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Reducing inequalities in lung cancer incidence through smoking policies

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ABSTRACT

Introduction: Lower social class has higher lung cancer incidence, largely attributable to higher smoking prevalence among the lower social classes. We assessed the magnitude and time dimension of potential impact of targeted interventions on smoking on socioeconomic inequalities in lung cancer.
Methods: Using population dynamic modelling, we projected lung cancer incidence up to 2050 in lowest and highest socioeconomic groups under two intervention scenarios (annual 10% increase in cigarette prices and health advertisement) and compared this to a scenario of no intervention. For the analysis we retrieved smoking prevalence data from the General Household Survey of England and Wales between 1980 and 2006 and cancer incidence data from the national cancer registry.
Results: By 2050, the model projected that lung cancer incidence inequality would almost double (Incidence Rate Ratio (IRR) = 4.2 in 2050 vs. 2.5 in 2005) in men and slightly decrease (IRR = 2.4 in 2050 vs. 2.7 in 2005) in women compared to what was observed in 2005. If annual increase in cigarette price targeting the lowest socioeconomic group was implemented, socioeconomic inequality in lung cancer incidence in 2050 might be largely reduced (IRR = 1.5 and 1.4 among men and women, respectively). If in addition to annual price increase (targeted to the lowest socioeconomic group) health advertisement was implemented and successfully reduced smoking prevalence in the highest socioeconomic group, the lung cancer gap between the socioeconomic groups would be reduced by 78% and 58% in men and women by 2050.
Conclusion: Even under the best scenarios, inequality in lung cancer was not fully eliminated within 45 years period. Though the process is lengthy, rigorous interventions may reduce the expected widening of the future inequalities in lung cancer. Modelling exercise such as ours relies heavily on the quality of the input data and the assumptions, thus caution is needed in interpretation of our findings and should consider all the assumptions taken in the analysis.

1. Introduction

Despite steady declines in smoking prevalence during recent decades, lung cancer remains the main cause of cancer death worldwide [1]. In 2002, more than 1 million deaths were caused by lung cancer alone [1], and in the UK, one in five cancer deaths were due to lung cancer [2]. In developed countries where the smoking epidemic has reached its final stage, the lowest socioeconomic groups are about twice as likely to die from lung cancer than their highest socioeconomic group counterparts [3]. A substantial part of this inequality has been attributed to higher smoking prevalence in the lower socioeconomic groups [4]. As disparities in smoking may continue to increase, lung cancer inequalities are expected to widen in the coming decades [3,5].

A number of policy interventions have proved effective in reducing smoking prevalence in the lower socioeconomic groups [6,7]. Although there is controversy on the effect of cigarette price increase and smoking among the different socioeconomic classes [8,9], some studies have suggested that tobacco taxation (and resultant price increase) effectively reduces smoking prevalence in the lower socioeconomic groups [6,10]. The Royal College of Physicians has recently proposed increasing the retail price of tobacco

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products by 10% annually using tax as part of a wider strategy of discouraging smoking [11]. This strategy could not only help reducing smoking prevalence in the UK, but also in turn may contribute to diminish the socioeconomic gap in smoking prevalence and lung cancer incidence.

In this paper, we examine the potential impact of implementing higher tobacco price on socioeconomic inequalities in lung cancer incidence during the coming decades. We especially wanted to examine the time needed to eradicate this inequality. Because in reality many interventions are running simultaneously in a population, therefore we also examined the impact on inequality if health promotion against smoking were implemented [10]. This model will provide insight of the prospect to reduce inequality in lung cancer where multiple interventions are being implemented. Additionally, we also examine the impact of recent changes in cigarette smoking among the highest and the lowest socioeconomic groups on the future trend in inequality of lung cancer.

2. Materials and methods

We obtained the general household survey (GHS) [12] data on three categories of cigarette smoking (smokers, ex-smokers and non-smokers) for a nationally representative population in England and Wales between 1980 and 2006. The GHS is a continuous survey which has been running since 1971 except in 1997/98 when the survey was reviewed and 1999/2000 when it was re-developed. It is based on a sample of the general population resident in private (non-institutional) and collects data on approximately 9000 households and 16,000 adults aged 16 and over. To derive yearly prevalence of smokers, data for intermediate years were interpolated using a cubic spline.

