The health and health system cost impacts of increasing vegetables prices over time

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Contents

Glossary

Acronym	Full name
BAU	Business As Usual
BMI	Body Mass Index
BODE^3	Burden of Disease Epidemiology, Equity and Cost-Effectiveness
BDS	Burden of Disease Study
CFR	Case Fatality Rate
CHD	Coronary Heart Disease
CPI	Consumer Price Index
DR	Disability Rate
HALY	Health Adjusted Life Years
MSLT	Multi-State Life-Table
NZANS	New Zealand Adult Nutrition Survey
PE	Price Elasticity
PIF	Population Impact Fraction
SD	Standard Deviation
SNZ	Statistics New Zealand
TFEe	Total Food Expenditure elasticity
TMREL	Theoretical minimum risk exposure level

Abstract

Background: It has been estimated that there will be a decrease in the volume of vegetable production of between 46 to 55% in a key NZ growing hub over the next 25 years. This is due to challenges such as urban encroachment, availability of skilled labour, and water access issues. This has been estimated to correspond to an increase in price of between 43% and 58%. This report aims to model two scenarios where the price of vegetables increases each year for the next 23 years, firstly by 2% a year and secondly by 2.5% a year to match this expected price increase.

Methods: An established multi-state life-table model using multiple input parameters (e.g., epidemiological and cost parameters for diet-related diseases) was used to model the impact of this cumulative price change. We calculated health adjusted life years (HALYs) lost and health system costs over the remainder of the lifespan of the NZ population alive in 2011 (N=4.4 million) using a 3% discount rate.

Results: The 2% and 2.5% cumulative increase in NZ vegetable prices from 2020 to 2042 results in a decrease in daily vegetable intake of 69 grams and 94 grams by 2042. The 2% cumulative increase results in a 58,300 reduction in HALYs and $490 million costs to the health system. The 2.5% price increase produced overall HALY losses that were 25% greater and costs to the health system that were 24% greater than the 2% cumulative price increase at 72,800 and $610 million. A greater decrease in HALYs and increase in health system costs are seen in females compared to males in both price increase scenarios. The per capita HALY loss is greater in non-Māori than Māori.

Conclusions: These small cumulative increases in the price of vegetables are likely to cause an important decrease in vegetable consumption in NZ over the next two decades. This is likely to lead to modest health loss to the NZ population and costs to the health system over time.

Introduction

In 2018, Deloitte conducted a report for Horticulture NZ on ‘New Zealand’s Food Story’ with a focus on the Pukekohe Hub (Deloitte, 2018). The Pukekohe hub straddles the Auckland and Waikato District boundaries, and it is key to sustaining the fresh food supply to Auckland. It found that, over the next 25 years, the Pukekohe hub could face constrained horticulture production which could result in higher prices for customers, among other negative effects.

Between 2002 and 2016 there has been a 30% reduction in vegetable-growing land across New Zealand. Significant and often swift land-use change is putting pressure on our growing hubs – like Pukekohe, Manawatū, Hawke’s Bay and Central Otago – to keep up with New Zealanders’ demand for fruit and vegetables. Population growth and changing consumer preferences mean demand for fruit and vegetables will increase. Urban encroachment means productive land is being used for other purposes. Growers are struggling with the cost of land, intensive growing, competition for water, and sourcing labour. With further growth in supply potentially constrained, and demand rising, the country runs the risk of not being able to provide its own population with affordable fruit and vegetables.

Deloitte carried out modelling to estimate the impact of these changes through two scenarios: a base case and a constrained ‘counterfactual’ scenario. Each scenario was modelled over 25 years, out to 2043 and over Auckland and the Waikato District. Under both the counterfactual and base case scenarios, demand for fruit and vegetables, and Auckland’s population, are projected to grow significantly.

Under the constrained counterfactual scenario consumers in Auckland would face prices 58% higher than they otherwise would be under the base case. Deloitte also considered two variations of the counterfactual scenario: ‘flexible’, where growers have the ability to change their practices and input mix in response to land access and other constraints on production and ‘rigid’, where land scarcity is further constrained by land use restrictions. Deloitte considers the rigid variation is more likely to occur. This is because growers’ ability to respond could be limited by environmental constraints, external regulations – like new taxes or land-use restrictions – or limited access to capital that could support alternative growing methods.

The modelling estimates a decrease in the volume of fruit and vegetable production of up to 55% under the rigid scenario for the Auckland economy. Consumers in Auckland could face prices 43% (under the counterfactual) to 58% (under the rigid scenario) higher than they otherwise would be under the base case.

The aim of this report is to model two scenarios where the price of vegetables increases each year for the next 23 years, firstly by 2% a year and secondly by 2.5% a year to approximate these price rises.

Methods

OVERVIEW

Main outputs from this modelling were incremental health gains/losses in health adjusted life years (HALYs) and health system costs in 2011 New Zealand dollars (NZ$) between business-as-usual (BAU) and two scenarios:

- 2% cumulative price increase each year from now for the next 23 years, such that in 23 years affected vegetables cost 58% more, relative to the baseline price
- 2.5% cumulative price increase each year from now for the next 23 years, such that in 23 years affected vegetables cost 76% more, relative to the baseline price

Both health impact and costs were discounted at 3% in the main model with 0% and 6% discounting used in scenario analyses. This modelling takes a health system perspective (i.e. only considers costs to the health system rather than including wider costs e.g. impacts on income loss), and models the expected increases in the price of vegetables so no intervention costs were included. Benefits and costs were modelled over a lifetime horizon in the whole New Zealand adult population alive in 2011 (N=4.4 million).

The DIET multi-state life-table model (MSLT) used for this modelling was built from an established tobacco control MSLT model (using many of the same diseases), from which we have published work previously (Blakely et al., 2015, Pearson et al., 2016, Van der Deen FS, 2017, Cleghorn et al., 2018). This BODE[3] (Burden of Disease Epidemiology, Equity and Cost-Effectiveness) DIET MSLT model has itself already being used for studying a number of dietary interventions (Cleghorn C et al., 2018, Cleghorn et al., 2019, Cleghorn et al., 2020, Drew et al., 2020). The DIET MSLT model is described further in an online technical report (Cleghorn et al., 2017).

The DIET MSLT model was used to simulate the entire New Zealand population that was alive in 2011 over their remaining lifetimes. This model is structured as a main life-table with projected all-cause mortality and morbidity rates by sex and age for Māori and non-Māori. The model has 17 diet-related diseases running in parallel (i.e., type 2 diabetes, coronary heart disease (CHD), stroke, osteoarthritis and multiple cancers: endometrial, kidney, liver, oesophageal, pancreatic, thyroid, colorectal, breast, ovarian and gallbladder). For the main analysis only disease affected by vegetable consumption contribute to the change in outcomes (CHD and stroke). For the scenario analysis including the effect of all dietary risk factors all diseases contribute to the overall results.

DIETARY DATA

The food groups in the NZ national adult nutrition survey (2008/09, NZANS) (Ministry of Health, 2011) that were labelled as 'vegetables' or 'potatoes, kumara and taro' were selected in the survey data. The individual level data was used to determine what percentage of the food groups were fresh and what percentage were frozen as price changes were likely to affect fresh vegetables only.

The database was searched for any instances of 'frozen' in the food descriptor. All food groups that had at least one food that was frozen were checked and each food was categorised as 'frozen' (if explicitly stated), 'likely to be frozen' (e.g. Peas, green (plain or minted), cooked; Vegetable, mix, peas/corn and other; Kfc, side order, hot chips / fries) or 'fresh'.

An additional percentage was applied to account for the likelihood that the food group would have been affected by the price change. The main issues considered in this decision include whether these vegetables are imported as the proportion frozen had already been considered in the previous calculation. The percentage 'fresh' and 'affected by price change' were multiplied together and the price change was just applied to this percentage of the overall food group. These percentages and the final percentage of the vegetable food groups that the price change was applied to are shown in Table 1.

