Evaluating the public health impact of partial and full tobacco flavour bans: A simulation study

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Summary

Background Tobacco flavours such as menthol and fruits, which appeal to youth, remain unregulated in Western Pacific countries. Our goal was to evaluate the potential impact of tobacco flavour bans in Singapore, which has the region's highest flavoured cigarette market share.

Methods Using an open-cohort microsimulation model, we estimated the impact of full ban and partial ban (excluding menthol and clove) scenarios versus the status quo (no ban) over a 50-year horizon. We used a Markov chain with four states (never, unflavoured, flavoured and ex-smokers), updating each individual's state across each year. We estimated between-state transition probabilities using Markov chain Monte Carlo, with prior distributions derived from national survey data.

Findings Without a ban, smoking prevalence gradually increases from 12.7% (2018) to 15.2% (2068). In both ban scenarios, smoking prevalence decreases immediately after the ban: by 1.6% points in the full ban, and 0.4% points in the partial ban scenario. In addition, there is a sustained long-term impact as fewer initiate. In the full ban scenario, smoking prevalence decreases to 10.6% by 2068 with a cumulative gain of over 40,000 QALYs. In the partial ban scenario, it remains stable at 12.5% with a cumulative gain of over 20,000 QALYs.

Interpretations A tobacco flavours ban would reap substantial public health benefits in countries that, like Singapore, have a large flavoured cigarette market share, especially with a full ban compared to a partial ban not covering menthol or clove-flavoured cigarettes.

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Introduction

Tobacco companies add flavours, such as menthol, mint, candy or fruit, to cigarettes to mask the harsh tobacco taste and encourage smoking initiation in youths.[1] Due to their substantial public health cost,[2] added cigarette flavours, including menthol, are now banned in the European Union, several African countries, Canada and parts of the United States, and partial flavour bans—banning all characterising flavours except menthol and clove—have been implemented in the United States and Niger.[3]

No country in the Western Pacific region has regulated tobacco flavours, even though this region is home to some of the world's largest flavoured cigarette markets. Menthol cigarettes comprise around a quarter of the cigarette market in Japan (21%), the Philippines (22%), Malaysia (29%) and Hong Kong (30%), while in Singapore they comprise almost half (48%).[4] These

market shares are far higher than pre-ban flavoured cigarette market shares in the European Union (1−10%)[5] and Canada (3%)[4] and, in the case of Singapore, also higher than the menthol cigarette market share in the United States (31%).[4] In addition, the market for capsule cigarettes, which contain a crushable flavour capsule inside the filter, has grown rapidly in many Western Pacific countries,[6] especially in South Korea where their market share is 16%.[4] Tobacco companies have aggressively targeted youths, women and health-conscious people with menthol and other flavoured or capsule cigarettes in Western Pacific countries, which helps to explain the large market shares in some of these countries.[7−16]

Studies evaluating the public health impact of tobacco flavour bans in the United States, European Union and Canada reported declines in cigarette use,[17−20] decreased cigarette sales,[17,21] and improved cessation outcomes.[17,22−24] Two studies have simulated the impact of a menthol cigarette ban in the United States. A 2011 study estimated a 9.7% reduction in smoking

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Research in context

Evidence before this study

Prior to undertaking this study, from October 2020 to May 2021, we conducted extensive searches in academic literature databases (PubMed, Science Direct) for studies of tobacco flavours in Western Pacific countries, as well as tobacco flavour regulations globally using relevant keywords such as "tobacco flav* ban" or "tobacco flav* Philippines". We identified a number of countries in Europe, Africa and America that have passed or attempted to pass tobacco flavour regulations. We did more specific follow-up searches for each country (e.g. using keywords such as "menthol tobacco ban Canada") to find further studies. We found studies evaluating tobacco flavour bans in the United States, European Union and Canada. These studies mostly had some degree of limitation, for instance being cross-sectional, having a small sample size of flavored tobacco users (<200), or relying on estimates affected by other variables such as other tobacco policies implemented within the same timeframe. We found two simulation studies of a menthol tobacco ban in the United States, both which relied on estimates from national surveys of predicted behaviour changes, which may have over-estimated successful quitting attempts. Although we found evidence of tobacco flavours as a potential contributor to smoking in Singapore, the Philippines, Malaysia, Japan, South Korea and Hong Kong, we found no studies evaluating or simulating the impact of tobacco flavours regulations in a Western Pacific country.

