Original investigation

Economic Evaluation of Five Tobacco Control Policies Across Seven European Countries

Teresa Leão PhD1–3, Julian Perelman PhD1,2, Luke Clancy PhD4, Martin Mlinarić PhD5, Jaana M. Kinnunen MHS6, Paulien AW Nuyts MSc7,8, Nora Mélard MSc5,6, Arja Rimpelä PhD6,9, Vincent Lorant PhD8, Anton E. Kunst PhD2

1Escola Nacional de Saúde Pública, Universidade NOVA de Lisboa, Lisboa, Portugal; 2Centro de Investigação em Saúde Pública, Lisboa, Portugal; 3Local Health Unit of Matosinhos, Matosinhos, Portugal; 4TobaccoFree Research Institute Ireland, Dublin, Ireland; 5Institute of Medical Sociology, Medical Faculty, Martin Luther University Halle-Wittenberg, Halle, Germany; 6Unit of Health Sciences, Faculty of Social Sciences, Tampere University, Tampere, Finland; 7Amsterdam UMC, University of Amsterdam, Amsterdam, The Netherlands; 8Institute of Health and Society, Université catholique de Louvain, Brussels, Belgium; 9Department of Adolescent Psychiatry, Tampere University Hospital, Tampere, Finland

Corresponding Author: Teresa Leão, Escola Nacional Saúde Pública, Universidade NOVA de Lisboa, Av. Padre Cruz, 1600-560 Lisboa, Portugal. Telephone: 351-968-298-512; E-mail: ti.leao@ensp.unl.pt, teresa.de.leao@gmail.com

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. 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, 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. 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.

From an economic perspective, TCPs have proved to be highly cost-effective, or even cost saving. Sixteen economic evaluations of TCPs targeting adolescents were identified in a recent systematic review, 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, 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 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, 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.

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. 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 quantities 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). 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.5,26 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 Bosshuizen 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.21 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 19,27 and 21,4 the National Institute for Health and Care Excellence reviews,5,28 the Surgeon General report,3 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)

| Policy                                      | Minimum effectiveness | Maximum effectiveness | Mean   | References |
|---------------------------------------------|-----------------------|-----------------------|--------|------------|
| Bans on smoking in public places           | 0%                    | 31.9%                 | 11.35% | 1,2,36-32  |
| Bans on sales to minors                    | 0%                    | 50%                   | 25.6%  | 1,28       |
| Bans on advertising at points-of-sale      | 0%                    | 16%                   | 8%     | 1,2,35     |
| Bans on smoking in school premises        | 0%                    | 11%                   | 3.7%   | 1,29,32,34,35 |
| School education programs                 | 0%                    | 41.9%                 | 9.99%  | [4,5,36]   |

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

1These estimates were only measured among adults, as no data on adolescents were available.

2Estimates were measured among adolescents.
Further assumptions from the DYNAMO-HIA software, unrelated to these scenarios, are documented elsewhere.17

Validity
Internal validity has been previously evaluated by the DYNAMO-HIA team.19,20 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 TCs. 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 €37.80 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)

| Policy Type                        | 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 | 9127.30  |
| 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.
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. The cost-effectiveness for lower effectiveness scenarios, as 1% prevalence reduction scenario, is less favorable, but still below €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. 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. 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. Cost-effectiveness results also varied across countries, depending on

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

|                      | 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  | 160.70 | 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.

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. 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. 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. 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.

Funding
This study was funded by the SILNE-R project, funded by the European Union’s Horizon 2020 research and innovation program (grant agreement number 635056).

Declaration of Interests
None declared.

Acknowledgments
We thank Bruno Federico, Domenico Adesso, Laura Hoffmann, Pierre-Olivier Robert, and Elizabeth Breslin for collaborating in data collection. We also thank Joana Alves, Manuel Serrano Alarcon, and Pedro Pita Barros, from the NOVA Healthcare Initiative for their comments on this article. We further thank all informants for their time and availability. This study was previously presented at the European Congress of Epidemiology in Lyon, in July 2018.

