The consequences of tobacco tax on household health and finances in rich and poor smokers in China: an extended cost-effectiveness analysis

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Summary

Background In China, there are more than 300 million male smokers. Tobacco taxation reduces smoking-related premature deaths and increases government revenues, but has been criticised for disproportionately affecting poorer people. We assess the distributional consequences (across different wealth quintiles) of a specific excise tax on cigarettes in China in terms of both financial and health outcomes.

Methods We use extended cost-effectiveness analysis methods to estimate, across income quintiles, the health benefits (years of life gained), the additional tax revenues raised, the net financial consequences for households, and the financial risk protection provided to households, that would be caused by a 50% increase in tobacco price through excise tax fully passed onto tobacco consumers. For our modelling analysis, we used plausible values for key parameters, including an average price elasticity of demand for tobacco of –0·38, which is assumed to vary from –0·64 in the poorest quintile to –0·12 in the richest, and we considered only the male population, which constitutes the overwhelming majority of smokers in China.

Findings Our modelling analysis showed that a 50% increase in tobacco price through excise tax would lead to 231 million years of life gained (95% uncertainty range 194–268 million) over 50 years (a third of which would be gained in the lowest income quintile), a gain of US$703 billion ($616–781 billion) of additional tax revenues from the excise tax (14% of which would come from the lowest income quintile, compared with 24% from the highest income quintile). The excise tax would increase overall household expenditures on tobacco by $376 billion ($232–505 billion), but decrease these expenditures by $21 billion (–$83 to $5 billion) in the lowest income quintile, and would reduce expenditures on tobacco-related disease by $24·0 billion ($17·3–26·3 billion, 28% of which would benefit the lowest income quintile). Finally, it would provide financial risk protection worth $1·8 billion ($1·2–2·3 billion), mainly concentrated (74%) in the lowest income quintile.

Interpretation Increased tobacco taxation can be a pro-poor policy instrument that brings substantial health and financial benefits to households in China.

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Introduction

Many low-income and middle-income countries, such as China, have undergone an epidemiological transition from communicable to non-communicable diseases in recent years, which imposes a growing economic burden on these nations.[1,2] Tobacco use is a leading modifiable risk factor for non-communicable diseases, and in 2010 there were an estimated 5 million premature deaths attributable to smoking worldwide.[3] Asia has the highest number of tobacco users and is the prime target of tobacco companies.[4,5] Health behavioural changes have accelerated rapidly in China, including increasingly higher numbers of cigarettes smoked in the already very large male smoker population.[6] Furthermore, the prevalence of smoking in women is still relatively low.[7] In 2010, 1 million premature deaths were attributable to smoking in China, and the three leading causes of death (stroke, ischaemic heart disease, and chronic obstructive pulmonary disease) were linked to tobacco consumption.[8,9]

Tobacco taxation is widely recognised as very effective at reducing smoking, its attributable morbidity and mortality,[10] and subsequently the burden of non-communicable diseases.[3,11] Additionally, it provides revenues and potential for redistributive health financing.[4,12,13] Tax comprises about two-thirds of the retail price of cigarettes in most high-income countries but less than half of the total price in most low-income and middle-income countries such as China, which indicates that there is potential room for taxation as a fiscal and health policy instrument.[10,12,14–18]

Although tobacco taxation is a cornerstone of the WHO Framework Convention on Tobacco Control,[19] which was ratified by China in 2005, some controversy exists because

Research in context

Evidence before this study

We did a search of PubMed using the search terms "China", "tobacco", "taxation", "impact", "socio-economic", "economic evaluation", "modeling", "income inequality", "youth", and "demand" in various combinations. We did not use any language or date restrictions. We did the same search on Google Scholar. We searched resources from relevant websites, especially from WHO and the International Agency for Research on Cancer. We also consulted with experts in the specialty.

Tobacco smoking is responsible for 5 million premature deaths worldwide. China has the highest number of tobacco users (>300 million) and is a prime target of tobacco companies. The deleterious health and economic consequences of smoking have been increasingly assessed and include modelling studies to identify suitable interventions. Tobacco taxation is widely recognised to be very effective at reducing tobacco use and initiation, and it provides financial revenues and potential for redistributive health financing. Tax comprises about two-thirds of the retail price of cigarettes in most high-income countries but less than half of the price in China, which indicates that there is potential room for taxation as a fiscal and health policy instrument. Few studies have assessed the distributional consequences of increased excise tobacco taxes in Asian economies, although the health and economic benefits of such a policy could be substantial.

Added value of this study

In this study, we used a unified analytical framework of extended cost-effectiveness analysis (ECEA) that models the distributional consequences (across income quintiles) in China of an increase in tobacco price of 50% through excise tax in terms of the health benefits (premature deaths averted), the additional tax revenues raised from excise tax, the net financial consequences for households, and the financial risk protection provided to households. We estimate substantial health gains, and find that reductions would occur in expenditures on tobacco-related disease, and financial risk protection from higher tobacco taxation; these benefits would disproportionally favour the lower-income population quintiles. We conclude that higher tobacco taxation can be a pro-poor policy device that brings substantial health and financial benefits to households in China.

