To: Health New Zealand

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Subject: *Effectiveness of ethnicity-based colorectal cancer screening in New Zealand*

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Summary

- Colorectal cancer (CRC) poses a significant health challenge in New Zealand. To reduce its burden, a national screening program targets individuals aged 60 to 74 using the fecal immunochemical test (FIT).
- Since a large proportion of CRC cases presents before the age of 60 in Māori individuals, there is funding to lower their screening starting age to 50. This research evaluates the current programme, the proposed expansion of screening in Maori as well as alternative screening expansion to see how they affect CRC incidence, CRC mortality, colonoscopy demand, and costs.
- The study used the MISCAN-Colon microsimulation model, calibrated to New Zealand data, to evaluate various CRC screening strategies. This yielded the following results:
    - Screening the entire population aged 60-74 effectively reduces CRC mortality.
    - Lowering the starting age for Māori from 60 to 50 would prevent approximately 300 more CRC deaths, necessitating an additional 30,000 colonoscopies.
    - Increasing Māori participation to 60% appears more efficient in terms of the number of colonoscopies required per CRC death prevented compared to lowering the starting age.
    - Lower the starting age across the entire population proved more efficient compared to solely lowering the starting age for Māori to 50.

- The findings underscore:
    - The need to prioritize increased Māori participation for optimizing CRC screening in New Zealand
    - Lowering the starting age by 2 years for Māori, followed by extension to the total population, enhances preventive benefits and is efficient.
    - The importance of policy decisions that balance equity, efficiency, and colonoscopy capacity to achieve optimal CRC screening outcomes nationwide.

Introduction

Colorectal cancer (CRC) is a significant public health issue globally, including in New Zealand, where it ranks among the leading causes of cancer-related morbidity and mortality (1). Early detection through effective screening programmes is crucial for reducing both incidence and mortality rates of CRC. New Zealand has implemented a national CRC screening programme aimed at identifying CRC at earlier, more treatable stages and detecting and removing pre-cancerous polyps to limit the development of CRC.

The national CRC screening programme was initiated in 2017, following the Waitematā CRC screening pilot that began in 2011. This pilot offered a biennial fecal immunochemical test (FIT) for individuals aged 50–74 years. Due to restricted colonoscopy resources and the fact that approximately 80% of the cancers detected in the pilot study were found in people aged 60 to 74 years (2), the national programme was rolled out with a starting age set at 60.

However, there is an ongoing discussion about the need to adjust the screening programme to better serve New Zealand's indigenous Māori population and reduce disparities. Currently, just over half of CRC cancers in Māori present before the age of 60 years (58% in females and 52% in males), whereas just under a third of CRC cancers in non-Māori are diagnosed before the same age (27% in females and 29% in males) (3). Additionally, Māori people have a lower life expectancy, which means they gain fewer benefits from CRC screening if the starting age remains at 60 years old. To address this inequality, funding was announced to lower the eligible starting age for CRC screening from 60 to 50 years for Māori people.

A critical consideration arises regarding the allocation of colonoscopy resources, particularly given the lower lifetime incidence of CRC in Māori compared to non-Māori populations. With limited capacity, it is essential to evaluate whether lowering the starting age exclusively for Māori to 50 years represents the most optimal strategy. While this adjustment aims to enhance early detection and reduce disparities, alternative approaches could potentially achieve greater overall public health benefits. Therefore, the research question emerges:

How do the current New Zealand CRC screening programme and alternative screening strategies compare in terms of their impact on colorectal cancer mortality and incidence, colonoscopy demand, and effectiveness?

This report aims to answers this research question and inform policy decisions.

Methods

To evaluate different CRC screening strategies in New Zealand, we used the microsimulation model MISCAN-Colon, which simulates population demographics, natural CRC progression, and the impact of screening interventions. This model was applied to both Māori and non-Māori populations, using age- and ethnicity-specific data, to assess the benefits, colonoscopy demand and costs of various screening approaches.

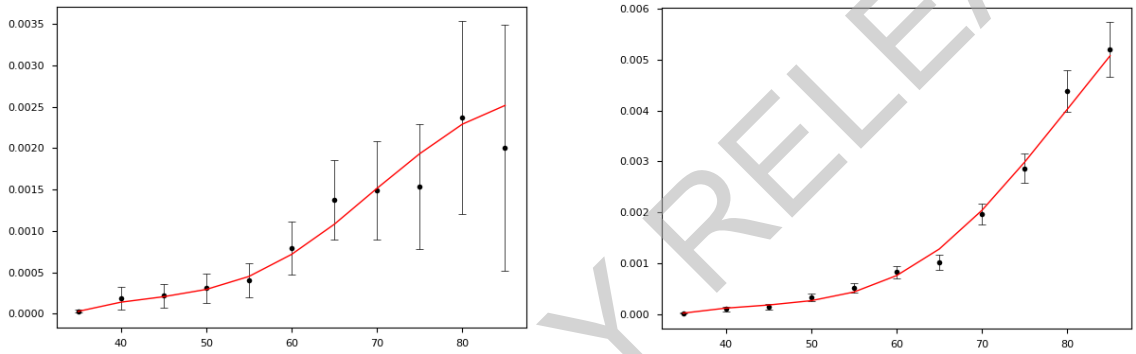
MISCAN-Colon

To evaluate different screening strategies, the microsimulation model MISCAN-Colon was used. MISCAN-Colon consists of three main components: a demography module, a natural history module and a screening module. In the demography module, life histories are generated to simulate population demographics and dynamics without CRC. In the natural history module, MISCAN-Colon simulates the development of adenomas and CRC in the absence of screening interventions. MISCAN simulates three categories of adenoma sizes (small (1-5 mm), medium (6-9 mm), and large (10+ mm)). Adenomas initially begin as small and can progress to larger sizes. The model differentiates between two types of adenomas: progressive and nonprogressive. Nonprogressive adenomas grow in size but do not progress to cancer. Progressive adenomas have the potential to develop into cancer over time, though other causes of death may intervene before reaching the preclinical or clinical cancer stages. Preclinical cancers progress through stages I through IV and can become clinical during each of these stages.

The screening module subsequently implements screening, which disrupts the natural development of CRC. The intervention alters the simulated life histories by preventing cancer through early detection and removal of adenomas. It also increases the likelihood of detecting cancers at earlier, more treatable stages compared to clinical diagnosis, which improves survival rates. By comparing different screening strategies applied to identical life histories, the effectiveness of screening interventions can be assessed based on aggregated changes in outcomes. MISCAN-Colon is described in more detail in a prior publication (4).

Study population

We used the MISCAN-Colon model to simulate New Zealand's CRC screening program for both the Māori and non-Māori population, using a sample size of 10 million individuals for each group. The model was adjusted to account for differences between Māori and non-Māori populations by using age- and ethnicity-specific CRC incidence data from 2015, prior to the initiation of the screening programme. This data was used to calibrate the age of onset for adenomas and the transition probabilities from pre-clinical to clinical cancer, ensuring the model accurately reflected observed disparities in incidence (Figure 1). The data was obtained from New Zealand's National Collections.



A. Maori *B. non-Maori*

Figure 1 Age- and ethnicity-specific colorectal cancer incidence data from 2015 with 95% confidence intervals (black), along with projected incidence from MISCAN-Colon after calibration (red). The x-axis represents the age group and the y-axis represents the incidence rate.

Screening

New Zealand's CRC screening programme

New Zealand's national CRC screening programme targets individuals aged 60 to 74, inviting them to participate in screening every two years. The primary screening test used is the fecal immunochemical test (FIT), which detects hidden blood in stool samples, a potential indicator of CRC or polyps. The FIT positivity cut-off level is set at 40 micrograms (µg) of hemoglobin per gram feces. Participants with positive FIT results are referred for further investigation via colonoscopy, where any detected polyps can be removed, and biopsies can be taken to confirm the presence of CRC. The screening programme began its phased rollout across New Zealand by district starting in 2017 and has been offered

throughout the whole country since May 2022. The gradual roll-out of the screening program from 2017 to 2022 was taken into account in MISCAN-Colon.

Follow-up and surveillance

Upon a positive screening FIT result, individuals are referred for diagnostic colonoscopy. This procedure allows for direct visualization of the colon and rectum to confirm findings and, if necessary, biopsy or remove suspicious polyps. Surveillance followed New Zealand's protocols, which consider the characteristics and size of polyps detected during colonoscopy (5).

Test characteristics

The sensitivity and specificity of the FIT were determined so that the model's predicted positivity and detection rates for advanced adenomas and CRC closely matched those observed in New Zealand's CRC screening program between 2017 and 2023 (Supplementary Table 1) (6). For colonoscopy, we assumed sensitivity and specificity levels comparable to those in the Netherlands (Supplementary Table 1). The costs for FIT, colonoscopy, and CRC treatment were derived from a prior cost-effectiveness study on CRC screening in New Zealand (7) and adjusted for inflation using the general Consumer Price Index (Supplementary Table 2).

Screening strategies

The following screening strategies were evaluated to assess their effectiveness:

- No screening;
- Base case: screening individuals aged 60 to 74 biennially;
- Introducing a one-time screen at age 56, 54, 52 or 50 and continue biennial screening from age 60 to 74; either for Māori only or for the entire population;
- Lowering the starting age for biennial screening to: 58, 56, 54, 52 or 50; either for Māori only, or for the entire population.

We then calculated the most effective strategies under three different scenarios:

1. Identifying the most effective strategies specifically for Māori, while non-Māori remain with the base case strategy of biennial screening from ages 60 to 74.
2. Identifying the most effective strategies for the entire population, with a uniform screening approach for everyone.
3. Identifying the most effective strategies for the entire population, allowing for different screening approaches between Māori and non-Māori.

Participation

We assumed a 60% participation rate for FIT among non-Māori individuals and 52% among Māori individuals. For diagnostic colonoscopy, we assumed that 85% of individuals with a positive FIT result participated. These participation rates for FIT and diagnostic colonoscopy were derived from the average participation observed in New Zealand's national CRC screening program from 2017 to 2023 (6). For surveillance, we assumed 100% participation.

Given the ongoing efforts in New Zealand to increase screening participation among Māori, we also evaluated the outcomes of the base case strategy with participation rates set at 60% for both Māori and non-Māori individuals.

Outcomes

For each simulated scenario, projected outcomes were calculated separately for Māori and non-Māori and reported for the upcoming four years, ten years and 25 years starting from 2025. Benefits were assessed based on the number of CRC cases and CRC-related deaths prevented, specifically in comparison to no screening. Going forward, when referring to CRC deaths prevented, it implies comparison to the scenario of no screening. Total expenses consisted of costs linked to FIT screening, diagnostic and surveillance colonoscopies, and CRC care. Programme costs included solely costs for FIT and diagnostic colonoscopies. All future costs were discounted using an annual rate of 3%.

Efficiency Analyses

We conducted three distinct analyses to identify the most efficient CRC screening strategies. Firstly, we performed an analysis specifically for Māori. Secondly, we assessed the efficiency assuming a uniform programme for Māori and non-Māori populations. Thirdly, we explored the efficiency when considering all possible combinations of strategies for Māori and non-Māori.

For each analysis, we used a systematic approach to identify the most efficient CRC screening strategies. We plotted all possible screening strategies, detailing the total number of colonoscopies (diagnostic and surveillance) required and the anticipated CRC deaths prevented for each strategy for the upcoming 25 years. Strategies that required more colonoscopies for fewer CRC deaths prevented were deemed strictly dominated and excluded from consideration among efficient strategies.

Subsequently, we identified the strategies that maximize the number of CRC deaths prevented per additional colonoscopy performed compared to the next less colonoscopy-intensive strategy. The line connecting these efficient strategies forms what is known as the efficient frontier. Strategies on the efficient frontier represent those that achieve the most effective balance of CRC deaths prevented relative to colonoscopy resource utilization.

Results

New Zealand's current CRC screening programme

The base case strategy is projected to prevent 15,103 CRC cases and 10,814 CRC-related deaths over a 25-year period (Table 1). In terms of financial implications, the total costs for screening and treatment of CRC are estimated to be NZ$2.4 billion for the first four years, and NZ$13.2 billion over 25 years. Programme costs are projected at NZ$119 million in the short term, and NZ$582 million in the long term. Over a 4-year period, approximately 9,000 diagnostic and 3,400 surveillance colonoscopies are anticipated annually. These numbers are expected to rise to 9,200 diagnostic and 4,200 surveillance colonoscopies annually over the 25-year period.