Added value of this study

This study is, to our knowledge, the first to simulate the public health impact of a tobacco flavours regulation in a country other than the United States and the first study to compare the impact of full (covering all characterising flavours) and partial (excluding menthol and clove) tobacco flavours bans. Our open-cohort microsimulation model mimics predicted changes in the population's demographic structure and enables the entry of new cohorts each year, providing more accurate estimates that reflect real-world demographic changes in a multi-ethnic, urban, Western Pacific setting.

Implications of all available evidence

Our findings are consistent with studies from the United States, Canada and European Union which indicate that both partial and full tobacco flavours bans reap public health benefits, with a more substantial impact observed with a full flavours ban. Compared to our Singapore study, the simulation studies from the United States predicted more modest impacts from a full tobacco flavours ban, likely a result of differences in the population demographics, smoking prevalence trends, and the market for flavoured cigarettes which is larger in Singapore. Our findings suggest that a tobacco flavours ban, if implemented in countries with large flavoured cigarette market shares such as Singapore, the

Philippines and South Korea, would result in significant public health gains in the immediate term due to more people quitting, as well as in the long term as a result of fewer people initiating smoking.

prevalence with over 600,000 deaths averted by 2050, assuming 30% quitting and 30% fewer initiations.[25] A 2021 study estimated an overall 15% decline in smoking prevalence, with over 11.3 million life years saved by 2060.[26] These simulation studies suggest that a tobacco flavours ban would reap substantial public health benefits, especially in countries such as the United States, Singapore, Malaysia and the Philippines where flavoured cigarettes comprise a large portion of the total cigarette market. However, no studies have, to our knowledge, quantified the potential impact of a tobacco flavours ban in a Western Pacific country.

Singapore is a city-state in Southeast Asia which, with its multi-ethnic (predominantly Chinese, Malay and Indian) population, acts as a microcosm of the Western Pacific region. Singapore has a strong and well-established tobacco policy dating back to 1970.[27] Smoking prevalence has decreased steadily over time with a daily smoking prevalence of 10.6% as at 2019; a further 3.1% smoke on a non-daily basis.[28] Singapore's tobacco market is heavily dominated by cigarettes as shisha, snus, e-cigarettes and heated tobacco products are banned and remaining non-cigarette products, such as roll your own, cigars and cigarillos, comprise only 2.4% of tobacco sales volume.[4] Singapore's menthol cigarette market share, the region's largest at 48%, grew in the 1980s as tobacco companies looked for new ways to target youth in the face of ever-increasing tobacco advertising restrictions.[16] As at 2020, flavoured cigarette use was still common, with a survey of smokers having estimated that 53% of Singapore smokers use flavoured cigarettes as their regular brand (35% menthol non-capsule, 15% capsule, and 2% clove). This proportion was higher in the younger age group (59%, age 20-29); see Supplement 1 for more detailed estimates of the age distribution of flavoured cigarette use in Singapore.[15]

Given that Singapore has a mature flavoured tobacco market with the region's largest reported market share for menthol-flavoured cigarettes, our goal was to estimate the potential impact of a tobacco flavours ban there, in terms of the impact on smoking prevalence and quality-adjusted life years (QALYs), over a 50-year time horizon.

Methods

Simulation model

We developed an open-cohort microsimulation model to measure the impact of ban scenarios on future prevalence. An open-cohort, which allows new entry of

younger individuals at each time step during the simulation, was selected to allow the long-term effects on initiation of policy changes to be adequately characterised, and in particular to ensure sufficient opportunities for the effect of policies that have their primary impact on younger individuals to be assessed. The initial state of the model is the population in the starting year of 2018, aged 11–80 years, as estimated by the Department of Statistics Singapore.[29] We set the current age-specific mortality rates to fall by 3% per annum, extending historic trends from 1970 to 2010,[30] and numbers of incoming cohorts aged 11 from 2018 to 2068 as estimated in the R package wpp2017,[31] forecasted numbers and age distribution of Singapore's population over the period 2018 to 2068 were simulated. We restrict the model to ages under 80 as data beyond this point is often not collected in Singapore.

Transition model

To project the future smoking prevalence and QALYs, we used a Markov chain with four different states for an individual in each given year: never smoker (N), unflavoured smoker (U), flavoured smoker (F) and ex-smoker (Q), and updated each individual's state across each year. We defined (U) as smokers who use regular (non-flavoured) cigarettes as their usual brand, and (F) as smokers who use flavoured cigarettes as their usual brand. All transition rates are age-specific and we allowed a total of eight between-state transitions (Figure 1).