Implications of all the available evidence

Higher tobacco taxes in China can reduce a substantial proportion of the global burden of smoking-related morbidity and mortality. Since tobacco use is a strong risk factor for many non-communicable diseases, for which health policy is still formulating in low-income and middle-income countries, large and immediate tax increases could have far-reaching health benefits, lower health care costs, and reduced disparities in health and economic outcomes, especially for the poorest populations. The estimation of financial risk protection of tobacco control policy is an especially fertile topic for further studies when considered in conjunction with the movement towards universal health-care coverage, which is gathering strong momentum in many countries.

of the potential regressivity of excise taxes such as those for tobacco. This regressivity is caused by the fact that poor people already spend a larger proportion of their income on smoking than do their wealthy counterparts, and taxes paid by the poor would constitute a larger proportion of their income than that of the rich,[20] which is a source of concern to policy makers.[21] Although a given tobacco tax could be viewed as progressive depending on the specific methods used to assess the tax burden and the data source used,[22] most researchers conclude that tobacco taxes exert a negative distributional effect. However, poor people are substantially more responsive to price changes than are their wealthy counterparts, which means that their consumption and tax burden could be lower,[21,23–25] and therefore policy might reduce regressivity.

The effect of tobacco taxation should also be considered alongside the fact that tobacco and tobacco-related disease expenditures exacerbate the effects of poverty. Excessive medical spending attributable to smoking and consumption spending on cigarettes combined were estimated to impoverish 55 million Chinese people in the late 1990s.[26] Smoking could also contribute to cycles of impoverishment if expenditures on education are displaced by those on smoking.[27–30]

In 2009, China launched a US$125 billion 3-year health reform plan, the goals of which included achievement of universal health coverage and prevention of medical impoverishment.[31] Since then, impressive progress has been made in provision of health insurance coverage, resulting in narrowing of the health care access gap between poorer and richer individuals. However, in one important area—financial risk protection—advances still need to be made because insurance covers only about 50% of inpatient costs and 30–40% of outpatient costs.[31,32] In 2011, the poorest quartile of households in China had about twice as much catastrophic expenditure on health as those in the wealthiest quartile.[33]

Little work has studied the distributional consequences of increased tobacco taxation, although the health and economic benefits of such a policy could be substantial in Asian economies.[4] Previous studies have assessed the policy outcomes including health benefits, health-care costs, regressivity, and financial risk protection separately and with different analytical devices. Here, we use the analytical method of extended cost-effectiveness analysis (ECEA)[34] that can provide insights into these questions simultaneously in a unified model. We apply ECEA[34–36] to a hypothetical excise tax that would raise the retail price

of cigarettes by 50% in China. In the Chinese male smoking population, we estimate the distributional consequences (across income quintiles) of this hypothetical excise tax in terms of: health benefits (years of life gained); additional tax revenues raised from the excise tax; net change in expenditures on both tobacco products and tobacco-related disease (eg, stroke) treatment; and the financial risk protection provided to households by avoiding impoverishing health-care expenditures.

Methods

Model

Our modelling approach draws substantially from the Asian Development Bank's framework[4] that estimates the effect of taxation-created cigarette price shocks. It accounts for price responsiveness across age and socioeconomic groups to compare the tax burden and health gains in each stratum based on existing and projected numbers of future smokers.[4] Since Chinese men comprise the vast majority (96%) of smokers in the country (53% of men are smokers *vs* 2% of women[37]), this study focuses solely on the male population, which we model for 50 years. The population is replenished as older individuals die. The population is divided into five age groups of smokers: those younger than 15 years of age (representing potential future smokers); 15–24-year-olds; 25–44-year-olds; 45–64-year-olds; and those older than 65 years. These groups are further divided into income quintiles. Specifically, these quintiles were defined from four income cutoff values dividing the population into five groups (table 1).

We simulate a one-time excise tax fully passed onto consumers that results in the retail price of a pack of cigarettes increasing by 50%. We use a pre-increase tax rate (41% or US$0·30) and cigarette pack price (US$0·74) extracted from MPOWER 2011,[39] to capture an average tax and price per pack purchased. Many different cigarette brands with a wide price range are available in China.[15,56–58] Hence, any tax increase will only benefit poor people if designed to reduce the so-called switching down effect to cheaper cigarette brands.[3,4,10]

The introduction of the excise tax has five main consequences: it reduces the number of premature deaths and associated years of life lost because of tobacco through induced smoking cessation; it brings excise tax revenues as tobacco price increases and cigarette consumption changes; it affects the household expenditures on tobacco depending on the tobacco price increase and cigarette consumption changes; it decreases expenditures on the treatment of tobacco-related disease as a consequence of the reduction in tobacco-related disease burden; and it brings financial risk protection to households by preventing medical expenditures related to the treatment of tobacco-related disease.