Table 1 Projected outcomes of the base case scenario, in which the total population in New-Zealand is invited for screening from age 60 to 74. CRC = colorectal cancer.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
2025-2029 (4 years)	2,417	119	35,389	13,627	1,148	848
2025-2035 (10 years)	5,849	279	90,205	38,560	4,091	2,975
2025-2050 (25 years)	13,168	582	230,054	104,882	15,103	10,814

Increasing Māori participation

Increasing Māori participation from 52% to 60% is projected to yield additional benefits, including the prevention of 195 more CRC cases and 116 additional CRC-related deaths over a 25-year period (Table 2). However, this increase in participation also translates to an additional requirement of 4,500 diagnostic and 1,925 surveillance colonoscopies. Although program costs are expected to rise by NZ$10.5 million over a 25-year period, the total costs are anticipated to decrease by NZ$0.9 million. Consequently, preventing one additional CRC death requires 55 extra colonoscopies and NZ$90,520 in program costs. Moreover, there are total savings of NZ$7,500 per additional CRC death prevented. It is important to note that we did not include any additional costs to increase participation.

Table 2 Changes in outcomes for base case strategy if Māori participation rates increase from 52% to 60%. CRC = colorectal cancer.

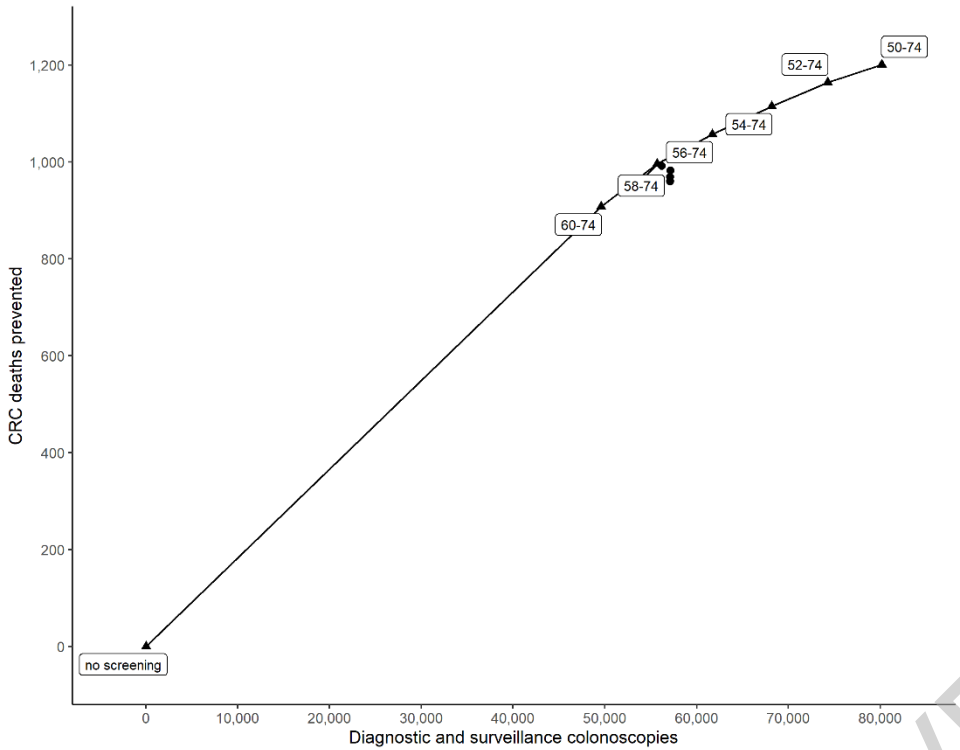
	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
2025-2029 (4 years)	+1.5	+2.0	+642	+247	+16	+9
2025-2035 (10 years)	+2.7	+4.9	+1,714	+691	+102	+14
2025-2050 (25 years)	-0.9	+10.5	+4,500	+1,925	+195	+116

Optimal strategies for Māori

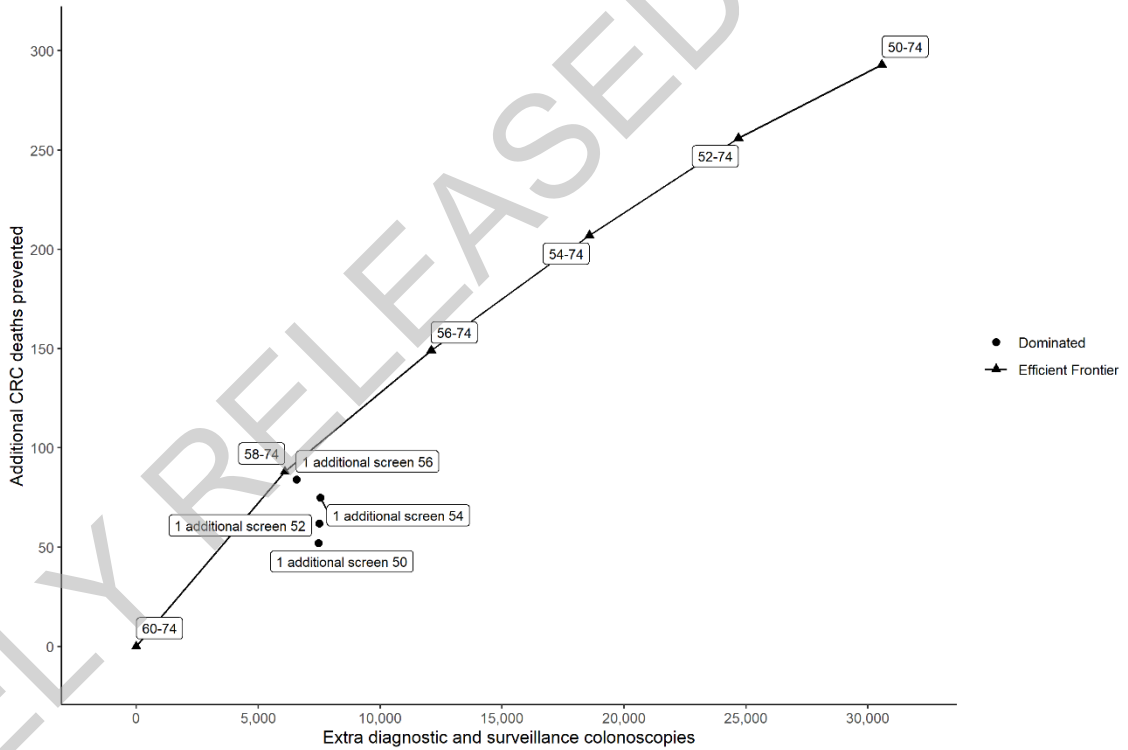
Adding one additional screen before age 60 resulted in an increase in colonoscopies and deaths prevented (Figure 2). Adding the screen at age 58 resulted in most additional deaths prevented, and least additional colonoscopies and was optimal. Further expansion of biennial screening to starting at ages 56, up to 50 resulted in proportionally more colonoscopies and cancer deaths prevented. Lowering the starting age for Māori from 60 to 50 would prevent approximately 300 more CRC deaths, at the cost of an additional 30,000 colonoscopies. This represents an approximate 9% increase in total colonoscopy capacity over the next 25 years (Tabel 1), assuming biennial screening continues from age 60 for non-Māori individuals.

Population-wide optimal uniform strategies

Similar to the Māori-specific analysis, introducing one additional screening before age 60 for the total population resulted in an increase in colonoscopies and a higher number of CRC deaths prevented (Figure 3). Adding a screening at age 56 resulted in the most additional deaths prevented and was optimal. However, adding a screening at age 58 was nearly as effective in terms of additional deaths prevented and the number of colonoscopies required. Expanding biennial screening to begin at earlier ages, from 56 down to 50, led to a proportional increase in both the number of colonoscopies performed and CRC deaths prevented. Screening the entire population from age 50 would necessitate an additional 156,000 colonoscopies, a 47% increase in capacity, to prevent slightly more than 2,000 additional deaths.

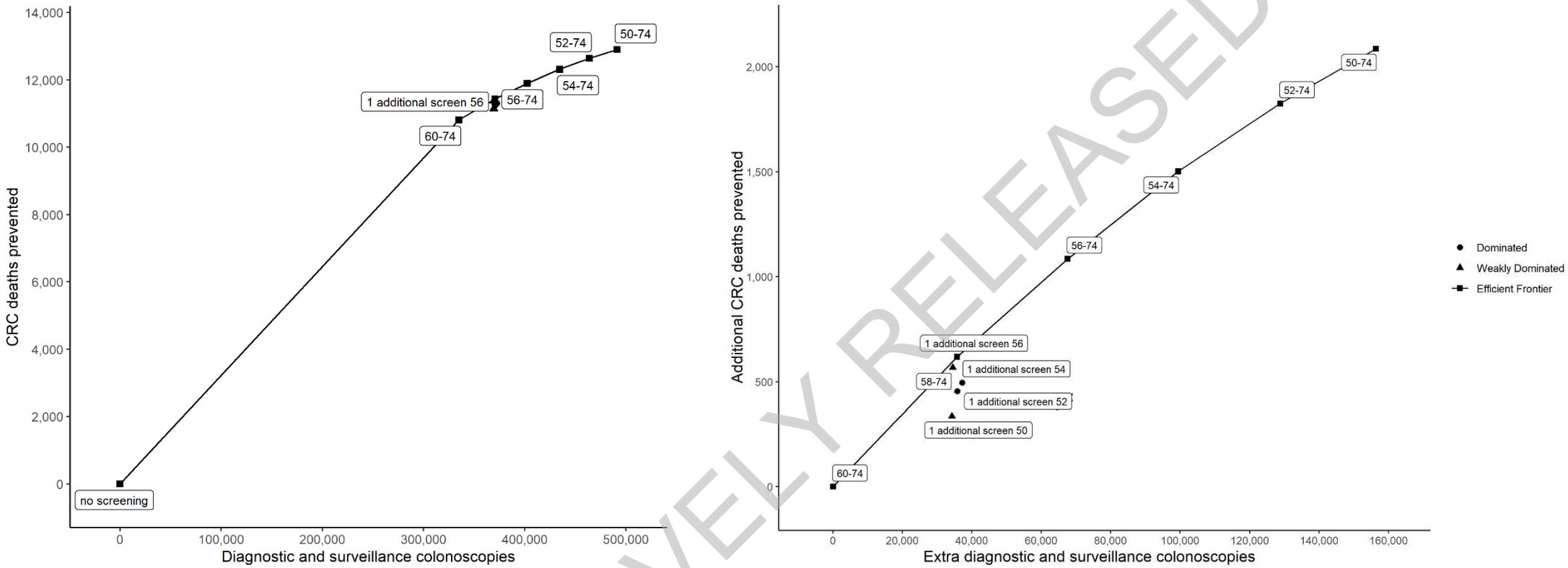


A. Compared to no screening



B. Compared to screening age 60-74

Figure 2 Efficiency frontier presenting the (additional) CRC deaths prevented for Māori individuals (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.



A. Compared to no screening

B. Compared to screening age 60-74

Figure 3 Efficiency frontier presenting the (additional) CRC deaths prevented for total population (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.

Population-wide optimal strategies with varied strategies by ethnicity

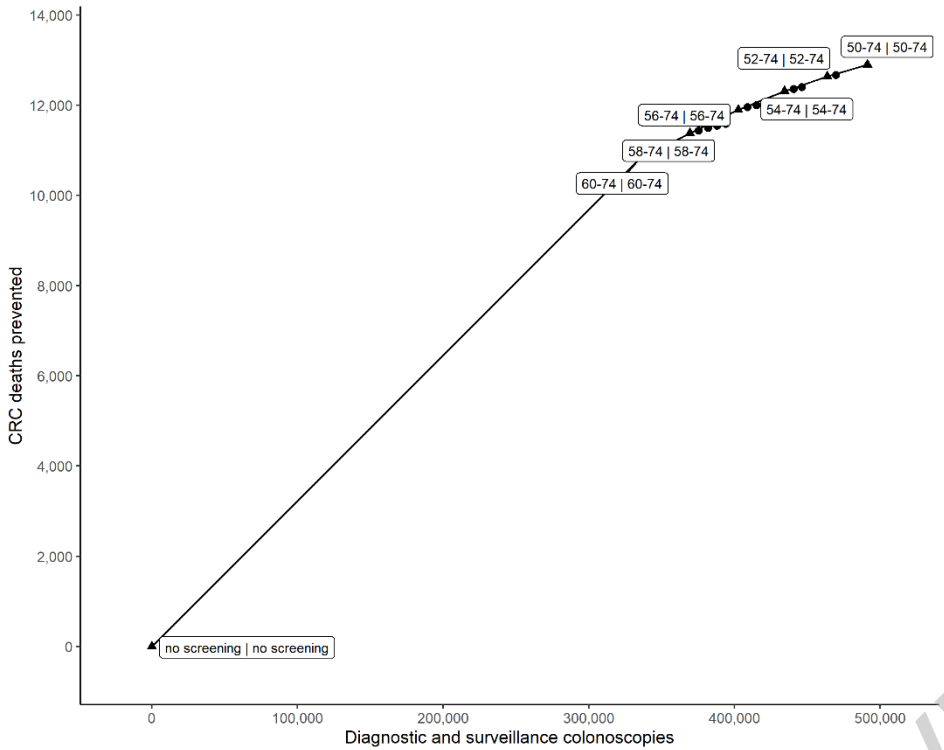
Starting CRC screening at age 58 for the Māori population, is almost as efficient as beginning at age 60 for the entire population (Figure 4). This indicates that it is beneficial to initiate screening for Māori two years earlier than non-Māori.

