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The health and economic burden of smoking in 12 Latin American countries and the potential effect of increasing tobacco taxes: an economic modelling study

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Summary

Background Worldwide, smoking tobacco causes 7 million deaths annually, and this toll is expected to increase, especially in low-income and middle-income countries. In Latin America, smoking is a leading risk factor for death and disability, contributes to poverty, and imposes an economic burden on health systems. Despite being one of the most effective measures to reduce smoking, tobacco taxation is underused and cigarettes are more affordable in Latin America than in other regions. Our aim was to estimate the tobacco-attributable burden on mortality, disease incidence, quality of life lost, and medical costs in 12 Latin American countries, and the expected health and economic effects of increasing tobacco taxes.

Methods In this modelling study, we developed a Markov probabilistic microsimulation economic model of the natural history, medical costs, and quality-of-life losses associated with the most common tobacco-related diseases in 12 countries in Latin America. Data inputs were obtained through a literature review, vital statistics, and hospital databases from each country: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Paraguay, Peru, and Uruguay. The main outcomes of the model are life-years, quality-adjusted life-years, disease events, hospitalisations, disease incidence, disease cost, and healthy years of life lost. We estimated direct medical costs for each tobacco-related disease included in the model using a common costing methodology for each country. The disease burden was estimated as the difference in disease events, deaths, and associated costs between the results predicted by the model for current smoking prevalence and a hypothetical cohort of people in each country who had never smoked. The model estimates the health and financial effects of a price increase of cigarettes through taxes, in terms of disease and health-care costs averted, and increased tax revenues.

Findings In the 12 Latin American countries analysed, we estimated that smoking is responsible for approximately 345 000 (12%) of the total 2 860 921 adult deaths, 2·21 million disease events, 8·77 million healthy years of life lost, and $26·9 billion in direct medical costs annually. Health-care costs attributable to smoking were estimated to represent 6·9% of the health budgets of these countries, equivalent to 0·6% of their gross domestic product. Tax revenues from cigarette sales cover 36·0% of the estimated health expenditures caused by smoking. We estimated that a 50% increase in cigarette price through taxation would avert more than 300 000 deaths, 1·3 million disease events, gain 9 million healthy life-years, and save $26·7 billion in health-care costs in the next 10 years, with a total economic benefit of $43·7 billion.

Interpretation Smoking represents a substantial health and economic burden in these 12 countries of Latin America. Tobacco tax increases could successfully avert deaths and disability, reduce health-care spending, and increase tax revenues, resulting in large net economic benefits.

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Introduction

Worldwide, smoking tobacco is expected to cause 7·5 million deaths in 2020 and is the second biggest risk factor for death and disability.[1,2] Tobacco is responsible for 65% of deaths due to lung cancer worldwide, 44% of deaths due to chronic obstructive pulmonary disease, and 22% of deaths due to ischaemic heart disease.[1,3] Moreover, smoking-related diseases cause a substantial economic burden on individuals and health systems, which can be up to US$500 billion globally per year, including costs of productivity loss, illnesses, and premature deaths, representing up to 1·5% of the gross domestic product of individual countries and up to 15% of all national health expenditures.[4]

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Research in context

Evidence before this study

We searched PubMed on Sept 15, 2019, using the search terms (tobacco use disorder[MeSH] OR tobacco use[tiab] OR smoking[MeSH] OR smoking[tiab] OR cigar*[tiab]) AND (cost of illness[MeSH] OR models, economic[MeSH] OR "costs and cost analysis"[MeSH] OR taxes[MeSH] OR taxation*[tiab]) AND (Argentina[MeSH] OR Bolivia[MeSH] OR Brazil[MeSH] OR Chile[MeSH] OR Colombia[MeSH] OR Costa Rica[MeSH] OR Ecuador[MeSH] OR Honduras[MeSH] OR Mexico[MeSH] OR Paraguay[MeSH] OR Peru[MeSH] OR Uruguay[MeSH] OR Latin America[MeSH]). We searched for primary research, modelling studies, and reviews published between Jan 1, 2010, and Aug 31, 2019, with no language restrictions. We found 20 studies on models and disease burden, 16 reviews, 15 articles about taxation, and three primary research reports. Smoking is a leading risk factor for premature morbidity and mortality. If trends are not reversed, the tobacco-attributable burden on health and economies will continue to increase in low-income and middle-income countries. High excise taxes on tobacco could be essential to reduce tobacco use, but they are underused in Latin America. There are few published studies that have quantified both the burden of tobacco and the impact of higher tobacco taxes on health and financial outcomes in Latin America.

Added value of this study

Our study shows that smoking tobacco causes a substantial proportion of the burden of disease and health-care costs in 12 Latin American countries each year. Current tobacco taxes cover just 36·0% of the direct medical costs caused by smoking in these countries. We estimate that a 50% increase in tobacco prices would save around 300 000 deaths and 9 million healthy life-years in the next 10 years; and would produce economic benefits of more than US$40 billion because of averted treatment costs and increased tax revenues.

Implications of all the available evidence

Higher tobacco taxes could be one of the most powerful tools to decrease the use of tobacco. In Latin America, tobacco taxation is underused, and cigarettes are more affordable than in other regions. Evidence supports that higher tobacco taxes can reduce tobacco use, avert tobacco-related mortality and morbidity, and lead to reduced health-care expenditures and poverty.