First, we estimate the years of life gained as a consequence of the price increase, solely among those who quit. We assume no health benefits would arise from reduced consumption caused by price changes among continuing smokers. Upon quitting, smokers gain a particular number of years of life, depending on their age

	Value	Data source
Size of male population in China	677 million	UN data;[38] authors' assumptions
Age group (years)		UN data[38]
<15	18%	
15–24	17%	
25–44	33%	
45–64	24%	
≥65	8%	
Smoking prevalence per age group (%)		Asian Development Bank[4] and WHO[37]
15–24	34%	
25–44	59%	
45–64	63%	
≥65	40%	
Relative smoking prevalence per income quintile		Authors' assumptions based on education levels in references[4,37]
Income quintiles 1–4	1·14-times average per age group	
Income quintile 5 (richest)	0·86-times average per age group	
Cigarette consumption (cigarettes per day) per income quintile		Authors' assumptions based on education levels in references[4,37]
Income quintile 1 (poorest)	15·6	
Income quintile 2	15·5	
Income quintile 3	13·8	
Income quintile 4	12·7	
Income quintile 5 (richest)	12·7	
Price per pack of 20 cigarettes (2011 US$)	$0·74 (before excise tax increase), $1·11 (after excise tax increase)	Asian Development Bank[4] and WHO[39]
Price elasticity of demand for cigarette per income group		See table 3
Distribution of tobacco-related disease mortality, by cause (%)		Global Burden of Disease Study 2010[9]
Chronic obstructive pulmonary disease	11%	
Stroke	46%	
Heart disease	23%	
Neoplasm	20%	
Years of life gained upon tobacco cessation, per age group		Authors' assumptions based on Asian Development Bank data,[4] Doll et al,[40] and Jha et al[41]
15–24 year-olds	10 years	
25–44 year-olds	9 years	
45–64 year-olds	6 years	
≥65 year-olds	3 years	
Tobacco-related disease treatment costs (2011 US$)		Based on several studies[42–50]
Chronic obstructive pulmonary disease	$2078	
Stroke	$2024	
Heart disease	$10 845	
Neoplasm	$13 626*	

(Table 1 continues on next page)

	Value	Data source
(Continued from previous page)		
Use of health care by tobacco-related disease (%)		Based on several studies[51-53] and authors' assumptions
Chronic obstructive pulmonary disease	33%	
Stroke	80%	
Heart disease	81%	
Neoplasm	50%	
Relative use of health care per income quintile		Authors' assumptions based on reference[54]
Income quintile 1 (poorest)	0·79-times average	
Income quintile 2	0·98-times averages	
Income quintile 3	1·00-times average	
Income quintile 4	1·08-times average	
Income quintile 5 (richest)	1·15-times average	
Fraction of health care costs reimbursed by insurance schemes (%)	50%	Authors' assumptions based on Yip et al[31]
Individual annual income (2011 US$)		Income distribution based on gross national income per person of $4940 and Gini coefficient of 0·42[42,55]
Income quintile 1 (poorest)	<$1652	
Income quintile 2	$1652–3075	
Income quintile 3	$3075–4850	
Income quintile 4	$4850–7645	
Income quintile 5 (richest)	>$7645	

*Note that although many neoplasms are affected by smoking (eg, oesophageal, mouth, trachea, bronchial, and lung cancers), for simplicity, we associate here neoplasm treatment cost with lung cancer treatment cost because of the significance of lung cancers among neoplasms affected by smoking and data availability.

***Table 1*: Inputs used in the modelling for the tobacco excise tax increase (50% retail price increase) in China**

	Total	Income quintile 1	Income quintile 2	Income quintile 3	Income quintile 4	Income quintile 5
≥65-year-olds	24	5	5	5	5	4
45–64-year-olds	97	20	20	20	20	17
25–44-year-olds	142	30	30	30	30	22
15–24-year-olds	43	9	9	9	9	7
Future smokers (ie, <15-year-olds)	43	9	9	9	9	7

***Table 2*: Assumed number of smokers (in millions) by age group and income quintile, before excise tax increase**

	Average	Income quintile 1	Income quintile 2	Income quintile 3	Income quintile 4	Income quintile 5
≥65-year-olds	–0·38	–0·64	–0·51	–0·38	–0·25	–0·12
45–64-year-olds	–0·38	–0·64	–0·51	–0·38	–0·25	–0·12
25–44-year-olds	–0·38	–0·64	–0·51	–0·38	–0·25	–0·12
15–24-year-olds	–0·76	–1·28	–1·02	–0·76	–0·50	–0·24
Future smokers (ie, <15-year-olds)	–0·76	–1·28	–1·02	–0·76	–0·50	–0·24

These values are the authors' assumptions based on several studies.[4,10,58,61] A price elasticity of –0·38 equals a 38% fall in demand for every 100% increase in price.

***Table 3*: Assumed price elasticity of demand for cigarette by age group and income quintile**

at cessation.[40] We express years of life gained as a function of age *a* at cessation. At present, China's mean male life expectancy is 71 years,[59] and the number of years of life gained is assumed to be realised 71–*a* after cessation. The number of quitters at age *a* is related to the participation elasticity, which is assumed to be half of the total price elasticity of demand for tobacco. In other words, we assume that half of price increases affects smoking rates (participation elasticity), and the other half affects the consumption of non-quitters. This proportion is consistently represented in findings and assumptions from studies over 25 years.[10,25,60,61] The total price elasticity (hereafter referred to as the price elasticity) refers to the change in number of cigarettes purchased by a population when price changes, owing to both outright quitting and reduced consumption of cigarettes. The change in smoking-related premature mortality is the product of the change in price increase, the price elasticity, the net effect of half this price change on smoking prevalence, and the life-years gained in those who quit depending on their age at quitting. The future smoking prevalence of those currently younger than 15 years of age is assumed to be the current prevalence rate for those aged 15–24 years. The model assumes that no additional smoking initiation occurs in those aged 15 years and older. This approach is conservative because the prevalence for those 15–24 years old is likely to rise in view of the peak for those aged 25–44 years.[62] Additionally, we assume that the price elasticity is twice as large in young populations (15–24-year-olds and future smokers [ie, those <15 years old]) than in older smokers.[4,10,61] Young smokers are generally believed to be more price responsive than older smokers because compared with older smokers they have less disposable income, lower addiction levels, and are more responsive to peer pressure.[63,64] Recent reviews[10,61] assessing tobacco use in youths showed that they can be two to three times more responsive to price than older people, with estimated price elasticities between –0·50 and –1·20 (where –0·5 and –1·20 equal a 0·5% and 1·20% fall in demand for every 1% increase in price) in most high-income countries. Although little research has been done on youth smoking in low-income and middle-income countries, similar conclusions generally apply.[10] As a case in point, results from the Global Youth Tobacco Survey[65] suggest that the price elasticity might be –1·8[66] or even –2·2.[67]