Lowering the screening age for Māori to 50 required approximately 30,600 additional colonoscopies to prevent 293 CRC deaths over a 25-year period, averaging about 100 additional colonoscopies to prevent one CRC death (Table 3). In contrast, lowering the starting age to 58 for the entire population resulted in 34,500 additional colonoscopies and prevented 566 CRC deaths, averaging 60 colonoscopies per prevented CRC death. Therefore, it is more efficient to first lower the starting age by 2 years for everyone rather than lowering the starting age by 10 years solely for Māori. The results over a 4- and 10-year period are presented in Supplementary Table 3 and 4.

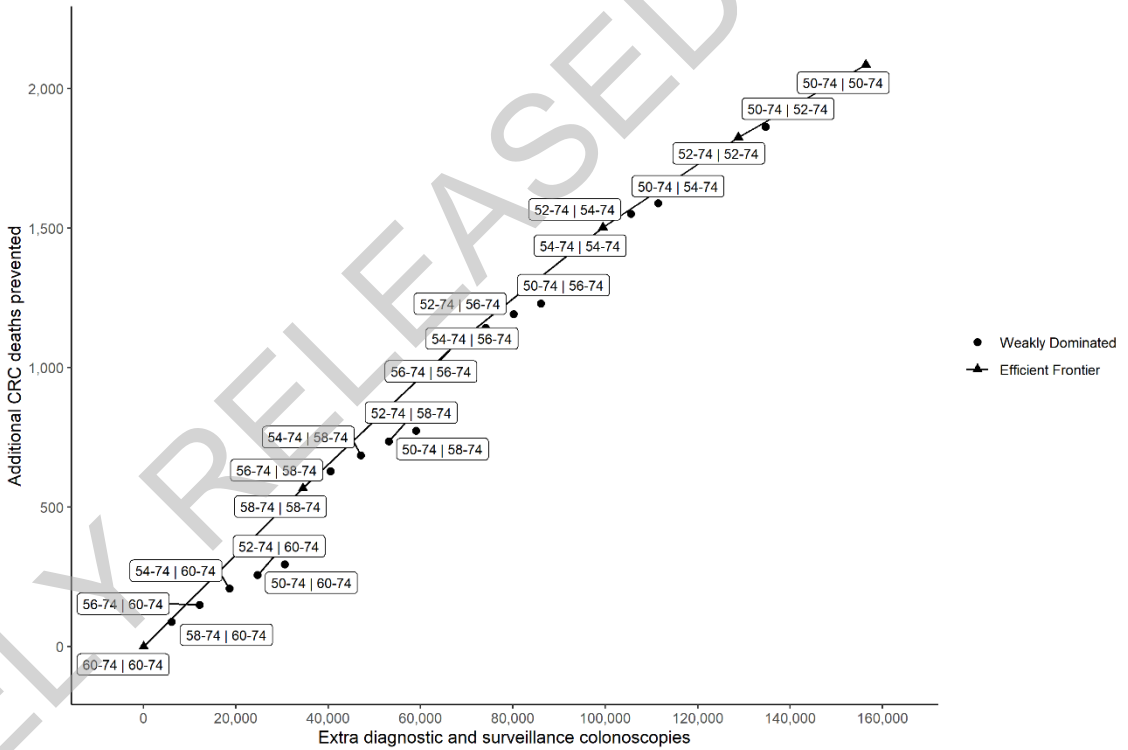
Once everyone is invited to screening from age 58, lowering the screening age to 56 for Māori is almost as efficient as starting screening at age 58 for the entire population (Figure 4). However, it is more efficient to first lower the starting age to 56 for the entire population rather than lowering it to 50 solely for Māori. Gradually reducing the screening age for Māori by 2 years initially, followed by doing the same for the rest of the population, appears more efficient than making a substantial reduction in the screening age solely for Māori while leaving non-Māori unchanged.

Table 3 Outcomes for different ethnicity-based screening strategies over 25 years (2025-2050). The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
58-74 | 60-74	+2.7	+10.0	+4,045	+2,045	+129	+87
50-74 | 60-74	+32.6	+54.1	+21,789	+8,784	+443	+293
58-74 | 58-74	+26.3	+68.5	+23,255	+11,251	+771	+566
56-74 | 58-74	+31.7	+78.9	+27,463	+13,043	+870	+627
50-74 | 58-74	+56.2	+112.6	+40,999	+17,989	+1,084	+772



A. Compared to no screening



B. Compared to screening age 60-74

Figure 4 Efficiency frontier presenting the additional CRC deaths prevented for the total population (x-axis) and the extra number of colonoscopies required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

With a 5% increase in total colonoscopy capacity, resources are insufficient to lower the starting age for the entire population (Figure 5). However, it is feasible to lower the starting age to 58 or 56 specifically for Māori, as they represent a smaller group. With a 10% capacity increase, we are nearing the ability to lower the starting age to 58 for everyone, however we have not yet reached that threshold. At this level of capacity, the most effective strategy to reduce the highest number of CRC deaths is to lower the starting age to 50 exclusively for Māori. With a 15% increase in capacity, we have sufficient resources to lower the screening age to 58 for the entire population. Additionally, we have the capacity to further reduce the starting age for Māori to either 56 or 54 years of age. An additional 25% capacity enables lowering the starting age to 56 for everyone, with the potential to lower it further to 54 or 52 for Māori. Alternatively, screening Māori from age 50 and non-Māori from age 58 requires a similar number of colonoscopies as screening everyone from age 56, albeit with fewer benefits in preventing CRC deaths. With 50% more colonoscopy capacity, it would be feasible to lower the starting age to 50 for the entire population.

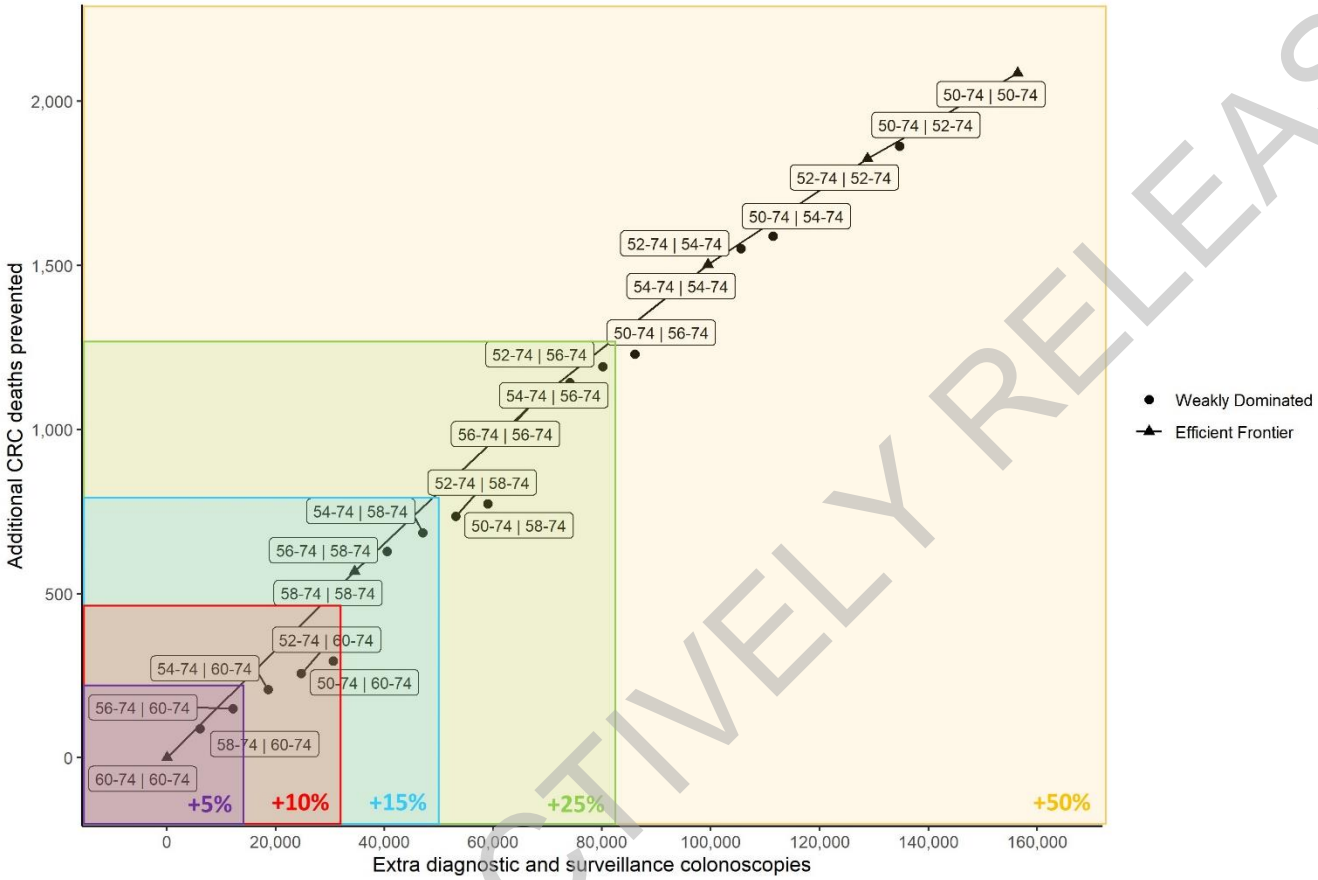


Figure 5 Efficiency frontier presenting the additional CRC deaths prevented for the total population (x-axis) and the extra number of colonoscopies required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period. The coloured boxes indicate which strategies are possible if the colonoscopy capacity is limited to the current required colonoscopy capacity plus and additional x%. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

Discussion

Based on our findings, the current biennial screening program for individuals aged 60 to 74 effectively reduces CRC deaths compared to no screening. Increasing participation rates among Māori individuals further enhance the effectiveness of the programme. Initiating CRC screening at age 58 for Māori is nearly as efficient as starting at age 60 for the entire population and prevents more CRC deaths, suggesting a benefit to earlier initiation for Māori. However, lowering the screening age to 50 exclusively for Māori requires significantly more colonoscopies per prevented CRC death compared to initially lowering it by 2 years for all, which proves more efficient.

We observed that adding a one-time CRC screening at older ages, specifically 56 or 58, proved more efficient compared to one-time screening at younger ages (50, 52 or 54). This is likely due to the higher CRC risk associated with advancing age. Moreover, biennial screening starting at ages 56 to 50 resulted in proportionally more colonoscopies and prevented more CRC deaths compared to one-time screening before age 60. We hypothesize that regular screenings can detect adenomas and CRC earlier, leading to earlier interventions and better management of conditions. This can reduce the overall cost and resource requirements of treatment while improving health outcomes over time, making the investment in more frequent screenings more efficient in the long run compared to a single screening. Another advantage of biennial screening is that it is more easily explained to the public and simpler to implement compared to an additional single screening at a younger age, making it a more practical choice for widespread adoption.

Gradually lowering the screening age for Māori by two years initially, and subsequently extending this to the rest of the population, demonstrated a more efficient approach compared to implementing a substantial age reduction exclusively for Māori while leaving the starting age for non-Māori screening unchanged. This is primarily attributed to the lower incidence rate of CRC among Māori individuals (1). This lower incidence rate means that strategies targeting Māori populations may not achieve a significant reduction in CRC cases and deaths proportional to the resources required for their implementation, potentially impacting overall efficiency. However, when addressing population health interventions, there is often the additional objective of minimizing 'unfair' health

inequalities. One way to do this is by looking at the distribution of health gains due to the intervention via a distributional cost-effectiveness analysis. This approach would provide deeper insights into balancing efficiency and equity, ensuring that the benefits of the intervention are distributed equitably across different population groups.

The results of our analysis also highlight the potential benefits associated with increasing Māori participation in CRC screening to 60% over various time frames. In the short term (2025-2029), a higher participation increased the costs of screening with similar number of CRC deaths prevented. Looking further into the future (2025-2050), the benefits in terms of preventing CRC deaths were significant, and the total costs were lower compared to those associated with 52% participation. This is because increased participation leads to earlier detection and prevention, thereby reducing the incidence of advanced-stage CRC among Māori. This, in turn, lowers healthcare costs associated with intensive and less effective treatments.

An important consideration is whether to prioritize increasing participation or lowering the starting age among Māori communities. Our findings showed that increasing participation to 60% resulted in approximately 55 extra colonoscopies per CRC death prevented, whereas lowering the starting age to 58 results in about 70 extra colonoscopies per CRC death prevented. Thus, while both strategies offer significant benefits, increasing participation to 60% appears slightly more efficient in terms of the number of colonoscopies required per CRC death prevented. A combination of both strategies is expected to amplify the benefits.

