The economic and emissions impacts of rail infrastructure improvements

An MDG-NZ dynamic Computable General Equilibrium analysis

Final report, April 2024

SENSE PARTNERS
DATA LOGIC ACTION

Key points

Auckland's rail network faces several key challenges

- The current rail network faces three key challenges that will not be addressed by KiwiRail's business-as-usual (or 'baseline') investment programme:
    - **Capacity constraints** – the existing network cannot accommodate expected growth in freight and passenger rail travel.
    - **Poor level of service** – some passengers and freight users are deterred from using rail due to concerns over reliability, frequency, travel times, accessibility and safety.
    - **Inadequate network maintenance and renewals** – these contribute to reliability and punctuality problems and will worsen as train volumes increase and assets age and deteriorate.
- KiwiRail is concerned that without adequate capital investment, these problems will mean that rail will be unable to meet demand, requiring more people and goods to use roads and missing opportunities for reduced emissions from the transport sector.

KiwiRail and AT have developed a programme to invest up to an additional $21.2bn of capital into Auckland's rail network across 3 decades, plus boost renewals and maintenance spending, to address these challenges…

- KiwiRail and Auckland Transport jointly undertook a Programme Business Case across 2021-23 which developed a strategic rail investment programme for the rail system in Auckland over the next 10-30-years. This work outlines several investment programme options, which inform the scenarios developed in this report:
    - A **baseline scenario** ('do minimum') that assumes no investment in capacity beyond that already committed for 2024-2027, except for ongoing investment in maintenance and renewals (capital cost of $1.15bn, plus renewals of $7.0bn and maintenance of $8.5bn).
    - A **core investment scenario** that seeks to address expected constraints and enable most projected demand (additional capital cost of $21.2bn relative to baseline between 2025 and 2051, plus an additional $2.6bn of renewals and $10.2bn of maintenance later in the projection period). It is a whole-of-system approach, key aspects of which include:
        - A step change in maintenance and renewals levels and delivery methods which will drive improved reliability and reduce disruption from track works
        - Four-tracking the North Island Main Trunk (NIMT) between Westfield Junction and Pukekohe

- Completing the East-West Crosstown (Avondale-Southdown) rail corridor via Onehunga
- 72 new electric trains and accompanying stabling requirements
- Removal of 24 level crossings
- Station upgrades
- Improved signalling and power equipment.

  - A **delayed investment scenario** based on the above has been developed for this report, which envisages limited and later investment in the most congested part of the network (southern corridor) taking place between 2043 and 2060 (additional capital cost of $8.9bn relative to baseline, plus additional $1.5bn of renewals and additional maintenance of $4.75bn, largely after 2050)[1].

- In addition, a variation on the core investment scenario has been developed and included as Appendix A. This scenario considers the changes to the core scenario that would result from **growth of Northport**. The main core scenario assumes that Port of Auckland would be capped and that future freight growth will occur principally at Tauranga. The Northport scenario also assumes Port of Auckland would be capped and future volumes would instead be serviced by Tauranga and Northport (Marsden).

…and asked Sense Partners to estimate the wider economic and emissions impacts of its planned investments

- We use an advanced dynamic computable general equilibrium (CGE) model of the New Zealand economy – MDG-NZ – for this analysis.
- MDG-NZ comprises 72 industries operating across 8 regions of New Zealand. Regional economies are linked through cross-border flows of goods, services, labour and capital, facilitated by road and rail transport services.
- We first project the economy and its associated emissions out to 2100. We draw on Treasury's economic forecasts and longer term projections to 2060 and the Climate Change Commission's emissions projections to 2050.
- In the later decades of the projection period we rely on simple assumptions to generate this business-as-usual (BAU) or baseline scenario.

The Core scenario delivers significant capital investment in Auckland, and subsequently lifts passenger and freight volumes

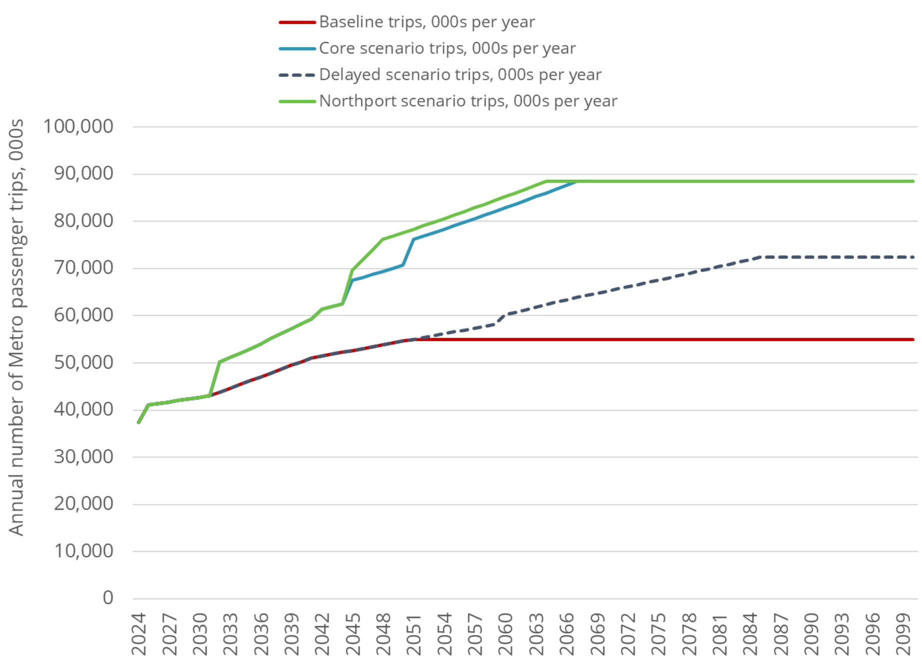
- The Core modelling scenario comprises three sets of 'shocks' that we impose on the model to knock it off its baseline:

[1] The delayed investment scenario includes infrastructure to address the worst congestion problem on the network. As well as being implemented far behind demand, its limited scope does not provide for future growth, improved journey times or improved service options for passengers.

  - Investment shocks that primarily lift activity in the construction sectors as they are contracted to build more tracks, stations, remove level crossings, etc. This investment is funded through a combination of local government and central government sources, assumed to be largely offshore borrowing.
  - Increased Auckland Metro passenger and nationwide freight volumes as capacity increases and the timeliness, reliability and quality of rail services improve following the boost in investment (see Figure 1 and Figure 2 below).
  - Labour and capital productivity improvements in the rail sector as the new tracks and accompanying infrastructure lift reliability, improve user experience and reduce maintenance costs per tonne/kilometre.

- We assume the additional rail freight is diverted from road. This delivers emissions benefits for a given amount of output as rail is more emissions-efficient than road freight.
- The additional Auckland Metro passenger patronage is assumed to substitute partly for private car trips, partly for other public transport or active modes, and partly reflects an induced demand as quality lifts.

FIGURE 1 SCENARIO PASSENGER VOLUMES



SOURCE: KIWIRAIL

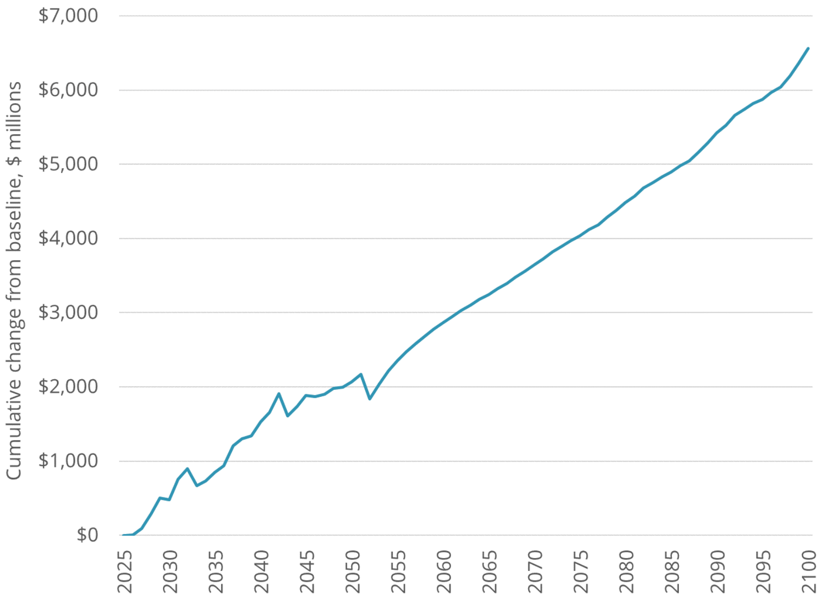
FIGURE 2 SCENARIO FREIGHT VOLUMES

SOURCE: KIWIRAIL

The Core scenario investment programme delivers solid and ongoing improvements in New Zealand's real GDP over time

- Real GDP rises by 0.35% above baseline by 2042 during the construction phase, before easing back to 0.32% above baseline by 2075 and 0.27% by 2100.
- In dollar terms, this equates to an additional $1.9 billion, $4.0 billion and $6.6 billion respectively (Figure 3).
- These GDP impacts take into account the cost of the programme, so can be thought of as its additional economic impacts over and above its costs (i.e. the benefit cost ratio is greater than 1).