Second, we estimate the additional tax revenues raised from the excise tax. The annual change is related to the change in cigarette consumption (which in turn is related to price elasticity), the change in excise taxes per pack (from US$0·30 to $0·67 here), and the number of smokers in a particular age group. Similarly, we estimate the net change in expenditures on tobacco, related to price elasticity, the change of price per pack (from $0·74 to $1·11), and the number of smokers in a given age group.

Third, we estimate the net change in expenditures on treatment of tobacco-related disease, following the reduced number of tobacco-related premature deaths.

The number of premature deaths averted is estimated on the basis of the assumption that about 50% of smokers die of smoking-related illness and that this risk is reduced upon quitting by 97% in 15–24-year-olds, 85% in 25–44-year-olds, 75% in 45–64-year-olds, and 25% in those older than 65 years.[4,40,41] The Global Burden of Disease Study 2010 classifies deaths caused by tobacco smoking as a risk factor among 20 possible disease outcomes (appendix),[68] which are aggregated into the following four largest tobacco-related causes of death in China: stroke, ischaemic heart disease, chronic obstructive pulmonary disease, and neoplasms.[9] Subsequently, we attribute the share of the premature deaths averted from these four causes. Based on these causes, and accounting for the proportion of people who will seek formal health-care treatment (health-care use), we assign treatment-related costs, to which we deduce the share reimbursed by insurance. Although many neoplasms are affected by smoking (eg, oesophageal, mouth, trachea, bronchus, and lung cancers), for simplicity, we associate neoplasm treatment cost with lung cancer treatment cost due to the significance of lung cancers in neoplasms affected by smoking and data availability.

Finally, we quantify the financial risk protection provided to the households related to the reduction in the risk of expenditures on the treatment of tobacco-related disease. We use a money-metric value of insurance as our financial risk protection metric, which has been described elsewhere[34] and is detailed in the appendix. The results are then aggregated by income quintile. Complete details of the model are given in the appendix. We used R statistical software (R 3.1.0) for all statistical analyses.

Model parameters

Tables 1–3 present all model key inputs. When relevant and where available data allow, parameter values vary by income quintile. For example, smoking prevalence and intensity (cigarettes per day) increase marginally as income quintile decreases.[4,37] For simplicity and in view of the difficulty in extrapolating outcomes for the future in rapidly evolving China, we assume no price increases and no changes in household incomes and socioeconomic status over time after the one-time tobacco price increase.

One key driver of the analysis is the price elasticity by income quintile. Estimated Chinese price elasticities range from –0·01 to –0·84[15,58,69–76] owing to variations in datasets and estimation methods, and as reviewed by Hu and colleagues[15,58] can be classified into: high-end elasticities (around –0·80) as obtained from two time series and often cited for developing countries;[10,61] middle-range elasticities (between –0·50 and –0·60), as estimated in half of studies and often cited for middle-income and high-income countries;[10,61] and low-end elasticities (lower than –0·15), as estimated from recent studies.[15,58] The latter elasticities could be explained by the wide price variation (more than ten-fold) across cigarettes, which enables smokers to switch to cheaper cigarettes without quitting, and the rising affordability of cigarettes concomitant to the rapidly growing economy.[15,56,58] In our analysis, we use –0·38 as our price elasticity, which corresponds to the mean elasticity from all studies reviewed by Hu and colleagues.[15,58] In general, poorer populations, whether within a country or between countries, have higher price elasticities than do wealthier ones.[10] We assume that the poorest income quintile is the most price elastic; the other quintiles are progressively less price elastic (based on data from Hu and colleagues[58]).

	Total	Income quintile 1	Income quintile 2	Income quintile 3	Income quintile 4	Income quintile 5
Years of life gained (millions)	231 (194–268)	79 (61 to 96)	63 (45 to 80)	47 (30–65)	31 (16–51)	11 (2–27)
Additional tax revenues raised from excise tax						
2011 US$ billion	703 (616–781)	98 (60 to 142)	134 (93 to 175)	152 (114–187)	170 (134–200)	149 (119–167)
% of individual income	..	3·87%	2·10%	1·43%	1·03%	0·65%
Change in expenditures on tobacco						
2011 US$ billion	376 (232–505)	–21* (–83 to 52)	40 (–27 to 107)	89 (27–147)	132 (73–182)	135 (86–164)
% of individual income	..	–0·82%	0·63%	0·84%	0·80%	0·59%
Expenditures on tobacco-related disease treatment averted						
2011 US$ billion	24·0 (17·3–26·3)	6·6 (4·9 to 8·6)	6·9 (3·9 to 7·5)	5·3 (2·7–6·1)	3·7 (1·7–5·9)	1·5 (0·3–3·3)
% of individual income	..	0·26%	0·11%	0·05%	0·02%	<0·01%
Financial risk protection afforded† (2011 US$ billion)	1·8 (1·2–2·3)	1·3 (0·8–1·8)	0·3 (0·1 to 0·4)	0·1 (0·06–0·2)	0·1 (0·02–0·1)	<0·1 (0·00–0·03)