Socioeconomic categories were based on the occupation and approximated socio-economic group [13]. The occupational class was classified on the basis of last main job, and never worker or long-term unemployed are classified into a distinctive group that were not included in our analysis. For women, the socioeconomic group of the household head was used. Between 1980 and 2000, we used professionals, employers and managers to represent the highest socio-economic group, while the semi-skilled manual and unskilled manual occupations represented the lowest group. In 2001 the socioeconomic classification was improved by combining information on current or last main job and employment status i.e. whether an employer, self-employed, a manager, a supervisor or an employee. Therefore, since 2001, the highest socio-economic group refers to large employers and higher managerial occupations, while the lowest socio-economic group refers to semi-routine and routine occupations.

One of our outcome measures was the future incidence rate of lung cancer. Because lung cancer incidence is mainly driven by smoking prevalence, we firstly modelled the future smoking prevalence. For this purpose, we used an existing prediction method, which has been described elsewhere [14]. This model calculates prevalence of smoking based on the dynamics in people who initiate smoking, quit smoking and those who die because of smoking [15]. The net cessation rates (i.e. the proportional changes in smoking prevalence) and initiation rates according to sex, age, socio-economic groups and period are presented in Table 1 (Table 1). The predicted estimates based on the model produced a good to reasonable fit to the observed data in 1980–2006 (R^2 = 0.98 and 0.85 for highest and lowest socio-economic group, respectively). The cessation rates produced here were used in Prevent (see below) to calculate the future smoking prevalence as proposed by Mendez to derive lung cancer incidence.

Incidence rates of lung cancer were retrieved by sex and 5-year age groups for the year 2005 (base year) from the office for national statistics [13]. Incidence rates for the highest and lowest socioeconomic groups were calculated by weighing the general incidence rate to the lung cancer incidence rate of the specific socioeconomic group (either I: highest socioeconomic group or V: lowest socioeconomic group) as reported by Shack et al. [5]. Reported incidence rates in the present article are age standardized using the standard European population (ESR).

We retrieved the following demographic data: (a) annual number of births and death rates by age and sex from 1980 to 2006; (b) population size at January 1, 1980 for 1-year age groups by sex; and (c) population projection up to 2050 [13,16,17]. We did not use socioeconomic specific demographic data because demographic projection is highly uncertain. Therefore in this paper we do not present number of lung cancer cases by socioeconomic groups. As for annual mortality rates by age and sex, they were corrected for socioeconomic groups by weighing the general population rates to mortality rates by socioeconomic group [18].

To model the impact of intervention on cancer incidence we used Prevent. The validity of this model has been tested as compared to the Peto method [19]. Prevent is a state-transition simulation model that estimates the health benefits in a population due to changes in risk factor prevalence [20]. The details of calculation within Prevent are described in Appendix 1. In short, the model firstly calculates the incidence of disease that would be observed if no intervention to prevent smoking is implemented (autonomous trend). In this first part, the incidence of lung cancer is calculated based on the current change of smoking prevalence influenced by the current policy on tobacco smoking. Here, trend impact fraction (TIF) is calculated and applied to cancer incidence. TIF is based on the relative risk and past prevalence data of the risk factor (smoking) [21]. We used the relative risk for lung cancer as reported by Gandini et al. (Risk Ratios; 9.9 among men and 7.6 among women) [22]. Secondly, after an intervention is specified, the model calculates the development of the potential impact fraction (PIF) due to changes in smoking prevalence, which is caused by both the intervention and the autonomous trend. The difference between the first and the second estimate is attributable to the intervention [23].

Prevent models the relation between risk factor exposure and disease risk dynamically with latency (LAT) and lag time (LAG) variables. LAT is the time that is needed between changes in risk factor and any change in cancer risk. In this study we defined the latency time to be 5 years [24]. LAG is the time that is needed for a former smoker to return to the risk of a non-smoker. We set LAG to be 15 years, declining of the risk in an exponential manner [24]. This means that after a total 20 years since the intervention took place the risk of lung cancer of a former smoker will return to the risk of a non-smoker.