Between-state transition probabilities were estimated using Markov chain Monte Carlo to project smoking prevalence across the 50-year time period in a status quo scenario and were based on Singapore's average annual transition probabilities from 2004 to 2018. Under the status quo scenario, population ageing and the absence of additional restrictions on smoking lead to a rise in the prevalence of current smokers. Posterior distributions of the transition rates were estimated based on Singapore National Health Surveys in 2004 and 2010, and National Population Health Survey (NPHS) 2018.[28,32,33] Detailed prior distributions can be viewed in supplement 1. As only cross-sectional (U) and (F) smoking prevalence data could be retrieved from NPHS data, we obtained proportions of (U) and (F) smokers from a 2020 survey of flavoured cigarette use in Singapore.[15] The relationship between age and flavoured cigarette use was fitted with polynomial regression using the survey data. According to the 2020 survey,[15] the proportion of flavoured cigarette use is 53% among Singapore smokers and the proportion progressively decreases with increasing age (see Supplement 1, Figs. S1–3). (U) versus (F) proportions were then estimated by applying the flavoured use proportion by age to 2004, 2010 and 2017 data, assuming the relationship remains unchanged throughout this time

period. Prior transition probabilities between (U) and (F) states were based on the 2020 local survey data where participants were asked to state the cigarette type they initiated with and their current cigarette type use. Age-specific ratios of the four states were obtained from NPHS 2018. Reported prevalence in each state is aggregated over the age range 11–80, with an assumed smoking prevalence of 1% prior to age 18, a few years before the current minimum legal age of 21, from which it was allowed to rise. More details are provided in supplement 1.

Tobacco flavours ban scenarios

As countries have implemented both full bans (covering all characterising added flavours including menthol, fruits, clove and other such flavours), and partial bans (covering all characterising added flavours except menthol and clove), we modelled the impact of each policy versus the status quo scenario (no ban). Under each scenario, we projected the change in smoking prevalence and annual QALYs using the open-cohort microsimulation model.

The simulation starts with the actual Singapore local population in 2018 and ends in 2068, with the ban taking effect in 2025. When the ban takes effect, we assumed that immediate changes in both smoking prevalence as well as proportion of ex-smokers (Q) will be detected, as prior studies[17,18,20,22−24,34] have noted that most smokers whose preferred products are banned either switch to other cigarettes that remain legal or quit smoking. We further assumed that this immediate change ends within 2025. For both scenarios, and consistent with data evaluating Canada's tobacco flavours ban[22] and statistics which estimate Singapore's illicit cigarette trade volume at 3.6%,[4] we conservatively assumed that, after 2025, 5% of flavoured users continue to use flavoured cigarettes obtained illegally.

To model the impact of bans on annual transition rates, we introduced new variables that affect the transition probabilities when the ban policies take effect in 2025 for both the full and partial ban scenarios. The estimation of transition probabilities with the impact of the bans was based on results from the 2020 survey of flavoured cigarette use in Singapore,[15] in which participants were asked to select a behavioural response in a hypothetical ban scenario. These were further compared to and adjusted for in view of quitting and switching rates observed from evaluative studies of partial and full bans in the United States, European Union and Canada and read in the comparative contexts of Singapore's flavoured use proportions and low illicit trade volume.[5,20,22,24,25] Post-ban transition probabilities for smoking initiation were similarly estimated from these evaluative studies. Supplements 2 and 3 present the parameters for the transition probabilities across the

Figure 1. Schematic of the transition model structure. States and rates are age- and time- specific. Arrows indicate permissible state changes (note that arrows from the *N* state are unidirectional).

Full ban	*Immediate effect:* Most flavoured users switch to unflavoured cigarettes immediately, with a smaller number quitting and an even smaller number continuing to illicitly smoke flavoured cigarettes.
	Long-term effect: There are no changes to quitting and relapse rates for unflavoured cigarettes. It is assumed that relapse to flavoured tobacco no longer happens; nor do transitions from unflavoured to flavoured. A proportion of new smokers who would have smoked flavoured tobacco is assumed to initiate unflavoured instead, and a small proportion is assumed to initiate flavoured tobacco illicitly. It is assumed that a small fraction of those who remain or become flavoured tobacco users despite the ban 'give up' and switch to unflavoured each year.
	Sensitivity analyses: We explored different levels of the proportion initiating banned flavours, initiating unflavoured in lieu of flavoured tobacco, and switching from flavoured to unflavoured users.
Partial ban	*Immediate effect:* A fraction of flavoured users switch to unflavoured cigarettes immediately, with the rest continuing to smoke the permitted flavours. A smaller number quit.
	Long-term effect: There are no changes to quitting and relapse rates for unflavoured cigarettes, and no change in quitting rates for flavoured. It is assumed that initiation rates of unflavoured cigarettes is a bit higher and of flavoured cigarettes is a bit lower in the presence of the ban. It is also assumed that fewer people transition to flavoured users from unflavoured state; and that relapse rates are lower too.
	Sensitivity analyses: We explored different levels of the proportion initiating banned flavours, initiating unflavoured in lieu of flavoured tobacco, and switching from unflavoured, or ex-smokers, to current flavoured users.