The WHO Framework Convention on Tobacco Control (FCTC) is included in the Sustainable Development Goals, signed by more than 100 countries in September 2015, at the UN General Assembly. Among the measures proposed in the FCTC, an increase in the inflation-adjusted price of tobacco is a realistic and effective strategy to reduce smoking because, despite the highly addictive nature of cigarettes, the demand for tobacco is strongly influenced by its price.[5] However, only a few countries have substantially increased specific excise taxes on tobacco in an attempt to reduce smoking.[5] Indeed, raising taxes on tobacco is the least often implemented measure of those established by the FCTC. It is estimated that increasing cigarette taxes by 10% would increase tax revenues by an additional 7%; however, in most low-income and middle-income countries, cigarette taxes are underused.[3] Many countries have extremely low tobacco tax rates, and some countries do not levy any tobacco taxes.[6]

In Latin America, smoking is among the five leading risk factors for death and disability, and contributes to poverty via decreased productivity and an impact on out-of-pocket expenses.[2,7] Smoking accounts for $34 billion in direct medical costs every year, which represents a substantial proportion of Latin American health budgets.[8] Most Latin American countries have signed the FCTC, but many still do not have a strong tobacco-control policy. Misinformation, prejudice, an absence of country-level comprehensive data, and pressure from interest groups have delayed the implementation and the enforcement of key measures in Latin America.[9] Many of these measures, such as tax increases, are also politically challenging. To foster the implementation of effective tobacco-control policies in the region, it is necessary to obtain relevant, country-level information on the health and economic consequences of smoking tobacco and how these relate to individuals, families, communities, and countries. Moreover, this information is needed to raise awareness and advocate for the adoption of measures and mobilisation of resources to control tobacco. The absence of reliable information in several countries in the region on the true burden of smoking, and on the potential effect of the interventions, delays the application of stronger measures. The aims of this study are to estimate the tobacco-related burden on disease, mortality, and direct medical costs in 12 countries in Latin America, and to estimate the health and financial effect of different levels of tobacco taxation.

Methods

Study design and model development

This economic modelling study estimated the tobacco-related burden on disease and the potential effect and cost-effectiveness of tobacco control interventions in 12 Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Paraguay, Peru, and Uruguay. The study was part of a collaborative project that included researchers, decision makers, and academic institutions from these 12 countries.

To inform the model development, we did a comprehensive analysis of the availability and quality of

epidemiological and health-care cost data in the region, and of policy makers' information needs for the implementation of tobacco-control interventions. The model is a state transition or Markov probabilistic microsimulation of individuals (first-order Monte Carlo technique) including natural history, direct medical costs, and quality-of-life losses associated with the most common tobacco-related diseases (coronary and non-coronary heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, pneumonia, influenza, lung cancer, and nine other neoplasms).

During the past 9 years, the model was validated and used in various Latin American countries to estimate the burden of disease attributable to smoking and the potential effect of different interventions. More detail can be found in previous publications[8,10–14] and in the reports and technical documents for the 12 countries included in this analysis.

Baseline incidence risks in people who had never smoked tobacco were estimated for each health condition and each country from mortality statistics. For acute events, age and sex specific incidence (absolute risk) was calculated on the basis of specific mortality and the lethality of the event as

$$R_{\text{pop.event}} = \frac{R_{\text{death}}}{L}$$

where R_{death} is the specific mortality per age and sex and L is lethality. Once the absolute risk was obtained, the baseline risk for people who had never smoked tobacco was calculated from the specific prevalence of tobacco use per age and sex, as well as the relative risk (RR) for each condition for people who currently smoke or formerly smoked:

$$R_{\text{nonsmk}} = \frac{R_{\text{pop.event}}}{(\text{RR}_{\text{smk}} \times f_{\text{smk}}) + (\text{RR}_{\text{frsmk}} \times f_{\text{frsmk}}) + f_{\text{nonsmk}}}.$$

In this calculation, R_{nonsmk} is the annual incidence of the acute disease event for people who have never smoked, $R_{\text{pop.event}}$ is the specific population risk per age and sex (from the previous formula), RR_{smk} and RR_{frsmk} are the relative risks of the event in people who smoke and people who used to smoke versus people who have never smoked, and f_{smk}, f_{frsmk}, and f_{nonsmk} are the specific proportions of people who smoke, people who used to smoke, and people who have never smoked per age and sex (the RRs by condition are in the appendix, p 3).

For lung cancer, the annual incidence for each age and sex strata was calculated from annual mortality rates from national statistics and the annual estimated survival after diagnosis:

$$R_{\text{dxi}} = \left(\sum_{n=0}^{10} \text{RM}_{(i+n)} \times \text{P}_{(i+n)} \right) \times \frac{1}{1 - S_{10}}$$

where R_{dxi} is the estimated incidence at age i, $\text{RM}_{(i+n)}$ is the general population risk of death at age $i+n$, P_n is the conditional probability of dying in year n after being diagnosed, and S_{10} is the proportion of individuals surviving after 10 years. For other cancers, specific incidence rates for each age and sex strata were estimated from Global Cancer Observatory data for each country.[15]

Individuals were followed up in hypothetical cohorts, from age 35 years to death, and the model estimated in annual cycles the individual risks of disease incidence, disease progression, and death, on the basis of the individual's demographic attributes, smoking status, previous clinical conditions, and underlying risk equations. Using the simulation of each individual's lifetime, health outcomes were calculated to obtain aggregated results. The main outcomes of the model are life-years, quality-adjusted life years, disease events, hospitalisations, disease incidence, disease cost, and healthy years of life lost (which aggregate health losses both due to years lost by premature mortality as well as quality of life losses).

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Information sources

Data to populate the model were obtained through a comprehensive review of the literature. The following electronic databases were used: MEDLINE, Embase, Cochrane Central Register of Controlled Trials, SocINDEX, EconLit, Latin American and Caribbean Health Sciences Literature, National Bureau of Economic Research, Centre for Reviews and Dissemination and Cost Effectiveness Analysis Registry, the International Tobacco Health Conference Paper Index, and Cochrane Tobacco Addiction Review Group register. Grey literature was reviewed from ministries of health, ministries of finance, Pan American Health Organization, and databases containing regional congress proceedings. Updated information on tobacco use prevalence was obtained from local tobacco Global Adult Tobacco Surveys, where available, or national risk factor surveys. Researchers from the participating countries provided additional information on civil registrations, vital statistics, and hospital discharge databases to estimate specific case fatality rates.

Cost data

The direct medical costs (including of diagnosis, treatment, and follow-up), from the perspective of the public health-care systems, were estimated for each of the tobacco-related diseases included in the model. A common costing methodology was developed for the 12 countries, including a microcosting or macrocosting approach, depending on the availability and quality of information in each country. A Microsoft Excel spreadsheet was designed for each event, identifying health resources and measuring quantities, utilisation rates, and unit costs for each resource used in each event. These ad-hoc microcosting exercises were constructed on the basis of communications with experts, clinical guidelines, and a review of health-care facility records. Costs of

See **Online** for appendix

malignancies other than lung cancer were estimated on the basis of lung cancer costs and an expert consensus obtained through a modified Delphi panel method. When sufficient local information was unavailable, indirect estimates were used to approximate costs of events (eg, for each country with information on the cost of a particular health event, the ratio between the cost of the health event and the country's gross domestic product per capita was calculated; then, for each country with missing cost data, the average of these ratios was applied to their gross domestic product per capita to derive the cost of the health event). All direct medical costs were estimated in local currency units; then consumer price indices (published by the statistics institutes of each country) were used for adjustments. Finally, costs were converted to US dollars using the exchange rates of December, 2015, published by the central banks of each country.