Table 1 Proportion of the food groups that are fresh vegetables to be targeted by the price change

Overall food group	Food group description	Fresh (%)	Affected by price Δ (%)	Targeted in model (%)
Vegetables	Leafy greens includes lettuce, spinach, silver beet, bok choy etc.	100%	100%	100%
Vegetables	Beans/peas/corn	46%	50%	23%
Vegetables	Cooked or canned tomatoes	100%	5%	5%
Vegetables	Purees and pastes	100%	5%	5%
Vegetables	Raw	100%	100%	100%
Vegetables	Carrots	98%	100%	98%
Vegetables	Pumpkin/squash/butternut	100%	80%	80%
Vegetables	Yams	100%	100%	100%
Vegetables	Cauliflower/Broccoli/Brussel sprout/cabbage/turnip & other brassicas	100%	100%	100%
Vegetables	Onion/garlic/leeks.	100%	50%	50%
Vegetables	Other vegetables includes parsnip, marrow/courgettes and eggplant etc.	100%	100%	100%
Vegetables	Carrots/peas/beans/corn mixes	1%	5%	0%
Vegetables	Stir-fry mixes	45%	5%	2%
Vegetables	Mature legumes and pulses	100%	0%	0%
Vegetables	Mature legumes and pulse products and dishes (includes baked beans)	100%	0%	0%
Vegetables	Meat substitutes and dishes	100%	0%	0%
Vegetables	Stuffed vegetables and vegetable dishes	100%	100%	100%
Vegetables	Salad recipes (includes green salads, coleslaw, vegetable salads etc.)	100%	100%	100%
Potatoes, kumara and taro	Potato (includes boiled and baked potatoes)	100%	80%	80%
Potatoes, kumara and taro	Potato chips/wedges/croquette/hash browns	13%	5%	1%
Potatoes, kumara and taro	Potato crisps - regular fat	100%	5%	5%
Potatoes, kumara and taro	Potato crisps - reduced fat	100%	5%	5%
Potatoes, kumara and taro	Mashed potatoes with cheese added	100%	80%	80%
Potatoes, kumara and taro	Scalloped potatoes	100%	80%	80%
Potatoes, kumara and taro	Stuffed potatoes and other potato dishes	100%	80%	80%
Potatoes, kumara and taro	Potatoes with additions (e.g. mashed with fat/milk added)	91%	80%	73%
Potatoes, kumara and taro	Kumara	100%	100%	100%
Potatoes, kumara and taro	Taro	100%	100%	100%

COST DATA

The retail prices of New Zealand specific Nutritrack supermarket data (collected between December 2010 and April 2011) (Luiten et al., 2015) were used to estimate food prices of the NZANS food groups. The brand name and product name in the Nutritrack database were grouped by Nutritrack food category (for example, beverages or bread products). NZANS food groups and Nutritrack food products are not the same groupings. At maximal disaggregation, there were 346 NZANS food groups, and 6192 Nutritrack food products. Therefore, NZANS food groups and associated food group codes were matched to an assortment of Nutritrack food products to provide price information for each food group. Product price was considered when matching food groups to the corresponding food products to ensure the range of products were most appropriate in terms of cost. Each food group required matching to at least one food product, and where possible food groups were matched to at least 10 different food products.

Where there were a limited number of appropriate Nutritrack food products available to match to NZANS food groups, food products were duplicated to allow more than one NZANS food group to be matched to one Nutritrack product. Food groups that reflected recipes (for example, casseroles/stews with sauce only) were matched to the most appropriate food products resembling the same or similar food components, and with probable similarities in terms of cost.

Prices for food groups that could not be matched to Nutritrack data were obtained from online supermarket data. This included food products such as fresh fruit, vegetables and meat and poultry. The prices for these food products were obtained using the Countdown online supermarket (http://shop.countdown.co.nz). An unweighted average price was calculated across a range of food products considered to be most commonly consumed to obtain an average price for that food. Prices obtained from the online supermarket (year 2014) were scaled using the consumer price index (CPI) to reflect 2011 prices.

For this analysis, 2011 cost data in the dietary intervention model was updated to 2020 using a CPI adjustor ratio (https://www.bls.gov/data/inflation_calculator.htm) of 1.17.

MODELLING APPROACH

BUSINESS-AS-USUAL (BAU) INPUT PARAMETERS

All input parameters, specified by sex, age and ethnicity unless stated differently, are shown in Table 2. Incidence, prevalence and case-fatality rates in 2011 are included for each disease. Morbidity was quantified for each disease. This was calculated as prevalent years of life lived with disability (YLDs) from the New Zealand Burden of Disease Study (BDS), divided by the population count.

Individually-linked data for publicly-funded (and some privately-funded) health events occurring in 2006-10 was used to calculate sex and age specific health system costs in 2011 NZ$. These costs included hospitalisations, inpatient procedures, outpatients, pharmaceuticals, laboratories and expected primary care usage. Costs that were assigned in the model fell into the following three categories. Firstly, sex and age-specific annual cost of a citizen who does not have a diet-related disease and is not in the last six months of their life. Secondly, disease-specific excess costs for people in the first year of diagnosis, last six months of life if dying of the given disease, and otherwise prevalent cases of each disease in the model. Lastly, the costs associated with the last six months of life if dying from a disease not in the model.

Table 2 Baseline input parameter table used in modelling the effect of a change in vegetable price

Baseline input Parameter	Source and application to model	Expected Value and 95% UI	Distribution
Intervention model			
Baseline dietary consumption	Mean dietary consumption by sex by ethnic groups from the New Zealand Adult Nutrition Survey 2008 to 2009 (University of Otago and Ministry of Health, 2011)	Uncertainty: +/- 10% Standard Deviation (SD).	Normal
Price elasticities	From the NZ SPEND study (Mhurchu et al., 2013, Ni Mhurchu et al., 2015). These are in a 24 by 24 matrix (see Figure 1) of own- and cross-Price Elasticities.	Uncertainty using reported SD	Normal
Height of the NZ adult population (for body mass index (BMI) calculations used in scenario analyses)	Mean and SD of height from the New Zealand Adult Nutrition Survey 2008 to 2009 (University of Otago and Ministry of Health, 2011)	Uncertainty using reported SD	Normal
Multi-state life-table model			
Baseline population count	Statistics NZ (SNZ) population estimates for 2011.	Nil uncertainty.	
All-cause mortality rates	SNZ mortality rates for 2011.	Nil uncertainty.	
Disease-specific incidence, prevalence, case fatality rate (CFR) and remission rates	For each diseases, coherent sets of incidence rates, prevalence, CFR, and remission rates (set to zero for non-cancers, the complement of the CFR for cancers to give the expected 5-year relative survival) were estimated using DISMOD II using data from New Zealand Burden of Disease Study (BDS), HealthTracker and the Ministry of Health.	Uncertainty: rates all +/- 5% standard deviation (SD).	Log-normal
Disease trends	Trends are applied to incidence, case-fatality and remission. These are switched on until 2026 and then kept constant for the remainder of the lifetime of the modelled population.	Uncertainty: +/- 0.5% absolute change. Type 2 diabetes: Uncertainty +/- 1.5% absolute change.	Normal

Total morbidity per capita in 2011	The per capita rate of years of life lived with disability (YLD) from the NZ BDS.	Uncertainty: +/- 10% SD.	Log-normal
Disease morbidity rate per capita	Each disease was assigned a disability rate (DR; by sex and age) equal to the YLDs (scaled down to adjust for comorbidities) from the 2006 NZ BDS projected forward to 2011, divided by the disease prevalence. This DR was assigned to the proportion of the cohort in the disease tabs.	Uncertainty: +/- 10% SD.	Normal
Health system costs	Linked health data (hospitalisations, inpatient procedures, outpatients, pharmaceuticals, laboratories, and expected primary care usage) for each individual in NZ for the period 2006–2010 had unit costs assigned to each event, and then five health system costs (2011 NZ$) were estimated.	Estimated at SD = ±10% of the point estimate.	Gamma
Time lags for intervention effect	It takes time for a change in risk factor to impact on disease incidence. As there are no precise data on just how long these are, we have used wide windows of time lags. For cancers, the time lag is assumed to range between 10 and 30 years. For CHD, stroke, diabetes, and osteoarthritis (the non-cancers), the time lag is assumed to be shorter and ranges between 0 and 5 years. Wide uncertainty is included around these estimates.	Uncertainty: ±20% SD	Normal
Theoretical minimum risk exposure level (TMREL)	TMREL is the level of risk exposure that is theoretically possible and minimizes overall risk and is derived from the latest Global Burden of Disease 2013 study (Forouzanfar et al., 2015). This allows us to estimate how much of the disease burden could be lowered by shifting the distribution of a risk factor to the level that would lead to the greatest improvement in population health.	Uncertainty: uniform distribution between 0 and 1	Uniform

MODEL STRUCTURE

Price change mechanism

The BODE[3] intervention model, which merges food price changes with price elasticities to generate changes in 346 foods consumed, is complex. The conceptual process is that a change in price of food(s) leads to change in purchasing (and in parallel consumption), modelled through price elasticities (PEs). This change in consumption then leads to percentage changes in food (vegetables, fruit, SSBs, red meat, processed meat, nuts and seeds) and nutrient (sodium, polyunsaturated fat) and total energy intake onto BMI, which in turn changes disease incidence. The most complicated component is the change in food price to change in consumption, through PEs, for reasons such as:

- There are many possible foods that can have a price change, yet price elasticities are only (usually) calculated for aggregate groupings of foods.
- For any single food with a price change, one has to not only model its own change in purchasing/consumption (through own-PEs), but also how the change in this food effects consumption in all (or some) other foods (through cross-PEs).
- Price elasticities are calculated as a system in a different context to that in which they are applied in modelling. For example, the starting consumption of foods may differ between the context in which the PEs were calculated, compared to the population to be modelled. For a price set change the predicted purchasing/consumption of many foods changes, and it is possible to see 'implausible' changes in energy intake. Put another way, the PE modelling may 'correctly' see decreases and increases in consumption of foods <u>relative</u> to one another, but the net energy intake change may be implausibly large.