Table 1: Summary of the assumed effect of policy scenarios. Full details of the numerical values are provided in Supplements 2 and 3.

scenarios, and a summary of the scenarios is provided in Table 1.

To assess if the estimated impacts of the bans are robust to assumptions made about the variables, we did a sensitivity analysis in which we derived upper and lower bounds for the two baseline scenarios. Possible results were modelled under different situations by varying smokers' residual addiction to flavoured cigarettes, their preference for switching to remaining legal cigarettes instead of quitting, and initiation with banned cigarettes (illicitly) and remaining legal cigarettes. The sensitivity analysis is presented in Supplements 2 and 3, as the important findings are preserved across the varied parameters.

Quality adjusted life years

In each of the 50 iterations of the microsimulation model, we also calculated annual QALYs gained compared to the status quo scenario. We adopted the more conservative assumption that the health condition of individuals who are currently smoking and individuals who used to smoke are the same. We used 2.8 as the relative risk of mortality rate for all ever-smokers who are below age 60, 2.5 for ever-smokers between age 60 and 70, and 2.0 for ever-smokers above age 70 (Supplement 1 has detailed calculation methods).[35]

Role of the funding source

This project was supported by funding from the Singapore Ministry of Health. The funder was not involved in data collection, interpretation or analysis, or in the decision to submit the study for publication.

Results

Transitions

According to the posterior distributions of between-state transition rates estimated using Markov Chain Monte Carlo, smoking initiation was estimated to be highest at around age 18. The probability of unflavoured cigarette initiation, $P(N \rightarrow U) = 0.02$ at age 18, decreased to <0.001 after age 21, while the probability of flavoured cigarette initiation, $P(N \rightarrow F)$, was 0.07 at age 18, 0.03 at age 19−20, 0.02 at age 21−26, and <0.001 after age 29. This difference in relationship between un- and flavoured cigarette initiation and age is the result of a higher proportion of flavoured cigarette use among Singapore teenagers and young adults. We assumed that quitting rates increase by age as a restriction to the prior support in our Markov chain Monte Carlo model (Supplement 1). As a result, quitting rates for unflavoured cigarette users, $P(U \rightarrow Q)$, were 0.04 at age 18, 0.06 at age 45, and increased to 0.12 at age 80, while quitting rates for flavoured cigarette users become greater than 0.2 after age 60 and 0.25 at age 80. The switching rates between unflavoured and flavoured smokers had a mean value of 0.10, with fewer older people switching to flavoured cigarettes, $(P(U \rightarrow F) \leq 0.075)$ for age 70 and above. Detailed transition probabilities can be viewed in Supplement 1.

Smoking prevalence among those aged 11−80

In all scenarios (full ban, partial ban and status quo), the smoking prevalence is 12.7% in 2018 and 12.9% by 2024. In the status quo scenario this is expected to rise to 15.2% by 2068, due in part to rising life expectancies and the absence of other tobacco control interventions under this scenario. In the full ban scenario, there is an

immediate drop in smoking prevalence by 1.6% points, to 11.3%, following the ban in 2025; it then slowly falls to 10.6% by 2068, 4.6% points lower than in the status quo scenario. In the partial ban scenario, smoking prevalence drops slightly to 12.5% in 2025, immediately after the ban, and plateaus at 12.5% until 2068 (Figure 2).

In both ban scenarios, the numbers of ex-smokers would eventually be lower than under the status quo scenario, also due to lower initiation rates resulting in a reduced overall smoking prevalence. Under the full ban scenario, some illicit use continues, albeit at low levels (0.2% by 2030), but in the partial ban scenario, prevalence of using the remaining flavours is estimated at 4.8% in 2025, and projected to remain stable at that level until 2068.