References
1. World Health Organization. WHO MPOWER Report on the Global Tobacco Epidemic, 2017. Geneva: World Health Organization; 2017.
2. U.S. Department of Health and Human Services. Preventing Tobacco Use Among Youth and Young Adults. A Report from the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2012. http://www.surgeongeneral.gov/library/reports/preventing-youth-tobacco-use/factsheet.ht. Accessed February 2, 2017.
3. Russo P, Nastrucci C, Alzetta G, Szalai C. Tobacco habit: historical, cultural, neurobiological, and genetic features of people’s relationship with an addictive drug. Perspect Biol Med. 2011;54(4):557–577.
4. Jit M, Barton P, Chen Y-F, Uthman O, Aveyard P, Meads C. School-Based Interventions to Prevent the Uptake of Smoking among Children and Young People: Cost-Effectiveness Review. Birmingham: National Institute for Health and Clinical Excellence; 2009. http://www.nice.org.uk/guidance/ph23/resources/schoolbased-interventions-to-prevent-smoking-economic-modelling-report-full-report2. Accessed February 5, 2017.
5. National Cancer Institute, World Health Organization. The Economics of Tobacco and Tobacco Control. . Bethesda, MD; Geneva, CH: National Cancer Institute, World Health Organization; 2016.
6. National Institute for Health and Care Excellence. Smoking: Preventing Uptake in Children and Young People. Manchester: National Institute for Health and Clinical Excellence; 2008. nice.org.uk/guidance/ph14. Accessed February 4, 2017.
7. National Institute for Health and Care Excellence. School-Based Interventions to Prevent the Uptake of Smoking Among Children and Young People. Manchester: National Institute for Health and Clinical Excellence; 2013. http://guidance.nice.org.uk/PH23. Accessed February 5, 2017.
8. Levy DT, Chaloupka F, Giovino GA. Tobacco control policies and smoking rates. J Public Health Manag Pract. 2004;10(4):336–333. doi:10.1097/0124784-200407000-00011
9. León T, Kunst AE, Perelman J. Cost-effectiveness of tobacco control policies and programmes targeting adolescents: a systematic review. Eur J Public Health. 2018;28(1):39–43.
10. Joossens L, Raw M. The Tobacco Control Scale 2016 in Europe. Brussels: Association of the European Cancer Leagues; 2016. http://www.tobaccocontrolscale.org/. Accessed March 30, 2017.
11. Lopez AD, Collishaw NE, Piha T. A descriptive model of the cigarette epidemic in developed countries. Tob Control. 1994;3:242–247. doi:10.1136/tc.3.3.242
12. Kraus L, Guttormsson U, Leifman H, et al. ESPAD Report 2015: Results from the European School Survey Project on Alcohol and Other Drugs. Luxembourg: European Monitoring Centre for Drugs and Drug Addiction and European School Survey Project on Alcohol and Other Drugs; 2016. doi:10.2810/66718

13. National Institute for Health and Care Excellence. Methods for the Development of NICE Public Health Guidance. London: National Institute for Health and Clinical Excellence; 2012. http://www.nice.org.uk/aboutnice/howwework/developingnicepublichealthguidance/

14. World Health Organization. Cost effectiveness and strategic planning (WHO-CHOICE). https://www.who.int/choice/cost-effectiveness/en/. Published 2014. Accessed August 21, 2017.

15. Lorant V, Soto VE, Alves J, et al. Smoking in school-aged adolescents: design of a social network survey in six European countries. BMC Res Notes. 2015;8:91. https://bmcresnotes.biomedcentral.com/articles/10.1186/s13104-015-1041-z

16. OECD. Purchasing power parities. http://www.oecd.org/sdd/prices-ppps/. Published 2017. Accessed December 1, 2017.

17. Boshuizen HC, Lhachimi SK, van Balz PH, et al. The DYNAMO-HIA model: an efficient implementation of a risk factor/chronic disease Markov model for use in Health Impact Assessment (HIA). Demography. 2012;49(4):1259–1283.

18. Lhachimi SK, Nusselder WJ, Smit HA, et al. DYNAMO-HIA—a dynamic modeling tool for generic health impact assessments. PLoS One. 2012;7(5):e33177.

19. Kulik MC, Nusselder WJ, Boshuizen HC, et al. Comparison of tobacco control scenarios: quantifying estimates of long-term health impact using the DYNAMO-HIA modeling tool. PLoS One. 2012;7(7):e32363.

20. Lhachimi SK, Cole KJ, Nusselder WJ, et al. Health impacts of increasing alcohol prices in the European Union: a dynamic projection. Prev Med. 2012;55(3):237–243.

21. DYNAMO-HIA project. DYNAMO-HIA. http://www.dynamo-hia.eu/. Published 2010. Accessed October 1, 2016.

22. Instituto Nacional de Estatística. Instituto Nacional de Estatística. http://ime.pt. Published 2017. Accessed September 1, 2017.

23. Centre for Operational Research in Public Health. Standardized Procedures for Mortality Analysis—Belgium. spma.wiv-isp.be/. Published 2017. Accessed September 1, 2017.

24. Van der Heyden J, Mimilidis H, Tafforeau J. http://www.dynamo-hia.eu/. Published 2017. Accessed December 12, 2016.

25. Brown T, Platt S, Amos A. Equity impact of population-level interventions and policies to reduce smoking in adults: a systematic review. Drug Alcohol Depend. 2014;138:7–16. https://www.sciencedirect.com/science/article/pii/S0376871614007741

26. National Cancer Institute. Monograph 19: The Role of the Media in Promoting and Reducing Tobacco Use. Bethesda, MD: National Cancer Institute. NIH Pub. No. 07-6242; 2008.

27. Richardson L, McCullough L, et al. NICE. Rapid Review: Interventions to Prevent the Uptake of Smoking in Children and Young People. British Columbia: Centre of Excellence for Women’s Health; 2007.

28. National Institute for Health and Care Excellence. Smoke Free Implementation at the Local Level: A Realist Review of Smoking Control Policies. London: National Institute for Health and Care Excellence; 2015. http://www.nice.org.uk/nicemedia/live/14783/69580/69580.pdf

29. Ventislavov T, Vlaisavljev S, Sotirovski B, et al. Effect of restrictions on smoking at home, at school, and in public places on teenage smoking: cross sectional study. BMJ. 2000;321(7257):333–337.