95% uncertainty ranges are indicated in parentheses. *A negative value implies expenditures on tobacco averted. †Measured by a money-metric value of insurance.

Table 4: **Cumulative results for the tobacco excise tax increase (50% retail price increase) in China, after 50 years**

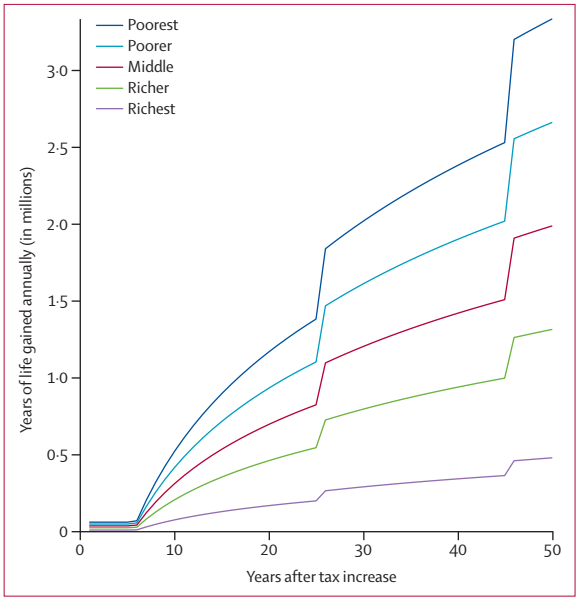

Figure 1: **Annual years of life gained for the tobacco excise tax increase (50% retail price increase) in China, over 50 years, by income quintile**

See **Online** for appendix

For **R statistical software** see www.r-project.org

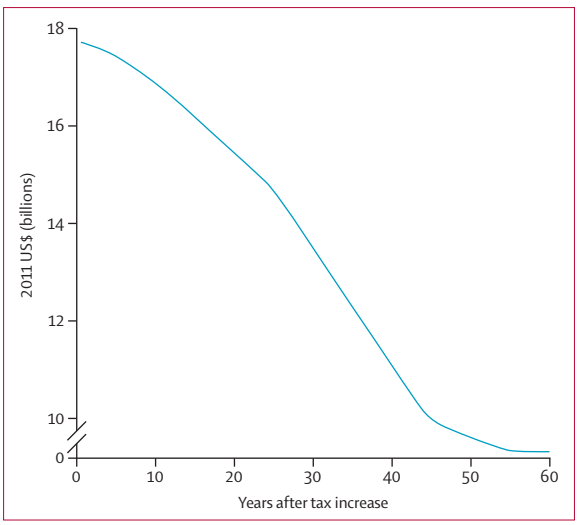

Figure 2: **Additional tax revenues raised by the tobacco excise tax increase (50% retail price increase) in China, annually, over 60 years**

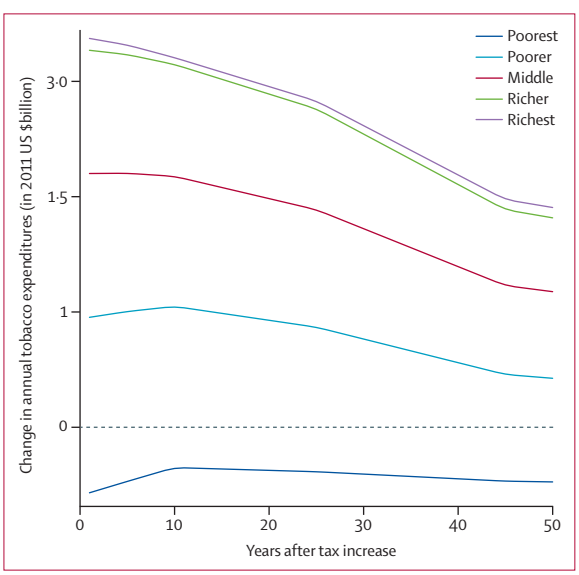

Figure 3: **Annual change in expenditures on tobacco, with the tobacco excise tax increase (50% retail price increase) in China, over 50 years, by income quintile**
A negative value suggests expenditures on tobacco averted.

Sensitivity analysis

To increase the robustness of our findings, we first did a multivariate sensitivity analysis, in which we simultaneously varied several key parameters (eg, price elasticity and treatment costs). For this purpose, we did Monte Carlo simulations (n=100 000 trials) to capture uncertainty in treatment costs, health-care use, and price elasticity of demand for tobacco inputs. Uncertainty was included by sampling n values for each parameter to which we assigned a beta distribution (eg, price elasticity and use) or a gamma distribution (eg, cost; appendix p 9). Finally, in the n samples, extraction of the 2·5 and 97·5 percentiles allowed 95% uncertainty ranges (URs) to be established.