Model calibration and validation process

We applied the International Society for Pharmacoeconomics and Outcomes Research criteria for model development and reporting.[16] To calibrate the model, disease specific mortality by sex and age were compared with local statistics; predicted mortality within 10% of the references were considered acceptable. In case of greater deviation, risk equations were modified. External validation was accomplished by checking the model results against those results of other epidemiological and clinical studies not used for equation estimation and development.

Estimation of the smoking-related disease burden

The disease burden was estimated as the difference in disease events, deaths, and associated costs between the results predicted by the model for each country for current smoking prevalence and a hypothetical cohort of people who had never smoked for each country. Given that the model does not directly calculate the consequences of passive smoking and perinatal effects, on the basis of the results of previous studies, it was estimated that these two causes impose an additional burden of 13·6% for men and 12% for women.[17] Disease burden results are reported for one calendar year (2015).

Estimation of the effect of taxation

The effect of price increases on the prevalence of smoking was calculated as

$$\text{Prevalence} = \text{PrevB} + (E_d \times \Delta P \times I_p \times \text{PrevB})$$

where PrevB is the baseline prevalence of smoking before price increase; ΔP is the price variation as a proportion of the baseline price; I_p is proportion of the variation on cigarette consumption expected to affect smoking prevalence; and E_d is the price elasticity of demand for cigarettes. Price elasticity gives the percentage change in quantity demanded for each percentage increase in price (eg, a value of –0·6 means that for every 1% increase in price the demand will decrease by 0·6%).

Three scenarios were considered to estimate the reduction of the health burden associated with the reduction in cigarette consumption. (1) A short-term and conservative scenario: different studies have estimated that in the short-term and medium-term, approximately half of the reduction in consumption is a consequence of reduced prevalence of smoking and the other half is explained by reduced consumption by people who continue to smoke.[18,19] In this scenario, we assume that 50% of the reduced consumption is a consequence of the reduction in prevalence (I_p=0·5), leading to an increase in the number of people who formerly smoked. (2) A medium-term scenario: similar to the short-term scenario but including potential health benefits associated with the reduction in the number of cigarettes smoked by people who continue to smoke. Considering that low-intensity smokers have an average of 75% less excess disease risk than high-intensity smokers when compared with people who have never smoked (82% less for lung cancer, 57% less for ischaemic heart disease, and 80% less for COPD),[20] we assumed that a reduction in the number of cigarettes smoked would result in a proportional reduction in the 75% of the excess risk difference between a person who smokes and a person who formerly smoked. (3) A long-term scenario: this is the maximum effect scenario analysed. It is similar to the medium-term scenario, but here I_p=0·75 and the entire reduction in prevalence results in an increased population of people who have never smoked, instead of one of people who formerly smoked (further details in appendix p 4).

To do a unified analysis of the three scenarios, we developed a base-case with the results accumulated over 10 years. We assumed a linear progression from scenario one to scenario two over 5 years and a progression to scenario three in years 6–10. The effect of a tax increase on revenues was estimated as

$$V_r = \Delta c \times \frac{\Delta P}{\text{pV}}$$

where V_r is the calculated variation in revenues; Δc represents the expected variation in consumption due to the price increase as a proportion of the baseline consumption; ΔP represents the change in cigarette prices as a proportion of the baseline price; and pV represents the proportion of the price, before the price increase, represented by taxes.

Role of the funding source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Ecuador	Honduras	Mexico	Paraguay	Peru	Uruguay
Population in 2015	43 416 755	10 724 705	207 847 528	17 948 141	48 228 704	4 807 850	16 144 363	8 075 060	127 017 224	6 639 123	31 376 670	3 431 555
Smoking prevalence												
Men	29·6%	20·0%	21·6%	44·2%	19·5%	20·0%	28·3%	19·6%	24·8%	23·7%	27·6%	27·7%
Women	20·9%	17·0%	13·1%	31·7%	7·4%	8·3%	9·3%	2·0%	7·8%	16·3%	12·7%	17·7%
Main direct medical costs in 2015, $*												
Acute myocardial infarction	$3917	$5122	$5021	$4246	$4538	$12 756	$4703	$2080	$5219	$2882	$2830	$13 054
Ischaemic event (not acute myocardial infarction)	$2938	$3863	$1886	$2909	$1815	$7215	$4942	$1460	$3428	$2306	$1966	$12 458
Annual follow-up coronary heart disease	$1550	$2039	$410	$1554	$412	$1075	$1381	$631	$1335	$1345	$1245	$4042
Stroke	$5187	$5270	$4317	$4771	$2572	$7348	$4092	$2159	$4434	$1921	$5376	$9503
Annual follow-up stroke	$1781	$1810	$798	$1639	$755	$1625	$1015	$557	$702	$1441	$853	$3824
Pneumonia or influenza	$262	$278	$362	$253	$385	$1924	$447	$189	$1410	$865	$185	$1208
Mild COPD (annual)	$152	$63	$695	$269	$130	$219	$257	$80	$322	$384	$155	$572
Moderate COPD (annual)	$362	$182	$1161	$594	$339	$587	$587	$200	$964	$961	$406	$1346
Severe COPD (annual)	$5309	$3998	$4838	$6603	$4097	$8087	$5229	$2262	$9941	$2882	$4637	$3749
Lung cancer 1st year	$21 011	$8927	$12 316	$23 392	$12 423	$22 583	$21 881	$6197	$14 845	$9991	$14 967	$39 716
Lung cancer 2nd year	$27 167	$11 542	$6900	$30 246	$11 141	$25 970	$15 881	$7141	$19 195	$9991	$19 353	$45 767

(Table 1 continues on next page)