We outline the methods used for applying these price elasticities and address some of these issues in detail in the model's Technical Report (Cleghorn et al., 2017).

Price elasticities were from the SPEND Study, conducted for New Zealand (Mhurchu et al., 2013, Ni Mhurchu et al., 2015). These are in a 24 by 24 matrix (see Figure 1) of own- and cross-PEs (with standard errors for default uncertainty). These 24 food groups have been matched to the 346 food groups used in the intervention model. This gives us 24 overall food groups and 338 food subgroups (ignoring 5 'alcoholic beverage' groups, 2 'dietary supplement' groups and 1 'not applicable' group). The 24 by 24 price elasticity matrix was then expanded to a 338 by 338 matrix (see Technical report (Cleghorn et al., 2017) for details).

As stated above, the PEs used in this model were calculated from a subset of the New Zealand population and do not 'fit' perfectly to the consumption data from the NZANS used in this model. Moreover, the PE values we use are from 'conditional' models, where the total expenditure on food is assumed fixed; if the interventions we model substantially change prices and therefore overall expenditure on food, we need to allow for how much total food expenditure changes as a result of price changes. These two problems can lead to implausible changes in food expenditure and energy intake if the price elasticities are naively used without constraints.

To address this issue, we need to consider how total food expenditure changes as a result of substantive changes in food prices. That is, we need PEs from studies that consider all food together as one category, compared to other household categories like education, housing, clothing, etc. The unconditional (i.e. all household expenditure included) and uncompensated (i.e. real income of the household is assumed fixed) own-PE for food can then be converted to an expenditure elasticity for food, what we call the Total Food Expenditure elasticity (TFE_e) (Blakely et al., 2020). The TFE_e used in the model (0.75) was based on eight studies that used multi-stage budgeting models to estimate unconditional and uncompensated food own-PEs, for high-income countries.

There was one additional prior step required too. Changing total household expenditure on food is equivalent to an income change for food consumption. Therefore, income elasticities for each food category were also applied. This step made little relative difference to food expenditure, and everything was still scaled to the 'set' new expenditure based on the TFE_e and percentage change in food price index. Full details on these method is available in the technical report (Cleghorn et al., 2017).

Figure 1 Price elasticity table from the SPEND Study for aggregated food groups (Ni Mhurchu et al., 2015) 24 by 24 matrix (shaded cells: own-PEs, other cells: cross-PEs)

	Fruit	Vegetables	Beef, lamb & hogget	Poultry	Pork	Prepared, preserved & processed meat	Fish & seafood	Bread & breakfast cereals	Cakes & biscuits	Pastry cook products	Pasta & other cereal products	Milk, yoghurt & eggs	Cheese & cream	Butter	Margarine & edible oil	Sauces, sugar & condiments	Chocolate, confectionary & snacks	Ice cream	Other grocery food	Non-alcoholic beverages	Carbonated soft drinks	Ready to eat food	Energy drinks
Fruit	-0.58	0.06	-0.05	-0.01	0.04	-0.04	0.01	0.06	-0.17	0.04	-0.05	0.01	0.08	0.05	-0.04	0.04	0.01	0.00	-0.25	0.00	-0.11	-0.21	-0.09
Vegetables	0.05	-0.88	-0.08	-0.04	0.00	-0.02	0.03	-0.03	-0.10	-0.02	0.03	-0.03	0.01	-0.08	0.03	0.06	0.02	0.00	-0.17	0.03	-0.11	-0.04	0.03
Beef, lamb & hogget	-0.07	-0.11	-0.93	0.05	0.01	-0.01	-0.05	-0.11	-0.12	-0.08	-0.02	-0.03	-0.04	0.03	-0.02	-0.05	0.00	-0.02	-0.28	0.04	-0.03	0.05	0.15
Poultry	-0.19	-0.14	0.03	-1.70	0.21	0.11	-0.02	0.08	0.27	0.16	-0.03	0.17	0.02	0.25	-0.01	-0.01	-0.04	-0.04	-0.20	0.05	0.03	0.09	0.21
Pork	-0.13	-0.34	0.05	0.43	-4.51	0.25	-0.23	-0.01	0.35	-0.02	-0.07	0.20	0.03	0.17	0.15	-0.04	0.11	-0.06	0.04	0.12	0.65	0.11	1.95
Prepared, preserved & processed meat	-0.07	-0.07	-0.02	0.12	0.10	-1.05	0.00	-0.09	-0.06	-0.01	0.05	-0.07	0.01	0.11	-0.09	-0.06	-0.09	-0.06	-0.18	-0.01	-0.06	-0.10	0.07
Fish & seafood	-0.02	0.21	-0.16	-0.06	-0.11	0.12	-1.68	0.26	0.03	0.06	-0.09	0.24	0.18	-0.02	0.05	0.03	-0.11	-0.04	-0.22	0.03	-0.23	-0.05	-1.04
Bread & breakfast cereals	0.02	0.01	-0.12	0.05	0.08	-0.05	0.05	-0.73	0.06	-0.02	0.01	-0.15	0.00	0.02	-0.09	0.00	0.07	0.00	-0.14	0.02	0.06	-0.09	0.24
Cakes & biscuits	-0.15	-0.10	-0.06	0.07	0.29	0.00	0.04	-0.05	-0.97	-0.09	0.01	-0.04	-0.05	-0.08	-0.06	-0.01	0.03	-0.03	-0.10	-0.01	0.11	-0.06	0.24
Pastry cook products	-0.05	-0.11	-0.20	0.05	0.33	-0.12	-0.15	-0.47	0.43	-1.52	0.15	-0.40	-0.09	0.55	-0.26	-0.09	-0.19	-0.06	0.32	-0.08	-1.90	0.32	1.23
Pasta & other cereal products	-0.05	0.10	-0.16	0.28	-0.05	0.20	0.08	0.27	-0.07	0.12	-1.70	0.11	0.02	-0.02	0.06	-0.06	-0.12	0.00	0.10	0.07	-0.14	0.25	-0.36
Milk, yoghurt & eggs	-0.02	-0.03	-0.01	0.07	-0.01	-0.07	0.06	-0.14	-0.04	-0.01	-0.01	-0.86	-0.03	0.07	-0.01	-0.02	0.04	0.00	-0.17	0.05	-0.03	-0.04	0.09
Cheese & cream	0.18	0.04	-0.07	-0.01	0.03	0.12	0.06	0.11	-0.10	0.04	0.00	0.00	-1.04	0.28	-0.10	-0.04	-0.20	-0.02	-0.21	0.01	0.04	-0.22	-0.07
Butter	0.03	-0.50	-0.34	-0.40	0.39	0.13	0.06	0.09	-0.35	-0.56	-0.50	-0.03	0.01	-0.67	0.50	-0.57	-0.15	-0.09	-0.49	0.07	1.01	-0.05	0.29
Margarine & edible oil	-0.27	-0.05	0.02	0.15	0.12	0.00	0.04	-0.32	-0.27	0.03	-0.04	0.00	-0.07	0.43	-1.04	-0.08	-0.13	0.01	-0.16	0.06	-0.47	0.04	-0.62
Sauces, sugar & condiments	0.13	0.11	-0.18	0.15	-0.01	-0.01	0.05	-0.04	-0.15	0.05	-0.06	0.16	-0.11	0.10	0.05	-1.32	-0.21	-0.04	-0.12	0.03	0.01	0.06	-0.22
Chocolate, confectionary & snacks	0.12	0.02	-0.02	0.03	0.18	0.01	-0.01	0.21	0.04	-0.01	0.04	0.08	-0.08	0.12	-0.02	-0.05	-1.27	-0.08	-0.05	-0.08	0.31	0.07	0.27
Ice cream	0.19	0.19	-0.13	0.55	-0.01	-0.10	-0.05	0.11	0.22	-0.11	0.08	0.01	-0.03	-0.03	0.02	0.01	-0.09	-1.74	0.24	-0.06	0.20	0.38	-0.47
Other grocery food	-0.09	-0.12	-0.09	-0.08	0.01	-0.07	0.00	-0.10	-0.04	-0.04	0.03	-0.10	-0.01	-0.07	0.02	0.03	0.04	0.05	-0.38	0.03	0.07	-0.09	-0.12
Non-alcoholic beverages	-0.10	-0.04	0.00	0.05	0.11	0.02	0.04	0.03	-0.17	-0.03	-0.03	0.11	0.09	0.01	-0.02	-0.10	-0.12	-0.01	-0.13	-1.31	0.26	-0.25	-0.42
Carbonated soft drinks	-0.14	-0.27	0.23	0.59	0.06	0.17	-0.14	-0.21	0.69	-0.25	0.13	0.11	-0.02	0.67	-0.24	-0.02	-0.01	0.03	0.15	-0.18	-1.23	0.05	0.77
Ready to eat food	0.03	0.06	0.15	0.08	0.13	0.03	-0.01	0.11	0.08	0.12	0.10	-0.06	0.03	0.02	-0.01	0.01	0.00	0.05	0.04	-0.08	0.10	-0.93	0.15
Energy drinks	-1.14	0.39	0.36	0.18	1.78	-0.08	-0.23	0.32	3.18	-0.06	0.19	0.25	-0.40	0.49	-0.25	-0.35	-0.58	-0.07	0.31	-0.71	2.73	0.10	-0.31

Life-table analysis

Life-tables are at the centre of the BODE[3] DIET MSLT model, both an overall life-table and multiple disease 'state' life-tables that are mathematically linked to the main life-table. In the baseline or BAU model, the New Zealand population is projected out into the future through all-cause and disease-specific expected trends in incidence, case-fatality and mortality. The contribution of the New Zealand diet to these trends is not *explicitly* modelled in the BAU model.