A strength of this analysis is the use of the MISCAN-Colon model, which is a well-established microsimulation model for CRC screening that has been extensively validated. Microsimulation modelling enables exploration of numerous screening strategies and their long-term impacts, providing policymakers and healthcare providers with valuable decision-making insights that are impractical to obtain through trials. Moreover, the emphasis on effectiveness provides critical insights into the efficient allocation of healthcare resources, guiding efforts to optimize CRC screening programmes.

However, this study also has limitations that warrant consideration. Our findings are based on fixed assumptions regarding screening uptake, incidence rates, survival, and healthcare costs for the long-term predictions (2025-2050). These assumptions may not accurately reflect potential changes over time, such as changes in health behavior, shifts in disease incidence, improvements in survival due to better treatments, or fluctuations in healthcare costs associated with evolving medical technologies. Additionally, it is important to note that our model was not specifically calibrated to data from Pacific Island people, as their numbers were small, and they were therefore grouped within the non-Māori category. Future research should carefully assess whether Pacific Island populations share closer health characteristics with Māori or with European/other ethnic groups, particularly in terms of CRC incidence rates, to refine the applicability of screening strategies.

The findings from this analysis have several important implications for policy makers aiming to optimize CRC screening strategies in New Zealand. Firstly, enhancing participation through strategies like community engagement and reducing barriers to healthcare access is crucial. These efforts can improve screening program effectiveness, resulting in reduced CRC mortality rates and long-term healthcare cost savings. Addressing disparities in participation not only improves health outcomes for Māori individuals but also contributes to overall health equity.

Secondly, while starting CRC screening for Māori at age 50 is anticipated to prevent more CRC deaths compared to the current screening program, a phased approach has shown to be a more efficient strategy. This approach involves initially starting screening for Māori at age 58, then extending this change to the rest of the population. If capacity allows, continuing lowering the starting age in this phased approach could be considered. However, the decision should carefully weigh the broader public health advantages of uniform screening against the specific health needs and priorities of Māori populations, aiming to establish the most effective and equitable CRC screening strategy. A distributional cost-effectiveness analysis could offer critical insights to inform and support these decisions. Moreover, determining the optimal strategy for New Zealand heavily relies on the availability of additional colonoscopy resources. Our findings indicate that with less than a 10% increase in capacity, lowering the starting age for Māori

is feasible but not for the entire population. Therefore, starting CRC screening at age 50 solely for Māori could be justified given limited resources.

In conclusion, optimizing CRC screening strategies in New Zealand demands a dual focus: enhancing participation among Māori communities and implementing a phased lowering of the starting age across the population. Our analysis supports the initiation of a 2-year reduction in the starting age for Māori, followed by extending this gradually to the general population, before potentially lowering the starting age further for Māori. However, the feasibility of this strategy relies on the availability of additional colonoscopy capacity in the coming years.

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Supplementary Material

Supplementary Table 1 Sensitivity and specificity assumptions for FIT and Colonoscopy

	FIT Māori	FIT non-Māori	Colonoscopy
Specificity	0.97	0.98	1.00
Sensitivity adenoma 1-5 mm	0.00	0.00	0.75
Sensitivity adenoma 6-9 mm	0.07	0.07	0.85
Sensitivity adenoma >9 mm	0.15	0.15	0.95
CRC early preclinical *	0.80	0.80	0.95
CRC late preclinical *	0.85	0.85	0.95

* We assumed that the sensitivity for CRC depends on the time until clinical diagnosis.

Supplementary Table 2 Cost assumptions

Screening and surveillance	Costs (in NZ$)
Negative FIT	54
Positive FIT	174
Colonoscopy (both diagnostic and surveillance)	1900

CRC care (costs per year in care phase)*	Stage I	Stage II	Stage III	Stage 4
Initial care	30821	63031	78943	51939
Continuous care	3914	7949	21292	4282
Terminal care, death from CRC	20590	20590	20590	20590
Terminal care, death other causes	20590	20590	20590	20590

* Cost for care were divided into three clinically relevant phases of care – initial, continuing, and terminal care. The initial phase was defined as the first 12 months following diagnosis, the terminal phase was defined as the final 12 months of life, and the continuing phase as the period between the initial and terminal phases of care. The terminal care phase of colorectal cancer patients was further subdivided into terminal care preceding colorectal cancer death

and terminal care preceding death of other causes. For patients surviving less than 24 months after diagnosis, the final 12 months of observation and costs of care were then allocated first to the terminal phase. The remaining time was allocated to the initial phase, with no contribution to the continuing phase.

Supplementary Table 3 Outcomes for different ethnicity-based screening strategies over 4 years (2025-2029). The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
no screening	2.34	0	0	0	0	0
60-74 | 60-74	2.42	0.12	35,389	13,627	1,148	848
58-74 | 60-74	2.42	0.12	36,109	13,770	1,150	850
50-74 | 60-74	2.43	0.13	38,874	14,215	1,153	860
58-74 | 58-74	2.44	0.14	39,575	14,368	1,162	874
56-74 | 58-74	2.44	0.14	40,342	14,490	1,161	876
50-74 | 58-74	2.45	0.14	42,340	14,812	1,165	882

Supplementary Table 4 Outcomes for different ethnicity-based screening strategies over 10 years (2025-2035). The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
no screening	5.78	0	0	0	0	0
60-74 | 60-74	5.85	0.28	90,205	38,560	4,091	2,975
58-74 | 60-74	5.85	0.28	91,869	39,205	4,116	2,993
50-74 | 60-74	5.88	0.31	98,299	41,148	4,173	3,038
58-74 | 58-74	5.88	0.32	99,896	41,971	4,240	3,120

56-74 | 58-74	5.88	0.32	101,653	42,516	4,259	3,134
50-74 | 58-74	5.90	0.33	106,325	43,914	4,296	3,165

Response to the first version of the report

In response to feedback on the initial version of the report and meetings within the Erasmus-Health New Zealand collaboration, we performed five sensitivity analyses and included additional explanations in this appendix.

1. *Realistic participation for surveillance colonoscopy*

We initially assumed a 100% participation rate for surveillance colonoscopies. However, after further discussion, we agreed that a more realistic approach would be to align this rate with the observed participation rates for diagnostic colonoscopies. Consequently, we adjusted the participation rate for surveillance colonoscopy to 85%.

2. *Disparities in survival rates between Māori and non-Māori*

In the initial version of the report, we assumed that survival rates following a CRC diagnosis were comparable for Māori and non-Māori individuals. However, we revised this assumption to reflect the lower survival rates observed for Māori. The model was recalibrated using survival data from Gurney et al.(8) with different calibration targets for Māori and non-Māori.

Table 1 shows the calibration targets, derived from relevant literature and the MISCAN output.

Table 1 5-year survival probability after CRC diagnosis

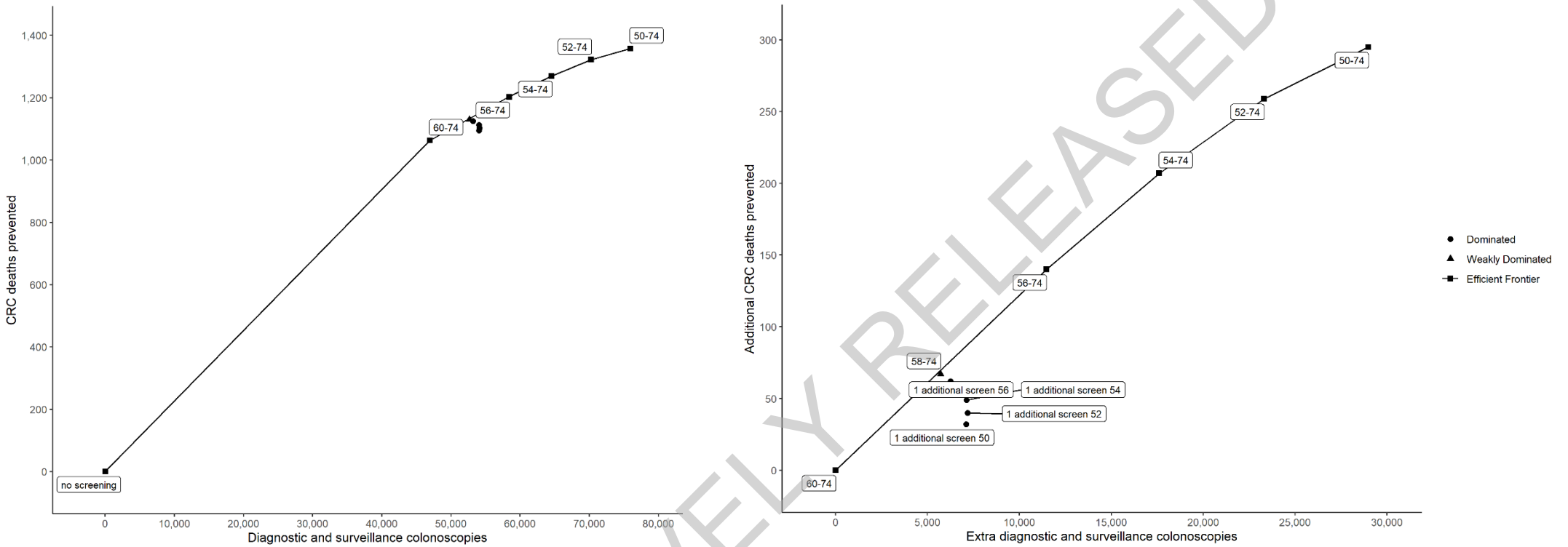
Ethnicity	Observed target (8)	Estimated survival by MISCAN-Colon model
Non-Maori	**61%**	**60%**
Maori	**53%**	**53%**

The changes described in sensitivity analyses (1) and (2) together resulted in the following outcomes:

Table 2 Sensitivity analysis illustrating the impact of reducing participation in surveillance colonoscopy from 100% to 85%, with distinct survival probabilities for Māori and non-Māori individuals. The outcomes represent projections for a scenario where the total population of New-Zealand is invited for screening from age 60 to 74.The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer; NZ$ = New-Zealand dollar.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
2025-2029	2,288	119	35,377	13,317	1,171	836
(4 years)	(-129)	(0)	(-12)	(-310)	(+23)	(-12)
2025-2035	5,528	279	90,162	37,559	4,139	3,012
(10 years)	(-321)	(0)	(-43)	(-1,001)	(+48)	(+37)
2025-2050	12,463	581	229,900	102,161	14,944	10,986
(25 years)	(-705)	(-1)	(-154)	(-2,721)	(-159)	(+172)

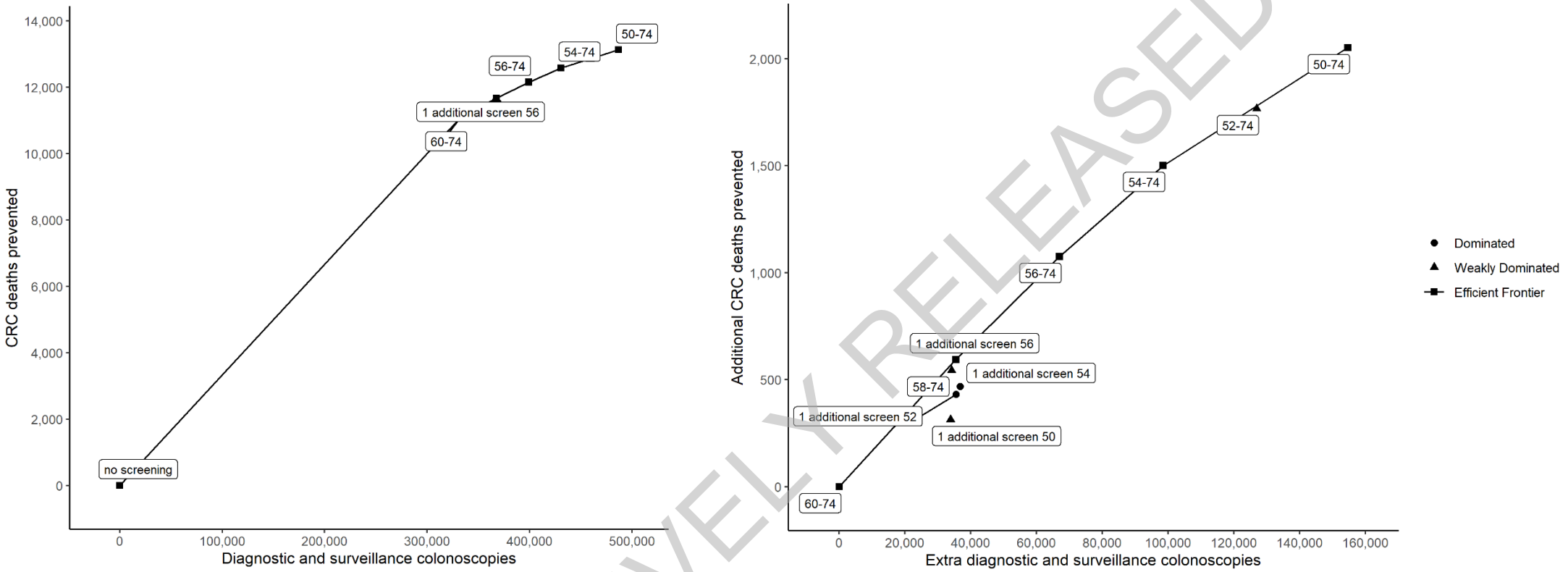
The reduced participation in surveillance colonoscopies and the lower survival resulted in nearly 3,000 fewer projected surveillance colonoscopies (Table 2). With fewer people participating in surveillance, the number of CRC cases prevented decreases, as some cases are missed. The lower survival rates for Māori resulted in more Māori individuals dying earlier from CRC. As more people die from CRC, the value of screening increases, which explains the higher number of CRC deaths prevented. Furthermore, a shorter lifespan with CRC leads to a reduced duration of CRC treatment, thereby decreasing the total costs. The results regarding the most efficient strategies remained robust despite changes in survival rates and participation rate to surveillance (Figure 1-3 and Table 3).