The Tobacco Advisory Group of the Royal College of Physicians (RCP) has proposed a yearly increase in cigarette price as one of the strategies to eradicate smoking prevalence in the UK [11]. Here we applied 10% yearly increase in cigarette price and assumed that the price increase was annually adjusted for inflation. In this study, we assumed that the price increase only decreases cigarette smoking in the lower socioeconomic group [7,10,25]. We recognized the controversies on the impact of cigarette price increase on smoking in different socioeconomic groups [8]. Therefore we examined the impact on changing this assumption on the sensitivity analysis (further describe below). A one percentage point increase in price was reported to decrease the demand for cigarettes by 1% and 0.9% in men and women from the lowest socioeconomic class [10]. For the main analysis, we assumed that it did not influence the demand for cigarettes for the highest socioeconomic group [10]. In the modelling, this means that every year the prevalence of smokers would decrease by 10% for men and 9% for women, in the lower socioeconomic class. In addition to the modelling based on the price indexing, we also estimated the lung cancer incidence if a

Table 1
Net cessations rates[a] in England and Wales according to sex, socioeconomic group and period, 1980–2006.

	Male			Female		
	1980–1990	1991–2000	2001–2006	1980–1995	1996–2001	2002–2006
Socioeconomic group I (highest)						
20–30 years	0.040	0.023	0.070	0.022	0.017	0.091
31–50 years	0.009	0.014	0.058	0.028	0.003	0.037
51+ years	0.060	0.022	0.069	0.077	0.036	0.065
Socioeconomic group V (lowest)						
20–30 years	0.000	0.016	−0.015	−0.003	0.018	0.006
31–50 years	−0.001	0.020	0.005	−0.004	0.012	0.029
51+ years	0.030	0.045	0.034	0.027	0.038	0.056

The proportional change is positive if prevalence declines or negative if prevalence increases.
[a] Net cessation rate: proportional change in smoking prevalence.

rigorous (yearly) health campaign against smoking was to be implemented. Anti-smoking counter-advertising has been reported to reduce the smoking prevalence among the higher socioeconomic groups [10,26]. This model will provide insight of the prospect to reduce inequality in lung cancer where multiple interventions are being implemented.

2.1. Sensitivity analyses

As with any prediction method, Prevent makes several assumptions and relies heavily on underlying input data. Therefore, baseline data including incidence, prevalence and population data were derived from comparable and established resources and are assumed to be reliable. To examine the robustness of our results we performed several sensitivity analyses. We examined the effect of assuming lag periods of 25 years (meaning that after 30 years since the start of the intervention the risk of lung cancer for the ex-smoker would be similar to the non-smoker); the effect of assuming an infinite lag time (meaning that risk of ex-smokers would never reach that of the non-smoker); and the effect of using a different relative risk estimates (23.9 and 8.7 for males and females, respectively) [27]. Recognizing that various studies have reported different price elasticities, we also examined the effect of having a higher price elasticity in the younger age group of the lowest socioeconomic group (those younger than 35 years had twice the price elasticity of those 35 years and older) [28]; the effect on lung cancer inequality if the highest socioeconomic group were also responsive to price change (the higher socioeconomic group was reported to have half of the price elasticity of the lowest socioeconomic group) [8]; and the effect of using different price elasticity estimates (0.45% for men and 0.41% for females) [8].

3. Results

Fig. 1 illustrates the projected proportion of cigarette smokers according to socioeconomic group and sex. In 1980, 69% and 56% higher smoking prevalence was observed among the male and female lower socioeconomic group as compared to the highest socio-economic group. The relative difference increased markedly over time and was observed in the projections. In the 1980s smoking prevalence was 50–70% higher in the lowest socioeconomic group. In 2050 we expected the lowest socioeconomic group (men) would be four times more likely to smoke as compared to the most affluent group.

Table 1 presents the net annual cessation rates for three age groups according to sex, socioeconomic group and time period. In general, net cessation rates were higher among the highest socioeconomic group as compared to the lower socioeconomic group. In the last period (2002–2006), we estimated high age-specific quitting rates ranging from 5.8% to 9.0% annually among the highest socioeconomic group and only 0.5–6.0% among the lower socioeconomic group.