Second, we did univariate sensitivity analyses. We varied the price elasticity and set it to –0·38 across all income quintiles. We also varied the increase in the retail price of a pack of cigarettes attributable to excise tax, and alternatively set it to 25% (price increase from $0·74 to $0·92) and 100% (from $0·74 to $1·48).

Role of the funding source

The funder of the study had no role in study design or data collection. SV and coauthors had full access to all the data in the study. SV and DTJ had final responsibility for the decision to submit for publication.

Results

After 50 years of a 50% tobacco price increase in China, 231 million years of life would be gained (95% UR 194–268 million), of which 79 million (34%) would accrue to the lowest income quintile (table 4). The additional tax revenues raised from excise tax would be US$703 billion (95% UR 616–781), $98 billion (14%) of which would be borne by the bottom income quintile, compared with $149 billion (24%) in the highest income quintile and 170 billion (21%) in the second highest income quintile (table 4). Total expenditures on tobacco would increase by about $376 billion (95% UR 232–505); however, these expenditures would decrease by $21 billion (95% UR –83 to 52) in the bottom income quintile and would increase in the other four income quintiles, ranging from US$40 billion (95% UR –27 to 107) in the second income quintile to $135 billion (86–164) in the fifth income quintile (table 4). The expenditures on treatment of tobacco-related disease would decrease by $24 billion (95% UR 17–26), $6·6 billion (27%) of which would be concentrated in the poorest quintile. The financial risk protection afforded would amount to about $1·8 billion overall (95% UR 1·2–2·3) and would also be concentrated ($1·3 billion [74%]) in the poorest quintile (table 4). Short-term results (within 10 years) are also given in the appendix.

The annual health gains are increasing over time because the younger age groups (15–24-year-olds and future smokers) contribute more substantially to the years of life gained and face a higher price elasticity than do older smokers (figure 1). The annual additional tax revenues from excise tax decrease over time as younger age groups, who are more price elastic than older people, replace older age groups and account for the majority of the population. The annual additional revenues raised start at US$17·7 billion per year (95% UR 15·5–19·7) in year 1, which accounts for about 15·9% of cigarette tax and industry profit and 1·2% of government revenue in China in 2011,[58,77,78] to eventually fall to $9·2 billion (8·0–10·3) in year 60, which represents about 8·3% of cigarette tax and industry profit and 0·6% of government revenue in China in 2011[58,77,78] (figure 2). Finally, the annual change in expenditures on tobacco decrease over time as younger age groups, who are more price elastic

than older people, replace older age groups and account for the majority of the population (figure 3).

The paid out additional excise taxes represent a larger share of income of the low-income quintiles (3·9% and 2·1% for the bottom and second lowest income quintiles, respectively), than of the higher income quintiles (1·0% and 0·7% for the second highest and highest income quintiles, respectively; table 4). In terms of expenditures on tobacco, the lowest income quintile sees decreases in expenditures, representing –0·8% of their income, by contrast with the two highest income quintiles that see increases in expenditures on tobacco of 0·8% and 0·6% of their incomes, respectively (table 4). Similarly, expenditures on tobacco-related disease averted as a fraction of income are higher in the bottom two quintiles (0·3% and 0·1%) than in the top two quintiles (0·02% at most). Therefore, in our base case scenario, although increased tobacco excise tax represents a larger share of income of the lower income quintiles, its other effects are largely positive and benefit poor populations disproportionately.

By contrast, when price elasticity is held constant at –0·38 across all income groups, the distributional consequences change substantially, as would be expected (table 5). The health benefits are similar (47 million years of life gained) across all income quintiles apart from the fifth (35 million years of life gained), in view of the fact that smoking prevalence was assumed to be similar across the four quintiles, except for the fifth quintile (the richest quintile), which has a lower smoking prevalence than the other quintiles. Additionally, the bottom two income quintiles contribute to the additional tax revenues to a greater extent than the top two quintiles (table 5). Furthermore, expenditures on tobacco increase for all income groups, with larger increases in the bottom two quintiles than the top two quintiles (table 5). Finally, the expenditures on tobacco-related disease averted are evenly distributed across all income groups, between US$4 and $6 billion, although the financial risk protection afforded remains mainly concentrated in the poorest groups. In this latter scenario, tobacco taxation is more regressive, and the diminished benefits do not accrue as strongly to the lowest income groups, but nevertheless substantial financial risk protection is disproportionately achieved because of the decrease in tobacco-related health-care expenditures.