FIGURE 3 CORE SCENARIO REAL GDP IMPACTS, CHANGE FROM BASELINE, $ MILLIONS



SOURCE: MODELLING RESULTS

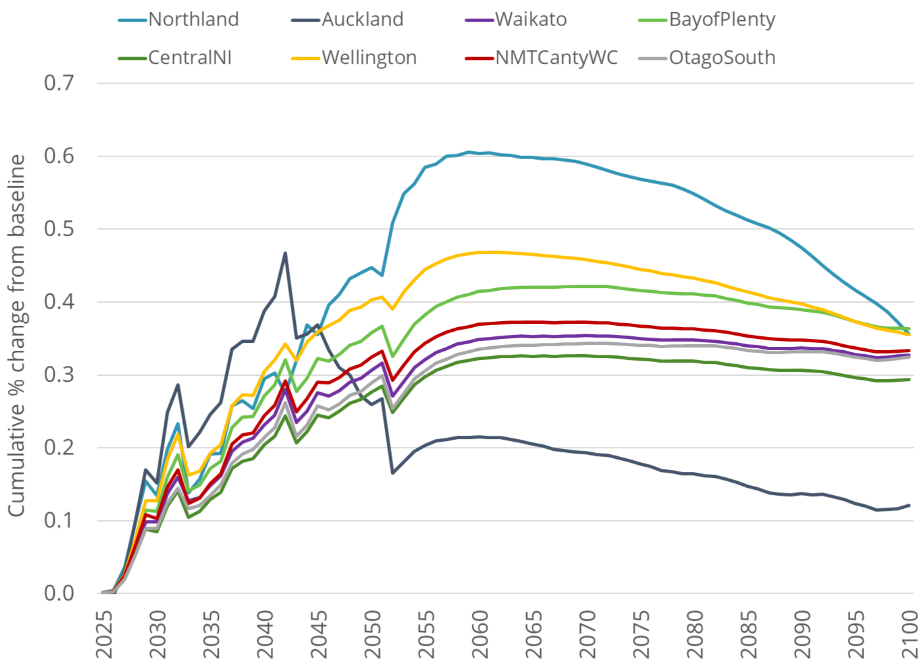
Our formal modelling is only part of the benefits story

- Our empirical analysis focuses on what might be considered the 'conventional' macroeconomic and emissions impacts of the proposed rail expansion programme.
- The proposed rail investment would generate several other social and economic benefits that are challenging to include in a CGE model but should be seen as additional to the quantified estimates we present here:
    - Safety benefits and time savings associated with the greater use of rail.
    - Time savings from reduced road congestion.
    - Improved urban design and liveability, which will also present the possibility of opportunities for value capture.
    - Reduced road and vehicle maintenance for a given amount of economic activity.
- These benefits will be experienced by a wide range of businesses and households. With more time and resources they could be incorporated into the wider modelling framework.

Auckland gains the most during the construction phase, but all other regions benefit too

- The **Auckland** economy is 0.47% ($880 million) larger than the baseline in 2042. Further out beyond 2050, the additional investment for the rail programme is funded more by domestic savings than accessing overseas savings, which softens its GDP growth. However, it is still almost $1.1 billion larger than baseline by the end of the projection period.

FIGURE 4 CORE SCENARIO, % CHANGE IN REAL REGIONAL GDP FROM BASELINE,



SOURCE: MODELLING RESULTS

- **Northland** expands the fastest of our regions, as it benefits from improved rail links[2] and greater activity at Northport.
- The **Waikato** and **BOP** regions experience proportionately more moderate increases in economic activity, in part reflecting resources being diverted towards Auckland as it grows strongly. Mining and other capital-intensive sectors suffer slightly as their capital costs rise. Primary processing sectors perform better, however.
- The **Central North Island's** growth above baseline is softened by contractions in the beverage manufacturing industry (largely wine in Hawke's Bay as labour costs rise), printing and paper products (as more wood is directed to the construction sectors), and heavy manufacturing industries (as they compete for capital with the rail sector's expansion and face a higher cost base).
- **Wellington's** services firms – especially construction, professional and technical services, and media and communication services – benefit from Auckland's growth as they feature in many growing Auckland industries' supply chains.
- The **Canterbury, West Coast, Nelson, Marlborough and Tasman** composite region grows moderately above baseline. The largest percentage gains come in metal ore and

[2] This is in part due to the underlying assumption that the Marsden Point Rail Link is built. In the core investment scenario, no additional growth beyond that prompted by rail-enabling the Port has been assumed for Northland. See Appendix A for the Northport growth scenario which demonstrates the expected impact of additional growth at Northport.

non-metallic minerals mining (due to cheaper rail freight costs), construction, wood products, and professional services.

- The **Otago and Southland** economy grows marginally above baseline but is held back somewhat by its reliance on labour-intensive and export-focused sectors such as tourism and international education, which face challenges from higher real wages and a stronger exchange rate. It also has less intensive industry linkages with the Auckland economy due to distance.

A larger economy means more jobs and higher real wages…

- The number of full time equivalent (FTE) jobs across the economy is around 10,600 higher by the end of the initial construction phase in 2050 and 22,800 higher by 2100 as the economy grows above the baseline.
- FTE employment in Auckland is around 5,200 higher than baseline by 2050 and almost 11,700 higher by 2100. The most significant job gains come in construction services in Auckland. This highlights the importance of the rail construction industry being retained in New Zealand.
- Average real wages across the national economy are also pushed higher by the investment programme as the economy expands. They are 0.72% higher than baseline at the peak of the construction phase and remain above baseline out to 2100 (0.70%).

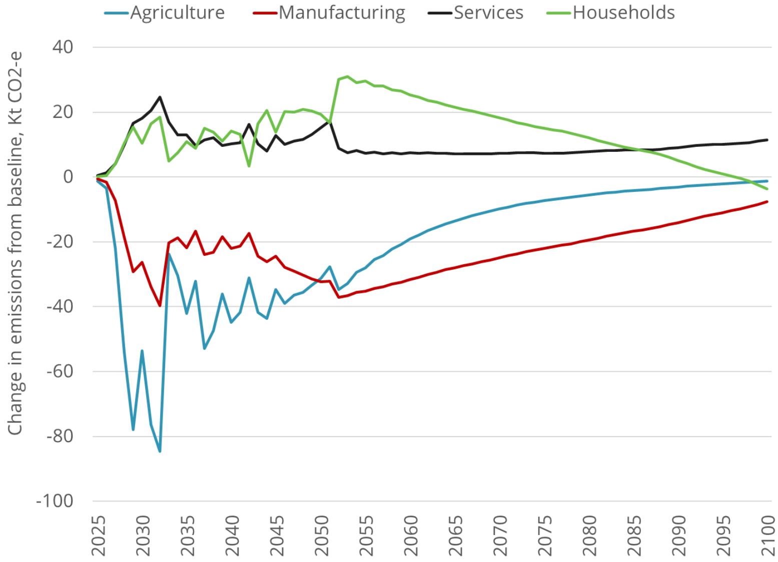
…and a boost to household spending

- The combined effect of more jobs and higher real wages is higher household incomes and spending.
- Household spending rises by $1.9 billion above baseline in 2050, rising to an additional $5.3 billion by 2075.

The investment programme delivers environmental benefits as well as economic gains: emissions per unit of output decrease

- The setup of the Emissions Trading Scheme means that *total* emissions (outside of agriculture) cannot change in response to a policy shock – total emissions are set administratively by government. Consequently, outside of agriculture, total emissions do not change between the baseline and Core scenarios.
- However, the programme changes the composition and location of emissions generated. The primary sector and manufacturing sector, both of which are heavy users of rail freight, see their emissions fall below baseline over time, despite their output growing faster (Figure 5).
- Services emissions rise primarily because construction activity is included in this sector. Household emissions grow above baseline for most of the projection period as real wages and employment grow, before dropping marginally below baseline as consumption eases in the outyears.