Fig. 2a shows the lung cancer incidence rate for the highest and lowest socio-economic groups for males as projected by the model with and without intervention among men in the period 2005–2050. In 2005, the standardized lung cancer rate in the lowest socioeconomic group was 2.5 times higher than the rate in the highest socioeconomic group. For both socioeconomic groups, lung cancer incidence is predicted to decrease, but more so for the highest socioeconomic group. Under the scenario of no intervention, the model predicts that lung cancer inequality will double by 2050 (Incidence Rate Ratio (IRR) = 4.2 in 2050). The model projected that a yearly increase in cigarette price would decrease the socioeconomic gap in lung cancer incidence by 86% in 2050 i.e. IRR = 1.5 (with price increase) vs. 4.2 (without intervention). If anti-smoking counter-advertising were implemented, lung cancer incidence rate among the highest socioeconomic group is estimated to decrease to 14.1 per 100,000. This would diminish the impact of the price indexing in inequality: 78% of inequality will be reduced by 2050 IRR = 1.7 (with both interventions) vs. 4.2 (without intervention).

Fig. 2b presents the same projection of lung cancer incidence but for women. Under the scenario of no intervention, socioeconomic group inequalities in lung cancer incidence will slightly decrease in 2050 (IRR = 2.4 and in 2005 IRR = 2.7). If annual increases in cigarette prices were introduced, inequalities in lung cancer incidence would be reduced by 74% in 2050 (IRR = 1.4). If anti-smoking counter-advertising was also included in the model, the lung cancer incidence rate among the highest economic group would decrease to 9.9 from the predicted 11.6 per 100,000 cases in 2050. Implementing an intervention targeted to both the lowest and the highest socioeconomic group would reduce the inequality in lung cancer incidence by 58% i.e. IRR = 1.6 (with both interventions) vs. 2.4 (without intervention).

We undertook several sensitivity analyses by varying the lag time and the relative risk estimates (Table 2). There was little effect

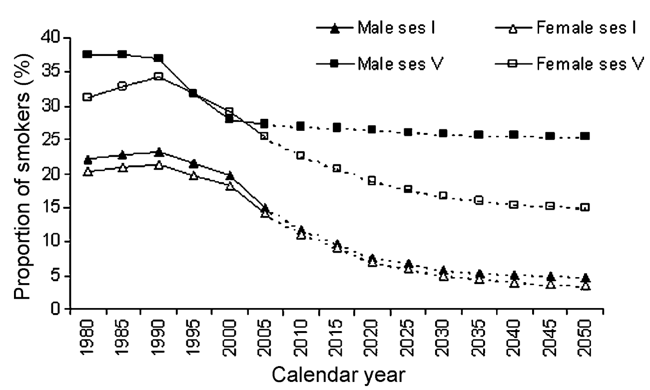

Fig. 1. Predicted proportion of smokers according to socioeconomic group and sex in 1980–2050.

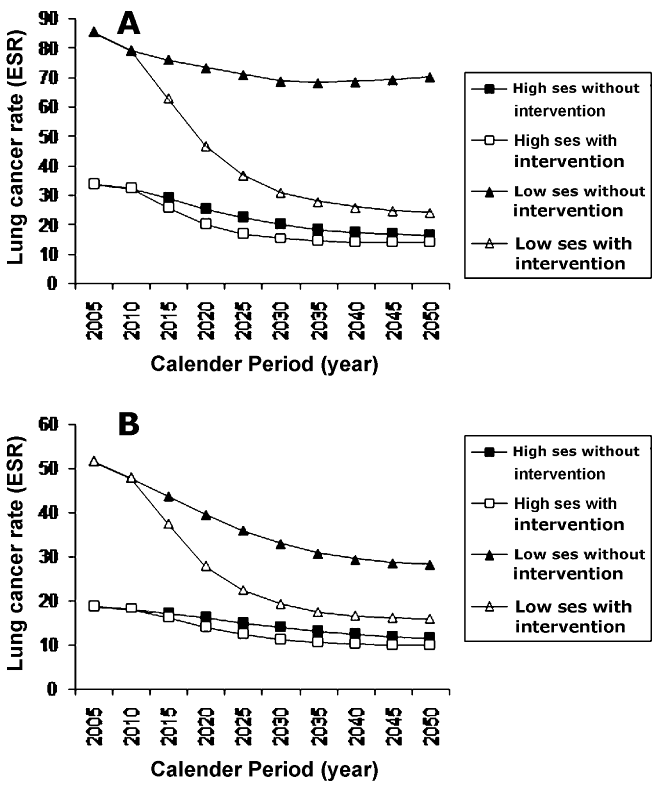

Fig. 2. Predicted lung cancer incidence (European Standardised Rate, ESR) in England and Wales according to socioeconomic status (SES) group with and without intervention (intervention: yearly 10% price increase for low socioeconomic group and yearly health advertisement for high socioeconomic group). (A) Male; (B) female.