The population is divided into five-year age group cohorts (from age 0 to age 105-109), modelled as four separate sex by ethnic (Māori, non-Māori) populations, and simulated in the life-table until death.

The model is a proportional multi-state life-table model (Blakely T, 2020 (in press)). This basically means that:

- Everyone still alive in each cycle of the model (more specifically, the alive proportion for whichever five-year cohort is currently being modelled) is represented in the main life-table. In this main life-table, age-specific all-cause mortality and morbidity rates are applied in each cycle to the 'alive cohort', until the age of 110 years when all remaining alive people are assumed to die. As such, the sum of HALYs can be tallied.

- In parallel, proportions of the cohort can simultaneously reside in one or more parallel disease-specific life-tables or states. Or put more correctly, multiple disease states are modelled independently.[1] Within these disease-specific life-tables, disease incidence rates, remission and case-fatality rates, and disease-specific morbidity (disability weights from the NZ BDS (Ministry of Health, 2013) and the Global Burden of Disease Study (Salomon et al., 2012)), and disease-specific costs, are modelled.

- The disease-specific life-tables have both a BAU and intervention model. The latter intervention model differs from the BAU model, in that incidence rates are changed based on population impact fractions (PIFs; a 'merging' of changes in risk factor distributions and relative risks). This allows a calculation of differences in disease-specific mortality and morbidity rates, and differences in disease-costs per capita.

These differences are then summed across all parallel disease states, and added or subtracted to the all-cause mortality and morbidity rates in the main life-table and captured as cost differences between BAU and intervention, allowing estimation of HALYs gained or lost and health system cost change between the BAU and intervention scenarios for the population overall – the main objective of the modelling.

Diseases are modelled, within each disease process or parallel disease state as above, using a set of differential equations that describe the transition of people between four states (healthy, diseased, dead from a disease in the model, and dead from all other causes, see Figure 2), with transition of people between the four states based on rates of background mortality, incidence, case-fatality and remission.

[1]With the exception of diabetes, which has been 'linked' to CHD and stroke states.

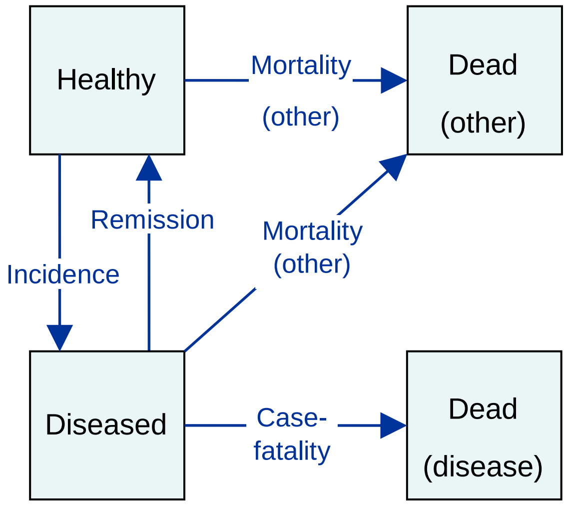

Figure 2: Each disease is modelled with four states (healthy, diseased, dead from the disease, and dead from all other causes) and transition probabilities between states of incidence, remission, case-fatality and mortality from all other causes.

The default model structure was that diseases were modelled independently. Specifically, the sex-, age- and ethnic-specific incidence, remission, and CFR for each disease were modelled independently. However, we include dependency for type 2 diabetes as a disease state, essentially treating it both as a disease state and a risk factor itself for CHD and stroke.

INTERVENTION INPUT PARAMETERS

Cumulative price change

The two intervention scenarios were a continuous price increase year on year from 2020 to 2042. We firstly calculated the new prices for each of these years and ran the price increases through the PEs to generate changes in consumption of all food groups in the model and more specifically the dietary risk factors we use in the DIET MSLT model.

The two modelled scenarios:

- 2% cumulative price increases each year from now for the next 23 years, such that in 23 years affected vegetables cost 58% more, relative to the baseline price
- 2.5% cumulative price increases each year from now for the next 23 years, such that in 23 years affected vegetables cost 76% more, relative to the baseline price

Change in vegetable intake (and all dietary risk factors in the relevant scenarios) for each year until 2042 were calculated and added to the DIET MSLT model in the corresponding year (see Table 3). The changes in dietary risk factors were held constant from 2042 until 2121 (the lifetime of the cohort).

MODELLING AND ANALYSIS

An Ersatz add-in (Barendregt, 2012) to Microsoft Excel was used to incorporate parameter uncertainty and run the multiple sex by age by ethnic group cohorts through the model 2000 times each. Each iteration involved a random draw from the probability density function about the Table 2 parameters, specified with uncertainty. The main results produced by the model were incremental HALYs lost and health system costs. Results for the base case are presented for the total population and by sex, age and ethnicity (Māori and non-Māori).

SCENARIO AND SENSITIVITY ANALYSES

Māori have higher background mortality and morbidity, resulting in a lesser 'envelope' for potential health gains which disadvantages Māori in the analysis. Therefore, an additional equity analysis was included whereby non-Māori all-cause mortality and population morbidity rates were used for Māori (McLeod et al., 2014) (Table 4 and Table 5).

A scenario analysis that includes all the dietary risk factors in the DIET MSLT model (change in vegetables, fruit, sugar sweetened beverages, nuts and seeds, red meat, processed meat, sodium, polyunsaturated fat) is included and another which includes all dietary risk factors in addition to a change in BMI. Sensitivity analyses when the discount rate is altered from the base model (3%) to 0% and 6% are also included in Table 6. For the 0% discount rate scenario future health gains are valued to the same degree as current health gains, for the 6% discount rate scenario, future health gains are valued less than current health gains (and more so than in the main analysis of 3% discounting).

Results

Table 3 shows a decrease in vegetable intake of 68.8 grams and 93.7 grams by 2042 with the 2% and 2.5% cumulative price increase. The greatest percentage change in price for a food group expected to be affected by the drivers of the price change was 58% in the 2% cumulative increase and 76% in the 2.5% cumulative increase scenarios. Due to a proportion of many relevant food groups being unlikely to be affected by the price change, the average price change per food group was 36% and 47% respectively.

The 2% cumulative increase in vegetable prices in NZ from 2020 to 2042 results in a modelled 58,300 reduction in HALYs and $490 million costs to the health system over the life course of the population alive in 2011. A greater decrease in HALYs and increase in health system costs are seen in females (35,800 and $290 million) compared to males (22,500 and $200 million). The decrease in per capita HALY loss is greater in non-Māori (14.2/1000 people) than Māori (8.0/1000 people) but this increases to 12.2/1000 people in Māori when the equity analysis is applied (Table 4). Health system costs per person are $110 over the life course of the cohort. HALY losses and health system costs are highest for those aged 25 to 44 years (see Table 4 and Figure 3 to Figure 6).

Similar patterns by age, sex and ethnicity are seen with the 2.5% cumulative price increase (see Figure 3 to Figure 6) with overall HALY losses 25% greater and costs to the health system 24% greater than the 2% cumulative price increase at 72,800 and $610 million. The per capita HALY loss is greater in non-Māori (17.8/1000 people) than Māori (9.7/1000 people) and again the per capita HALY loss in Māori increases to 14.8/1000 people when the equity analysis is applied. Health system costs are $140 per person.

Smaller health losses and health system costs are seen when all dietary risk factors (changes in vegetables, fruit, sugar sweetened beverages, nuts and seeds, red meat, processed meat, sodium, polyunsaturated fat intake) are included in the modelling (2% price increase: -23,500 HALYs and $36 million in health system costs. 2.5% price increase: -31,700 HALYs and $126 million in health system costs). Health losses increase to 105,000 and 192,000 HALYs for the 2% and 2.5% price increase respectively when all dietary risk factors and BMI are included in the modelling. Health system costs reach $1,610 and $3,230 million respectively.

