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Theoretical impacts of a range of major tobacco retail outlet reduction interventions: modelling results in a country with a smoke-free nation goal

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Received 25 September 2013
Revised 11 June 2014
Accepted 24 June 2014
Published Online First 18 July 2014

To cite: Pearson AL, van der Deen FS, Wilson N, *et al. Tob Control* 2015;**24**: e32–e38.

ABSTRACT

Objective To inform endgame strategies in tobacco control, this study aimed to estimate the impact of interventions that markedly reduced availability of tobacco retail outlets. The setting was New Zealand, a developed nation where the government has a smoke-free nation goal in 2025.

Methods Various legally mandated reductions in outlets that were phased in over 10 years were modelled. Geographic analyses using the road network were used to estimate the distance and time travelled from centres of small areas to the reduced number of tobacco outlets, and from there to calculate increased travel costs for each intervention. Age-specific price elasticities of demand were used to estimate future smoking prevalence.

Results With a law that required a 95% reduction in outlets, the cost of a pack of 20 cigarettes (including travel costs) increased by 20% in rural areas and 10% elsewhere and yielded a smoking prevalence of 9.6% by 2025 (compared with 9.9% with no intervention). The intervention that permitted tobacco sales at only 50% of liquor stores resulted in the largest cost increase (~$60/pack in rural areas) and the lowest prevalence (9.1%) by 2025. Elimination of outlets within 2 km of schools produced a smoking prevalence of 9.3%.

Conclusions This modelling merges geographic, economic and epidemiological methodologies in a novel way, but the results should be interpreted cautiously and further research is desirable. Nevertheless, the results still suggest that tobacco outlet reduction interventions could modestly contribute to an endgame goal.

INTRODUCTION

Easy access to tobacco retailers is thought to facilitate uptake and to influence the success of cessation.[1–6] As such, there is growing interest in reducing the quantity and/or density of tobacco retail outlets, and several jurisdictions have proposed bans on the location or number of outlets (eg, see Tilson *et al*[7]). However, evidence of the effect of reducing outlets on smoking behaviours is limited, due to the current lack of intervention studies.

Much of the theoretical push for exploring tobacco outlet reductions stems from similar research on access to alcohol outlets and harmful consumption, where there is strong evidence of the effectiveness of population-level interventions to limit alcohol sales availability on reducing alcohol consumption and related health problems.[8 9] To date, the evidence of the effects of access to tobacco on smoking behaviours is derived from cross-sectional and a few longitudinal studies.[1–6] Studies in the USA have found that outlet density was associated with individual-level smoking among adults[1] and youth[3] and that proximity was associated with smoking among youth[6] and reduced cessation among adults.[2 5] Other evidence suggests that the neighbourhoods with the highest outlet density (>5 outlets) had higher adolescent smoking prevalence[10] and that banning tobacco sales at distances at least 200 m from schools was associated with decreased risk of smoking among students.[4] In contrast, however, a New Zealand study indicated that access to tobacco outlets was associated with individual smoking, but not after adjustment for neighbourhood deprivation.[11] Because access to retail tobacco outlets is, at present, quite high across New Zealand,[12] it may be difficult to detect the influence of access on smoking behaviours.

In March 2011, the New Zealand Government adopted the goal to (further) reduce the prevalence of smoking and the availability of tobacco products with the ultimate target to be essentially a smoke-free nation by 2025.[13 14] But plans for major new strategies to achieve this goal are lacking,[15] even though modelling work suggests that these are probably required.[16] Given the suggested evidence detailed above (for tobacco as well as alcohol outlets), a potential major endgame strategy could be to substantially reduce the number or density of tobacco retail outlets at a country level. To explore this in New Zealand, a combination of geographic and econometric approaches were used to calculate the potential impact of a range of major tobacco retail outlet restrictions, and considered the impact in the context of a smoke-free nation goal.