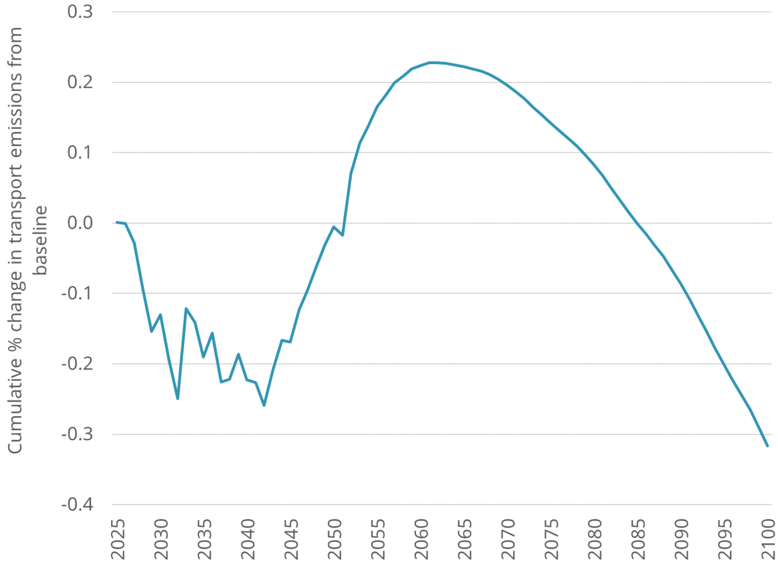
FIGURE 5 CORE SCENARIO BROAD SECTOR CHANGE IN EMISSIONS FROM BASELINE, KT CO2-E



SOURCE: MODELLING RESULTS

- Total transport emissions, which includes road, rail, domestic air and sea transport, fall below the baseline during the construction period as traffic is disrupted. They then rise above baseline as economic activity increases – more output generates more emissions (Figure 6).
- Over time, the transport sector becomes more emissions-efficient with the shift from road to rail. Total transport emissions are lower than baseline by the mid-2080s. Emissions are lower than they would have been had the freight and passenger demand been met by road transport instead.

FIGURE 6 CORE SCENARIO TOTAL TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



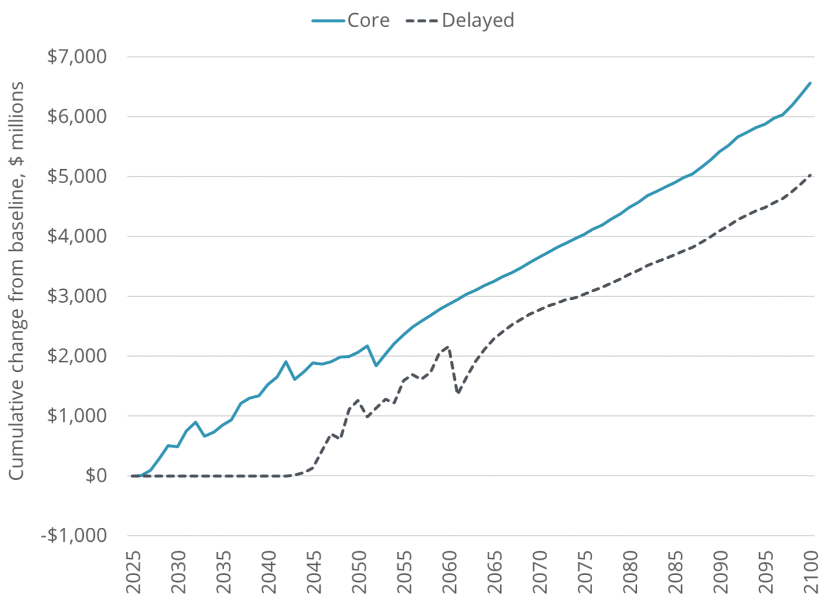
SOURCE: MODELLING RESULTS

- Auckland's emissions fall below the baseline throughout the projection period, while its economy grows above the baseline. This means the Auckland regional economy becomes more emissions-efficient because of the investment programme: emissions per dollar of GDP decreases.
- The Core scenario sees GDP grow above the baseline over the projection period. With ETS emissions fixed at their baseline level, and agricultural emissions also dropping slightly, this demonstrates an improvement in the nationwide emissions-efficiency of GDP – there are fewer emissions per unit of GDP generated.

The economic benefits from the Delayed investment scenario are around 25% smaller by 2100

- The Delayed investment scenario expands real GDP above baseline by $1.3 billion by 2050, $3.0 billion by 2075 and $5.0 billion by 2100. In contrast the Core scenario expands real GDP by $1.9 billion, $4.0 billion and $6.6 billion respectively.

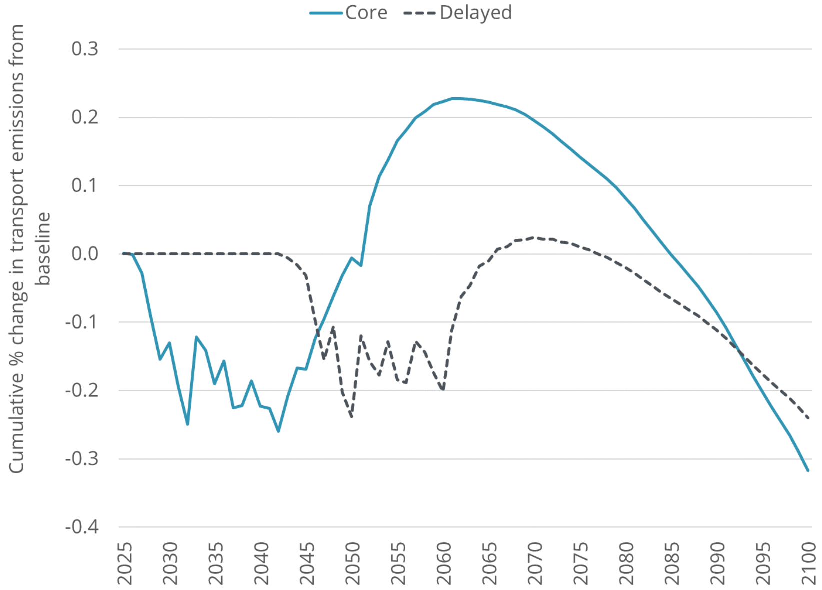
FIGURE 7 REAL GDP IMPACTS, CHANGE FROM BASELINE, %



SOURCE: MODELLING RESULTS

- It also delivers delivers transport sector emissions savings (Figure 8).
- As in the core scenario, emissions initially drop as traffic is disrupted during the construction phase. Once in place, the improved rail sector supports higher income growth and more economic activity, which sees emissions increase very slightly above the baseline in the decade from 2065.
- Later on in the projection period, the household spending impulse to the economy eases back as domestic savings rise to fund the investment activity. This, alongside modal switch from road to rail, sees total transport emissions fall below baseline from the mid-2070s.
- As with the Core scenario, a combination of a growing economy and fixed ETS emissions results in the Delayed scenario driving an improvement in the emissions-intensity of GDP.

FIGURE 8 TOTAL TRANSPORT EMISSIONS, % CHANGE FROM BASELINE

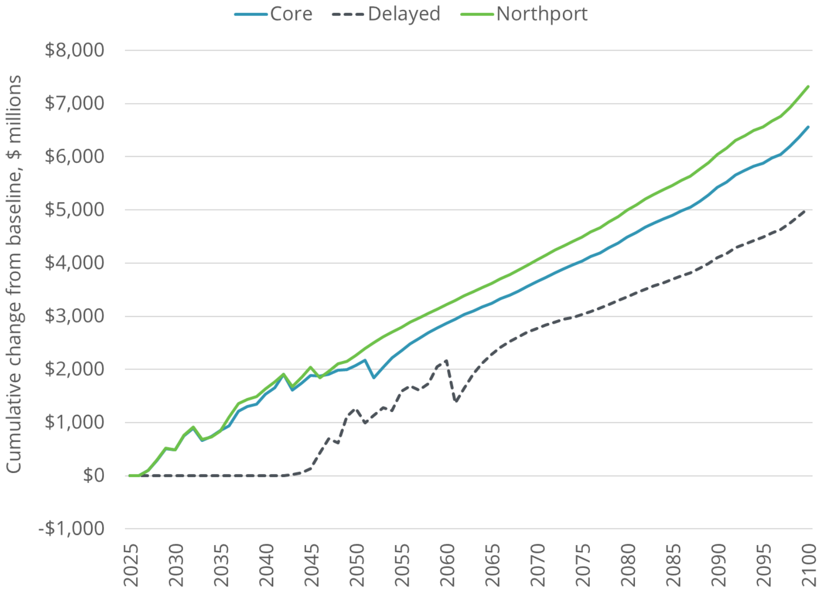


SOURCE: MODELLING RESULTS

The Northport scenario enables freight and passenger growth earlier than the Core scenario, resulting in larger GDP impacts…

- The Northport scenario leads to national real GDP being $3.22 billion above baseline by 2060, compared to $2.88 billion in the Core scenario, due to the investment phase starting six years earlier, facilitating earlier freight and passenger growth. The key driver of the earlier GDP boost is that investment into the Crosstown (Avondale-Southdown) rail corridor occurs six years sooner than in the Core scenario.
- By 2100, real GDP in the Northport scenario is $7.32 billion above baseline, around $650 million higher than in the Core scenario.