For both the 2% and 2.5% price increase health losses increase substantially (-296,000 and -369,000 HALYs respectively) when no discounting is applied into the future. Conversely health losses are much less when a higher discount rate, 6%, is applied (-15,100 and -18,700 HALYs) compared to the 3% rate applied in the base model. This pattern is replicated in health system costs for 0% ($1,411 and $1,768 million) and 6% discounting ($184 and $228 million respectively). The total health losses are 5% higher and costs to the health system are 0.6% lower when the equity analysis is applied in the 2% price increase scenario and 4% higher and 1.1% lower in the 2.5% scenarios.

Table 3 Change in average vegetable intake by year under a 2% and a 2.5% cumulative price increase

Year	Δ average vegetable intake (2% ↑ price)	Δ average vegetable intake (2.5% ↑ price)
2020	-2.5	-3.1
2021	-5.0	-6.3
2022	-7.5	-9.4
2023	-10.1	-12.7
2024	-12.7	-16.0
2025	-15.3	-19.3
2026	-18.0	-22.7
2027	-20.7	-26.2
2028	-23.5	-29.8
2029	-26.3	-33.4
2030	-29.1	-37.2
2031	-32.0	-41.0
2032	-35.0	-44.9
2033	-38.0	-49.0
2034	-41.1	-53.2
2035	-44.3	-57.5
2036	-47.5	-62.0
2037	-50.8	-66.6
2038	-54.2	-71.5
2039	-57.7	-76.6
2040	-61.2	-82.0
2041	-65.0	-87.7
2042	-68.8	-93.7

Table 4 HALYs lost and health system costs among the New Zealand adult population alive in 2011 (with uncertainty) from a 2% cumulative increase in vegetable prices in NZ from 2020 to 2042 (3% discounting)

	Non-Māori	Māori		Ethnic groupings combined	
Sex and starting age (in 2011)	**HALYs**	**HALYs**	**HALYs – equity†**	**HALYs**	**Health system costs (NZ$ million)**
Total					
Sex and age groups combined	-52,900 (-72,700 to -35,600)	-5,400 (-7,500 to -3,500)	-8,200 (-11,400 to -5,400)	-58,300 (-80,300 to -39,200)	$490 ($290 to $740)
Males					
15-24 year olds	-3,310 (-4,910 to -1,830)	-730 (-1,080 to -410)	-1,060 (-1,580 to -610)	-4,030 (-6,000 to -2,250)	$40.0 ($23.1 to $60.2)
25-44 year olds	-7,330 (-11,000 to -3,990)	-880 (-1,310 to -490)	-1,360 (-2,020 to -760)	-8,210 (-12,300 to -4,470)	$79.0 ($45.3 to $118.1)
45-64 year olds	-5,290 (-8,080 to -2,690)	-340 (-530 to -160)	-590 (-940 to -290)	-5,630 (-8,620 to -2,860)	$41.0 ($23.0 to $62.7)
65+ year olds	-560 (-890 to -260)	-20 (-30 to -10)	-30 (-60 to -10)	-570 (-920 to -270)	$2.3 ($1.1 to $3.7)
All ages	-19,600 (-29,300 to -10,500)	-3,000 (-4,400 to -1,700)	-4,500 (-6,700 to -2,500)	-22,500 (-33,900 to -12,200)	$200 ($116 to $303)
Females					
15-24 year olds	-4,880 (-6,530 to -3,340)	-540 (-710 to -370)	-780 (-1,040 to -540)	-5,410 (-7,240 to -3,710)	$53.0 ($31.2 to $78.2)
25-44 year olds	-12,670 (-17,100 to -8,610)	-810 (-1,090 to -550)	-1,260 (-1,690 to -850)	-13,500 (-18,200 to -9,180)	$120 ($69.5 to $178)
45-64 year olds	-9,890 (-13,500 to -6,700)	-350 (-480 to -240)	-620 (-840 to -420)	-10,200 (-14,000 to -6,930)	$63.0 ($35.1 to $97.6)
65+ year olds	-1,200 (-1,670 to -790)	-20 (-30 to -10)	-40 (-60 to -30)	-1,220 (-1,700 to -810)	$4.0 ($1.8 to $6.6)
All ages	-33,300 (-44,700 to -22,700)	-2,400 (-3,300 to -1,700)	-3,700 (-5,000 to -2,600)	-35,800 (-48,000 to -24,400)	$290 ($171 to $437)
Per capita (HALYs/1000 people, $ per person)	-14.2 (-19.5 to -9.5)	-8.0 (-11.2 to -5.2)	-12.2 (-17. to -8.0)	-13.2 (-18.2 to -8.9)	$110 ($65.8 to $168)

HALYs, Health adjusted life years; Results rounded to either two or three meaningful digits
† Māori "HALYs—Equity" are calculated using non-Māori background mortality and morbidity rates so as not to "penalise" Māori because of worse background mortality and morbidity (McLeod et al., 2014).

Table 5 HALYs lost and health system costs among the New Zealand adult population alive in 2011 (with uncertainty) from a 2.5% cumulative increase in vegetable prices in NZ from 2020 to 2042 (3% discounting)

	Non-Māori	Māori		Ethnic groupings combined	
Sex and starting age (in 2011)	**HALYs**	**HALYs**	**HALYs – equity†**	**HALYs**	**Health system costs (NZ$ million)**
Total					
Sex and age groups combined	-66,000 (-89,600 to -45,000)	-6,500 (-9,000 to -4,300)	-10,000 (-13,500 to -6,500)	-72,800 (-98,500 to -48,800)	$610 ($366 to $907)
Men					
15-24 year olds	-4,100 (-6,100 to -2,300)	-880 (-1,290 to -500)	-1,280 (-1,870 to -730)	-5,000 (-7,400 to -2,800)	$49.0 ($29.0 to $74.5)
25-44 year olds	-9,200 (-13,700 to -5,000)	-1,050 (-1,540 to -590)	-1,630 (-2,370 to -880)	-10,200 (-15,200 to -5,600)	$97.0 ($56.6 to $146)
45-64 year olds	-6,600 (-10,000 to -3,400)	-400 (-620 to -200)	-700 (-1,070 to -330)	-7,000 (-10,600 to -3,600)	$50.0 ($28.3 to $75.5)
65+ year olds	-690 (-1,100 to -340)	-20 (-30 to -10)	-40 (-70 to -10)	-710 (-1,130 to -340)	$2.7 ($1.3 to $4.6)
All ages	-24,000 (-37,000 to -13,000)	-3,600 (-5,200 to -2,000)	-5,410 (-7,860 to -2,940)	-28,000 (-41,800 to -15,300)	$250 ($144 to $373)
Women					
15-24 year olds	-6,100 (-8,300 to -4,200)	-640 (-860 to -450)	-950 (-1,250 to -660)	-6,800 (-9,100 to -4,700)	$66.0 ($40.8 to $98.5)
25-44 year olds	-15,900 (-21,600 to -10,800)	-970 (-1,310 to -670)	-1,530 (-2,060 to -1,050)	-16,900 (-22,900 to -11,400)	$150.0 ($87.6 to $223.5)
45-64 year olds	-12,400 (-16,800 to -8,400)	-420 (-570 to -290)	-750 (-1,010 to -500)	-12,800 (-17,300 to -8,700)	$78.0 ($43.2 to $121)
65+ year olds	-1,470 (-2,040 to -970)	-20 (-30 to -20)	-50 (-70 to -30)	-1,490 (-2,080 to -990)	$4.8 ($2.2 to $8.1)
All ages	-42,000 (-56,000 to -29,000)	-2,900 (-3,900 to -2,000)	-4,550 (-6,040 to -3,130)	-44,800 (-60,200 to -30,600)	$360 ($215 to $548)
Per capita (HALYs/1000 people, $ per person)	-17.8 (-24. to -11.9)	-9.7 (-13.3 to -6.3)	-14.8 (-20.1 to -9.7)	-16.5 (-22.4 to -11.1)	$140 ($83.0 to $206)

HALYs, Health adjusted life years; Results rounded to either two or three meaningful digits
† Māori "HALYs—Equity" are calculated using non-Māori background mortality and morbidity rates so as not to "penalise" Māori because of worse background mortality and morbidity (McLeod et al., 2014).