METHODS

Identifying potential interventions

Literature searches were conducted using PubMed, MEDLINE and Google Scholar (for the period 1 January 2000 to 31 January 2013). Key words included 'tobacco outlet', 'tobacco outlet density' and 'tobacco stores'. For example, in PubMed, these searches yielded 35 results for 'tobacco outlet', 22 results for 'tobacco outlet density' and 174 results for 'tobacco stores'. From these studies, a total of 11 unique papers were applicable to this modelling focus, in that they provided evidence of association between access to tobacco and smoking behaviours or different ways of measuring locational access to tobacco retailers. Hypothetical interventions were designed based on: (1) those used in other countries (often in regard to alcohol outlets); and (2) theoretical possibilities (building on analogies with other interventions). The selected interventions focus on one or more factors found to be associated with smoking behaviour: outlet quantity, location and density. Currently, there is no licensing or control of the location or number of tobacco retailers in New Zealand. So, for all of the hypothetical interventions, licensing of outlets was assumed to be required and any law would also: (1) limit sales to one pack of 20 cigarettes per person per day; (2) prohibit internet and mail order sales and (3) prohibit tobacco outlets in any new locations. For each intervention, total travel costs were calculated (details below). Then, interventions were assumed to be phased-in over a 10-year period starting at the base year (2011) with reductions in outlets selling tobacco occurring each year. For two of the interventions (1 and 2), it was assumed that an auction system would be used to reduce licences available each year. In the other two interventions (3A and 3B), it was assumed that distance measures would be used to legislate which outlets would remain each year. Finally, travel costs were calculated for each hypothetical intervention, and incremental cost increases were then used to predict changes in smoking prevalence over time.

Current tobacco outlet data

While the exact number and location of outlets in New Zealand is unknown, supermarkets, dairies/convenience stores[17] and vehicle fuel stations are common sources of tobacco products.[11 18] Often omitted from research, another source of tobacco products is off-licence alcohol outlets. These venues were included as other recent research in New Zealand included liquor stores as vendors of tobacco.[12] For convenience stores, supermarkets and petrol stations, previously compiled geographic locations were used.[19] For alcohol outlets, the 2011 licensed addresses available from the Alcohol Advisory Council were used. In total, 5979 tobacco outlets throughout New Zealand were mapped, as described elsewhere.[12] A recent geographic study using outlet data compiled from district health boards in New Zealand mapped similar types of outlets selling tobacco (n=5008).

Geographic boundary files for territorial local authorities (TLAs) and census area units (CAUs) and their population-weighted centroids from the 2006 census were obtained from the Statistics New Zealand website. Chatham Islands and other small islands (eg, Waiheke and Great Barrier) were excluded from analyses. CAUs (n=1542 nationwide were used) are the second smallest unit of aggregation and are considered useful approximations of neighbourhoods in urban areas.

Intervention (1): reduce total number of tobacco outlets by 95%

For this intervention, a sinking lid on annual licences to sell tobacco would be required by national law. This law would require, by TLA, a 50% reduction in the first year and a further 5 percentage points each year thereafter (until n=304, due to whole integer rounding). The 95% threshold was selected as being below the level at which the tobacco industry could plausibly attempt and win a legal case on the grounds that it was 'being eliminated' from the New Zealand market. Although such a case may have no strong grounds in existing New Zealand law, it is possible that New Zealand may in the future sign international trade agreements where such legal action became more plausible.

To determine which outlets would remain each year, population density (per km^2) was used as a proxy for demand, whereby if retailers bid for a limited number of available licences, those envisaging the largest turnover (ie, those with highest demand, or population density) would be likely to bid the highest amount to secure the licence. Thus, the first year each outlet was assigned its CAU population density plus the average population density of all neighbouring CAUs (not crossing a TLA boundary). Over time, the geographic reach expanded to sum the population density and select which outlets remained. The iterative summed population densities were ranked to determine which outlets remained until the appropriate percentage of the original outlets remained in each TLA.

Intervention (2): permit sales at half the liquor stores (and nowhere else)

This intervention assumed a law to limit tobacco sales to just 50% of liquor stores within 10 years (n=386 stores). As such, this intervention was designed to utilise existing official compliance and monitoring structures which penalise sales of alcohol from such outlets to minors. Similar to intervention 1, we assumed that the total number of all types of tobacco outlets would be reduced by 50% in the first year, and a further 5 percentage points each year thereafter. In the final year, there would be an auction process in which licences for tobacco sales are limited to 50% of all the liquor stores in the country (with the assumption being that those in areas with the highest population density would be the successful bidders).