of varying the lag time on the lung cancer inequality i.e. the incidence rate ratio between the lowest and the highest socioeconomic group if the two intervention scenarios (price increase and health advertisement) was 1.7 in males and 1.6 in females in 2050 if 30 years lag was used (similar to the baseline scenario with 15 years lag time). If we assumed that the risk of ex-smokers never reached that of the non-smoker, than the inequality the gap would be slightly smaller than the baseline estimate (IRR = 1.4 for both genders). If we used 23.9 instead of 9.7 for the relative risk estimate in men, the inequality in lung cancer would decrease slightly more than the baseline estimate with IRR of 1.6. As for changing the price elasticity estimates, the largest difference (as compared to the main analysis) was found if the price elasticity was reduced by half for the lowest socioeconomic group. Other changes i.e. highest socioeconomic groups being responsive to price change or the younger age group being more responsive that other age groups, did not change the results of the modelling as compared to the main model.

4. Discussion

Our study illustrates the potential and the time needed to reduce socioeconomic inequalities in lung cancer in England and Wales using a targeted smoking intervention policy. If the current course of smoking continued, we projected a widening of inequality in lung cancer as has been expected by others [3]. Under the most rigorous intervention i.e. annual price increase was implemented, the disparity in lung cancer was reduced but not eradicated. Among men, the scenario of a yearly price increase would only eliminate the socioeconomic gap in lung cancer by 86% in 2050. Among women, 74% of socioeconomic relative inequalities in lung cancer might be reduced after 45 years. If another intervention that influences prevalence among the higher socioeconomic groups e.g. health promotion efforts are included in the model, closing the gap is further delayed.

As predicted by others [3,29], we projected an increase in lung cancer inequality in men in the future in the UK. Although smoking has been decreasing in all socioeconomic groups, we still observed higher uptake among the adolescents in the lower socioeconomic group. Furthermore, they are also more likely to become regular smoker and less likely to stop smoking [30]. These all contribute to the increasing gap in smoking among men, that in the future will be reflected in the inequality in lung cancer rates.

In reality, many intervention programs are currently in place in the UK and these will affect our findings [31]. New legislations have also been implemented such as the smoke-free UK, which may further increase quit rates [32]. If the higher socioeconomic group responds the most to an intervention, it may potentially increase inequalities in smoking. However, a current review on population tobacco control strategies showed little evidence of adverse effects on inequality from population intervention programs such as restrictions in workplaces, public places or schools, restrictions of sales to minors, restrictions on tobacco advertisement and health

Table 2
Sensitivity analysis.

Models/scenarios	SES	Male, 2040		Female, 2040	
		IR	IRR	IR	IRR
Model A (Baseline): 20 years latency time, intervention for both SES groups[a]	Highest	14.1	1	10.0	1
	Lowest	24.2	1.7	16.0	1.6
Model B: 30 years latency time, intervention for both SES groups[a]	Highest	13.5	1	9.6	1
	Lowest	22.8	1.7	15.6	1.6
Model C: lung cancer risk in ex-smokers never equal to non-smoker, intervention for both SES groups[a]	Highest	15.9	1	11.11	1
	Lowest	22.3	1.4	15.5	1.4
Model D: relative risk 23.9 (male) and 8.7 (female) instead of 9.7 and 8.7 in Model A, intervention for both SES groups[a]	Highest	7.6	1	9.3	1
	Lowest	12.1	1.6	14.4	1.6
Model E: younger age group more price sensitive (price elasticity <35 years: 2% (men) and 1.8% (women) instead of 1% and 0.9% in Model A), intervention for both SES groups[a]	Highest	14.1	1	10.0	1
	Lowest	23.5	1.7	15.7	1.6
Model F: highest SES group also price sensitive (price elasticity in highest SES 0.5% (men) and 0.45% (women) instead of 0 in Model A), intervention for both SES groups[a]	Highest	14.1	1	10.2	1
	Lowest	24.2	1.7	16.0	1.6
Model G: different price elasticities for lowest SES group (0.45% for men and 0.41% for women instead of 1% and 0.9% in Model A), intervention for both SES groups[a]	Highest	14.1	1	10.0	1
	Lowest	31.7	2.2	26.6	2.7