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Ecuador	Honduras	Mexico	Paraguay	Peru	Uruguay
(Continued from previous page)												
Economic parameters												
Tobacco tax revenues in 2015, million $†	$2112	$15	$3031	$1500	$174	$63	$195	$29	$2237	$61	$73	$211
Taxes as a proportion of cigarette price	69·7%	40·4%	64·3%	81·6%	49·5%	71·8%	62·3%	38·1%	65·8%	62·7%	39·5%	65·6%
GDP in 2015, million $†	$594 749	$33 000	$1 802 214	$243 999	$293 481	$54 775	$99 290	$20 979	$1 170 564	$36 164	$189 926	$53 274
GDP per capita in 2015, $‡	$13 698	$3077	$8750	$13 737	$6085	$11 393	$6150	$2341	$9298	$5447	$6053	$15 525
Price elasticity of demand§	−0·30	−0·85	−0·48	−0·45	−0·78	−0·43	−0·87	−0·43	−0·45	−0·43	−0·70	−0·55
Total health expenditure, proportion of GDP‡	8·74%	6·42%	11·46%	8·30%	6·02%	7·78%	8·59%	7·71%	5·12%	7·82%	5·26%	9·01%

All costs are in 2015 US dollars. COPD=chronic obstructive pulmonary disease. GDP=gross domestic product. Exchange rate per US$ (World Bank 2015): Argentina 9·23 ARS; Bolivia 6·91 BOL; Brazil 3·33 R$; Chile 654·12 CLP; Colombia 2741·88 COL; Costa Rica 534·56 CRC; Ecuador 1·00 US$; Honduras 21·95 HNL; Mexico 15·85 MXN; Paraguay 5204·91 PYG; Peru 3·18 PEN; Uruguay 27·33 UYU. *Cost of other cancer is shown in the appendix p 1. †Sources: ministries of economy and tax revenues agencies. ‡Source: The World Bank.[21] §Sources: Argentina: Chaloupka F, et al (2014).[22] Bolivia: Alcaraz VO (2006).[23] Brazil: Iglesias R, et al (2007).[24] Chile: Debrott Sánchez D (2006).[25] Colombia: Maldonado N, et al (2016).[26] Costa Rica, Honduras, and Paraguay: Guindon GE, et al (2016).[9] Ecuador: Chávez R (2016).[27] Mexico: Jimenez-Ruiz JA, et al (2008).[28] Peru: Gonzalez-Rozada M and Ramos-Carbajales A (2016).[29] Uruguay: Carbajales AR and Curti D (2010).[30]

Table 1: **Summary of key model parameters for each of the 12 Latin American countries analysed**