Intervention (3): eliminate sales from outlets within 1 km (A) and 2 km (B) of all schools

Since some studies have found that increased exposure to tobacco sales decreased the likelihood of cessation, particularly for some population groups,[20] reducing density theoretically lowers intensified exposure. Therefore, a national law that required a phased (over 10 years) elimination of all types of tobacco outlets near schools was assumed. More specifically, in interventions 3A and 3B, annually expanding buffer rings were used around all schools (primary, intermediate and secondary) at even increments to reach a maximum buffer size of 1 km and 2 km, respectively, at the 10-year point. All tobacco outlets within each annual buffer expansion were removed. This resulted in 641 and 260 remaining outlets at the national level, respectively.

Calculating travel time/costs for baseline and interventions

To calculate total travel costs, the costs associated with travel (eg, fuel, car maintenance, etc) and costs associated with time spent travelling were estimated. Distances along roads from the population-weighted centroid of CAUs to the nearest outlet and back to the centroid were calculated. For the baseline scenario, all existing tobacco outlets were used for the travel cost calculations. For each intervention, specified reduced locations were used. Distances were then assigned a cost, including the marginal cost of this travel and excluding fixed costs (eg, depreciation, licensing and insurance). The Ministry of Health mileage reimbursement rate for private vehicles under the National Travel Assistance Scheme was used as an approximation of the cost for private travel. This rate was NZ$ 0.28/km (2011 NZ dollars).[18]

To generate the costs associated with the time spent in travel, travel speeds of 50 km/h in urban/semiurban areas and 70 km/h in rural areas were used. This time was valued using data from the New Zealand Transport Agency, which outlines values for time by transport type and trip type.[21] The car, non-work travel time value was NZ$7.18/h.

These two costs were summed to generate a total travel cost for the baseline scenario and for each intervention. In year 1, baseline costs were subtracted from intervention costs and then the incremented net cost increases for each year thereafter were calculated. Travel explicitly for the purchase of tobacco after the intervention was assumed to be up to 50% of the round trip travel in the final year of the intervention. In two scenarios (A and B), incremental increases in the travel explicitly for tobacco (up to 20% or 80%) were examined. These calculations yielded net cost increases for each intervention, outlined in the example formula below.

$$X_i \text{ in year } 10 = 0.5 \times (((0.28 \times t1_i) + (7.18 \times t2_i)) - ((0.28 \times b1_i) + (7.18 \times b2_i)))$$

where X_i=net cost increase for intervention i; $t1_i$ is the kilometres travelled for intervention i; $t2_i$ is the time spent travelling for intervention i; $b1_i$ is the kilometres travelled for baseline and $b2_i$ is the time spent travelling for baseline.

To take some account for geographic heterogeneity in travel costs, CAUs were divided into three categories: urban, semiurban and rural, using the rural/urban schema developed by Statistics New Zealand. Average net costs were calculated for each of these groups for each intervention. To run the forecasting model, averages by rurality category were used.

Baseline costs were the sum of estimated pack price (mean purchase price of $14.01 for a 20-cigarette pack)[26] plus travel costs under current conditions (with all existing outlets). The mean price to purchase a pack of 20 cigarettes in 2011 was back calculated from mid-February 2013 prices in the only national online supermarket 'Countdown' (shop.countdown.co.nz/), adjusted for changes in tax and consumer price index. A survey of prices in this outlet included all varieties of products sold including cartons and pouches of loose tobacco (at 0.7 g/cigarette equivalent; n=181 products, database available on request).

Intervention net costs for the first year were calculated by subtracting baseline costs from the intervention costs. Intervention costs for subsequent years were incremental increases over the previous year. Inflation rates were not used.

Analyses of potential impacts of outlet reduction interventions on demand for tobacco and smoking prevalence

The modelling approach used is as described in a published Australian model by Gartner *et al*.[22] Briefly below, features of that model and its previous adaptations for modelling in the New Zealand context are highlighted.[16]

Base model to 'business-as-usual' smoking prevalence

The method involved first establishing recent trends (base model), using observed population, mortality, smoking prevalence (current, former and never-smokers, from 2006 and 2013 census data), and smoker mortality risks in New Zealand, to determine current trends in smoking uptake by age 20 and probability of cessation, by age, sex and ethnicity. In this model, cessation reflects the net effect of current smokers quitting and former smokers relapsing in any one year. The outputs from 2006 to 2013 of this base model were used as inputs for future business-as-usual (BAU) forecasting (or dynamic population model), which assumes that the current trends in uptake and cessation would continue into the future (2011–2040).