Finally, when retail price increase for a packet of cigarettes is set at $0·92 (25% price increase) or $1·48 (100% price increase), the distributional consequences for health benefits, expenditures on tobacco-related disease, and financial risk protection change only a little (although the overall changes are substantial). When cigarette packet retail price is $0·92, total health benefits are reduced to 115 million years of life gained, total expenditures on tobacco-related disease averted are reduced to $12·1 billion, and total financial risk protection provided to households falls to $0·9 billion. When retail price is $1·48, total health benefits are increased to 462 million years of life gained,

	Total	Income quintile 1	Income quintile 2	Income quintile 3	Income quintile 4	Income quintile 5
Price elasticity is set at –0·38 across all income quintiles						
Years of life gained (millions)	223	47	47	47	47	35
Additional tax revenues raised from excise tax						
2011 US$ billion	736	171	170	152	139	104
% of individual income	..	6·77%	2·67%	1·43%	0·84%	0·45%
Change in expenditures on tobacco						
2011 US$ billion	432	100	100	89	82	61
% of individual income	..	3·97%	1·56%	0·84%	0·49%	0·26%
Expenditures on tobacco-related disease treatment averted						
2011 US$ billion	24·9	4·1	5·2	5·3	5·7	4·6
% of individual income	..	0·16%	0·08%	0·05%	0·03%	0·02%
Financial risk protection afforded* (2011 US$ billion)	1·3	0·8	0·2	0·1	0·1	<0·1
Cigarette price is set at $0·92 (retail price increase is set at 25%)						
Years of life gained (millions)	115	39	31	23	16	6
Additional tax revenues raised from excise tax						
2011 US$ billion	421	74	87	89	93	78
% of individual income	..	2·93%	1·36%	0·84%	0·56%	0·34%
Change in expenditures on tobacco						
2011 US$ billion	258	15	40	58	74	71
% of individual income	..	0·58%	0·63%	0·55%	0·45%	0·31%
Expenditures on tobacco-related disease treatment averted						
2011 US$ billion	12·1	3·3	3·5	2·7	1·9	0·7
% of individual income	..	0·13%	0·05%	0·03%	0·01%	<0·01%
Financial risk protection afforded* (2011 US$ billion)	0·9	0·7	0·1	0·1	<0·1	<0·1
Cigarette price is set at $1·48 (increase in retail price is set at 100%)						
Years of life gained (millions)	462	157	126	94	62	23
Additional tax revenues raised from excise tax						
2011 US$ billion	851	–5†	108	198	275	275
% of individual income	..	–0·21%†	1·70%	1·86%	1·66%	1·19%
Change in expenditures on tobacco						
2011 US$ billion	197	–242†	–80†	73	199	247
% of individual income	..	–9·6%†	–1·25%†	0·68%	1·20%	1·07%
Expenditures on tobacco-related disease treatment averted						
2011 US$ billion	48·3	13·4	13·9	10·6	7·5	2·9
% of individual income	..	0·53%	0·22%	0·10%	0·05%	0·01%
Financial risk protection afforded* (2011 US$ billion)	3·6	2·6	0·6	0·2	0·1	<0·1

Three scenarios are assessed in this table: 1) price elasticity is set at –0·38 across all income quintiles (all other parameters remain identical as in the base case scenario); 2) increase in retail price of cigarettes is set at 25% (all other parameters remain identical as in the base case scenario, including price elasticity of demand for cigarette varying by income quintile); and 3) increase in retail price of cigarettes is set at 100% (all other parameters remain identical as in the base case scenario, including price elasticity of demand for cigarette varying by income quintile). *Measured by a money-metric value of insurance. †A negative value implies that expenditures on tobacco were averted.

Table 5: **Sensitivity analysis results (cumulative) for the tobacco excise tax increase (through retail price increase) in China after 50 years**

total expenditures on tobacco-related disease averted to $48·3 billion, and total financial risk protection provided to $3·6 billion. Nonetheless, we note variations for the additional revenues raised from excise tax and the net change in expenditures on tobacco. When the price of a cigarette pack is $0·92, the distribution of additional tax revenues raised remains almost unchanged: the bottom quintile contributes more substantially (in terms of income) than the other quintiles; however, it now sees an increase in tobacco expenditures. When the price of a packet of cigarettes is $1·48, the distribution of additional tax revenues raised changes substantially: the lowest income quintile sees a decrease in excise taxes paid and a substantial decrease in tobacco expenditures; the second lowest income quintile also undergoes a decrease in tobacco expenditures. In the 100% price increase, tobacco taxation is especially progressive: all health and financial outcomes provide substantial benefit to the poorest groups.

Discussion

Tobacco tax hikes are essential in view of the increasing relative affordability of tobacco.[79,80] Since China's economy has grown enormously, cigarettes have become cheaper to smokers, which means that more aggressive tobacco taxation is now needed.

This study assesses the distributional consequences on four policy-relevant outcomes of a 50% retail price hike on tobacco products in China. Through the use of plausible values for key parameters, we find that in a 50-year period, in the male population, a 50% increase in tobacco price would lead to 231 million years of life gained (a third of these in the poorest group) and US$703 billion of additional tax revenues from excise tax (14% of this in the poorest group). It would increase overall household expenditures on tobacco by $376 billion, but reduce these expenditures by $21 billion in the poorest quintile; it would also decrease expenditures on tobacco-related disease by $24 billion (28% of which would be in the poorest group). Finally, it would provide financial risk protection worth US$1·8 billion, mainly concentrated (74%) in the poorest households. This situation means that tobacco taxation can be a pro-poor policy instrument that brings notable health and financial benefits to households and substantial revenues to society, which is especially important in the poor population of China, which has the highest number of smokers of any country worldwide.[3]

We also show that it is important to comprehensively integrate distributional aspects into analyses. We found that important insights into the equity of tobacco taxation can be otherwise missed when, as is done conventionally, a constant rather than an income-group-specific price elasticity is used. In China, where major reforms in health care are being made with the aim of reducing inequalities, proper assessment of policy instruments might be difficult unless explicit recognition of the income-specific variation in tobacco demand and health-care use and expenditures are made. In particular, Chinese price variation is more than ten-fold across different brands of cigarettes[15,56,58] as opposed to only about two-fold in most high-income countries,[3] which enables smokers to switch down with modest consumer tax increases.[80] Specifically, an effective price increase in China would need substantial increases in excise tax on the cheaper cigarettes[3,10] to narrow the large gap between cheap and more expensive cigarettes. The Indian Government, for example, has recently taken on cheaper cigarettes directly by raising the tax on lower end cigarettes more than that on more expensive brands. An important consideration is the weighing of taxation regressivity against the health benefits and financial risk protection resulting from reduced tobacco-related diseases in a consistent and similar framework such as here.