FIGURE 9 REAL GDP IMPACTS, CHANGE FROM BASELINE, $ MILLIONS



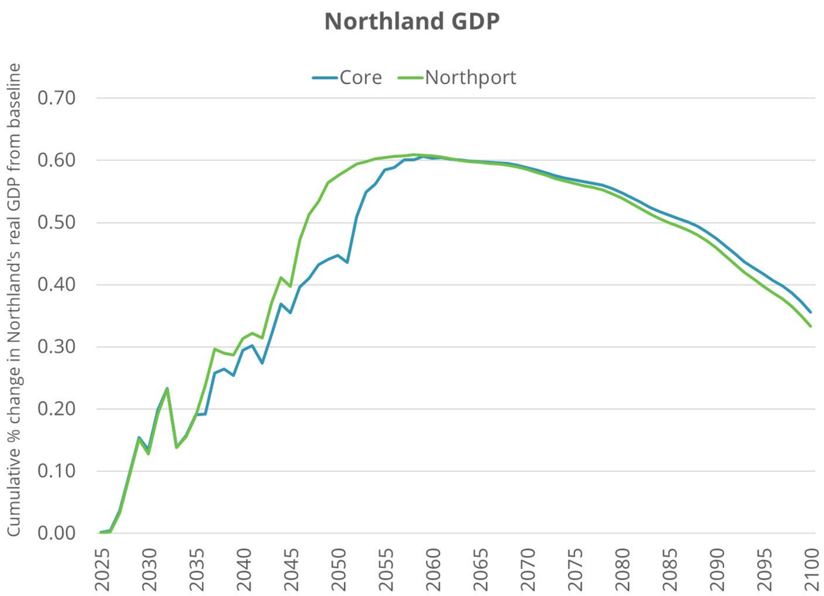
SOURCE: MODELLING RESULTS

- The earlier investment activity supports slightly stronger employment growth than in the Core scenario; the number of FTE jobs nationwide is around 9,100 above baseline in the Northport scenario in 2040, compared to around 8,500 in the Core scenario. By 2100, the Northport scenario would see an additional 23,700 FTE jobs created, around 1,000 more than in the Core scenario.
- The emissions impacts are very similar to those in the Core scenario, but very slightly higher.

...and better outcomes for Northland

- As a result of more investment activity in Northland, the Northport scenario delivers better economic outcomes for Northland than the Core scenario out to 2060.
- Towards the end of the projection period, the additional growth of the Auckland regional economy draws resources away from the Northland economy, which tempers Northland's growth at the margin. However, the differences between the Core and Northport scenarios this far out into the future are immaterial in the context of a 75-year projection period.

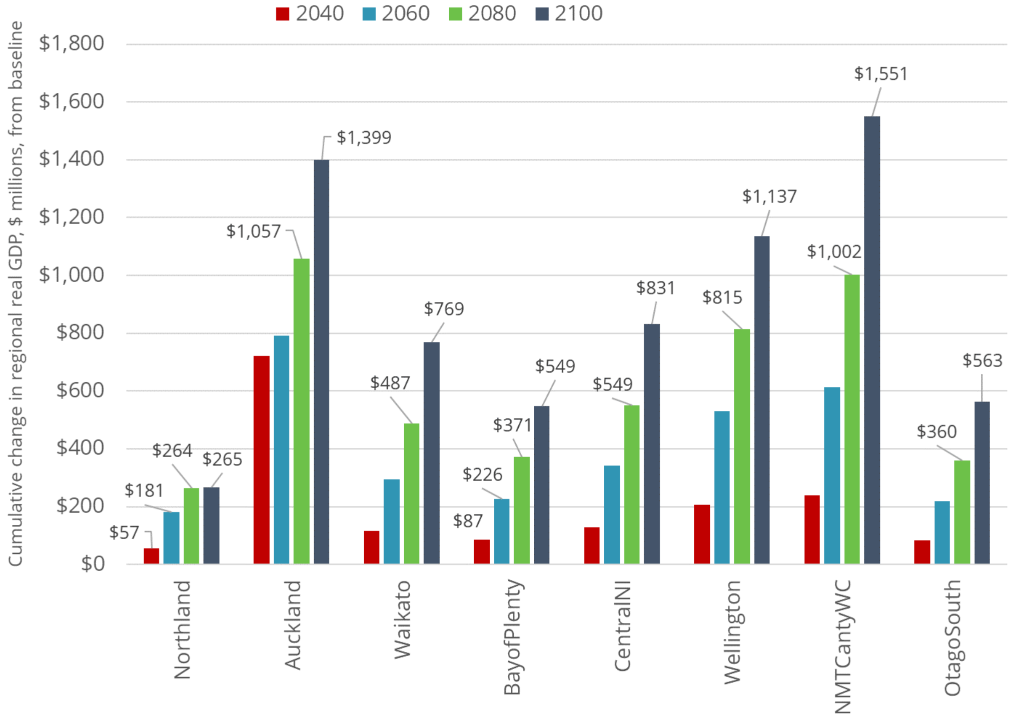
FIGURE 10 IMPACTS ON REAL GDP, NORTHLAND, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

- As in the Core scenario, the Northport scenario leads to all regional economies growing above baseline throughout the projection period (Figure 11).
- The regional impacts are in general higher than in the Core scenario, although the pattern over time and distribution across regions are very similar.

FIGURE 11 NORTHPORT SCENARIO: IMPACTS ON REGIONAL REAL GDP, CHANGE FROM BASELINE, $ MILLIONS



SOURCE: MODELLING RESULTS

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1. Background, scope and limitations

1.1. KiwiRail wanted economic modelling to inform its future rail investment planning

KiwiRail and Auckland Transport jointly developed a strategic rail investment programme for the rail system in Auckland over the next 10-30-years. To inform its thinking on the benefits and justification for the investment, KiwiRail has engaged Sense Partners to:[3]

1. Estimate the economic benefits to Auckland and the rest of New Zealand from rail capacity expansion that supports higher passenger numbers and higher freight volumes. Both effects reduce the demand for road transport.
2. Assess the environmental benefits associated with this mode shift away from road to rail, primarily due to a reduction in greenhouse gas emissions associated with greater use of rail.
3. Explore the wider socio-economic benefits of maintaining a specialist rail construction industry in New Zealand, as opposed to potentially losing that expertise and intellectual property overseas.

This report focuses on 1 and 2 above, summarising the results of a dynamic Computable General Equilibrium (CGE) modelling exercise using the MDG-NZ model of the New Zealand economy.

The socio-economic benefits of maintaining a specialist rail construction industry in New Zealand are presented in a separate report.

1.2. Background[4]

Across the period November 2021 to November 2023, KiwiRail and Auckland Transport jointly undertook a 30-year assessment, via a Programme Business Case (PBC), of future demand, network capacity constraints, reliability and maintenance, and resultant investment requirements for the rail network in Auckland.

This assessment encompasses the needs of all users of the rail network (metro and inter-regional passenger services, as well as rail freight for imports/exports and domestic markets). It included consideration of a range of different demand scenarios, including different decisions that may be made in respect of upper North Island ports (which drives rail freight capacity requirements).

The outcome of this assessment was a recommended strategic rail investment programme for Auckland, which was endorsed by the Boards of KiwiRail and Auckland Transport in November 2023.

[3] See RFP, KiwiRail (2022).
[4] Material provided by KiwiRail.

The 30-year rail investment programme is a holistic assessment of the rail system. It encompasses maintenance and renewals, maximising existing capacity, new capacity in the form of additional track and trains, and downstream investments in depots, stabling and station upgrades to cater for increased demand. The programme therefore includes the whole of life costs of construction, ongoing operation and maintenance, and renewals, for all elements of the programme.

This report seeks to provide information on the value to the New Zealand economy of the recommended investment, as well as an indication of the costs of no investment or of a slower and smaller programme than required by demand.

This is achieved by modelling the following investment scenarios:

1. A **baseline** scenario that assumes no investment in capacity beyond that already committed, except for ongoing investment in maintenance and renewals. Although investment in maintenance and renewals is not yet committed and funded, it is required to operate the existing network, regardless of whether further investment in capacity is undertaken.[5]

2. A **core investment scenario** – investment that mirrors the strategic rail programme of investment that emerged from the PBC. The programme seeks to address expected constraints and enable most projected demand. It is noted that investment still lags demand projections by up to 10 years.

3. A **delayed investment scenario** that acknowledges that the congestion that would occur without further investment would eventually need to be addressed in the future. This scenario therefore envisages limited investment in the most congested part of the network (southern corridor) taking place at a later stage.[6]

These scenarios and the investments included therein are described in more detail below in section 3.

In addition, a variation on the core investment scenario has been developed and included as an appendix. Whereas the core scenario assumes most future freight growth occurs at Auckland and Tauranga ports, this variation considers the distribution of impacts that would result from greater growth of Northport.

1.3. Interpretation of scenarios and results

We are not forecasting what *will* happen. Rather we explore what *could* happen to the economy and emissions under rail investment scenarios that align with strategic rail investment programme, given certain assumptions about the ways households, firms and

[5] Without the additional maintenance and renewals, timeliness, reliability, and quality of service will be adversely affected. Baseline passenger and freight volumes would likely be lower, but this has not been modelled.