Reductions in smoking prevalence from outlet reduction interventions

To calculate the estimated reduction in demand and thus smoking prevalence (below the forecasted BAU), the increased net cost (travel) each year was treated as if it were an increase in the cost of purchasing tobacco. The demand reduction effect size of these cost increases was determined using age group-specific price elasticity for cigarettes. Elasticities were based on an overall price elasticity of demand for tobacco in New Zealand (−0.47 for manufactured cigarettes over the 2002–2011 period),[23] albeit using the age gradient pattern as used in the SimSmoke model,[24] and an assumption that the prevalence elasticity is around half that of the overall demand elasticity (as per a recent review by IARC[25]). This gave final age group-specific elasticities in the range −0.10 to −0.38 for smoking prevalence. Full details on the effects of price elasticity over time were described elsewhere.[26] A scenario was also run which involved 50% lower price elasticities, for comparison (scenario F) to allow for the more indirect nature of the price signal associated with vehicle running costs and travel time.

The net travel costs were included as annual incremental cost increases over the 10-year phased implementation of each intervention. The dynamic population model was run for each of the rural/urban area categories. Accordingly, changes in smoking prevalence over and above BAU were predicted from 2011 to 2040. A national smoking prevalence estimate was estimated by weighting estimates from rurality categories by their proportion of the national population in New Zealand (using 2006 census data[27]) and summing. For example, rural areas comprise 7% of the population, semiurban areas comprise 9% of the population and urban areas comprise 84% of the population.

RESULTS

Table 1 shows the estimated increases in notional cost of a pack of 20 cigarettes (pack price plus travel costs) in 2025 for all interventions compared with baseline conditions. For all interventions, effects were largest in rural areas followed by semiurban areas (relative to urban areas; table 1). By 2025, the notional pack cost increased by 20% in rural areas and by 10% elsewhere for the 95% reduction in outlets, with an estimated smoking prevalence of 9.6% in 2025, or 0.3% less than the BAU estimated prevalence for that year (table 1 and figure 1).

Permitting sales at 50% of liquor stores as the only tobacco outlets (a 94% reduction in current outlets) resulted in the highest notional cost of a pack in 2025, at around $60 in rural areas. Thus, this intervention also led to the lowest estimated national smoking prevalence in 2025 at 9.1%, or 0.8% less than BAU (table 1 and figure 1). Elimination of all outlets within 1 km of schools (an 89% reduction in outlets) had the least impact on cost and likewise the lowest impact on smoking prevalence. However, elimination of outlets within 2 km of schools (a 96% reduction in outlets) led to lower estimated smoking prevalence than the 95% reduction in outlets, at 9.3% by 2025. Figure 2 shows that under the 95% outlet reduction intervention, although smoking prevalence in rural areas is lowest in 2025 (~9% shown in figure 1), the estimated national prevalence was higher (9.6%, table 1). This difference is due to the large proportion of the population residing in urban areas.

In terms of scenario analyses for assumptions in the models, cost estimates appeared to be sensitive to the assumption regarding amount of travel explicitly for purchasing tobacco (table 2). However, even attribution of up to 80% of travel for tobacco purchasing (scenario B) for the 95% reduction in outlets intervention

Table 1 Cigarette pack costs from increased travel costs and adult smoking prevalence in New Zealand for all the modelled tobacco retail outlet reduction interventions*

Intervention (phased in over 10 years)	Pack of 20 cigarettes in 2025	Total travel costs in 2025			Notional cost of a pack in 2025=(pack+travel)			Ratio of costs Intervention:baseline			National smoking prevalence in 2025 (%)	Percentage reduction in outlets (%)
		Rural	Semiurban	Urban	Rural	Semiurban	Urban	Rural	Semiurban	Urban		
Baseline	$14.01	$8.91	$6.22	$0.92	$22.92	$20.23	$14.93	1	1	1	Business-as-usual=9.9	0
Reduce total number of tobacco outlets by 95%		$13.46	$8.56	$2.53	$27.47	$22.57	$16.54	1.2	1.1	1.1	9.6	95
Permit sales at half the liquor stores (and nowhere else)		$44.97	$20.50	$9.93	$58.98	$34.51	$23.94	2.6	1.7	1.6	9.1	94
Eliminate sales from outlets within 1 km of all schools		$11.92	$7.93	$2.43	$25.93	$21.94	$16.44	1.1	1.1	1.1	9.7	89
Eliminate sales from outlets within 2 km of all schools		$13.59	$11.28	$5.74	$27.60	$25.29	$19.75	1.2	1.3	1.3	9.3	96