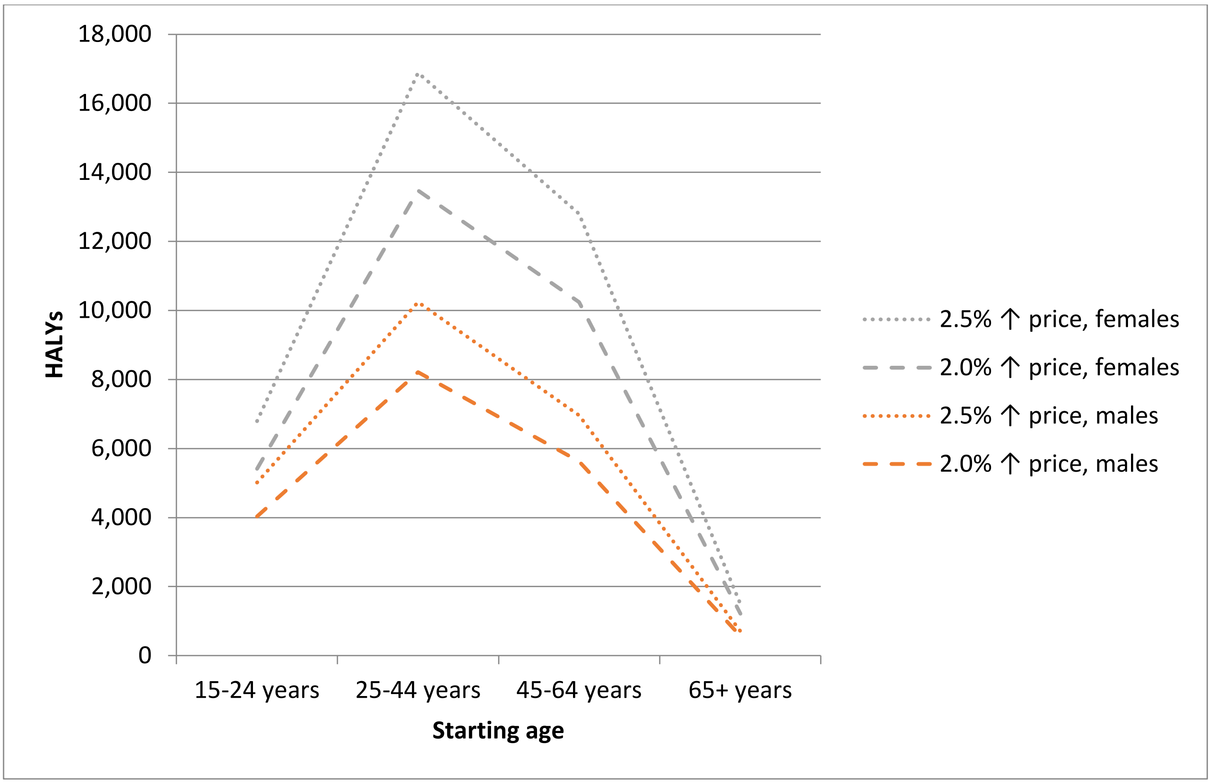

Figure 3 Total HALY losses over age by sex and price increase

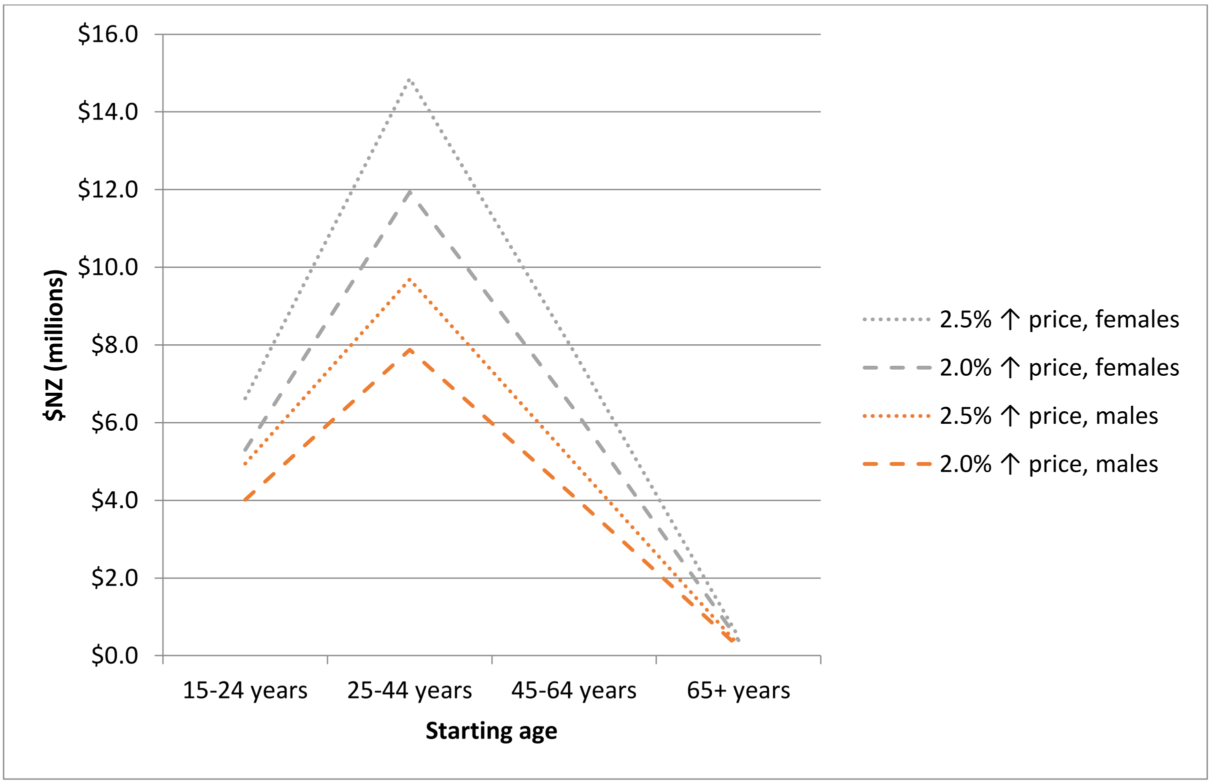

Figure 4 Total health system costs over age by sex and price increase

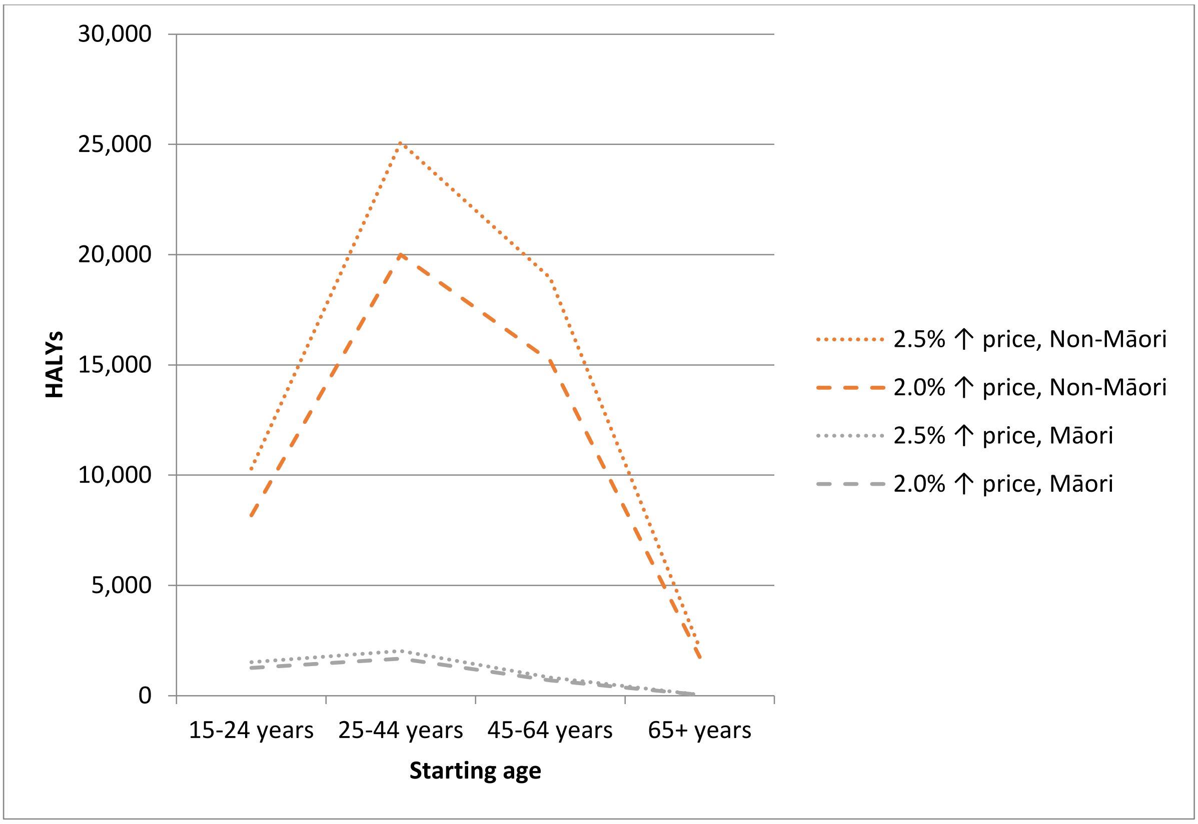

Figure 5 Total HALY losses over age by ethnic group and price increase

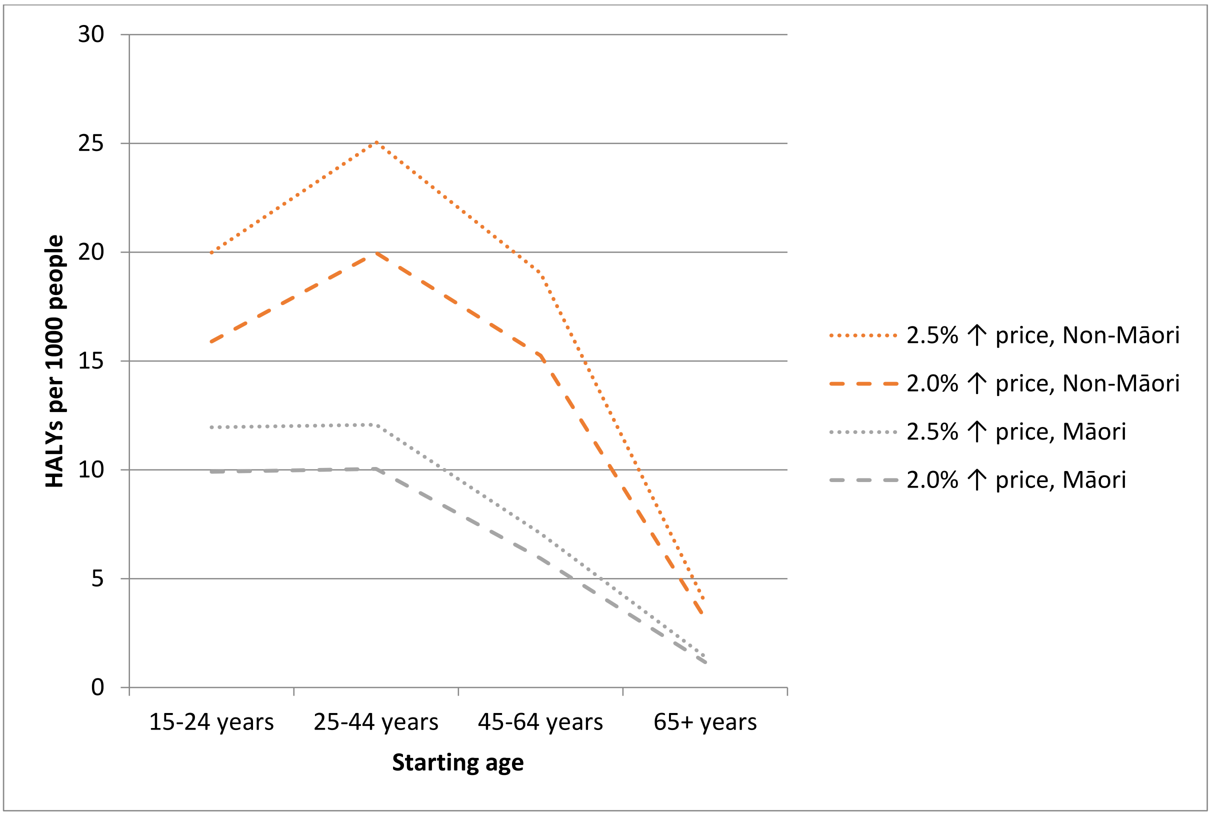

Figure 6 Per capita HALY losses (per 1000 people) over age by ethnic group and price increase

Table 6 Scenario analyses about HALY losses and health system costs for a 2% and 2.5% cumulative increase in vegetable prices in NZ from 2020 to 2042

Scenario	**HALYs**	**Health system costs (NZ$ million)**
2% cumulative price increase		
Variation in risk factors used in the model		
Vegetables only	-58,500	$495
All dietary risk factors*	-23,500	$36
BMI and all dietary risk factors*	-105,000	$1,610
Discount rate		
0% per annum	-296,000	$1,410
6% per annum	-15,100	$184
Equity analysis†	-61,000	$487
2.5% cumulative price increase		
Variation in risk factors used in the model		
Vegetables only	-73,000	$618
All dietary risk factors*	-31,700	$126
BMI and all dietary risk factors*	-192,000	$3,230
Discount rate		
3% per annum	-369,000	$1,770
6% per annum	-18,700	$228
Equity analysis†	-76,000	$611

HALYs, Health adjusted life years; Results rounded to either two or three meaningful digits

All scenario analyses presented in table 6, including ‘vegetables only’ are run without uncertainty

*includes a change in vegetables, fruit, sugar sweetened beverages, nuts and seeds, red meat, processed meat, sodium, polyunsaturated fat

† Māori “HALYs—Equity” are calculated using non-Māori background mortality and morbidity rates so as not to “penalise” Māori because of worse background mortality and morbidity (McLeod et al., 2014).

Discussion

A cumulative 2% or 2.5% increase in the price of vegetables results in a substantial decrease in vegetable intake over time - 69 grams and 94 grams per person per day by the year 2042. These price increases over time result in modest modelled health loss to the population and costs to the health system.

These health losses and costs were greater in females, non-Māori and those aged 25-44 years compared to males, Māori and other age groups. As the price changes effect percentage intake in the model the fact that females and non-Māori have higher baseline intakes of vegetables probably account for their higher impact. It should be expected that the younger ages will have a higher impact through this modelling as the price change effect is maintained over the lifetime of the cohort and the younger age groups have a longer period of time to be effected by the change in vegetable intake. That the youngest age group (15-24) has a lower impact is to be expected as this covers a smaller proportion (10 year age cohort) of the population than the other age groups.

Per capita health losses are calculated to compare how this price change affects Māori compared to non-Māori on a per person basis. The greater effect in non-Māori is likely due to their greater baseline vegetable intake as mentioned above however this difference is reduced when the equity analysis is applied. The equity analysis attempts to "value" potential health gains from preventing diet related diseases similarly between Māori and non-Māori or, in the case of health loss to more accurately represent the health loss that would be expected if Māori had the same background mortality and morbidity rates as non-Māori. These health losses assume that the price change of vegetables will affect Māori in the same way as non-Māori, it is likely that the reduction in vegetable intake would be greater in Māori and the health losses even greater than modelled.