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Ecuador	Honduras	Mexico	Paraguay	Peru	Uruguay	Total
Total deaths*	48 723/ 359 196 (14%)	4474/ 55 274 (8%)	156 217/ 1 240 068 (13%)	19 731/ 107 545 (18%)	32 088/ 198 738 (16%)	1747/ 18 706 (9%)	7798/ 57 999 (13%)	1526/ 19 457 (8%)	49 189/ 613 123 (8%)	3354/ 27 410 (12%)	15 715/ 130 930 (12%)	4811/ 32 475 (15%)	345 373/ 2 860 921 (12%)
Total disease events†	224 007	27 867	1 103 421	111 526	221 811	13 718	51 280	9919	308 840	22 360	95 879	20 165	2 210 720
Total direct medical cost, millions $	$3817·3	$249·7	$11 830·1	$1901·3	$1708·5	$241·5	$476·0	$56·3	$4767·7	$301·3	$796·0	$800·1	$26 946·3
Total healthy years of life lost‡	1 072 979 (73%)	113 736 (72%)	4 203 389 (72%)	495 988 (67%)	789 587 (65%)	44 278 (68%)	204 686 (68%)	39 034 (67%)	1 237 488 (70%)	88 473 (67%)	380 749 (71%)	104 015 (73%)	8 774 402 (70%)
Cardiovascular disease†													
Deaths	11 127/ 87 543 (13%)	696/ 4750 (15%)	34 999/ 222 550 (16%)	3104/ 15 777 (20%)	8160/ 50 529 (16%)	431/ 3785 (11%)	1330/ 9331 (14%)	258/ 1823 (14%)	13 302/ 103 555 (13%)	692/ 3573 (19%)	2029/ 11 724 (17%)	768/ 5588 (14%)	76 896/ 494 755 (16%)
Event incidence	63 162/ 261 258 (24%)	2580/ 12 897 (19%)	470 666/ 2 007 840 (23%)	22 397/ 64 613 (35%)	91 505/ 389 672 (23%)	6495/ 35 936 (18%)	4897/ 16 196 (22%)	3033/ 15 009 (20%)	106 369/ 527 342 (20%)	9075/ 36 628 (25%)	8429/ 35 505 (24%)	6571/ 26 681 (22%)	795 179/ 3 429 576 (23%)
Direct medical cost, millions $	$1096·4/ $4818·8 (23%)	$71·1/ $310·3 (23%)	$3082·5/ $13 768·9 (22%)	$438·7/ $1283·1 (34%)	$546·9/ $2468·6 (22%)	$97·1/ $584·0 (17%)	$77·0/ $293·1 (26%)	$23·6/ $117·5 (20%)	$1656·3/ $8038·4 (21%)	$123·4/ $525·8 (23%)	$125·7/ $480·4 (26%)	$273·6/ $1272·3 (21%)	$7612·3/ $33 961·2 (22%)
Stroke†													
Deaths	2786/ 21 960 (13%)	522/ 2896 (18%)	10 812/ 80 857 (13%)	1792/ 9929 (18%)	2195/ 17 007 (13%)	125/ 1338 (9%)	440/ 3357 (13%)	65/ 561 (12%)	3740/ 39 731 (9%)	270/ 1770 (15%)	1114/ 6735 (17%)	173/ 1559 (11%)	24 034/ 187 698 (13%)
Event incidence	14 740/ 99 878 (15%)	3728/ 20 839 (18%)	59 509/ 385 523 (15%)	14 473/ 67 421 (21%)	23 233/ 160 477 (14%)	500/ 5088 (10%)	3064/ 23 671 (13%)	263/ 2175 (12%)	15 273/ 153 259 (10%)	1414/ 8433 (17%)	7871/ 47 571 (17%)	718/ 5940 (12%)	144 786/ 980 275 (15%)
Direct medical cost, millions $	$277·4/ $1753·7 (16%)	$78·3/ $380·7 (21%)	$653·0/ $3903·9 (17%)	$244·8/ $1029·3 (24%)	$198·5/ $1229·3 (16%)	$9·4/ $83·1 (11%)	$34·0/ $254·8 (14%)	$1·7/ $13·0 (14%)	$139·7/ $1315·3 (11%)	$20·8/ $110·2 (19%)	$95·2/ $531·1 (18%)	$26·2/ $194·6 (13%)	$1779·0/ $10 799·9 (16%)
Pneumonia†													
Deaths	3714/ 23 022 (16%)	1002/ 5853 (17%)	10 90085 442 (13%)	878/ 4196 (21%)	1102/ 6231 (18%)	75/ 588 (13%)	543/ 3665 (15%)	75/ 575 (13%)	2084/ 16 304 (13%)	8/ 52 (16%)	2738/ 14 874 (18%)	164/ 1096 (15%)	23 283/ 160 054 (15%)
Event incidence	26 699/ 134 859 (20%)	9894/ 58 380 (17%)	121 152/ 705 548 (17%)	6174/ 23 445 (26%)	9440/ 52 954 (18%)	754/ 5339 (14%)	5783/ 28 429 (20%)	840/ 6850 (12%)	21 062/ 143 005 (15%)	102/ 625 (16%)	24 303/ 128 188 (19%)	1060/ 5573 (20%)	227 309/ 1 300 328 (17%)
Direct medical cost, millions $	$7·0/ $35·4 (20%)	$2·7/ $16·2 (17%)	$43·8/ $255·2 (17%)	$1·5/ $5·9 (26%)	$3·6/ $20·4 (18%)	$1·5/ $10·3 (20%)	$2·0/ $12·7 (20%)	$0·1/ $1·3 (12%)	$29·7/ $201·6 (15%)	$0·1/ $0·5 (16%)	$4·5/ $23·7 (19%)	$1·4/ $6·7 (20%)	$97·9/ $590·3 (17%)
COPD†													
Deaths	9259/ 12 367 (75%)	932/ 1293 (72%)	31 120/ 41 924 (74%)	5526/ 6750 (82%)	8028/ 10 425 (77%)	432/ 672 (64%)	2467/ 3223 (77%)	461/ 731 (63%)	12 635/ 18 164 (70%)	907/ 1174 (77%)	3933/ 5065 (78%)	1030/ 1354 (76%)	76 730/ 103 142 (74%)
Event incidence	96 569/ 142 818 (68%)	10 349/ 16 863 (61%)	378 594/ 557 944 (68%)	60 470/ 79 636 (76%)	85 120/ 124 833 (68%)	5212/ 9150 (57%)	35 528/ 47 501 (75%)	5141/ 9621 (53%)	147 449/ 238 741 (62%)	10 385/ 14 887 (70%)	49 516/ 69 728 (71%)	9558/ 14 029 (68%)	893 891/ 1 325 751 (67%)
Direct medical cost, millions $	$569·0/ $767·2 (74%)	$35·3/ $48·3 (73%)	$4801·8/ $6748·6 (71%)	$495·6/ $612·7 (81%)	$405·1/ $531·6 (76%)	$40·2/ $63·2 (64%)	$206·0/ $270·8 (74%)	$13·5/ $21·8 (62%)	$1617·7/ $2364·7 (68%)	$84·5/ $114·5 (84%)	$234·9/ $305·3 (77%)	$136·3/ $180·3 (85%)	$8640·0/ $12 028·9 (72%)

(Table 2 continues on next page)

	Argentina	Bolivia	Brazil	Chile	Colombia	Costa Rica	Ecuador	Honduras	Mexico	Paraguay	Peru	Uruguay	Total
(Continued from previous page)													
Lung cancer†													
Deaths	9416/ 11 488 (82%)	292/ 378 (77%)	23 762/ 30 519 (78%)	2774/ 3212 (86%)	4401/ 5483 (80%)	188/ 263 (71%)	859/ 1159 (74%)	205/ 329 (62%)	5838/ 8007 (73%)	607/ 728 (83%)	1889/ 2350 (80%)	1183/ 1389 (85%)	51 414/ 65 306 (79%)
Incidence	10 876/ 13 256 (82%)	313/ 405 (77%)	26 850/ 34 313 (78%)	3026/ 3515 (86%)	4723/ 5869 (80%)	269/ 384 (70%)	887/ 1196 (74%)	228/ 366 (62%)	6375/ 8733 (73%)	644/ 772 (83%)	2031/ 2524 (80%)	1285/ 1511 (85%)	57 507/ 72 845 (79%)
Direct medical cost, millions $	$770·0/ $937·1 (82%)	$8·9/ $11·5 (78%)	$686·3/ $871·2 (79%)	$218·9/ $256·0 (86%)	$146·2/ $180·5 (81%)	$25·3/ $36·2 (70%)	$38·0/ $51·7 (76%)	$4·2/ $6·8 (62%)	$303·0/ $414·4 (73%)	$17·3/ $20·8 (74%)	$97·4/ $121·0 (81%)	$155·7/ $177·3 (73%)	$2471·3/ $3084·5 (80%)
Other cancers†													
Deaths	6815/ 21 689 (31%)	516/ 2574 (20%)	26 651/ 79 405 (33%)	3388/ 9842 (34%)	4511/ 16 769 (27%)	296/ 1420 (21%)	1261/ 5456 (23%)	287/ 1833 (16%)	5931/ 28 206 (21%)	484/ 1669 (29%)	2204/ 9253 (24%)	940/ 2572 (36%)	53 284/ 180 688 (29%)
Incidence	11 961/ 36 993 (32%)	1003/ 4631 (21%)	46 650/ 134 242 (35%)	4986/ 14 328 (35%)	7790/ 27 723 (28%)	486/ 2290 (21%)	1832/ 7736 (24%)	414/ 2604 (16%)	11 461/ 50 628 (22%)	766/ 2585 (30%)	3385/ 14 921 (22%)	1314/ 3676 (36%)	92 048/ 302 359 (30%)
Direct medical cost, millions $	$658·4/ $1932·0 (32%)	$24·7/ $115·8 (21%)	$1201·7/ $3498·2 (35%)	$283·0/ $846·8 (37%)	$211·6/ $783·8 (27%)	$40·2/ $188·0 (21%)	$64·0/ $271·5 (25%)	$6·7/ $42·6 (16%)	$472·6/ $1837·0 (22%)	$20·6/ $73·3 (31%)	$146·7/ $601·6 (24%)	$114·7/ $317·2 (36%)	$3244·9/ $10 707·9 (30%)
Second-hand smoking and other causes†													
Deaths	5605 (100%)	515 (100%)	17 972 (100%)	2270 (100%)	3692 (100%)	201 (100%)	897 (100%)	176 (100%)	5659 (100%)	386 (100%)	1808 (100%)	553 (100%)	39 734 (100%)
Direct medical cost, millions $	$439·1 (100%)	$28·7 (100%)	$1361·0 (100%)	$218·8 (100%)	$196·6 (100%)	$27·8 (100%)	$55·0 (100%)	$6·5 (100%)	$548·5 (100%)	$34·6 (100%)	$91·6 (100%)	$92·2 (100%)	$3100·4 (100%)