*All assumed to have a maximum of 50% of increased travel time attributed to buying tobacco; national smoking prevalence estimated using proportional population weighting by rural, semiurban and urban areas.

did not yield smoking prevalence reductions adequate to meet the 2025 national smoke-free goal (which is typically considered to involve an adult smoking prevalence of less than 5%[28]). Permitting sales at only 50% of existing liquor stores led to the largest cost increases over baseline, for all scenarios. For scenario B, this intervention led to a tripling of costs in rural areas and a doubling for scenarios C–F. The lowest smoking prevalence (8.8% in 2025) was achieved in scenario B (up to 80% of travel explicitly for tobacco) for this intervention.

DISCUSSION

This study provides modelling-level evidence that various hypothetical tobacco outlet reduction strategies may accelerate progress towards tobacco endgame goals, albeit with substantial uncertainty (as discussed further below). Nevertheless, none of the modelled interventions, when added to BAU tobacco control activities, achieved the endgame 2025 goal for New Zealand (typically regarded as <5% smoking prevalence). Tobacco outlet reduction appears to be one potential component of an endgame strategy. The findings may have applicability to other countries with endgame aspirations or with rapidly declining adult smoking prevalence (especially if <20%).

Various assumptions used in this modelling work could lead to either underestimates or overestimates of the effects of outlet reduction. Regarding the latter, we assumed that the law would limit tobacco sales to one pack of 20 cigarettes per person per day and internet and mail order sales were prohibited. If this assumption is invalid (eg, enforcement of a maximum of one pack per day per smoker is impossible or impracticable, and the same shopper returns to the same shop many times in one trip away from home), then this modelling will overestimate the impact of outlet restrictions pro rata with the lack of enforcement of this one pack per day assumption.

Two of the interventions also assumed that licences were granted to the highest bidder and population density was a proxy for demand. If the licence granting scheme used different criteria for allocation of licences, results could vary and more

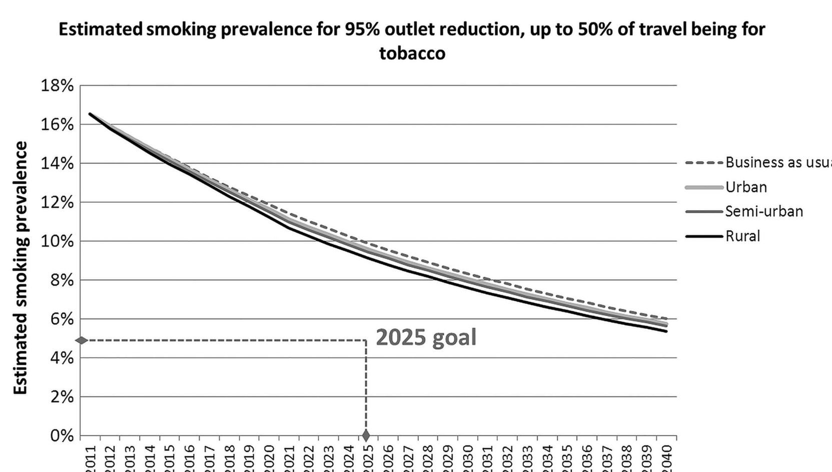

Figure 1 Estimated adult smoking prevalence in New Zealand with a modelled 95% reduction in outlets by area type for 2011–2040 (for travel costs increasing incrementally up to 50% of travel being for tobacco in year 10 of the intervention; compared with business-as-usual). Note: New Zealand's national smoke-free goal is marked at the intersection of the year 2025 and the 5% point (the goal is broadly accepted to involve achieving <5% adult smoking prevalence by this date).