A. Compared to no screening

B. Compared to screening age 60-74

Figure 1Efficiency frontier presenting the (additional) CRC deaths prevented for Māori individuals (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. A sensitivity analysis was performed with reduced participation in surveillance colonoscopy (100% to 85%) and a reduced survival probability for Māori (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.



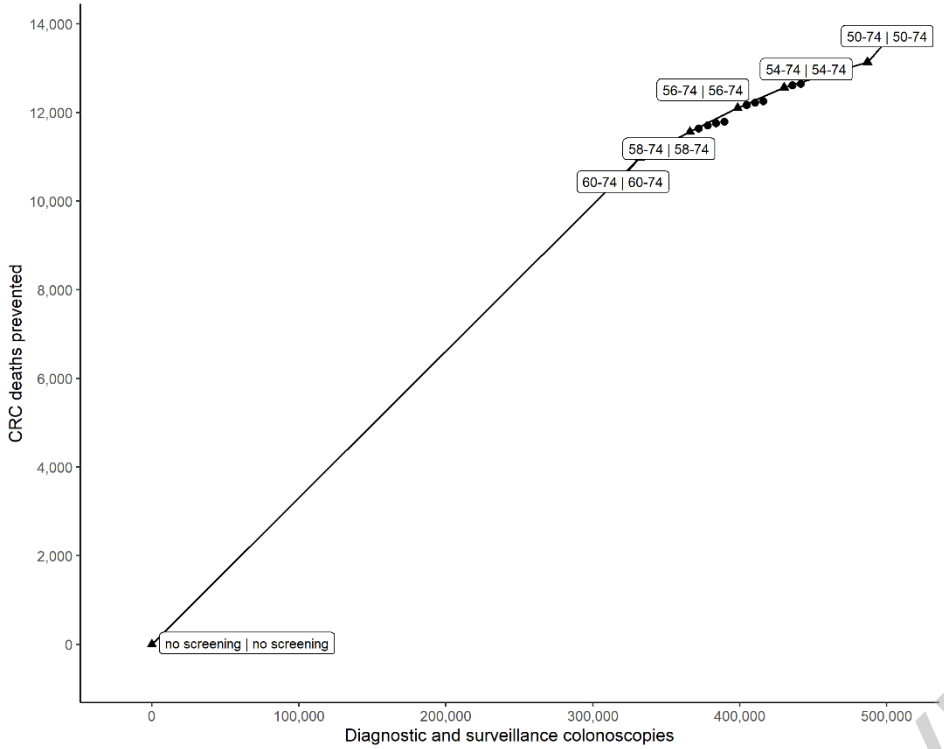
A. Compared to no screening

B. Compared to screening age 60-74

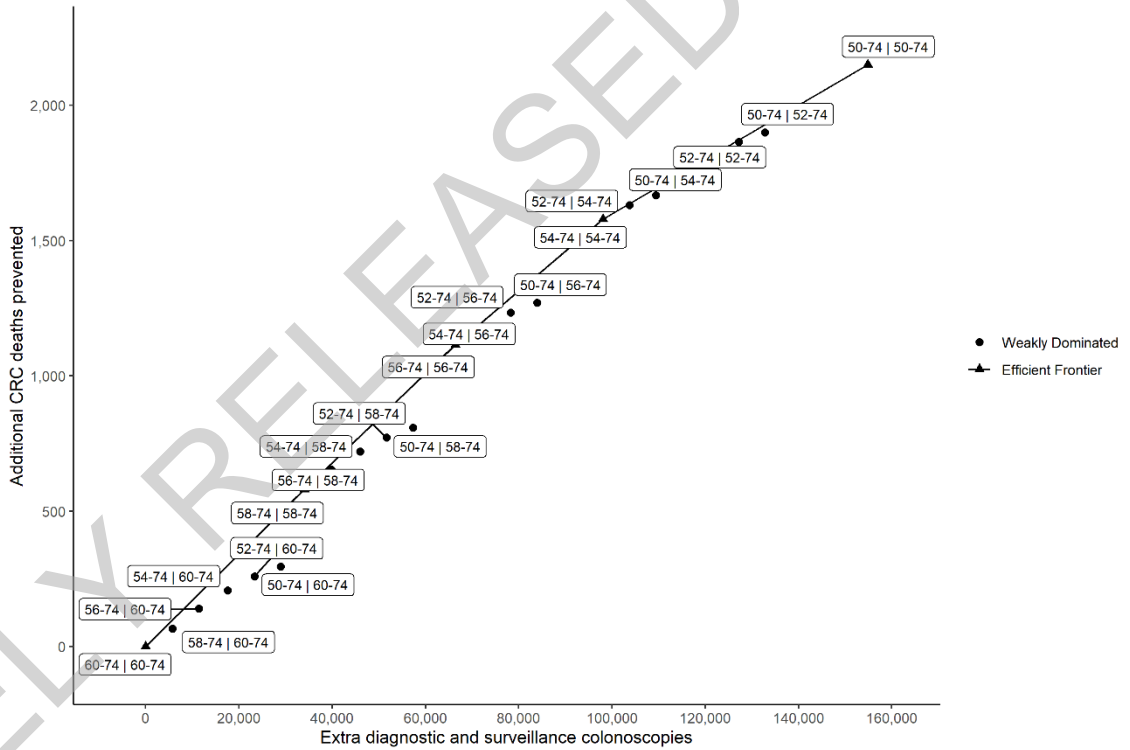
Figure 2 Efficiency frontier presenting the (additional) CRC deaths prevented for total population (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. A sensitivity analysis was performed with reduced participation in surveillance colonoscopy (100% to 85%) and a reduced survival probability for Māori (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.

Table 3 Outcomes for different ethnicity-based screening strategies over 25 years (2025-2050) compared screening the total population from ages 60 to 74. A sensitivity analysis was performed with reduced participation in surveillance colonoscopy (100% to 85%) and a reduced survival probability for Māori (60% to 53%). The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer; NZ$ = New-Zealand dollar.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
60-74 | 60-74	12,463 (-705)	581 (-1)	229,900 (-154)	102,161 (-2,721)	14,944 (-159)	10,986 (+172)
58-74 | 60-74	12,468 (-703)	591 (-1)	233,981 (-118)	103,792 (-3,135)	15,062 (-170)	12,468 (+151)
50-74 | 60-74	12,502 (-699)	635 (-1)	251,803 (-40)	109,242 (-4,424)	15,359 (-187)	12,502 (+174)
58-74 | 58-74	12,499 (-695)	650 (-1)	253,190 (-119)	112,923 (-3,210)	15,688 (-186)	12,499 (+186)
56-74 | 58-74	12,505 (-694)	660 (-1)	257,448 (-69)	114,419 (-3,506)	15,785 (-188)	12,505 (+198)
50-74 | 58-74	12,533 (-691)	694 (-1)	271,011 (-42)	118,373 (-4,498)	15,985 (-202)	12,533 (+208)



A. Compared to no screening



B. Compared to screening age 60-74

Figure 3 Efficiency frontier presenting the additional CRC deaths prevented for the total population (x-axis) and the extra number of colonoscopies required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period. A sensitivity analysis was performed with reduced participation in surveillance colonoscopy (100% to 85%) and a reduced survival probability for Māori (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

3. *Costs and QALYs*

For the third sensitivity analysis, we discussed that it would be helpful to analyze the results in terms of costs rather than the number of colonoscopies, and to focus on quality-adjusted life-years (QALYs) instead of prevented CRC deaths. The assumptions underlying the disutilities are shown in Table 4.

Table 4 Disutility assumptions

Screening and surveillance	Disutility
Negative FIT	0.000063
Positive FIT	0.001330
Negative Colonoscopy (both diagnostic and surveillance)	0.000496
Positive Colonoscopy (both diagnostic and surveillance)	0.001401

CRC care (disutility per year in care phase)*	Stage I	Stage II	Stage III	Stage 4
Initial care	0.12	0.18	0.24	0.7
Continuous care	0.05	0.05	0.24	0.7
Terminal care, death from CRC	0.7	0.7	0.7	0.7
Terminal care, death other causes	0.05	0.05	0.24	0.7

* Disutilities for care were divided into three clinically relevant phases of care – initial, continuing, and terminal care. The initial phase was defined as the first 12 months following diagnosis, the terminal phase was defined as the final 12 months of life, and the continuing phase as the period between the initial and terminal phases of care. The terminal care phase of colorectal cancer patients was further subdivided into terminal care preceding colorectal cancer death and terminal care preceding death of other causes. For patients surviving less than 24 months after diagnosis, the final 12 months of observation and disutilities of care were then allocated first to the terminal phase. The remaining time was allocated to the initial phase, with no contribution to the continuing phase.

The results remained robust when the outcome variables were changed to costs and QALYs (Figure 4-6, Table 5). The changes from sensitivity analyses (1) and (2) are also included here.

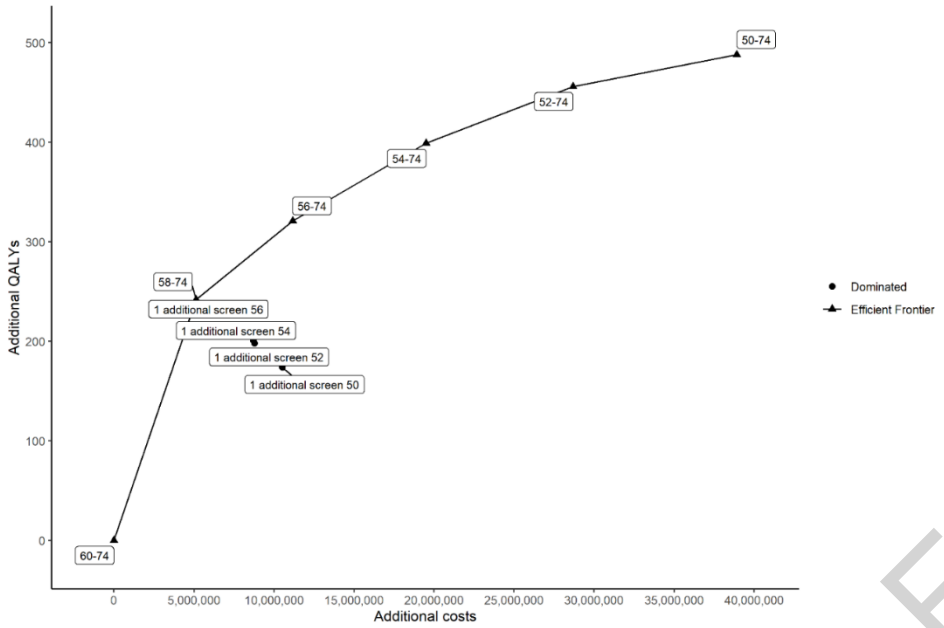


Figure 4 Efficiency frontier presenting the QALYs gained for Māori individuals (x-axis) and the (additional) costs (y-axis) under different screening scenarios over a 25-year time period compared to screening between age 60-74. In this sensitivity analysis the outcome variables changed to costs and QALYS, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that have more QALYs gained for the same or less costs. CRC = colorectal cancer. QALY = quality-adjusted life year