Data are n/N (%) or cost/total cost (%) except where otherwise stated. All costs are in 2015 US dollars. COPD=chronic obstructive pulmonary disease. *Proportions in parentheses are deaths attributable to tobacco as a proportion of total deaths in the population 35 years and older. †Proportions in parentheses are deaths, events, or costs attributable to tobacco as a proportion of total deaths, events, or costs in each condition that are attributable to smoking (eg, deaths caused by cardiovascular disease: 11 127 (13%) means that there are 11 127 deaths from cardiovascular disease attributable to smoking, which represent 13% of the total deaths caused by that condition). ‡Years of life lost due to premature mortality and quality of life lost attributable to tobacco; the proportion that is attributable to premature mortality is indicated within the parentheses.

***Table 2*: Annual burden of mortality, disease incidence, and direct medical costs attributable to tobacco, by cause and country for 2015**

Results

Epidemiological and economic data were obtained for each country for Jan 1 to Dec 31, 2015. The main parameters included in the model are shown in table 1 and in the appendix (p 1). After the model was calibrated, the mean rate of each disease-specific mortality predicted by the model was within 10% of the corresponding mortality reported by national statistics in each country (correlation between the observed and expected results yielded R^2 values ranging from 0·700 to 0·999). External validation also showed a good correlation between the results predicted by the model and those observed in epidemiological studies. The results of the calibration and validation process in Argentina are shown in the appendix (p 5).

In total, in the 12 countries included in this study, smoking is estimated to cause 345 373 (12%) of the total 2 860 921 adult deaths, 2·21 million disease events, 8 774 402 healthy years of life lost because of premature mortality and disability, and US$26·9 billion in direct medical costs every year (table 2). We estimated that cancer, COPD, and cardiovascular disease attributable to smoking caused the largest burden in terms of both lost health and medical costs. Tobacco use was responsible for an estimated 51 414 (79%) of 65 306 deaths and $2471·3 million (80%) of $3084·5 million in medical costs due to lung cancer, 76 730 (74%) of 103 142 deaths and $8640·0 million (72%) of $12 028·9 million in medical costs due to COPD, and 76 896 (16%) of 494 755 deaths and $7612·3 million (22%) of $33 961·2 million in medical costs due to cardiovascular disease (table 2).

In Chile, the country with the highest smoking prevalence, 19 731 (18%) of 107 545 deaths among adults were estimated to be related to smoking (the largest proportion of all of the 12 countries); the direct medical cost of smoking was estimated to be about US$1·9 billion. Brazil, the country with the largest population in the group, showed the largest estimated absolute number of deaths and costs attributable to tobacco with 156 217 annual deaths and a cost of approximately $11·8 billion, followed by Mexico with 49 189 smoking-related deaths and approximately $4·8 billion in costs. COPD was the single disease that caused the highest estimated proportion of smoking-related deaths (table 2). In the 12 countries combined, COPD was estimated to cause more than 76 000 smoking-related deaths and approximately $8·7 billion in costs. All cancers combined, including lung cancer, accounted for an estimated 104 000 deaths and $5·7 billion in costs in all countries.

Health-care costs attributable to smoking represented an estimated 6·9% of the health budgets of these 12 countries, ranging from 3·5% in Honduras to 16·7% in Uruguay; these health-care costs represented a mean of 0·6% of gross domestic product, ranging from 0·3% in Honduras to 1·5% in Uruguay. None of the countries recover through tobacco taxes the total of the resources allocated to treat smoking-attributable diseases; we estimated that tax revenues from cigarette sales cover 36·0% of health expenditures attributable to smoking across all 12 countries. We estimated that Bolivia recovers 6·0% of the expenses and that Chile, with the highest tobacco taxes in the region, recovers 78·9% of the health costs attributable to tobacco (table 3).

We estimated that a 50% increase in the price of cigarettes through taxes in the 12 Latin American countries analysed could produce substantial health and economic benefits in the next 10 years. In these 12 countries, we estimated that this price increase would lead to the aversion of 314 314 deaths, and approximately 1·27 million cardiovascular, cerebrovascular, and cancer events (table 4). We also estimated that this tax policy would result in gaining almost 8·67 million healthy life years by averting premature death and disability. Approximately $23·4 billion would be saved in health-care costs, and tax revenues could increase by approximately $35·1 billion, resulting in a total estimated economic benefit of $58·6 billion.