In terms of smoking initiations, for young adults aged 18–24, smoking prevalence is expected to rise in 2018–2024 (pre-ban) from 11.0% to 14.3% and, in the status quo scenario, to stay around that level (14.1%) by 2030. In the full ban scenario, it would decline to 10.1% in 2025 and stabilize at around 9.1% by 2030. In the partial ban scenario, it would also decline but to a lesser extent, to 11.7% in 2025 and 10.7% by 2030.

Quality adjusted life years

Compared to the status quo scenario, both the full and partial ban scenarios are predicted to lead to substantial QALY gains (Figure 3). By the 2040s, we expect that total QALYs gained would be over 20,000 in the full ban scenario and 10,000 in the partial ban scenario (Table 1). By the late 2060s, we expect gains of over 40,000 and 20,000 QALYs in the full ban and partial ban scenarios, respectively. In the sensitivity analysis for QALYs gained in the full ban scenario, we observed ±20,000 QALYs gained, while a far smaller variation was observed for the partial ban scenario (Table 2), mainly due to the relatively large volume of people initiating with flavoured or other cigarettes not covered by the partial ban.

Discussion

In the absence of flavour regulations, smoking prevalence is expected to slowly increase over the 50-year period from 12.7% (in 2018) to 15.2% (in 2068). A partial flavours ban would negate this increase, resulting in a prevalence similar to the starting year (2018) while a full ban would, compared to 2018, result in a net decrease of 2.1% points and an estimated 40,000 QALYs gained, mostly be averting the roughly 20% loss of quality of life experienced by ever smokers on reaching middle age; double that in the partial ban scenario. The stark differences observed between the full and partial ban scenarios are due to more people quitting immediately following the ban and fewer people

initiating in the long term. In the partial ban scenario, flavoured cigarette users would still have the option to use menthol or clove-flavoured cigarettes which comprise the majority of flavoured cigarettes sold in Singapore, resulting in a lower immediate decline in smoking prevalence following the ban (0.4% points, compared to 1.6% points in the full ban scenario). In a partial ban scenario, young people who would have initiated with menthol or clove-flavoured cigarettes remain unaffected, resulting in a lower overall decline in smoking prevalence and less QALYs gained in the long term compared to a full ban scenario. Thus in markets with large menthol cigarette markets, such as Hong Kong, Malaysia and Singapore, a full flavours ban is likely to have a far more significant public health impact compared to a partial ban not covering menthol or clove-flavoured cigarettes, especially among young people who have a higher tendency to switch to other flavoured alternatives. However, these are also populations in which greater disutility may arise by banning popular flavours, potentially lowering perceived quality of life.

Our simulation may have over-estimated the impact of a partial flavours ban relative to a full flavours ban as it does not account for tobacco industry tactics. In countries that attempted to pass a full flavours ban, tobacco companies have lobbied aggressively to dilute the regulation to a partial ban, excluding menthol,[36,37] as the majority of flavoured smokers then switch to menthol-flavoured cigarettes.[5,18,19] In Singapore,[38] as in many other countries,[6] cigarettes containing non-menthol flavours often take the form of capsule cigarettes, and also contain menthol flavours which may facilitate switching to menthol capsule variants not covered by a partial ban. Tobacco companies have, in other countries, encouraged such switching by using the same colour codes and design features to point current smokers to 'replacement' variants not covered by the ban.[17,39] In the United Kingdom, tobacco companies also exploited loopholes in flavour regulations by marketing cigarettes with synthetic additives purported to mimic the taste of menthol.[40] Hence the impact of a tobacco flavours regulation will depend on how comprehensive it is, as well as tobacco industry tactics and the strength of a country's regulations to counter these, with appropriate policies regulating tobacco packaging, flavour capsules, and marketing.

Our simulation focused only on cigarettes as these comprise the vast majority (97.6%) of tobacco products sold in Singapore. However, places that implemented flavour bans not covering non-cigarette products, such as cigarillos, smokeless tobacco products and e-cigarettes, observed an increased use of these products following the ban as users, especially young people, switched to flavoured non-cigarette alternatives.[3,17,18,20,41–45] Hence the overall public health impact of a tobacco flavours ban will also depend on the availability and popularity of non-cigarette

Figure 2. Prevalence trends of (left to right, starting at top left): current smokers, unflavoured smokers, flavoured smokers, never smokers and ex-smokers, and total smoking prevalence at 10-year intervals in the full ban, partial ban and status quo scenarios.