[6] The delayed investment scenario includes infrastructure to address the worst congestion problem on the network. As well as being implemented far behind demand, its limited scope does not provide for future growth, improved journey times or improved service options for passengers.

government respond to relative price shocks, technological change, implicit structural change, and other response factors.

All scenarios are compared to a baseline to 2100 that draws on publicly available economic and emissions projections. We provide modelling results for:

- Key economic aggregates (GDP, welfare, exports, employment, wages etc.) at the national and regional levels
- Investment, output and employment for 72 industries at the national and regional levels
- Economy-wide and industry-level emissions and emissions prices

These results are available for each year to 2100. For the sake of brevity, we do not present all results for all years.[7]

1.4. Limitations of analysis

See NZIER and Infometrics (2009) for an overview of general limitations associated with CGE modelling, including for climate policy.

Our focus is on New Zealand-wide and regional economic impacts. Our CGE model does not have the degree of spatial or hour-by-hour detail found in transport models.

This report is an assessment of a 30-year investment programme for which the majority of new infrastructure would come online in the 2042-51 period and encompasses 100+ year assets. An assessment that covered a shorter period would therefore only pick up benefits over 1-2 decades. KiwiRail has therefore requested that we project the economy and emissions out to 2100, some 50 years beyond programme completion. Analysing the economy out over 75 years is highly challenging. We do not know how technological change will affect the structure of the economy and the demands of households and businesses for rail services.

It is likely that we will see changes in global demand patterns for freight-intensive products such as logs, coal and primary products, as final consumers and purchasers (e.g. supermarkets) demonstrate stronger preferences for more sustainably-produced goods, and governments introduce more ambitious climate policies. We do not explicitly model these preference shifts here.

Similarly, there is no doubt emissions-reducing technologies will be developed that will influence how easily transport sector and economy-wide emissions targets can be met. We are not in a position to guess when such innovations will occur or their potential economic and emissions impacts. For both the structure of the economy and emissions-reducing technological change, we incorporate historical trends into our projections, so the make-up of the economy and innovation are not simply held constant in the baseline out to 2100.

The baseline and counterfactual modelling scenarios have been developed in conjunction with KiwiRail, drawing on its investment modelling and the outputs of the Auckland Forecasting

[7] More detailed results are available on request.

Centre's Macro Strategic Model. Essentially, we take KiwiRail's analytical outputs as given and translate them into assumptions in our CGE modelling scenarios. This ensures internal consistency between our modelling and KiwiRail's strategic rail investment programme. KiwiRail's outputs have been through extensive internal quality checks, and we have not sought to verify them.

We assume the additional rail investment is funded through a combination of central government sources and Auckland local government sources. We acknowledge there is no certainty about the use of these sources. Alternative funding sources can be considered in future work. We would not expect the macroeconomic results to vary considerably if alternative funding sources were to be used, although the fiscal impacts would differ.

Box 1: Our formal modelling is only part of the benefits story

Our analysis focuses on what might be considered the 'conventional' macroeconomic and emissions impacts of the rail expansion programme. But rail investment generates several other social and economic benefits that are challenging to include in a dynamic CGE model.

For most private sector firms' economic activity, the links between costs and revenue are easy to identify. For example, if a firm buys a new piece of equipment, its costs go up, but it can also generate more output and hence revenue. The benefits of the investment are 'tied' to its costs. This is not the case for many infrastructure projects, as Millstein et al (2017, p.14) note:

> *"[S]ome infrastructure projects simply do not generate the kinds of returns that would support private investment, in part because the benefits of those investments often accrue well beyond the immediate users of the given asset. For example, a mass transit system confers benefits not only on the subway rider who pays a fare for its use but also on passenger car commuters who benefit from reduced road congestion and commuting times, as well as on property owners and local merchants around each subway station who benefit from increased activity in their stores and enhanced property values. Private investors in such a system, with control only over the fares that can be charged for its use, cannot capture all of the benefits created by the system's construction and operation".*

In short, rail infrastructure investments generate streams of hard-to-measure benefits that are not directly 'tied' to the cost increases associated with rail investment. These 'positive externalities' should be seen as additional benefits to the quantified estimates we present here and are options for future analysis. They include:

1. The safety benefits of modal shift from rail to road.
2. Time savings from reduced road congestion.
3. Improved urban design and liveability, which will also present the possibility of opportunities for value capture.
4. Reduced road and vehicle maintenance for a given amount of economic activity.[8]

[8] These direct user benefits have been accounted for in the Benefit Cost Ratio for the programme, as reported in the Auckland Rail Programme Business Case. Given the interplay between direct user benefits and the assumptions in this report, it is not sensible to add the user benefits to the results of the CGE modelling we present, as it risks double counting.

2. Overview of methodology

We use an advanced dynamic CGE model of the New Zealand economy for this project. Titled MDG-NZ, our dynamic CGE model was built for Sense Partners in late 2019 by Dr Ashley Winston of MacroDyn Group (MDG) LLC, based in Washington DC.

MDG-NZ explores how the entire economy adjusts over time to changes in policy settings or shifts in the economic environment. It captures the interlinkages between industries, households, government, workers, investors, etc ('economic agents') and the greenhouse gas emissions associated with production and consumption.

The latest version of the model incorporates economic activity and GHG emissions across 140 industries, plus the emissions associated with household consumption. It is projected out to 2100 using the latest available Economic and Fiscal Update forecasts and Long Term Fiscal Model projections from the New Zealand Treasury to 2060, and assumptions on population growth and productivity beyond that.

2.1. CGE modelling in a nutshell

At a high level, a CGE model consists of:

1. A **database** capturing the economic interactions between firms, households, government and investors and the rest of the world and the emissions associated with this activity.

2. A **system of equations** that defines the theory of the model, explaining what the various economic agents are seeking to do. These equations are usually neoclassical in nature: consumers seek to maximise their utility, subject to their budget constraint; firms seek to minimise costs for a certain level of output; investors seek to maximise their returns; governments cannot spend more than they generate in tax revenue unless they borrow.

3. A set of behavioural **parameters** – mainly elasticities – that determine how the various agents in an economy respond to changes in relative prices. For example, as real wages rise, firms tend to employ less labour and more capital; or as the real exchange rate appreciates, exporting firms become less competitive and reduce the share of production for export.

All input, output, factor and emissions markets clear for a given set of prices, meaning the economy is initially in equilibrium.

Then we change relative prices by imposing 'shocks' on the economy, representing changes in policy settings or the external economic environment. Essentially, we feed new information into the model and knock it off its initial equilibrium.

In this project, additional rail investment initially drives more activity in the construction industry as more tracks are laid, stations remodelled, etc. Investment is also made in new rolling stock. Once the additional rail capacity is in place, service quality and reliability improve, which induces more passengers and freight onto rail relative to the alternatives.

The economy adjusts to a new equilibrium as firms and households respond to these changes. Emissions adjust in line with changes in industry output and assumed emissions-efficiency improvements over time.

The differences between the initial and post-shock equilibriums are the economic and emissions impacts of the shocks introduced.

2.2. Dynamic adjustments in MDG-NZ

A dynamic CGE model shows how the economy adjusts to shocks over time, considering adjustments in labour markets, capital accumulation, changes in government debt and net foreign liabilities.[9]

A dynamic modelling exercise typically consists of:

- A **baseline** set of projections for the economy and its various agents, as well as emissions.
- Projections of **counterfactual** or **policy scenarios** that capture the changes of interest (in this case, additional investment in the rail industry).

Results are reported as changes from the baseline scenario, either in percentage change terms or as changes in the dollar value of a variable.

2.3. MDG-NZ's credentials and features

The New Zealand CGE modelling suite is built on the foundation of MDG's pathbreaking and proven MDG model. Versions of the MDG modelling framework have informed key policy reform and other economic matters in dozens of countries, including advising The White House on US biofuels and other energy reform issues.

MDG-NZ has a lineage that traces back to the MONASH dynamic CGE model developed by the Centre of Policy Studies, then at Monash University, now at Victoria University, Melbourne. It is built and run in the GEMPACK software suite.[10]

In its fully disaggregated form, MDG-NZ contains projections for 140 New Zealand industries. It is initially calibrated using the latest official input-output tables from StatsNZ (for 2020, released in 2021).[11]

Our regional database comprises 8 regions[12], 140 industries producing 220 goods or services, and linked through inter-regional trade flows.

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[9] A static CGE model, in contrast, compares the 'before' and 'after' shock situations, with no sense of the adjustment path over time.
[10] See Horridge et al (2018).
[11] In developing the CGE modelling baseline, we explicitly account for historical changes in industry structure between 2020 (the date of the latest official IO tables) and 2023, using employment data as our guide. That is, the size and industry structure of the New Zealand economy in 2023 is calibrated to official data. See Appendix B for more detail on the updating process.
[12] Northland, Auckland, Bay of Plenty, Central North Island, Waikato, Wellington, Tasman/Nelson/Marlborough/Canterbury/West Coast, Otago/Southland.