The health and economic effects of a price increase of tobacco in each country depend on several factors, such as the prevalence of smoking, the current level of taxes, the elasticity of demand, and health-care costs. The figure shows the expected health and economic gains from a 50% increase in tobacco price in each country over 10 years. The health benefits are expressed as deaths avoided as a proportion of the current number of deaths that are attributable to smoking in each country; the economic benefits due to a reduction of health-care costs and increased tax collection are expressed as a proportion

	Smoking-attributable annual direct medical costs			Proportion of direct medical costs recovered through tobacco taxes
	Total costs, $	As a proportion of total health expenditure	As a proportion of GDP	
Argentina	$3 817 334 778	7·3%	0·6%	55·3%
Bolivia	$249 794 501	11·8%	0·8%	6·0%
Brazil	$11 830 140 911	5·7%	0·7%	25·6%
Chile	$1 901 333 725	9·4%	0·8%	78·9%
Colombia	$1 708 544 794	9·7%	0·6%	10·2%
Costa Rica	$241 569 268	5·7%	0·4%	26·1%
Ecuador	$476 043 817	5·6%	0·5%	41·0%
Honduras	$56 355 353	3·5%	0·3%	51·5%
Mexico	$4 767 757 221	8·0%	0·4%	46·9%
Paraguay	$301 307 227	10·7%	0·8%	20·2%
Peru	$796 045 581	8·0%	0·4%	9·2%
Uruguay	$800 146 359	16·7%	1·5%	26·4%
All 12 countries	$26 946 373 535	6·9%	0·6%	36·0%

All costs are in 2015 US dollars. GDP, total health expenditure as a proportion of GDP, and total tobacco tax revenue for each country are shown in table 1. GDP=gross domestic product.

Table 3: **Proportion of total health expenditures and GDP represented by smoking-attributable direct medical costs and proportion recovered through tobacco taxes in 2015**

	Health effect					Economic effect		
	Deaths averted	Healthy life-years lost averted*	Coronary heart disease events averted	Stroke events averted	Cancer events averted	Health-care costs savings, millions $	Increased tax revenue, millions $	Total economic benefit, millions $
Argentina	27 469	660 323	43 505	15 761	12 691	$2266	$9738	$12 004
Bolivia	10 868	279 060	6330	11 960	3141	$655	$43	$699
Brazil	136 482	4 076 353	507 451	100 365	64 383	$9761	$10 640	$20 401
Chile	20 502	536 701	25 794	23 996	8273	$2052	$3749	$5801
Colombia	45 049	1 173 703	142 162	62 967	17 401	$2554	$393	$2948
Costa Rica	1698	42 592	6847	787	726	$237	$209	$446
Ecuador	4946	133 607	3321	4221	1726	$294	$801	$1094
Honduras	1306	33 692	2992	416	587	$50	$238	$289
Mexico	38 358	1 047 689	99 066	24 113	14 418	$3502	$8138	$11 640
Paraguay	2507	67 537	7383	2112	1056	$221	$252	$473
Peru	20 588	505 153	12 482	19 343	7433	$1067	$344	$1411
Uruguay	4541	108 751	7485	1345	2652	$788	$586	$1374
Total	314 314	8 665 161	864 818	267 386	134 487	$23 448	$35 131	$58 580

All economic effects are in 2015 US dollars. *Healthy life-years lost averted are those that would have been lost because of premature mortality or quality of life losses.

Table 4: **Projected 10-year accumulated health and economic effect of a 50% price increase of cigarettes through taxes**

of the country's gross domestic product. In the long term, a 50% price increase of tobacco could prevent between 7·6% (Argentina) and 32·4% (Bolivia) of all deaths currently attributable to smoking per year and could produce economic gains equivalent to 0·09% of gross domestic product in Peru, to up to 0·31% of gross domestic product in Uruguay. In some countries, these economic benefits would be produced mainly by avoided health-care costs (eg, in Bolivia, Colombia, and Peru) and in others, by increased tax collection (eg, in Argentina, Honduras, and Mexico).

Discussion

To the best of our knowledge, this is the first study to analyse the disease burden of smoking in Latin America with an economic model developed in the region. Our findings show that smoking represents a substantial health and economic burden in 12 countries in Latin America, with more than 345 000 deaths, 2·2 million disease events, and $26·9 billion in medical costs that are estimated to be directly attributable to tobacco every year. Tax collections from tobacco products are barely enough to cover a third of these costs.

Taxation can be an effective strategy to reduce smoking, improve population health, and reduce health-care costs. According to our estimations, an increase of just 50% in the price of cigarettes through taxation, which is feasible in the region given the low prevailing prices, would prevent more than 300 000 deaths and more than 1 million cardiovascular events, strokes, and cancers, and would reduce health-care costs and increase tax revenues, leading to a total economic benefit of $58·6 billion over 10 years.

Our findings are consistent with previous studies in terms of both the estimation of the overall burden of tobacco and the potential reduction of this burden through taxation. Smoking is a leading risk factor for early death and disability in more than 100 countries and is responsible for 11·5% of deaths and 6·0% of disability-adjusted life-years worldwide.[31] Previous studies have estimated that health-care expenditures due to smoking-attributable diseases totalled 5·7% of global health expenditures in 2012.[4] It has been suggested that if cigarette prices increased 50% worldwide, approximately 20 million people could avoid poverty, millions of premature deaths could be prevented, and extra tobacco revenue could partly finance health care.[32]

A simulation model applied to 181 countries showed that a 43% increase in the retail price of cigarettes through taxes would lead to 15 million fewer smoking-attributable deaths among the adults who were alive in 2014, and cigarette excise revenue would increase by 47%.[33] In the EU, if all countries charged higher taxes, consumption of tobacco would be reduced, and revenue would be increased by an average of 6·76% with a 10% price increase.[34]

Previous studies have analysed the potential effect of a price increase on cigarette consumption in Latin America. In Colombia, one such study estimated that a 50% increase in the price of cigarettes, bringing it closer to the regional average, could result in a 31% decrease in consumption.[26] In Mexico, the SimSmoke model estimated that increasing excise taxes to 70% of the price could reduce the smoking prevalence by 16%, and in Argentina, it was estimated that an 80% price increase would reduce smoking prevalence by 20% within 30 years.[35,36]

A limitation of our study is that, although it offers a robust estimate of the health and financial burden of smoking using the best available information in each country and applying a uniform and replicable method,