Although this modelling uses own and cross price elasticities to calculate a change in consumption from a change in price no other dietary risk factors are included in the main analysis so any substitution to other foods is not translated through to the health loss and health system costs. When these other dietary risk factors are included in scenario analyses smaller health losses are seen as vegetable intake is substituted for fruit which has it associated positive health impact. Health loss is greater when BMI is included in the modelling due to the small average increase in energy intake and therefore BMI seen through the change in food intake generated through cross price elasticities.

This modelling was carried out using a well-established multi-state life-table model (Cleghorn C et al., 2018, Cleghorn et al., 2019, Drew et al., 2020) which uses high quality epidemiological data. The 'current' vegetable consumption is based on data from the Adult Nutrition Survey from 2008/09 (Ministry of Health, 2011), which was a large, nationally representative sample but is now approximately ten years old and vegetable intake may have changed in this time.

There is also inevitable uncertainty about price elasticities and the extent to which they can predict future changes in purchasing. The price elasticities matrix that we used was generated from a New

Zealand study (Ni Mhurchu et al., 2013) and changes in intake were scaled using Total Food Expenditure elasticity (TFEe, see pages 5-6 of methods for details) (Blakely et al., 2020). When comparing these price changes to the counterfactual business as usual (BAU) we assume no price change in the BAU scenario, that the price increase is passed through 100%, and that the price elasticities we use (with TFEe adjustment) are reasonable proxies for long-run responses to price changes.

The base year for demographic, epidemiological and costing specification is 2011, with trends out to 2026 – as per other evaluations in the Burden of Disease Epidemiology, Equity and Cost-Effectiveness (BODE[3]) Programme. This allows useful comparisons with other interventions. It was beyond the scope of this evaluation to update the entire model to a more recent base-year such as 2018. Had this been done, we anticipate the total health loss in HALYs would have increased slightly due to population growth, but the general pattern of findings would change little.

These findings have implications for changes in land use in New Zealand, an important area being the Pukekohe hub discussed in the introduction (Deloitte, 2018). Policy makers should consider these effects when putting policies in place that impact on land use, urban encroachment, competition for water and labour. These health and health system cost impacts should also be considered when assessing the impact of other factors that could also increase the price of vegetables in New Zealand.

Small cumulative increases in the price of vegetables are likely to cause an important decrease in vegetable consumption over the next two decades. This is likely to lead to modest health loss to the NZ population and costs to the health system over time.