Given the long projection period for this project (75+ years), and the degree of regional economic detail, we needed to reduce the number of industries and commodities to improve computational efficiency. We aggregated the initial 140 industries into 72 single-product industries.

We incorporate greenhouse emissions by type of gas (CO_2, CH_4, N_2O, F-Gases) that enter production functions in their raw tonnages and are then converted to CO_2-equivalents via Global Warming Potential (GWP) factors.

Energy accounts are coded with primary and final energy types, stationary and transport energy use, and electric generation distinguished on generation “sent out” (net of distribution losses) and “end use” (includes distribution and transmission losses) bases. Emissions data was sourced from MfE, supplemented with existing emissions intensity of output estimates from other CGE model databases.

Technical documentation is under development, and a draft is available from the authors on request.

More detail on MDG-NZ is provided in Appendix B.

3. Scenario description

3.1. Summary of scenarios

TABLE 1 OVERVIEW OF CGE MODELLING SCENARIOS[13]

Scenario	Key features
Baseline	• Business-as-usual projections with no material additional rail investment beyond that already scheduled for 2023-27 to enable the City Rail Link (CRL), plus additional maintenance and renewals to operate the existing network.[14] • Capital costs of $1.15bn, plus renewals of $7.0bn and maintenance of $8.5bn. • Annual passenger trips in Auckland lift from 37m now to 43m by 2031, 55m by 2060 and flat thereafter. • Freight volumes grow steadily from 7.5m net tonnes now to 10.8m net tonnes in 2035. Volumes are then capacity constrained around this level out to 2100.
Core	• Additional capital costs of $21.2bn between 2025 and 2051, relative to Baseline. • Additional renewals of $2.6bn relative to the baseline, mostly scheduled from 2060 onwards. Additional maintenance of $10.2bn, mainly after the mid-2050s. • New infrastructure per the recommended programme, including four-tracking the Southern corridor, the new Crosstown (Avondale-Southdown) rail corridor, level crossing removal as well as associated technology, new trains, station upgrades etc. • Annual passenger trips follow Baseline to 2031, then lift well above Baseline to reach 88m by 2067. Flat thereafter after network capacity is reached. • Freight volumes grow to 10.9m net tonnes by 2031, are capacity constrained at that level until 2041, grow steeply to 22.1m net tonnes by 2050, then grow steadily to reach 28.4m net tonnes by 2100.
Delayed	• In the Core scenario, four-tracking and supporting investment is completed in 2042, and a new Crosstown (Avondale-Southdown) rail corridor by 2050[15].

[13] An additional growth of Northport scenario is covered in Appendix A.

[14] Without the additional maintenance and renewals, timeliness, reliability, and quality of service will be adversely affected. Baseline passenger and freight volumes would likely be lower, but this has not been modelled.

[15] Per above, there are also associated level crossing removals, and investment in new trains, technology, station upgrades, etc. These are also scaled back to the Southern corridor only in the delayed investment scenario.

Scenario	Key features
	• In the delayed investment scenario, four-tracking of the Southern corridor is not operational until 2060. Supporting investments are also scaled back. The new Crosstown (Avondale-Southdown) rail corridor proposed in the Core scenario is not built. • Additional capital costs of $8.9bn between 2043 and 2060, relative to Baseline. • Additional renewals of $1.5bn and additional maintenance of $4.75bn, largely after 2050. • Annual passenger trips follow Baseline to 2051, then grow steadily to 72m by 2085. Flat thereafter. • Freight volumes follow Baseline to 2061, then grow to 15.2m net tonnes by 2075 and 17.3m net tonnes by 2100.

SOURCE: BASED ON KIWIRAIL INFORMATION

3.2. Establishing the model baseline

Determining an appropriate baseline is a crucial aspect of dynamic CGE modelling. A detailed explanation of our baseline for this project is provided Appendix C.

3.2.1. Economic baseline

For our economic baseline, we use Treasury's latest Economic and Fiscal Update[16] forecasts out to 2026, and Treasury's Long Term Fiscal Model[17] estimates out to 2060/61. Beyond 2060/61 we use assumptions on population and labour force growth and labour productivity growth.

The industry composition of the economy changes over time in line with historical trends (e.g., growth in the share of personal services as incomes rise).

3.2.2. Regional baseline projections

Regional economic growth and industry activity are projected forward based on industry growth rates from the national-level projections and each industry's share of the regional economy.

3.2.3. Emissions baseline

Economy-wide greenhouse gas emissions are initially generated from the baseline economic activity by industry projections, using emissions intensity coefficients, along with exogenously imposed energy efficiency improvements that largely reflect historical trends.

[16] Treasury (2023).
[17] Treasury (2021).

We then adjust aggregate gross emissions through technological change parameters to align with the Climate Change Commission's (CCC) 'Current Policy Reference' (CPR) track out to 2050 (CCC, 2022). We trend down agricultural emissions in line with the CPR track.

The baseline also draws on the CCC's projected NZU price for the CPR, at $35 real per unit.

The emissions baseline includes known emissions policies such as the Emissions Trading Scheme (ETS) but does not include 'step change' technologies such as hydrogen energy or electric planes, given uncertainty over their feasibility, effectiveness and timeframes.

Projected forestry removals for our baseline and policy scenarios were provided to us by Climate Forestry Association (CFA) for a previous consulting project.

Beyond 2050, no official projections are publicly available. We assume New Zealand reaches net zero for long-lived gases around 2050 and stays there, such that the remaining carbon dioxide emissions are exactly offset by forestry removals. Biogenic methane emissions are reduced to be broadly consistent with the legislated New Zealand domestic target of a 24-47% reduction from 2017 levels.

3.2.4. Climate policy assumptions

We assume the ETS remains in place out to 2100. To proxy an emissions cap for covered sectors, we hold total ETS emissions constant at the baseline level for all scenarios. Agricultural emissions outside the ETS are not constrained.

The emissions price varies to ensure the demand and supply of emissions units balances.[18] Emissions can vary by industry from the baseline in the scenarios, but any emissions reductions in one industry will be exactly offset by increases in others to meet the cap.

Under this approach to modelling the ETS, there can be no *economy-wide* ETS emissions reductions from the strategic rail programme investment, but if the investment makes meeting New Zealand's emissions targets easier, we will see a lower ETS price (and hence lower costs for firms and households). Alternatively, it implies the cap could be tightened faster for the same economic cost.

We make no explicit assumptions regarding global action on emissions reduction, measures such as Carbon Border Adjustment Mechanisms, or the physical impacts of climate change on the New Zealand economy. All of these can be explored in future work if required.

[18] The alternative approach is to set ETS prices exogenously and let emissions vary. However, this is not a good approximation of New Zealand's ETS settings.

3.3. Core investment scenario

3.3.1. Overview[19]

The Core investment programme scenario seeks to address the three key problems with the current network, which will not be solved by the baseline investment programme:

1. **Capacity constraints.** A range of constraints, predominantly related to infrastructure, limit the capacity of the rail network. The existing network cannot accommodate the required growth in freight and passenger rail travel. This means that the forecast freight growth and target mode shift to rail will not be achieved and the Government's committed emission reduction targets will not be met.
2. **Poor level of service.** Many passengers and freight customers are deterred from choosing rail because of inadequate levels of service. Contributing factors include:
    - Reliability and punctuality.
    - Frequency and service timing.
    - Service travel time and directness.
    - Metro station and overall network accessibility.
    - Safety concerns.

    This results in less efficient outcomes including road-based travel, congestion and higher carbon emissions, and poorer productivity because the rail network is insufficiently attractive to drive the required increase in rail mode share. This means that emissions targets can't be met.
3. **Inadequate network maintenance and renewals**. Service reliability and punctuality problems are typically related to maintenance issues that, without intervention, will worsen as train volumes increase and assets continue to age and deteriorate. These issues are compounded when capacity is constrained, as there is little to no redundancy within the system to respond to or recover from these issues.

The Core scenario investment programme seeks to address these problems through targeted investment in six key areas:

i. **Maintenance and renewals** – A step change in maintenance and renewals levels and delivery methods, improved reliability, and reduced disruption from track works.

ii. **Segregate rail modes** as much as possible:

- Four-tracking the North Island Main Trunk (NIMT) between Westfield Junction and Pukekohe (29.5km), including Westfield Junction grade separation and consideration of further additional capacity between Westfield and Wiri Junctions. Rail is a national and local system, with significant demands across all customer

[19] Material provided by KiwiRail.

markets. Four-tracking is required to allow all-stops metro services to be separated from non-stop freight, metro express, and inter-regional passenger services thereby increasing the capacity of existing infrastructure as well as adding new capacity and enhancing the reliability and resilience of the overall system.