Figure 3. Annual QALYs gained over the status quo scenario in the full ban (left) and partial ban (right) scenarios, with the upper and lower bounds of the sensitivity analysis illustrated by the outer lines.

products and whether the flavours ban also covers these. In Singapore, e-cigarettes and smokeless or heated tobacco products are banned which would likely result in lower switching rates than in countries such as the United States or South Korea, where they are legal and commonly used. While Singapore's market for cigars and cigarillos is small, this may grow as tobacco companies look for new ways to target youth with flavours and other product novelties.[16,17,24] Thus, even countries with small markets for non-cigarette tobacco products should consider including such products under the scope of a tobacco flavours ban.

Our simulation also considered the impact of illicit trade, for both current and prospective smokers, in both the partial and full ban scenarios. This is likely to vary between countries depending on the strength of border controls and other punitive or enforcement measures. In Singapore, the illicit trade volume is estimated to be stable and relatively low at 3.6%.[4,46] However, the impact of a tobacco flavours ban may be blunted in countries with higher illicit trade volumes or other

loopholes that increase the availability of flavoured cigarettes. Following the tobacco flavours ban in Canada, for instance, 19.5% of smokers who were using menthol-flavoured cigarettes before the ban continued using them after the ban as they were still legally available in First Nation reserves.[17] Such loopholes, as well as factors that affect illicit trade volume, should be considered when estimating the potential impact of a tobacco flavours ban.

Limitations

As in all modelling studies, our projected impacts were based on multiple assumptions. A limitation was the lack of reliable data for the estimation of transition probabilities with the impact of the bans, as most tobacco flavour bans were implemented recently and few robust evaluation studies are currently available. As the use of non-cigarette tobacco products (e.g. e-cigarettes, heated tobacco products, snus, cigars, cigarillos) is rare or illegal in Singapore, our model did not take into account the impact of switching to such products following a tobacco flavours ban. The projections assume recent market share of flavoured and non-flavoured cigarettes are indicative of future demand in the status quo scenario, which may not be the case as taste evolve and industry develops new products and campaigns. Furthermore, we simulated the implementation of the flavours bans independently of other policies and industry responses, when in reality, policies do not operate in siloed environments, and it is likely that other policies would be implemented to temper any rises in prevalence as seen in the baseline scenario presented herein. Our results should be read with consideration that the odds of better policy impact increases with a more comprehensive flavours ban and other tobacco control measures that counter possible tobacco industry tactics. A further limitation is the model's somewhat crude

| | QALYs gained (000s) relative to status quo | |
Year	Full ban	Partial ban
2030	11.3 (8.3−14.0)	5.2 (4.9−5.4)
2035	18.3 (12.9−23.4)	8.1 (8.1−8.4)
2040	24.4 (16.5−31.7)	10.8 (10.8−11.1)
2045	29.4 (19.1−38.9)	13.1 (12.7−14.3)
2050	32.8 (20.5−44.3)	15.3 (14.0−17.0)
2055	36.9 (22.5−50.3)	18.1 (16.3−20.5)
2060	40.3 (24.0−55.7)	20.9 (18.0−24.3)
2065	42.8 (24.5−60.1)	22.5 (18.6−27.4)

Table 2: **Total QALYs gained over the status quo scenario, with the lower and upper bounds of the sensitivity analysis indicated in parentheses, by each five-year interval in 2030−2065, in the full ban and partial ban scenarios.**

characterisation of smoking history which prohibited finer differentiation of the mortality risks in different groups. Specifically, for former smokers, as the model was unable to distinguish between the mortality risk of people who quit for longer versus shorter time periods, we adopted the more conservative assumption that the relative risks of former and current smokers were the same.

Conclusion

Our findings indicate that a tobacco flavours ban would reap substantial public health benefits in countries that, like Singapore, have a large flavoured cigarette market share, especially with a full flavours ban that also covers menthol and clove-flavoured cigarettes.

Contributorship statement

ZZ: data analysis, writing. ARC: conceptualisation, data analysis. JIPC: writing. YV: conceptualisation, writing. All authors reviewed the final draft before submission.

Data sharing statement

Multiple data sources were used to develop our microsimulation model. See the supplements for more information on our data sources. National population structure data are publicly available from the Singapore Department of Statistics. Reports of the national health survey data are publicly available from the Singapore Ministry of Health, although the dataset is not publicly available. Data from the Singapore survey of flavoured cigarette use are not publicly available but may be made available upon reasonable request. The data of tobacco sales volumes are, per legal agreement, not publicly available.

Declaration interests

There are no conflicts of interest.

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