IR: Incidence Rate (European Standardized Rate, per 100,000); IRR: Incidence Rate Ratio; SES: socioeconomic status.
[a] Price increase affecting the lowest socioeconomic group and health advertisement affecting the highest socioeconomic group.

warning on tobacco products [33]. Therefore the major tobacco control steps that have been taken by the UK government, e.g. media advertisement ban, smoking cessation services, clean indoor air laws and earmarking may have resulted in higher cessation rates than what we have predicted [34]. But this might be equally true for different socio-economic groups [7,31]. Although intuitively, workplace smoking bans in places with a high concentration of workers from a lower socioeconomic class would impact smoking more in this group, overall the impact of this intervention on daily cigarette smoked is the same in different socioeconomic groups [7].

The positive impact of cigarette price increases on smoking may be offset by increases in cigarette smuggling [35]. In the UK it is estimated that about 13% of cigarettes in 2005–2006 are smuggled [36]. Because the lower socioeconomic groups more often consume smuggled cigarettes, we may have overestimated the impact of cigarette prices on inequalities in smoking prevalence and lung cancer. However, over the last decades, the UK government seems to have been successful in reducing the prevalence of contraband tobacco which may continue in the future [36]. This study therefore also points to the importance of comprehensive smoking intervention strategies i.e. reducing the availability of smuggled and counterfeit tobacco, optimising smoking cessation services, international advocacy [11].

We used the price elasticity of demand for cigarettes from a study based on data from 1972 to 1990 as the impact of the intervention [10]. Our model assumed that the impact of price indexing on smoking prevalence is the same regardless of the price of cigarettes in each time period. However, the impact of price indexing on smoking prevalence may decrease as background cigarette prices increase [8]. On the other hand, the impact of price increases on smoking prevalence may increase as background cigarette price increases, because a 1% increase at a high price levels is in absolute terms larger than at low price levels. At this point, there is insufficient evidence on how the impact of cigarette price increases on smoking prevalence varies across different background cigarette prices. Furthermore, others have also reported different estimates on price elasticity by gender, age group or socioeconomic group [28,33]. In our sensitivity analysis we examined the impact of varying price elasticity in different age groups and socioeconomic status. Increasing price responsiveness among the younger age group did not result in different lung cancer inequalities in 2050 as compared to the base model where all ages have the same price elasticity. This is probably because changes in smoking prevalence among the younger age groups would only affect lung cancer incidence in a very long time perspective, beyond the end of this study period (2050). The largest difference to the main analysis was found if other estimate of price elasticity was used [8]. Thus interpretation of this study should consider all assumptions that were taken in the analysis. Another limitation that should be mentioned is the fact that we used self-reported smoking. Yet studies have shown that the validity of self-reported smoking is high and similar by socioeconomic status [37].

We projected a marked decline in the proportion of smokers in all groups that we studied except for males of the lower socioeconomic class. This is due to the low cessation rates (0.5% annual decrease) in the middle aged men. As we reported, the fit of our predicted model for smoking prevalence in this group is only reasonable. Yet, the data showed that between 2000 and 2006, the proportion of smokers in the middle age group (30–40) in men among the lowest socioeconomic class in our study was 40% in 2000 and 43% in 2006. Secondly, the analysis was restricted to groups I and V. Because of changes in the nature of works and occupation in the late twentieth century, group V is gradually becoming smaller over time i.e. in 1980 23% of the survey population was in this group compared to 19% in 2001 [12]. For this reason the national statistics office changed the Socioeconomic classification in 2001 [38]. For continuity reasons, we kept the analysis to this group. Further, increasing cigarette price by 10% annually is politically challenging [39]. Yet, in the UK there has been on average 5% annual increase in real price in cigarette [34]. From public health perspective it is ultimately more important how affordable cigarette price is. Yet in the UK cigarettes are still more affordable than they were in the 1960s [40]. Therefore there is ample room for price increase in retail price of cigarette.

Our study illustrated the future of inequality in lung cancer in UK and projected an increasing gap between the wealthy and the poor. A long time perspective is needed to decrease socioeconomic disparities in lung cancer rates. Yet, slow, rigorous and targeted interventions may reduce the expected widening of the future inequalities in lung cancer.

Conflict of interest

None.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.lungcan.2011.01.009.

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