References

BARENDREGT, J. 2012. Ersatz user guide.: EpiGear International Pty Ltd.

BLAKELY, T., COBIAC, L. J., CLEGHORN, C. L., PEARSON, A. L., VAN DER DEEN, F. S., KVIZHINADZE, G., NGHIEM, N., MCLEOD, M. & WILSON, N. 2015. Health, Health Inequality, and Cost Impacts of Annual Increases in Tobacco Tax: Multistate Life Table Modeling in New Zealand. *PLoS Med,* 12**,** e1001856.

BLAKELY T, M. R., COLLINS J, MIZDRAK A, SINGH A, CARVALHO N, WILSON N, GEARD N, FLAXMAN A 2020 (in press). Multistate lifetable modelling of preventive interventions: concepts, code and worked examples. . *International Journal of Epidemiology*.

BLAKELY, T., NGHIEM, N., GENC, M., MIZDRAK, A., COBIAC, L., MHURCHU, C. N., SWINBURN, B., SCARBOROUGH, P. & CLEGHORN, C. 2020. Modelling the health impact of food taxes and subsidies with price elasticities: The case for additional scaling of food consumption using the total food expenditure elasticity. *PloS one,* 15**,** e0230506.

CLEGHORN C, WILSON N, NAIR N, KVIZHINADZE G, NGHIEM N, MCLEOD M & T., B. 2018. Health benefits and cost-effectiveness from promoting smartphone apps for weight loss: Multi-state life-table modeling. . *JMIR mHealth and uHealth (JMU)*.

CLEGHORN, C., BLAKELY, T., MHURCHU, C. N., WILSON, N., NEAL, B. & EYLES, H. 2019. Estimating the health benefits and cost-savings of a cap on the size of single serve sugar-sweetened beverages. *Preventive Medicine*.

CLEGHORN, C., BLAKELY, T., NGHIEM, N., MIZDRAK, A. & WILSON, N. 2017. Technical report for BODE^3 intervention and DIET MSLT models, Version 1. Burden of Disease Epidemiology, Equity and Cost-Effectiveness Programme. Technical Report no. 16. *In:* DEPARTMENT OF PUBLIC HEALTH, U. O. O., WELLINGTON (ed.). Wellington.

CLEGHORN, C. L., BLAKELY, T., KVIZHINADZE, G., VAN DER DEEN, F. S., NGHIEM, N., COBIAC, L. J. & WILSON, N. 2018. Impact of increasing tobacco taxes on working-age adults: short-term health gain, health equity and cost savings. *Tobacco control,* 27**,** e167-e170.

CLEGHORN, C. L., WILSON, N., NAIR, N., KVIZHINADZE, G., NGHIEM, N., MCLEOD, M. & BLAKELY, T. 2020. Health benefits and costs of weight-loss dietary counselling by nurses in primary care: a cost-effectiveness analysis. *Public health nutrition,* 23**,** 83-93.

DELOITTE 2018. New Zealand's food story: The Pukekohe hub. Prepared for Horticulture New Zealand. Deloitte.

DREW, J., CLEGHORN, C., MACMILLAN, A. & MIZDRAK, A. 2020. Healthy and Climate-Friendly Eating Patterns in the New Zealand Context. *Environmental Health Perspectives,* 128**,** 017007.

FOROUZANFAR, M. H., ALEXANDER, L., ANDERSON, H. R., BACHMAN, V. F., BIRYUKOV, S., BRAUER, M., BURNETT, R., CASEY, D., COATES, M. M. & COHEN, A. 2015. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet,* 386**,** 2287-2323.

LUITEN, C. M., STEENHUIS, I. H., EYLES, H., MHURCHU, C. N. & WATERLANDER, W. E. 2015. Ultra-processed foods have the worst nutrient profile, yet they are the most available packaged products in a sample of New Zealand supermarkets. *Public health nutrition***,** 1-9.

MCLEOD, M., BLAKELY, T., KVIZHINADZE, G. & HARRIS, R. 2014. Why equal treatment is not always equitable: the impact of existing ethnic health inequalities in cost-effectiveness modeling. *Population health metrics,* 12**,** 15.

MHURCHU, C. N., EYLES, H., SCHILLING, C., YANG, Q., KAYE-BLAKE, W., GENÇ, M. & BLAKELY, T. 2013. Food prices and consumer demand: differences across income levels and ethnic groups. *PloS one,* 8**,** e75934.

MINISTRY OF HEALTH 2011. Data and Statistics, Nutrition Survey, 2008/09 Adult Nutrition Survey. Accessed 1st August 2011. Available at: http://www.moh.govt.nz/moh.nsf/indexmh/dataandstatistics-survey-nutrition.

MINISTRY OF HEALTH 2013. Health Loss in New Zealand: A report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study, 2006–2016. Wellington: Ministry of Health.
NI MHURCHU, C., EYLES, H., GENÇ, M., SCARBOROUGH, P., RAYNER, M., MIZDRAK, A., NNOAHAM, K. & BLAKELY, T. 2015. Effects of Health-Related Food Taxes and Subsidies on Mortality from Diet-Related Disease in New Zealand: An Econometric-Epidemiologic Modelling Study. *PLoS ONE [Electronic Resource]*.
NI MHURCHU, C., EYLES, H., SCHILLING, C., YANG, Q., KAYE-BLAKE, W., GENC, M. & BLAKELY, T. 2013. Food prices and consumer demand: differences across income levels and ethnic groups. *PLoS One,* 8**,** e75934.
PEARSON, A. L., CLEGHORN, C. L., VAN DER DEEN, F. S., COBIAC, L. J., KVIZHINADZE, G., NGHIEM, N., BLAKELY, T. & WILSON, N. 2016. Tobacco retail outlet restrictions: health and cost impacts from multistate life-table modelling in a national population. *Tobacco control***,** tobaccocontrol-2015-052846.
SALOMON, J. A., VOS, T., HOGAN, D. R., GAGNON, M., NAGHAVI, M., MOKDAD, A., BEGUM, N., SHAH, R., KARYANA, M., KOSEN, S., FARJE, M. R., MONCADA, G., DUTTA, A., SAZAWAL, S., DYER, A., SEILER, J., ABOYANS, V., BAKER, L., BAXTER, A., BENJAMIN, E. J., BHALLA, K., ABDULHAK, A. B., BLYTH, F., BOURNE, R., BRAITHWAITE, T., BROOKS, P., BRUGHA, T. S., BRYAN-HANCOCK, C., BUCHBINDER, R., BURNEY, P., CALABRIA, B., CHEN, H., CHUGH, S. S., COOLEY, R., CRIQUI, M. H., CROSS, M., DABHADKAR, K. C., DAHODWALA, N., DAVIS, A., DEGENHARDT, L., DÍAZ-TORNÉ, C., DORSEY, E. R., DRISCOLL, T., EDMOND, K., ELBAZ, A., EZZATI, M., FEIGIN, V., FERRI, C. P., FLAXMAN, A. D., FLOOD, L., FRANSEN, M., FUSE, K., GABBE, B. J., GILLUM, R. F., HAAGSMA, J., HARRISON, J. E., HAVMOELLER, R., HAY, R. J., HEL-BAQUI, A., HOEK, H. W., HOFFMAN, H., HOGELAND, E., HOY, D., JARVIS, D., KARTHIKEYAN, G., KNOWLTON, L. M., LATHLEAN, T., LEASHER, J. L., LIM, S. S., LIPSHULTZ, S. E., LOPEZ, A. D., LOZANO, R., LYONS, R., MALEKZADEH, R., MARCENES, W., MARCH, L., MARGOLIS, D. J., MCGILL, N., MCGRATH, J., MENSAH, G. A., MEYER, A.-C., MICHAUD, C., MORAN, A., MORI, R., MURDOCH, M. E., NALDI, L., NEWTON, C. R., NORMAN, R., OMER, S. B., OSBORNE, R., PEARCE, N., PEREZ-RUIZ, F., PERICO, N., PESUDOVS, K., PHILLIPS, D., POURMALEK, F., PRINCE, M., REHM, J. T., REMUZZI, G., RICHARDSON, K., et al. 2012. Common values in assessing health outcomes from disease and injury: disability weights measurement study for the Global Burden of Disease Study 2010. *Lancet,* 380**,** 2129-2143.
UNIVERSITY OF OTAGO & MINISTRY OF HEALTH 2011. A Focus on Nutrition: Key findings of the 2008/09 New Zealand Adult Nutrition Survey. . Wellington Ministry of Health.
VAN DER DEEN FS, W. N., CLEGHORN CL, KVIZHINADZE G, COBIAC LJ, NGHIEM N, BLAKELY T 2017. Impact of five tobacco endgame strategies on future smoking prevalence, population health and health system costs: two modelling studies to inform the tobacco endgame. *Tobacco control*.