- East-West Crosstown (Avondale-Southdown) rail corridor via Onehunga completes a long planned cross-isthmus rail corridor (13km). It enables more flexible, efficient freight operations including for rail to be able to respond to growth at upper North Island ports and decongests the inner-city track network to provide more frequent, faster journeys, as well as enabling all day express services on the Southern line. It will reduce freight movements in the inner city by more efficient routing of Northland services to Southdown (NZ's third largest port) without needing to pass through the inner Auckland network where capacity is limited, and complex operations have impacts on reliability. It will also enable new connectivity and urban development opportunities across the isthmus from Avondale to Glen Innes.

iii. **Level crossing removal** – 24 crossings to be grade separated or closed. For the network to operate at maximum efficiency and for optimum safety outcomes, rail needs to be separated from roads and active mode facilities.

iv. **Signalling and power** – upgrades including two new power feeds, European Train Control System level 2, Driver Assist, traffic management systems and signal block enhancement.

v. **Fleet, depots and stabling** – 72 new 3-car EMU and associated stabling requirements to meet increased demand.

vi. **Station upgrades** – Rail stations upgraded to Auckland Transport's Transport Design Manual standard, including platform fitout and amenities, new platforms for new tracks and turn-backs at strategic locations. Platform extensions to support 9-car services and future proofing for full 9-car operations beyond 2051.

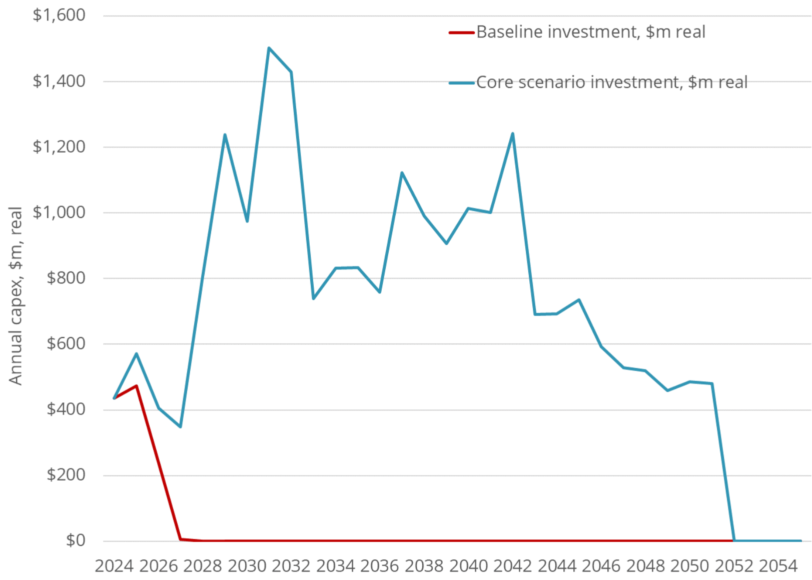
3.3.2. Capital expenditure

The Core scenario incorporates an accumulated change from the baseline in inflation-adjusted capital expenditure (capex) of $21.2 billion, occurring between 2025 and 2051 (Figure 12). All this investment occurs within the Auckland region. There is no change in capex from the baseline after 2051.

The additional capex is predominantly for track improvements, removal of level crossings and buildings in the first decade of the scenario (Figure 13). Spending on EMUs occurs in two main 'lumps', from 2029-2032 and 2038-2042. Investment will also include a heavy maintenance facility, three satellite stabling yards and two maintenance sidings for plant and equipment (locations not yet confirmed).

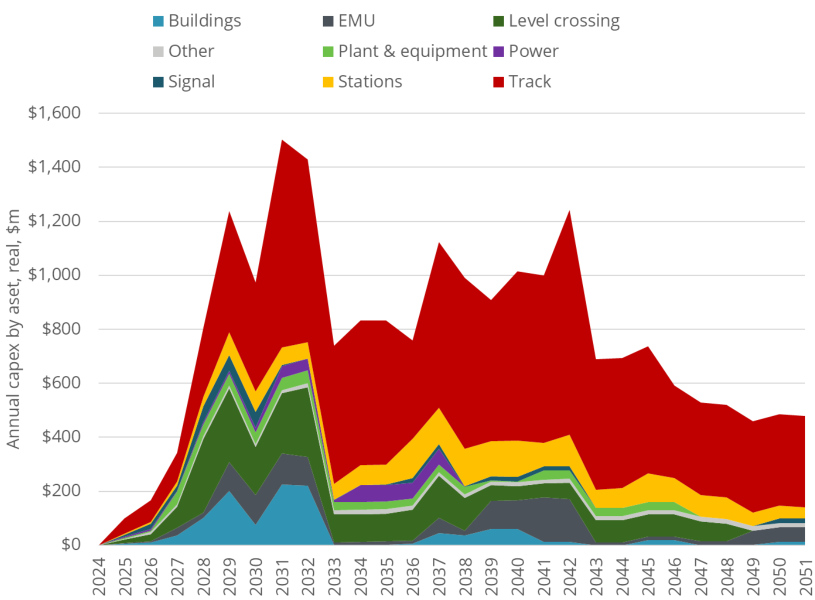
The capex is initially funded through overseas borrowing, which is repaid over time[20]. After 2040, we assume the investment is paid for by increased domestic savings.

FIGURE 12 BASELINE AND CORE SCENARIO CAPEX, $M, REAL



SOURCE: KIWIRAIL

FIGURE 13 CORE SCENARIO CAPEX BY ASSET TYPE, $M, REAL



SOURCE: KIWIRAIL

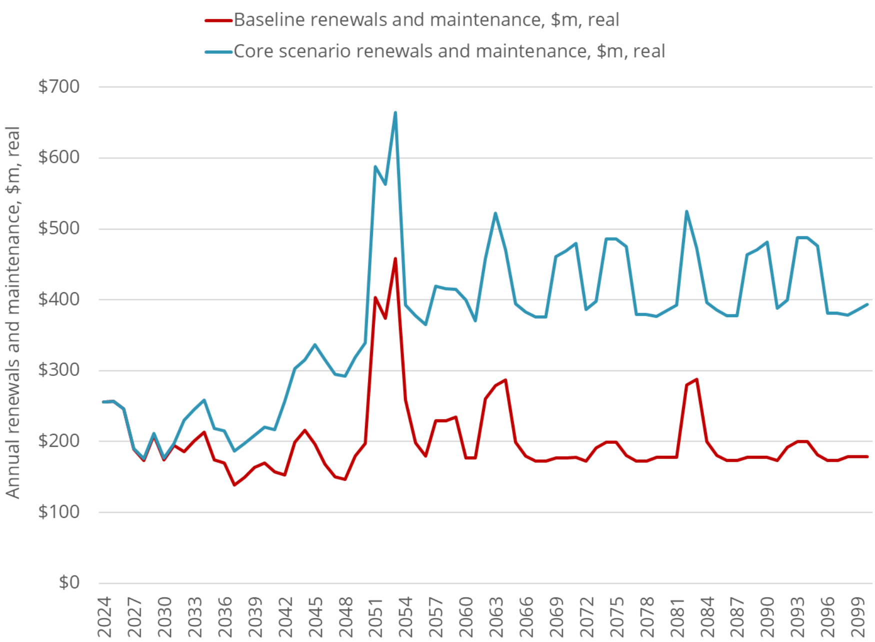
[20] This is a modelling assumption rather than a prediction of funding sources. From a macroeconomic perspective, precisely which entity does the borrowing or where it is sourced has no material effect on the economy-wide results. In the real world, opportunities may exist for KiwiRail to access alternative sources, particularly with respect to new rail corridor urban development.

3.3.3. Renewals and maintenance spending

The Core scenario sees a significant increase in renewals and maintenance spending, relative to the Baseline (which essentially completes the current programme of backlog renewals only). This spending will deliver more reliable, resilient, and robust infrastructure and services by:

- widening the effective maintenance window, planned proactively
- right sized plant and equipment to improve productivity and safety
- reduced reliance on blocks of line
- ability to run services during maintenance on adjacent main(s).

FIGURE 14 RENEWALS & MAINTENANCE IN BASELINE AND CORE SCENARIO, $M, REAL

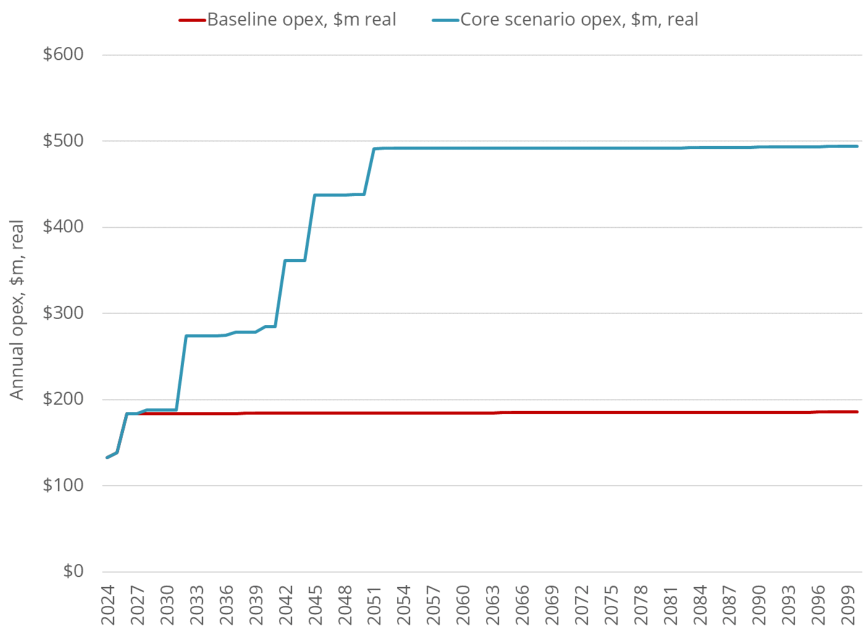


SOURCE: KIWIRAIL

3.3.4. Operating expenditure

Network, station and EMU operating expenditure (opex) is only slightly above baseline until 2031 (Figure 15). It then lifts in several steps as more capacity is added to the network. Beyond 2051, we assume opex holds steady out to 2100.