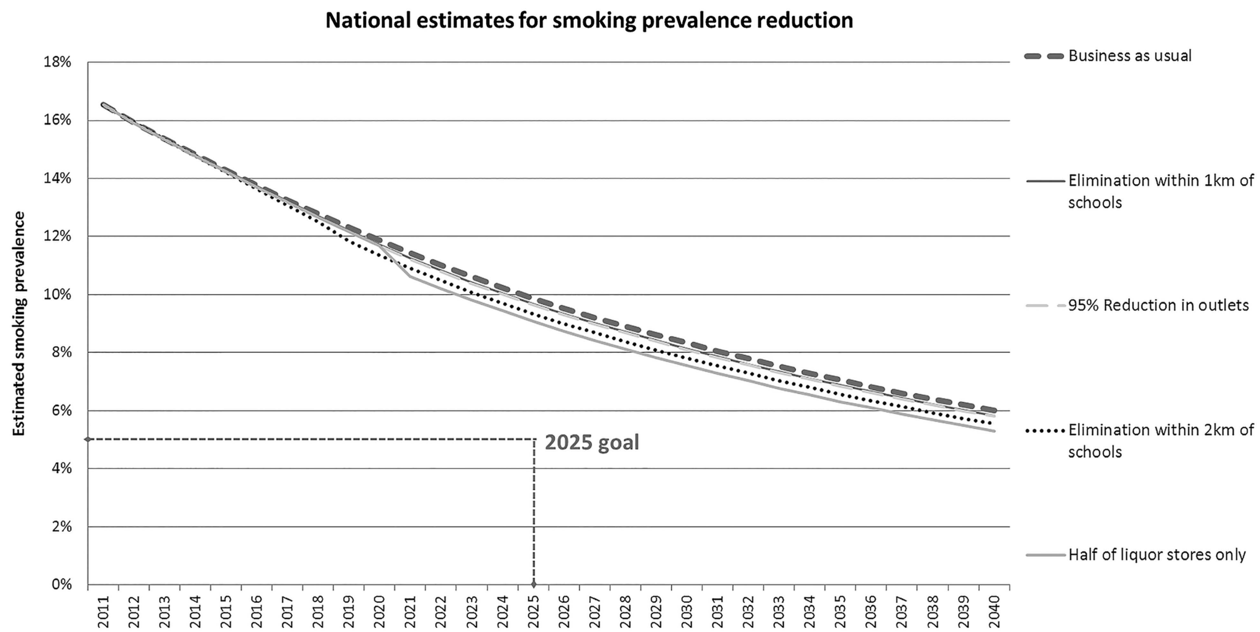

Figure 2 Estimated adult smoking prevalence in New Zealand for selected phased-in interventions for 2011–2040 (with up to 50% of travel being for tobacco and compared with business-as-usual).

research would be required to understand this, including both modelling studies such as this one but also careful analysis of 'real' intervention studies or natural experiments. The differences in smoking prevalence effects between the interventions in this study were largely due to differences in outlet reductions in urban areas. Thus, elimination of outlets in urban areas will likely have the greatest impact on smoking prevalence, as the population in New Zealand is highly urbanised (84% living in

Table 2 Sensitivity analyses: estimated cigarette pack costs and adult smoking prevalence for interventions—scenarios A–F