Our analysis has some limitations. First, uncertainty exists in the parameter inputs, of which the most important is the price elasticity of demand for tobacco. A wide range of elasticities has been estimated for China, and some studies have suggested that smokers in China could be quite insensitive to price changes compared with those in other countries.[81] We chose a middle value among the range of values for China, and one that is close to the accepted value for most countries (–0·4) and that would probably represent true price elasticities without the distortion of wide price variation that exists at present in China.[10] The wide variations in price including five classes of cigarettes[58] could change the brand selection of some smokers. Although we did not incorporate any such compensating behaviour (switching to lower price of cigarettes), as in Hu and colleagues' study,[15] we ran a sensitivity analysis with a low elasticity of –0·15, and noted that important health, additional excise tax revenues, and equity gains could still be realised (appendix p 11). Although value-added taxes as in China's tiered price system encourage smokers to switch down to cheaper cigarettes, specific excise taxes as studied here can be designed to narrow the gap between cheap and expensive cigarettes to prevent smokers from swapping to cheaper brands.[15,58,80] Furthermore, we did a multivariate sensitivity analysis and our results were robust with the uncertainty imposed.

Second, we assumed that no health benefits would arise from reduced tobacco consumption because of a price hike among continuing smokers. Because we do not take into account the changes in the intensity of smoking, our estimates are therefore conservative. Similarly, we excluded female smokers from our analysis because they represent a small population (4% of all Chinese smokers[37]), although women's behaviour and household situation might somewhat differ from that of men.

Third, our epidemiological model has some shortcomings. For example, the non-linear harm caused by smoking intensity is not modelled.[82] Additionally, a more exhaustive dynamic model with, say, age-specific

mortality with and without smoking would have yielded a more realistic and nuanced scenario, but simplicity of exposition, scarcity of data, and the benefits of transparency encouraged us to maintain our modelling approach. Furthermore, our results could have been discounted, treatment costs averted inflated using trends of the Chinese consumer price index, and individual incomes increased over the years with trends in the Chinese growth rate.[42] These adjustments would have unnecessarily complicated the results without providing any additional insight. Our financial analysis does not incorporate the effects of inflation and growth in gross domestic product and household income, which would ultimately strongly affect the benefits of tax increases of a fixed size. Neither does our model take into account consequences on tobacco consumers' utility, which is in any case ambiguous because of an (often) simultaneous willingness to pay for tobacco and for aid in cessation. Moreover, our model could have taken the household disposable income or used consumption data to estimate standards of living, but because of data shortcomings, gross national income distributed in income quintiles based on China's Gini coefficient was used as a substitute income indicator.[42,55] Likewise, we did not incorporate any perception of risks by individuals who smoke and the resulting effect on current consumption, or lagged consumption responses. Taxes could indeed serve as a self-control device to help reduce tobacco use and enable successful quitting.

Whether or not taxes are appropriately high depends in part on how excessively people underrate the harm from tobacco use.[83–86] However, these issues are not well explored in China or other low-income and middle-income countries, and extrapolation from studies done in high-income countries was judged to be inadvisable. Our analysis only focused on additional tax revenues raised from excise tax and did not estimate net government revenues through taxation. Since our intent is to take the consumer perspective, we did not model the Chinese tobacco tax structure. Indeed, China's tobacco industry operates under a system of monopoly that is able not to tie tax increases to cigarette retail prices.[16] Both a central government tax (eg, value-added tax) and a local government tax (eg, special tobacco leaf tax) are collected.[15,58] Hence, tobacco excise taxes will only have an effect when increases are passed onto the retail price.[16,80]

We show that it is possible and desirable to use the same framework to study distributional effects when a combination of outcomes related to different high-priority policy objectives need to be considered. This study shows that, despite potentially imposing a tax burden on low-income groups, tobacco taxation can bring substantial health benefits to poor people and can significantly reduce out-of-pocket expenditures for the poorest populations, especially as these lowest income groups are the most sensitive to increases in prices of tobacco products (panel). Increased tobacco taxation also brings significant financial risk protection to the poorest households through reductions in tobacco-related treatment expenditures.

More than 30 years ago the World Bank argued in support of Chinese government policies initiated in late 1981 to increase the retail price of cigarettes by 30%.[87] The current analysis has concluded that such policies are pro-poor in their financial as well as health consequences.

Contributors

SV and DTJ initiated and conceptualised the study. SV coordinated the research and did the analysis with CLG, SM, MM, SMM, and EDB. SV wrote the first draft of the report. RAN, KZ, PJ, and DTJ reviewed the report and provided advice and suggestions. SV and DTJ had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

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