent. Still, it is likely that countries with higher efforts (and costs) of implementation would experience a greater effectiveness.^{10,43} Thus, cost-effectiveness results are possibly lower than our estimates in countries with higher implementation efforts devoted to nonschool bans.¹⁰ As an example, in Finland the cost-effectiveness ratio should be lower, moving to the right in Figure 1, whereas in Germany it should be higher, moving to the left. The case of Ireland, however, contradicts this, because lower cost-effectiveness ratios are related to lower costs of implementation of TCPs. Low costs were found despite being considered one of the countries with stronger efforts of implementation of TCPs.¹⁰ An explanation may derive from the coexistence of strong TCPs, such as high taxation, implemented for a long time, and high smoking de-normalization, which may have had an impact in the prevalence of smoking and on the number of noncompliant cases, leading not only to a higher effectiveness, and but also to the decrease of the number of person-hours needed for monitoring or sanctioning.

Although we estimated the cost-effectiveness of TCPs for a 1%–50% range of short-term effectiveness and included the 0% prevalence reduction results to calculate the mean short-term effectiveness of these policies, we must acknowledge that some policies may be not effective. Bans that allow exceptions, that are not consistently monitored or strongly enforced may have low effectiveness outcomes, especially in contexts where smoking is still normalized, with low public support for TCPs, or where minors' social networks help to circumvent them.⁴⁴ If the policy is not effective due to its weak implementation, it signifies that money was spent for a zero benefit. Thus, as previously mentioned, the cost-effectiveness of these policies depends upon the social, cultural, and epidemiological contexts,¹¹ the mechanisms of implementation,⁴⁵ and the contribution of other TCPs.^{5,46,47} Comprehensive policies, strongly enforced, coordinated and associated with significant rise in the price of tobacco products, health warnings, and access to smoking cessation,

may enhance the effectiveness of each policy, lower their costs of implementation, and lead to greater cost-effectiveness.^{5,8,46,47} As an example, long-term and strong efforts in Finland to reduce smoking in the general population and in schools may have effectively led to reducing the number of noncompliant cases in schools, and also reducing the schools' costs on educating and sanctioning students; the same has been suggested to happen in Ireland.³⁹ Other complementary strategies were suggested⁴⁴ to raise these policies' effectiveness: Banning smoking at school and surrounding areas may reduce adolescents' access to tobacco from colleagues, raising parents consciousness of their role on smoking prevention, and strongly monitoring sales, or reducing the number of sales outlets to limit adolescents' access to tobacco from commercial sources.

In the light of these results, the reluctance to implement TCPs in some countries, as revealed by Joossens et al.¹⁰ might seem surprising at first sight. For comparison, highly expensive drugs with very unfavorable cost-effectiveness values have been approved in European countries, for example, for lung cancer treatment.⁴⁸ One reason may be that TCPs represent short-term costs with mostly long-run benefits, whereas acute treatments provide short-term gains; also, the so-called "rule of rescue" refers to decision makers and the population preferring to spend money on a few identifiable people at risk of death, than to achieve larger life gains in the future, saving "statistical lives."⁴⁹

Strengths and Limitations

This study presents several limitations regarding data collection on costs, and short- and long-term effectiveness. First, the cost-effectiveness of nonschool bans was assessed in an aggregated form, as costs were not available disaggregated by ban in most of our countries. Even though disaggregated estimates may be preferable for some purposes, public health institutions usually advocate their combined implementation. Our results demonstrate that independently of being monitored and enforced simultaneously or separately, they are highly cost-effective. Second, these policies were collected from a sample of local or school-level institutions, as data were not always available at the national level and it would be unrealistic to estimate the costs from all schools or institutions from the entire country. In order to estimate the cost-effectiveness of these policies, local-level costs were extrapolated to the national level. Though, the data from the respective cities may not be entirely representative of their countries, and this extrapolation may under- or overestimate the costs and cost-effectiveness of these policies at national levels. In order to enhance the external validity of our estimates, we estimated mean values from several low and high socioeconomic status schools, and from cities with socioeconomic characteristics similar to the national

average.¹⁴ In order to estimate cost-effectiveness under conservative cost-effectiveness scenarios, we used the highest costs reported in each country's institution.

Third, we did not have access to the relative prevalence reduction of smoking among adolescents in all seven countries for each policy. Indeed, these TCPs were implemented for a long time, often together or with other policies, and their effectiveness was rarely estimated. Instead, we used the mean of the various effectiveness estimates that were presented in the literature. However, these published estimates had limitations including (1) variations in study designs and outcome estimations, (2) variation in geographic reference population, which ranged from the local or regional to international levels, and (3) in the case of bans on smoking in public places data pertained to the adult population. Moreover, short-term effectiveness is likely to vary according to which effects are measured, the target population (adults or adolescents), the way in which TCPs are implemented, and a country's stage in the tobacco epidemic. This is why we performed a sensitivity analysis in which we assumed a wide range of potential relative prevalence reduction estimates (from 1% to 50%).

Fourth, the estimation of long-term effectiveness was based on the modification of prevalence of smoking in adolescents. We did not modify risks for smoking initiation or cessation, as data were not available for all five TCPs. However, in a realistic scenario, the risks for smoking initiation and reinitiation would probably decrease after the intervention, and the risk for cessation would increase.¹⁹ This means that our findings are likely conservative, and that more accurate effectiveness estimates would lead to even lower cost-effectiveness ratios.

Finally, we did not consider the healthcare costs related to the reduction of smoking. We opted to inform the decision maker about the cost-effectiveness directly related to these policies' implementation, disregarding other future savings or expenditures. Hence, our results are quite conservative, and would have been even more favorable had we been able to incorporate health care savings.

Despite these limitations, our costs, effectiveness, and cost-effectiveness results were, overall, in line with the literature.^{9,19} Considering that cost-effectiveness ratios were quite similar and all much below the World Health Organization threshold, we believe that high cost-effectiveness results would be found in the entire countries, and in countries with epidemiological and economic backgrounds similar to these seven. A major strength of this study is real-world and context-specific data, which were used for costs and effectiveness estimates, combined with numerous short-term effectiveness results from previous studies.

Conclusion

All five TCPs were highly cost-effective, in all seven countries and in all levels of implementation, even when considering the most conservative estimates. Large-scale interventions, such as smoking bans, were the most cost-effective interventions due to their lower costs of implementation per person. Decision makers should, therefore, be encouraged to implement smoking prevention policies, as we presented reasonable and evidence-based arguments on cost-effective adoption and adaptation of TCPs in seven real-world settings.

Supplementary Material

Supplementary data are available at *Nicotine and Tobacco Research* online.

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Declaration of Interests

None declared.

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