	Intervention (phased in over 10 years)	Notional cost of a pack in 2025			Ratio of costs Intervention:baseline			National smoking prevalence in 2025 (%)
		Rural	Semiurban	Urban	Rural	Semiurban	Urban	
Scenario A: incremental up to 20% of travel being tobacco related (rather than 50%)	Baseline	\$22.92	\$20.23	\$14.93	1	1	1	
	Reduce total number of outlets by 95%	\$24.74	\$21.17	\$15.57	1.1	1.0	1.0	9.8
	Permit sales at only half the liquor stores	\$33.98	\$24.02	\$17.94	1.5	1.2	1.2	9.5
	Eliminate sales within 1 km of schools	\$24.12	\$20.91	\$15.53	1.1	1.0	1.0	9.8
	Eliminate sales within 2 km of schools	\$24.79	\$22.25	\$16.86	1.1	1.1	1.1	9.6
Scenario B: incremental up to 80% of travel being tobacco-related (rather than 50%)	Baseline	\$22.92	\$20.23	\$14.93	1	1	1	
	Reduce total number of outlets by 95%	\$30.20	\$23.98	\$17.51	1.3	1.2	1.2	9.5
	Permit sales at only half the liquor stores	\$67.17	\$35.41	\$26.96	2.9	1.7	1.8	8.8
	Eliminate sales within 1 km of schools	\$27.72	\$22.97	\$17.33	1.2	1.1	1.2	9.6
	Eliminate sales within 2 km of schools	\$30.39	\$28.32	\$22.63	1.3	1.4	1.5	9.1
Scenario C: \$0 value on time (rather than \$7.18/h)	Baseline	\$20.53	\$18.12	\$14.62	1	1	1	
	Reduce total number of outlets by 95%	\$23.86	\$19.67	\$15.68	1.2	1.1	1.1	9.7
	Permit sales at only half the liquor stores	\$40.76	\$24.39	\$19.58	2.0	1.3	1.3	9.3
	Eliminate sales within 1 km of schools	\$22.72	\$19.25	\$15.61	1.1	1.1	1.1	9.7
	Eliminate sales within 2 km of schools	\$23.90	\$21.46	\$17.80	1.2	1.2	1.2	9.5
Scenario D: 50% lower value on time (\$3.59/h)	Baseline	\$21.73	\$19.17	\$14.77	1	1	1	
	Reduce total number of outlets by 95%	\$25.66	\$21.12	\$16.11	1.2	1.1	1.1	9.7
	Permit sales at only half the liquor stores	\$45.67	\$27.05	\$21.01	2.1	1.4	1.4	9.2
	Eliminate sales within 1 km of schools	\$24.32	\$20.59	\$16.02	1.1	1.1	1.1	9.7
	Eliminate sales within 2 km of schools	\$25.74	\$23.37	\$18.77	1.2	1.2	1.3	9.4
Scenario E: 50% greater value on time (\$10.77/h)	Baseline	\$24.12	\$21.28	\$15.08	1	1	1	
	Reduce total number of outlets by 95%	\$29.28	\$24.02	\$16.97	1.2	1.1	1.1	9.6
	Permit sales at only half the liquor stores	\$55.49	\$32.38	\$23.88	2.3	1.5	1.6	9.0
	Eliminate sales within 1 km of schools	\$27.52	\$23.28	\$16.84	1.1	1.1	1.1	9.7
	Eliminate sales within 2 km of schools	\$29.44	\$27.19	\$20.71	1.2	1.3	1.4	9.3
Scenario F: 50% lower price elasticities (ie, range −0.05 to −0.20 depending on age)	Baseline	\$22.92	\$20.23	\$14.93	1	1	1	
	Reduce total number of outlets by 95%	\$27.47	\$22.57	\$16.54	1.2	1.1	1.1	9.8
	Permit sales at only half the liquor stores	\$50.58	\$29.71	\$22.44	2.2	1.5	1.5	9.5
	Eliminate sales within 1 km of schools	\$25.92	\$21.94	\$16.43	1.1	1.1	1.1	9.8
	Eliminate sales within 2 km of schools	\$27.59	\$25.28	\$19.74	1.2	1.2	1.3	9.6

Scenarios use same parameters as those in table 1 (unless stated otherwise).

urban areas). Permitting sales only at 50% of liquor outlets led to the highest increase in notional cost of a pack and the lowest smoking prevalence of 9.1%. Eliminating outlets within 2 km of schools achieved notional average cost of a pack of \$20 (urban) to \$28 (rural), and a 2025 smoking prevalence of 9.3%. Eliminating sales near schools has the added benefit of denormalising tobacco, and some evidence suggests that banning tobacco sales at distances at least 200 m from schools was associated with decreased risk of smoking among students.[4] This intervention may also be the most plausible outlet reduction intervention, based on other international proposed legislation and noted public support within New Zealand.[29] Analyses also indicate that larger buffer zones (>2 km) around schools would be probably be needed to achieve smoke-free goals, at least in the New Zealand setting.