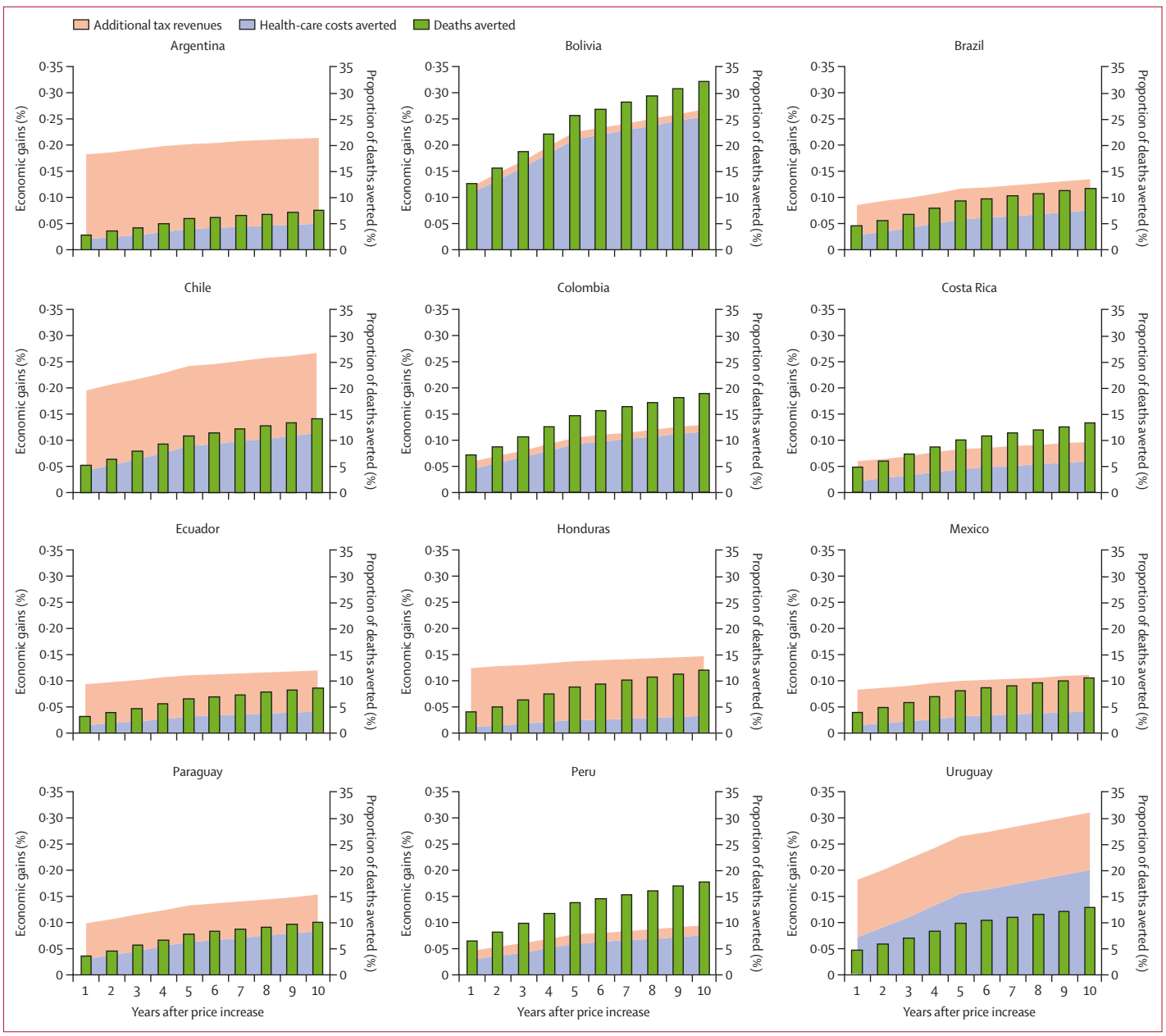

Figure: **Estimated proportion of deaths averted and economic benefits during the 10 years after a 50% increase in the price of cigarettes in 12 Latin American countries**
In each country, deaths averted are expressed as a proportion of current total tobacco-attributable deaths. Economic gains (due to increased tax revenues and reduction of direct medical costs) are expressed as a proportion of the GDP of each country. GDP=gross domestic product.

our results are highly dependent on the quality of information in each country. The availability and quality of epidemiological and cost information in Latin America is very variable and, in some countries, even basic data such as mortality statistics can be imprecise. Similar to all model-based studies, there is also uncertainty around many of the model's assumptions. For example, many changes could happen in the future that would affect the 10-year benefit estimate (eg, changes in smoking behaviours, emergence of new treatments, changes in health-care costs). Despite these limitations, both the burden attributable to smoking and the benefits of tobacco tax increases evidenced by our study are probably conservative estimates. Our analysis considered only the direct medical costs generated by tobacco consumption, which are only a portion of the total financial burden imposed by smoking on countries. Several studies have shown that the financial burden of smoking could be double or triple the estimates based on direct medical costs if the

cost of lost productivity and other social costs are also considered.[4,37,38] Results obtained using our model showed that in Brazil, when a conservative estimate of the productivity losses caused by tobacco was included in the analysis, the estimate of the economic burden of smoking increased by 50%, from 39·4 billion to 59·1 billion Brazilian Reais per year.[39] Another important limitation is that our model did not include the effects of passive smoking, perinatal effects, or other effects (such as losses from fires), although we did include an estimation of the effect of these factors based on estimates from other studies. For all these reasons, although our study is more comprehensive than most of the analyses that had been done so far in Latin America, our estimates of the potential benefits of higher tobacco taxes are probably an underestimation.

Although taxation could be the best strategy to curb the use of tobacco, many countries are lagging behind the level of taxation recommended by WHO. Cigarettes remain affordable, and prices are manipulated by the tobacco industry to ameliorate the effects of excise tax on smokers. Our results show that tobacco tax increases could successfully avert deaths and disability, as well as substantially reduce spending on health care, resulting in large net economic benefits in these 12 Latin American countries.

Contributors

AP-R, AB, and AA planned the study. AP-R, AB, and AP developed the method. BR, LMR-S, MP, MC-R, EPT, DIO, LH, CLM, BSdM-J, VG-R, CDLP, MdPN-B, and SAV obtained data. AP-R, AA, AP, BR, JC, SAV, FA, and AB did the analyses. All authors contributed to the interpretation of the data. AP-R, AA, AB, and JR drafted the manuscript. AP-R, AA, AB, and JR critically reviewed the manuscript. All authors reviewed the final version.

Declaration of interests

We declare no competing interests.

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