30. Robertson L, McGee R, Marsh L, Hoek J. A systematic review on the impact of point-of-sale tobacco promotion on smoking. Nicotine Tob Res. 2015;17(1):2–17.

31. Poulin CC. School smoking bans: do they help? do they harm? Drug Alcohol Rev. 2007;26(6):615–624.

32. Pentz MA, Brannon BR, Charlin VL, Barrett EF, MacKinnon DP, Flay BR. The power of the policy: the relationship of smoking policy to adolescent smoking. Am J Public Health. 1988;79(7):857–862.

33. Robertson L, McGee R, Marsh L, Hoek J. A systematic review on the impact of tobacco control policies towards youth across seven European countries: measurement, challenges and results - Oral Presentation at the European Congress of Epidemiology. Rev Epidemol Sante Publique. 2018;66 (suppl 5 Juillet 2018):S243. doi:10.1016/j.respae.2018.05.005.

34. Bibby B, Andersson B, Ahstrom S, et al. The 1999 ESPAD Report: Alcohol and Other Drug Use Among Students in 30 European Countries. Stockholm: The Swedish Government and The Swedish National Institute of Public Health; 2000. http://www.epid.ifc.cnr.it/AreaDownload/Report/ESPAD/ESPADEurope/The_1999_ESPAD_report.pdf. Accessed April 21, 2018.

35. Edejer T, Baltussen R, Adam T, et al. WHO Guide to Cost-Effectiveness Analysis. Geneva: World Health Organization; 2003.

36. OECD. Purchasing power adjusted GDP per capita. General and regional statistics. http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&pcode=sdg_10_10&language=en. OECD, Published 2018. Accessed June 4, 2018.

37. Kuipers MA, de Korte R, Soto VE, et al. School smoking policies and educational inequalities in smoking behaviour of adolescents aged 14–17 years in Europe. J Epidemiol Community Health. 2016;70(2):132–139.

38. Nuys PAW, Kuipers TG, Willemens MC, Kunst AE. How can a ban on tobacco sales to minors be effective in changing smoking behaviour among youth?—A realist review. Prev Med. 2018;115:61–67. https://www.sciencedirect.com/science/article/pii/S0091743518302445?via%3Dihub

39. Leao T, Perelman J. Cost-effectiveness of tobacco control strategies to reduce smoking in adults: a systematic review. Health Econ. 2015;24(3):237–243. doi:10.1002/hec.3476

40. Hibell B, Andersson B, Ahstrom S, et al. The 1999 ESPAD Report: Alcohol and Other Drug Use Among Students in 30 European Countries. London: National Institute for Health; 2000. http://www.epid.ifc.cnr.it/AreaDownload/Report/ESPAD/ESPADEurope/The_1999_ESPAD_report.pdf. Accessed April 21, 2018.

41. Edejer T, Baltussen R, Adam T, et al. WHO Guide to Cost-Effectiveness Analysis. Geneva: World Health Organization; 2003.

42. OECD. Purchasing power adjusted GDP per capita. General and regional statistics. http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&pcode=sdg_10_10&language=en. OECD, Published 2018. Accessed June 4, 2018.

43. Kuipers MA, de Korte R, Soto VE, et al. School smoking policies and educational inequalities in smoking behaviour of adolescents aged 14–17 years in Europe. J Epidemiol Community Health. 2016;70(2):132–139.

44. Nuys PAW, Kuipers TG, Willemens MC, Kunst AE. How can a ban on tobacco sales to minors be effective in changing smoking behaviour among youth?—A realist review. Prev Med. 2018;115:61–67. https://www.sciencedirect.com/science/article/pii/S0091743518302445?via%3Dihub

45. Milană R, Hoffmann L, Kunst AE, et al. Explaining mechanisms that influence smoke-free implementation at the local level: a realist review of smoking bans. Tobacco Res. 2018;29(9):2341–2386. doi:10.1093/tobacco/206

46. Felau A, Filippidis FT, Joossens L, et al. Impact of tobacco control policies on smoking prevalence and quit ratios in 27 European Union countries from 2006 to 2014. Tob Control. 2015;24(1):101–109. doi:10.1136/tobaccocontrol-2017-054119

47. Moyano CL, Martín-Sánchez JC, Saliba P, Graffelman J, Martín-Sánchez JM. Correlation between tobacco control policies, consumption of rolled tobacco and e-cigarettes, and intention to quit conventional tobacco, in Europe. Tob Control. 2017;26(2):149–152. doi:10.1136/tobaccocontrol-2015-052482

48. Claxton K, Schulper M, Palmer S, Culver AJ. Causes for concern? is NICE failing to uphold its responsibilities to all NHS patients? Health Econ. 2015;24(1):1–7.

49. Cookson B, McCabe C, Tsuchiya A. Public healthcare resource allocation and the Rule of Rescue. J Med Ethics. 2008;34(7):540–544.