A strength of this study is that it is the first to model four hypothetical endgame interventions to reduce tobacco outlets. One factor this work has not considered is the cost of implementation of these interventions. As such, a next step could be to conduct a cost-effectiveness analysis. For example, the cost of the law (which has been estimated for New Zealand[30]), potential increases in border control to prevent the growth of a black market circuit or costs of operating and creating a licensing system for outlets. Crime control costs may also increase if higher tobacco costs would stimulate more illegal sales of home-grown tobacco. However, other modelling work on tobacco taxation increases[31] suggests that this is unlikely to be a substantive problem. Furthermore, in terms of intervention costs, it is conceivable that this intervention could be self-funding from a government perspective if auction prices for licensing were set to cover such additional costs to society.

An important limitation of this research was its exclusion of other possible mechanisms through which tobacco retail reductions might affect the prevalence of smoking. For example, outlet reductions may facilitate enforcement of smoking laws restricting sales to youth, may further denormalise smoking and tobacco products through reduced availability, social acceptability and in potential signals to smoke. As such, these findings likely underestimate reductions in smoking prevalence achievable via outlet reduction. In addition, this modelling assumed a linear relationship between the value of time and distance travelled. For example, 1 h travelled in a car was considered equivalent to twice the time wastage and lost utility of 30 min of travelling. However, in reality, different population groups (based on rurality, ethnicity, sex, occupation, etc) may value time differently. Also, it is plausible that even in the BAU scenario as tobacco use declines nationally, some retail outlets may stop selling tobacco for purely commercial reasons or because of larger supermarkets replacing some smaller convenience stores over time. But inadequate data led to exclusion of such projections in this model. Last, the geographic location data for convenience stores, supermarkets and petrol stations were compiled using data from 2004. However, the type of retailer often remains the same, even if ownership changes. For example, petrol stations very rarely change to another retailer type. It is plausible that the price/demand relationship has non-linear aspects at very high cigarette prices—but there is no definitive literature on this. Perhaps some reassurance can be gleaned from literature on other drugs which are far more expensive per gram than tobacco is currently (10+ times more). For example, the price elasticities used here are not dissimilar to those identified from a meta-analysis of price elasticities for: marijuana (−0.15 to −0.31), cocaine (−0.53 to −0.56) and heroin (−0.47 to −0.54).[32]

From a central government perspective, it may be that continuously higher tobacco taxes are more optimal than retail restrictions as then the price signal is delivered to smokers in a direct way and the government will gain from higher tobacco tax revenue. This is preferable to the indirect price signal (via retail restrictions) involving smokers spending more time travelling and driving more. Downsides of the latter include more air pollution, greenhouse gas emissions and possibly vehicle crashes. But it might be politically difficult for a government to continue raising taxes and so incremental retail restrictions may ultimately be a more effective and publicly favourable[33] approach, especially if local government is also part of the leverage process. If so, then the most effective strategy suggested by this modelling would be to restrict tobacco sales to just 50% of liquor stores across the country, making use of existing licensing and monitoring schemes in New Zealand.

In conclusion, this modelling merges geographic, economic and epidemiological methodologies in a novel way, but the assumptions and results require cautious interpretation and refinements for other settings. Although apparently assisting in reducing smoking prevalence (eg, down to 9.1% for the liquor store intervention), none of the outlet reduction interventions modelled achieved the national 2025 smoke-free goal for New Zealand of <5% adult smoking prevalence. Tobacco outlet reduction interventions could contribute to advancing tobacco control, but they would probably need to be part of other endgame strategies.

What this paper adds

- This paper combines geographic, economic and epidemiological methodologies in a novel way to estimate the potential impacts of mandated reductions in tobacco outlet retailers and therefore changes in access to tobacco on national smoking prevalence.
- This paper offers a quantification (albeit with notable levels of uncertainty) of the potential effect of outlet reductions as a new endgame approach to help achieve smoke-free goals at the country level.

Acknowledgements The authors thank their colleagues particularly Dr Nhung Nghiem for helpful comments on draft versions of this manuscript.

Contributors ALP and NW designed the study. FSvdD conducted a literature review, and assisted in running analyses. LC developed the dynamic forecasting model and assisted in analyses. TB and NW supervised analyses and guided interpretation. ALP was the lead on all analyses including geographic techniques and drafted the manuscript. All authors reviewed and edited the manuscript.

Funding This work receives funding support from the Health Research Council of New Zealand (the BODE[3] Programme, project number 10/248).

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Raw data tables are available on request.

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