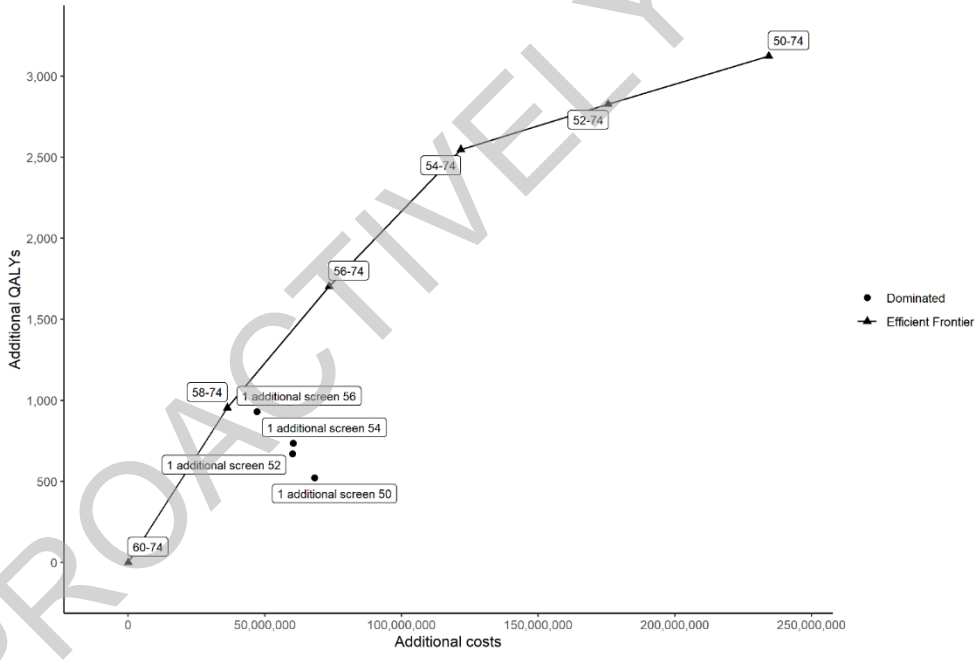


Figure 5 Efficiency frontier presenting the QALYs gained for total population (x-axis) and the (additional) costs required (y-axis) under different screening scenarios over a 25-year time period compared to screening between age 60-74. In this sensitivity analysis the outcome variables changed to costs and QALYS, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that have more QALYs gained for the same or less costs. CRC = colorectal cancer. QALY = quality-adjusted life year

Table 5 Outcomes for different ethnicity-based screening strategies over 25 years (2025-2050) compared to screening the total population from ages 60 to 74. In this sensitivity analysis the outcome variables changed to costs and QALYS, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%).The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer; QALYs = quality adjusted life years*; NZ$ = New-Zealand dollar.*

	Total costs (in million NZ$)	QALYs
60-74 | 60-74	12,463	37,303,015
58-74 | 60-74	12,468	37,303,257
50-74 | 60-74	12,502	37,303,503
58-74 | 58-74	12,499	37,303,969
56-74 | 58-74	12,505	37,304,049
50-74 | 58-74	12,533	37,304,216

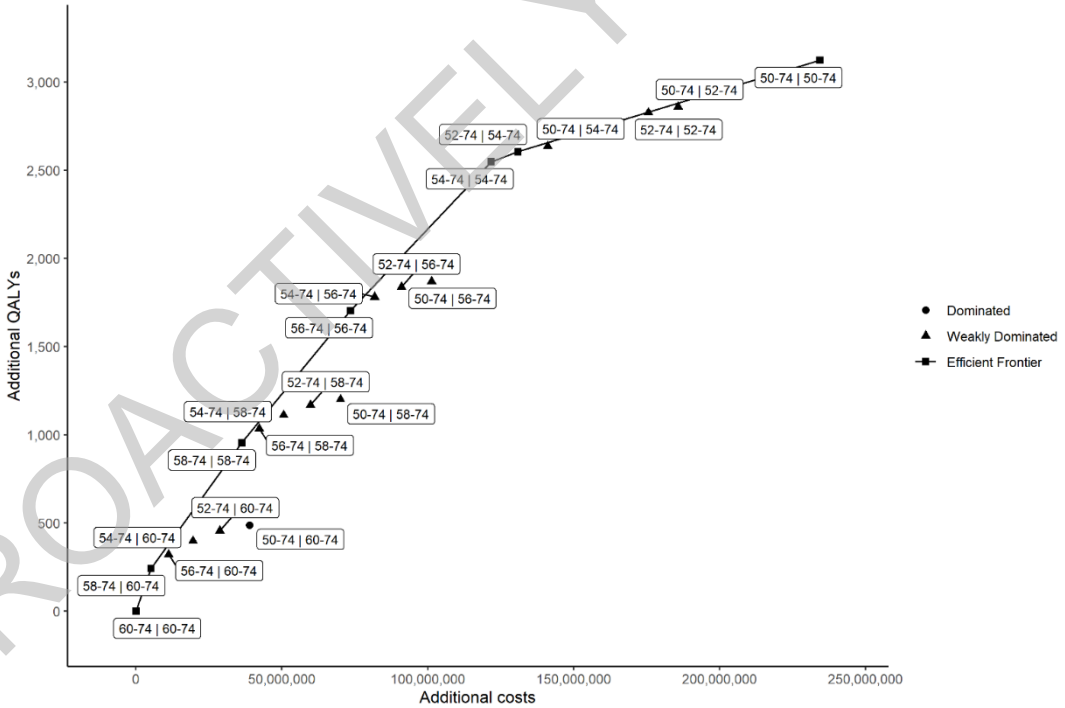


Figure 6 Efficiency frontier presenting the QALYs gained for the total population (x-axis) and the extra costs required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period compared to screening between age 60-74. In this sensitivity analysis the outcome variables changed to costs and QALYS, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that have more QALYs gained for the same or less costs. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer. QALY = quality-adjusted life year.

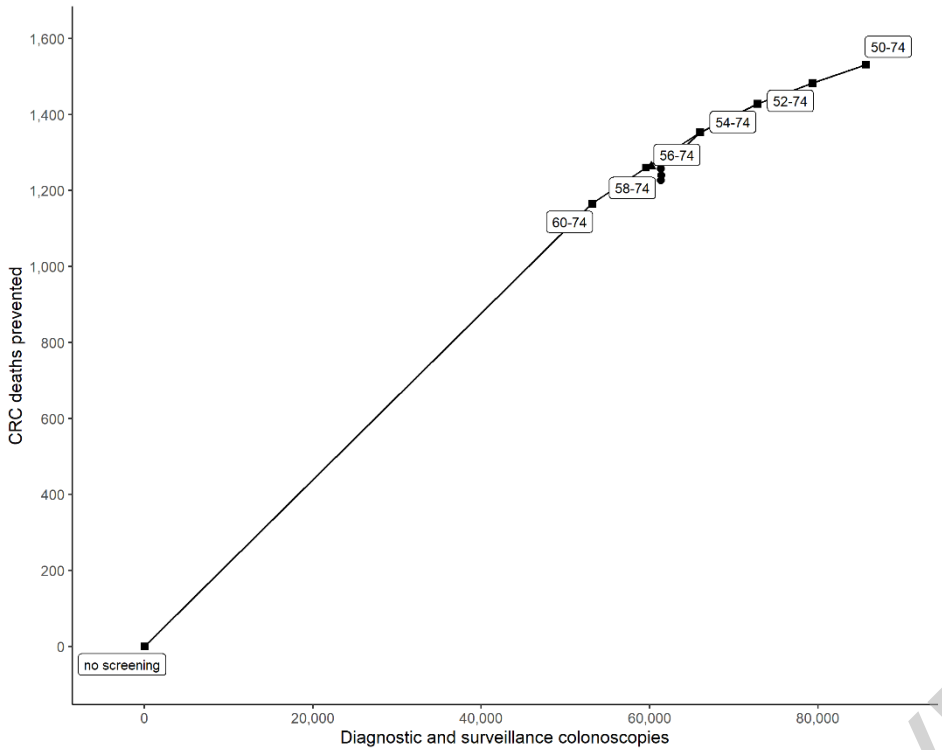
4. Similar participation for Māori and non-Māori

We were informed that campaigns are underway to boost participation, especially among Māori people. Based on this, we evaluated the projected outcomes, assuming a 60% participation rate in FIT screening for both Māori and non-Māori groups. Applying sensitivity analysis (1) and (2) alongside this increased participation yielded the following results:

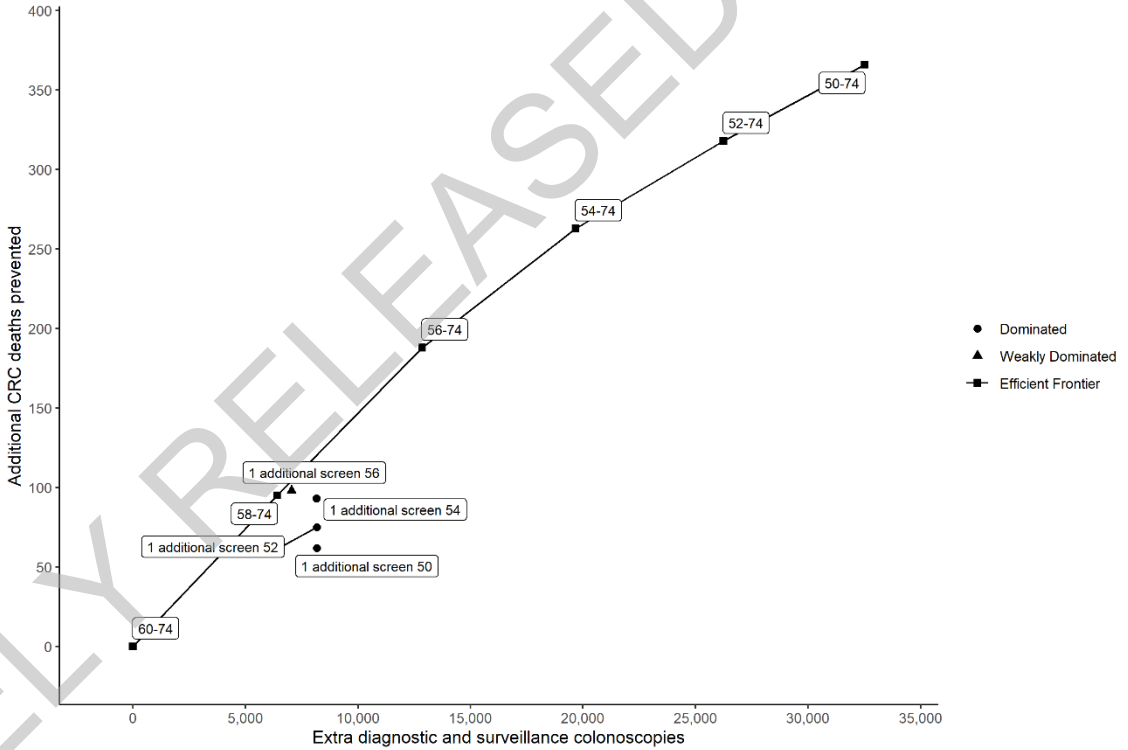
Table 6 Projected outcomes of the base case scenario, in which the total population in New-Zealand is invited for screening from age 60 to 74. In this sensitivity analysis the participation to FIT increased to 60% for Māori, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer; NZ$ = New-Zealand dollar.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
2025-2029	2,290	121	36,057	13,533	1,185	848
(4 years)	(-127)	(+2)	(+668)	(-94)	(+37)	(0)
2025-2035	5,531	284	91,910	38,158	4,185	3,047
(10 years)	(-318)	(+5)	(+1,705)	(-402)	(+94)	(+72)
2025-2050	12,465	592	234,500	103,782	15,118	11,087
(25 years)	(-703)	(+10)	(+4,446)	(-1,100)	(+15)	(+273)

Increased participation in screening led to a higher number of colonoscopies required, which slightly increased both the program and total costs (Table 6). The total costs over 25 years were estimated at 12,465 million NZ$, compared to 12,463 million NZ$ (Table 2) when considering only sensitivity analyses (1) and (2), or 13,168 million NZ$ as estimated in the main analysis. Since more individuals participated in FIT screening, more CRC cases were detected early or prevented, leading to an increase in the number of CRC cases and CRC deaths prevented. The results regarding the most efficient strategies remained robust despite changes in participation rate to FIT and surveillance colonoscopy, and changes in survival rates (Figure 7-9 and Table 7).

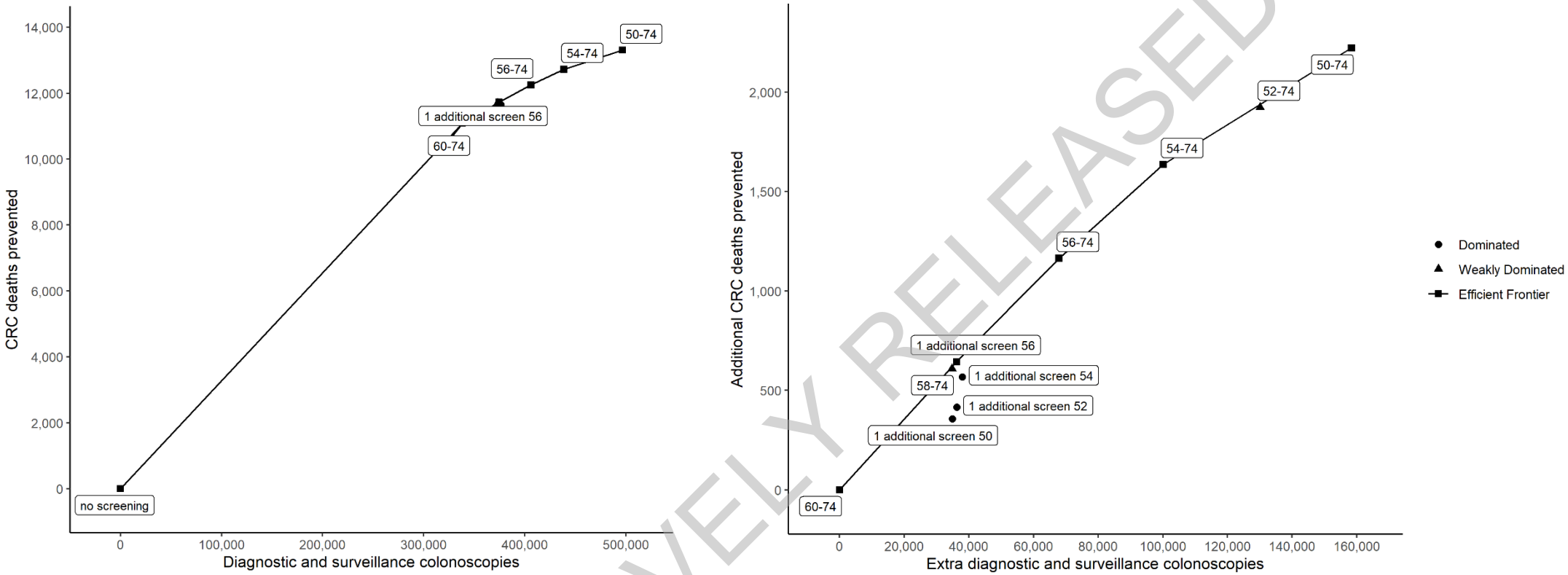


A. Compared to no screening



B. Compared to screening age 60-74

Figure 7 Efficiency frontier presenting the (additional) CRC deaths prevented for Māori individuals (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. In this sensitivity analysis the participation to FIT increased to 60% for Māori, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.



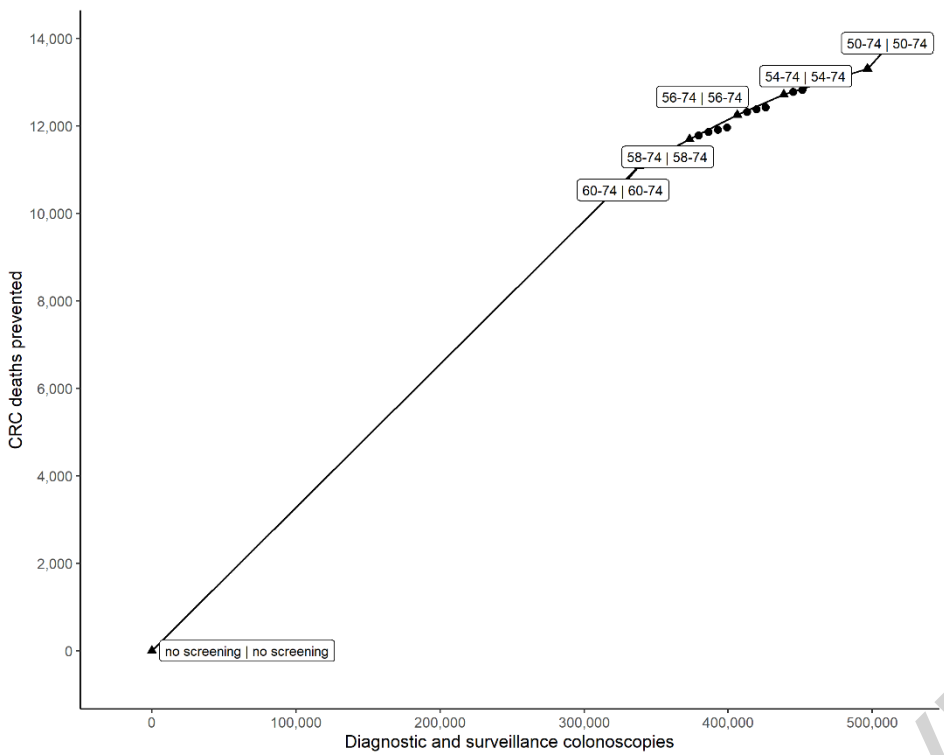
A. Compared to no screening

B. Compared to screening age 60-74

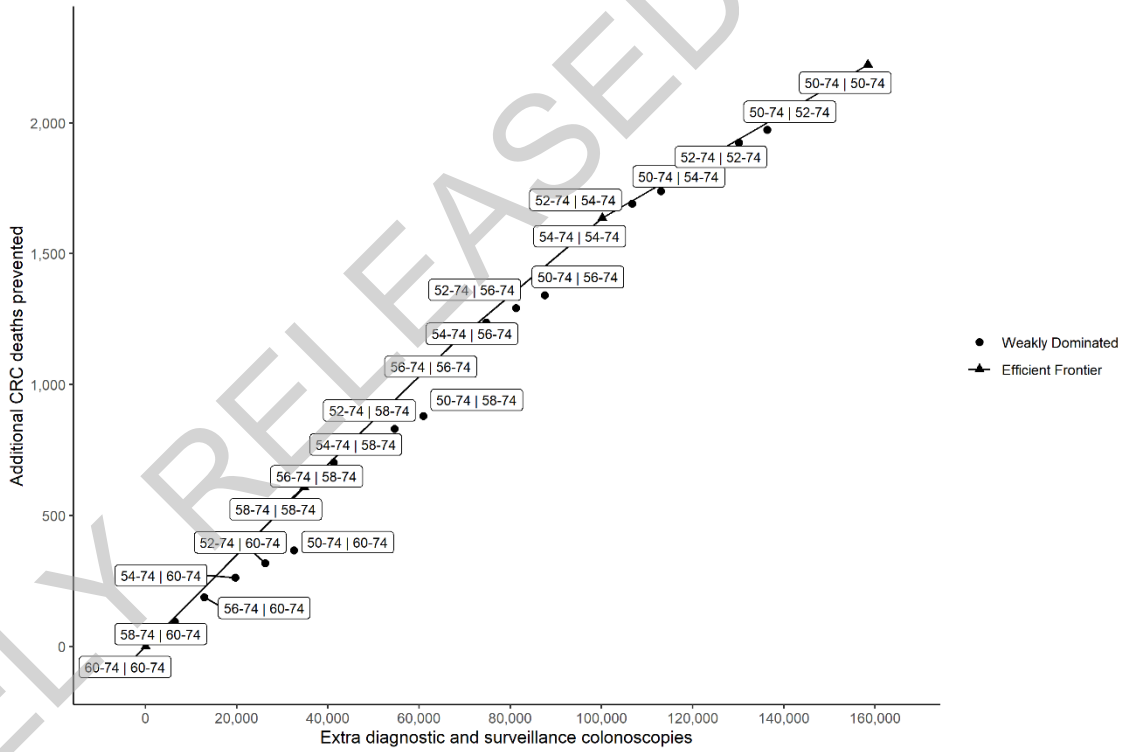
Figure 8 Efficiency frontier presenting the (additional) CRC deaths prevented for total population (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period. In this sensitivity analysis the participation to FIT increased to 60% for Māori, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.

Table 7 Outcomes for different ethnicity-based screening strategies over 25 years (2025-2050) compared screening the total population from ages 60 to 74. In this sensitivity analysis the participation to FIT increased to 60% for Māori, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer; NZ$ = New-Zealand dollar.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
58-74 | 60-74	12,465 (-703)	592 (+10)	234,500 (+4,446)	103,782 (-1,100)	15,118 (+15)	11,087 (+273)
58-74 | 60-74	12,472 (-699)	603 (+11)	239,117 (+5,018)	105,576 (-1,351)	15,240 (+8)	11,183 (+282)
50-74 | 60-74	12,510 (-690)	654 (+18)	259,161 (+7,318)	111,640 (-2,026)	15,590 (+44)	11,454 (+347)
58-74 | 58-74	12,503 (-692)	662 (+11)	258,325 (+5,016)	114,707 (-1,426)	15,867 (-7)	11,696 (+316)
56-74 | 58-74	12,510 (-690)	674 (+13)	263,081 (+5,564)	116,388 (-1,537)	15,984 (+11)	11,788 (+347)
50-74 | 58-74	12,541 (-683)	712 (+18)	278,369 (+7,316)	120,771 (-2,100)	16,217 (+30)	11,967 (+381)



A. Compared to no screening



B. Compared to screening age 60-74

Figure 9 Efficiency frontier presenting the additional CRC deaths prevented for the total population (x-axis) and the extra number of colonoscopies required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period. In this sensitivity analysis the participation to FIT increased to 60% for Māori, the participation in surveillance colonoscopy decreased (100% to 85%) and the survival probability for Māori was adjusted (60% to 53%). The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer.

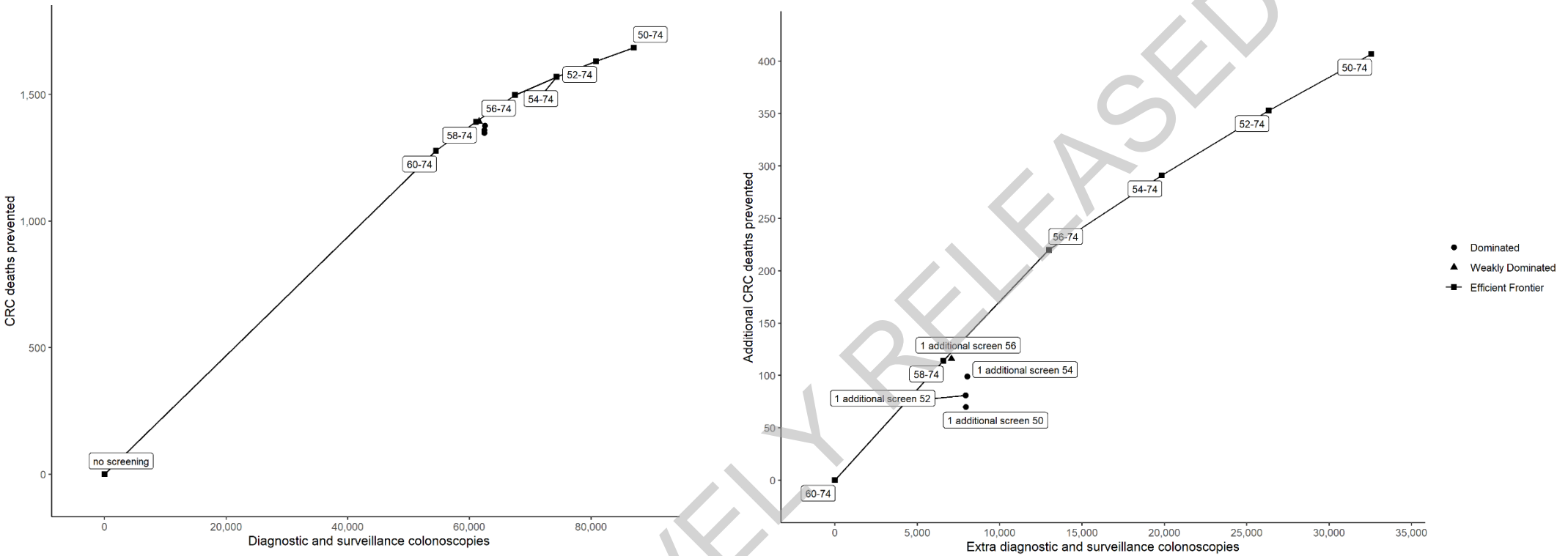
5. Increased incidence among Māori

In the initial version of the report, the incidence rates for both Māori and non-Māori were calibrated to 2015 incidence data. Waddell et al.(9) observed a rising incidence trend among the Māori population between 2010 and 2020. Therefore, we compared the incidence rates in Health New-Zealand's data between 2015 and 2020. Since screening was introduced during this period and could impact incidence, we focused on younger age groups (ages 0–59) who were not yet eligible for screening. Our analysis revealed that the incidence among younger Māori increased by a factor of 1.24, while for non-Māori, the incidence remained relatively stable, with a factor of 1.07. For that reason, we recalculated the results using an underlying risk that is 1.24 times higher for the Māori population. Incorporating sensitivity analyses (1) and (2) together with the increased incidence for Māori resulted in the following outcomes:

Table 8 Projected outcomes for inviting the total New-Zealand population for CRC screening from age 60 to 74, assuming increased incidence of CRC, reduced participation in surveillance colonoscopy (100% to 85%) and disparities in survival probability. The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer; NZ$ = New-Zealand dollar.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
2025-2029	2,325	120	36,023	13,665	1,183	850
(4 years)	(-92)	(+1)	(+634)	(+38)	(+35)	(+2)
2025-2035	5,622	282	91,830	38,602	4,222	3,069
(10 years)	(-227)	(+3)	(+1,625)	(+42)	(+131)	(+94)
2025-2050	12,688	587	234,395	105,232	15,268	11,201
(25 years)	(-480)	(+5)	(+4,341)	(+350)	(+165)	(+387)

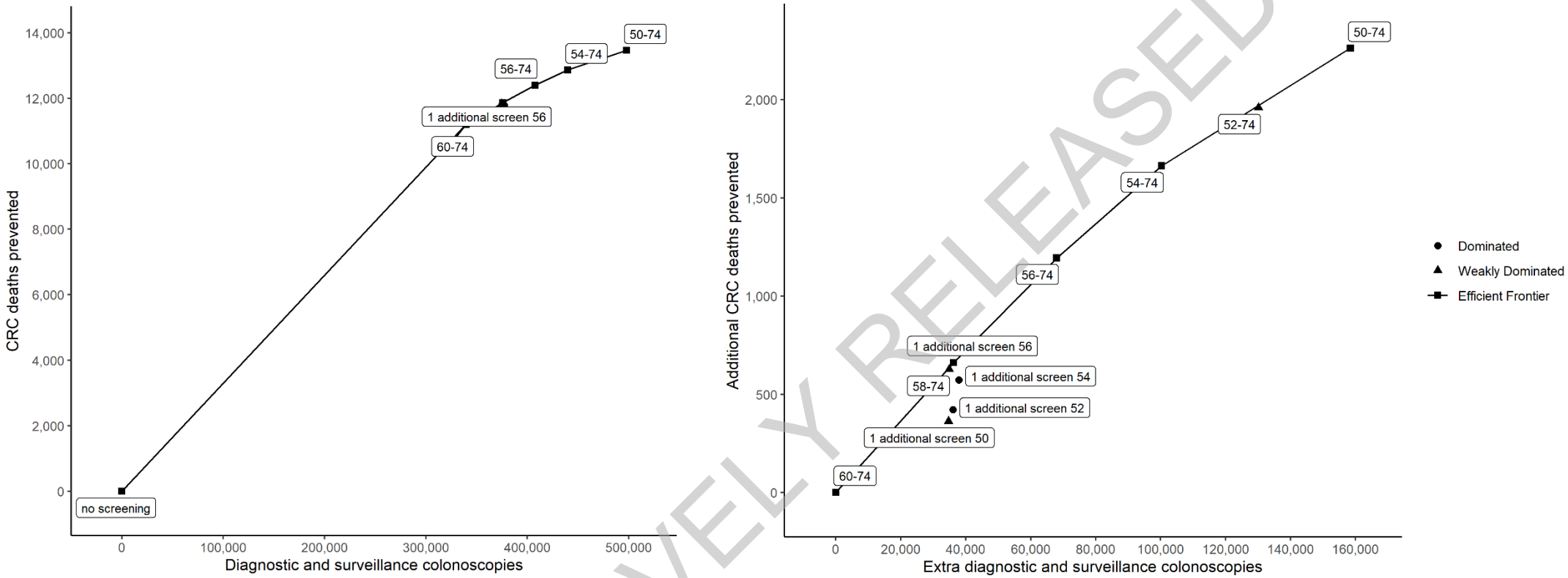
We found that the increased incidence led to a higher number of colonoscopies, as more people tested positive with the FIT (Table 8). As a result, the total costs over 25 years were estimated at 12,688 million NZ$, compared to 12,463 million NZ$ (Table 1) when considering only sensitivity analyses (1) and (2), or 13,168 million NZ$ as estimated in the main analysis. Thus, while the lower survival rates for Māori reduced the costs, an increase in incidence partially offset this effect. The higher incidence also resulted in more CRC cases and deaths being prevented through screening. Similar to sensitivity analyses (1)-(4), the results regarding the most efficient strategies remained robust when the incidence for Māori was increased (Figure 10-12, Table 9).



A. Compared to no screening

B. Compared to screening age 60-74

Figure 10 Efficiency frontier presenting the (additional) CRC deaths prevented for Māori individuals (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period, assuming increased incidence of CRC, reduced participation in surveillance colonoscopy (100% to 85%) and disparities in survival probability. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. CRC = colorectal cancer.



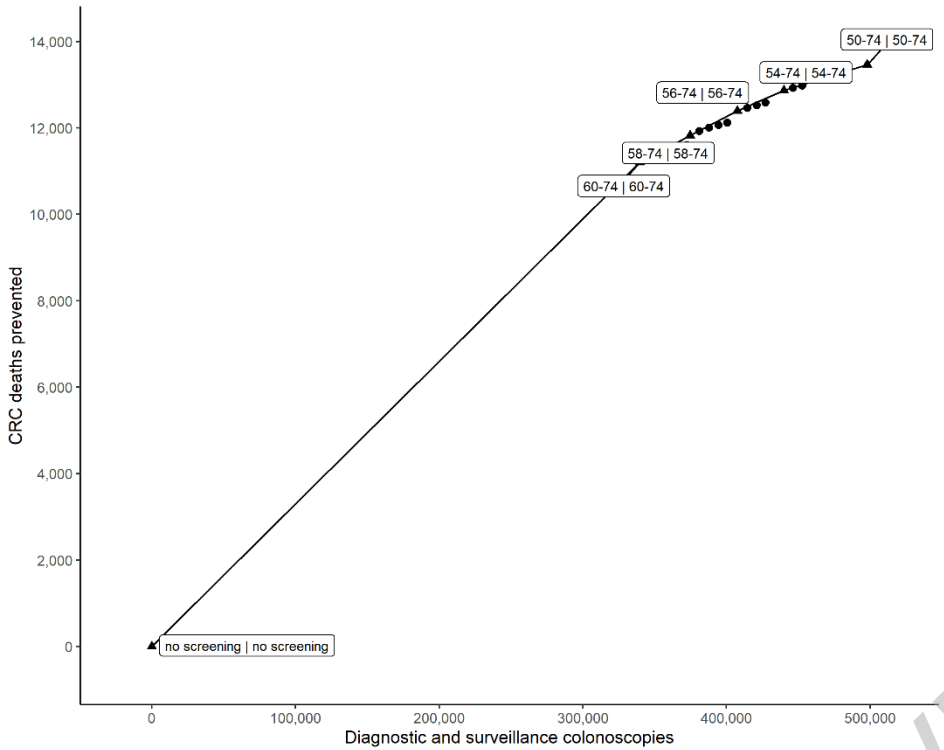
A. Compared to no screening

B. Compared to screening age 60-74

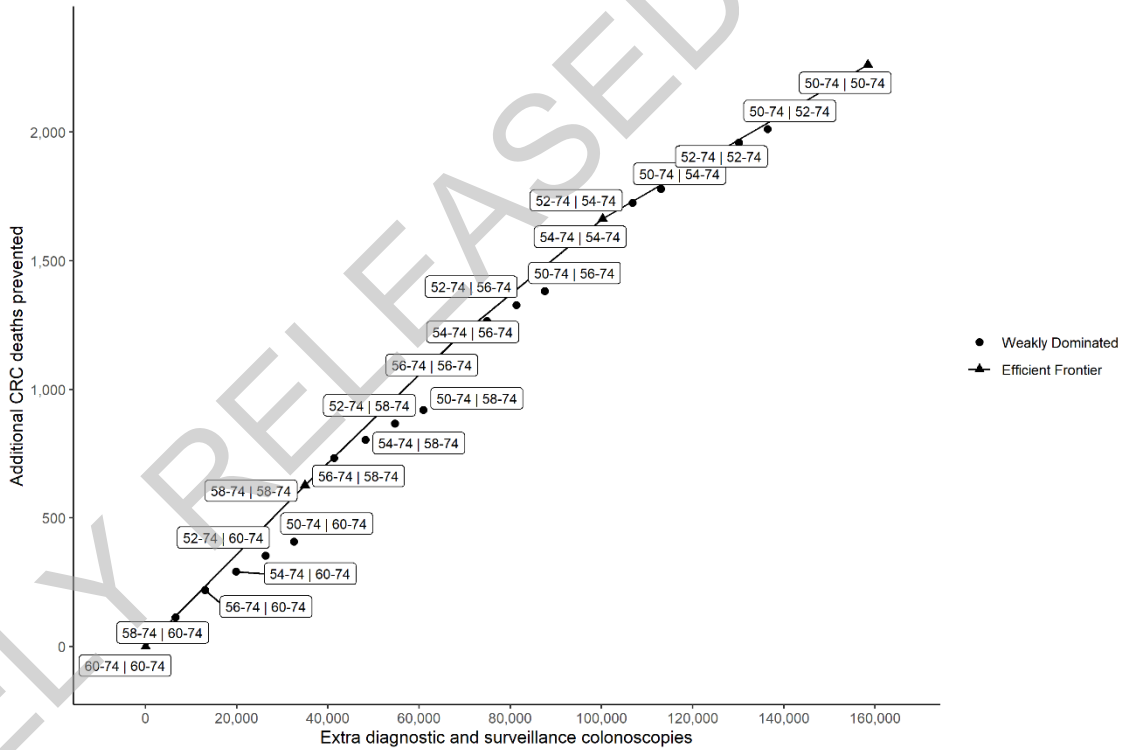
Figure 11 Efficiency frontier presenting the (additional) CRC deaths prevented for total population (x-axis) and the (extra) number of colonoscopies required (y-axis) under different screening scenarios over a 25-year time period, assuming increased incidence of CRC, reduced participation in surveillance colonoscopy (100% to 85%) and disparities in survival probability. CRC = colorectal cancer.

Table 9 Outcomes for different ethnicity-based screening strategies over 25 years (2025-2050) compared screening the total population from ages 60 to 74, , assuming increased incidence of CRC, reduced participation in surveillance colonoscopy (100% to 85%) and disparities in survival probability. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. The values in parentheses represent the differences compared to the outcomes from the main analysis of the report. CRC = colorectal cancer.

	Total costs (in million NZ$)	Programme costs (in million NZ$)	Diagnostic colonoscopies	Surveillance colonoscopies	CRC cases prevented	CRC death prevented
60-74 | 60-74	12,688 (-480)	587 (+5)	234,395 (+4,341)	105,232 (+350)	15,268 (+165)	11,201 (+387)
58-74 | 60-74	12,693 (-478)	598 (+6)	238,959 (+4,860)	107,241 (+314)	15,410 (+178)	11,314 (+413)
50-74 | 60-74	12,727 (-474)	644 (+8)	258,286 (+6,443)	113,894 (+228)	15,782 (+236)	11,608 (+501)
58-74 | 58-74	12,724 (-470)	656 (+6)	258,167 (+4,858)	116,372 (+239)	16,036 (+162)	11,828 (+448)
56-74 | 58-74	12,732 (-468)	667 (+6)	262,755 (+5,238)	118,199 (+274)	16,160 (+187)	11,934 (+493)
50-74 | 58-74	12,758 (-466)	702 (+7)	277,494 (+6,441)	123,025 (+154)	16,409 (+222)	12,121 (+535)



C. Compared to no screening



D. Compared to screening age 60-74

Figure 12 Efficiency frontier presenting the additional CRC deaths prevented for the total population (x-axis) and the extra number of colonoscopies required (y-axis) under different ethnicity-based screening scenarios over a 25-year time period, , assuming increased incidence of CRC, reduced participation in surveillance colonoscopy (100% to 85%) and disparities in survival probability. The strategies on the solid line are the most efficient strategies, meaning that there are no strategies that prevent more CRC deaths for the same or less additional colonoscopies. The notation "58-74 | 60-74" denotes a screening strategy where Māori individuals are screened from ages 58 to 74, and non-Māori individuals are screened from ages 60 to 74. CRC = colorectal cancer

Conclusion

In this Appendix, we included five sensitivity analyses to examine the effects of variations in participation, disparities in survival rates, increased incidence, and the use of costs and QALYs in a cost-effectiveness analysis. Aligning surveillance participation with diagnostic colonoscopy rates (85%) reduced the projected number of colonoscopies and CRC cases prevented. Including lower survival rates for Māori revealed increased benefits of screening in reducing CRC incidence and mortality for this group and lower costs. Assuming equal participation rates (60%) for Māori and non-Māori led to higher program costs and a greater number of colonoscopies. However, this adjustment prevented additional CRC cases and deaths, underscoring the importance of campaigns to boost screening uptake, particularly among Māori. Higher incidence rates among Māori necessitated more colonoscopies but also increased the benefits of screening. None of the five sensitivity analyses altered the conclusions regarding the most optimal strategies.