FIGURE 15 OPEX IN BASELINE AND CORE SCENARIO, $M, REAL



SOURCE: KIWIRAIL

3.3.5. Passenger numbers

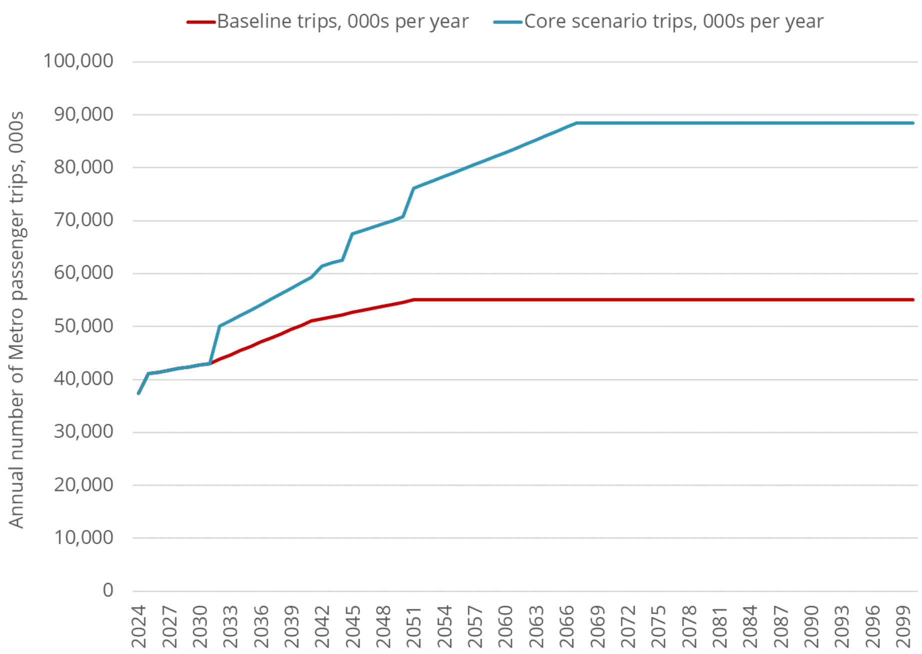
We assume all additional passenger trips (Figure 16) are within the Auckland region. For simplicity, we assume that Hamilton-Auckland inter-regional passenger numbers remain at baseline levels. In reality, improvements in journey time, routing and network access provided by the core investment are expected to enable and encourage increased patronage that may not occur in the baseline scenario. However, in the overall context of the overall passenger numbers considered, the impact is likely to be minor.

We assume 50% of the additional Auckland rail passenger trips were previously drivers of private cars, leading to a reduction in private car trips. This assumption is consistent with the Auckland Macro Strategic Model. The remaining 50% is made up of previous private car passengers, some substitution from other public transport modes, and pure induced demand from new trips that otherwise would not have been made.

To grow passenger demand beyond 2031, investment in capacity and broader levels of service is needed. At this point in time the first capacity improvements of the investment programme come online. Over the following decade passenger trips are 14-19% higher than baseline, before lifting again to around 29% above baseline for 2045-2050 (the point when the two major infrastructure capacity investments – four-tracking of the southern corridor and the new Crosstown (Avondale-Southdown) rail corridor – are completed).

After 2050, passenger use continues to grow steadily above baseline to 2067, hits capacity limits and stays there to the end of the projection period at around 60% higher than baseline.

FIGURE 16 BASELINE AND SCENARIO AUCKLAND PASSENGER TRIPS



SOURCE: KIWIRAIL

The additional rail passenger demand is modelled through changing consumer preferences for rail over road transport as the effective price of rail (i.e. price adjusted for greater reliability and service quality) falls after the strategic rail investment programme is implemented.

3.3.6. Freight volumes

We assume freight volumes increase above the baseline in the first decade as the freight network improvement programme gives certainty for freight investment. Freight volumes then hit a capacity constraint for the 2030-2041 period, and freight demand is spilled to road.

After 2043, additional capacity in the form of four-tracking of the southern corridor between Westfield to Pukekohe is completed, after which rail freight is able to grow again. Freight volumes increase sharply above the baseline to 2050. Freight volumes then grow more moderately out to the end of the projection period (Figure 17). By 2100, freight volumes are 160% higher than the baseline.

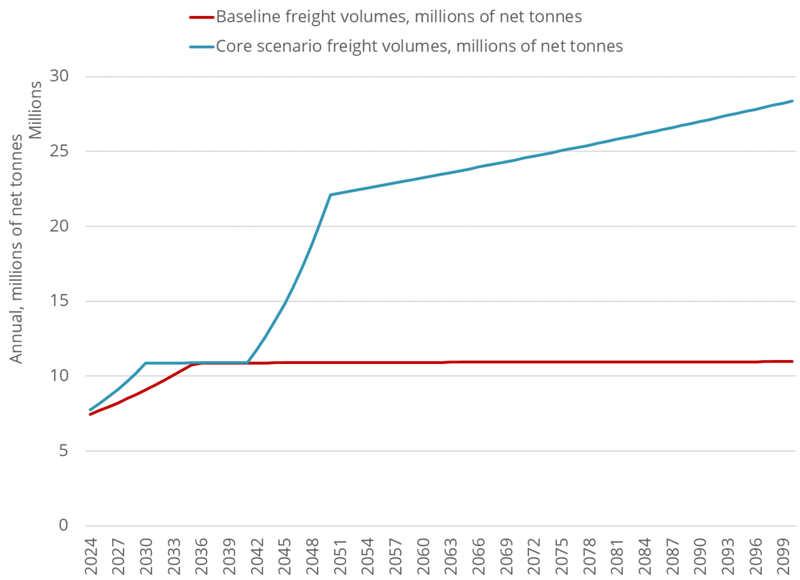
We assume the additional rail freight substitutes for road freight.[21]

We model the increase in freight volumes by expanding the cost function of the relevant sectors in appropriate scale and timing. Oversimplifying somewhat, additional rail kilometres and tonnage requires more labour, fuel, and so on. An exogenous increase in the level of

[21] Note that road freight becomes less emissions-intensive over time in both the baseline and investment scenarios due to technological change such as greater use of EVs. We do not model this as a competitive response to increased rail freight as it is likely to occur for other reasons such as congestion charging, rising ETS prices, etc. Furthermore, assumptions about decarbonisation of road freight have already been taken into account in the rail freight forecasts.

operations will draw in inputs via the production function, primarily through price competition in input markets.

FIGURE 17 BASELINE AND CORE SCENARIO FREIGHT VOLUMES



SOURCE: KIWIRAIL

3.4. Sensitivity analysis (Delayed) scenario

3.4.1. Overview

The delayed four-tracking investment programme scenario, “Delayed”, is based on the baseline scenario, but with an acknowledgement that some form of investment is likely to be needed in the future. This investment will provide some additional capacity to accommodate growth in passenger and freight demand.

In this scenario, the investment programme involves investment in four-tracks between Westfield and Pukekohe and enabling infrastructure to ensure that the additional capacity is unlocked. The key difference between four-tracking in the recommended programme and this scenario is the timing of the investment.

In the preferred investment scenario, four-tracking and supporting investment is completed in 2042. In this delayed investment scenario, four-tracking is not operational until 2060.

The package of investment in this option includes the investment in the baseline, plus the following:

- Four-tracking the North Island Main Trunk (NIMT) between Westfield Junction and Pukekohe (29.5km), including Westfield Junction grade separation.
- Fleet, depots and stabling – 48 new 3-car EMU and increased stabling at Henderson, Tamaki and Paerata.

- Station upgrades – Rail stations between Westfield and Pukekohe upgraded to Auckland Transport's Transport Design Manual standard, including platform fit-out and amenities, new platforms for new tracks and turn-backs at strategic locations.
- Signalling and power – upgrades including two new power feeds and one power feed upgrade.
- Level crossing removal – removal of all level crossings between Westfield and Pukekohe.

3.4.2. Costs and demand impacts

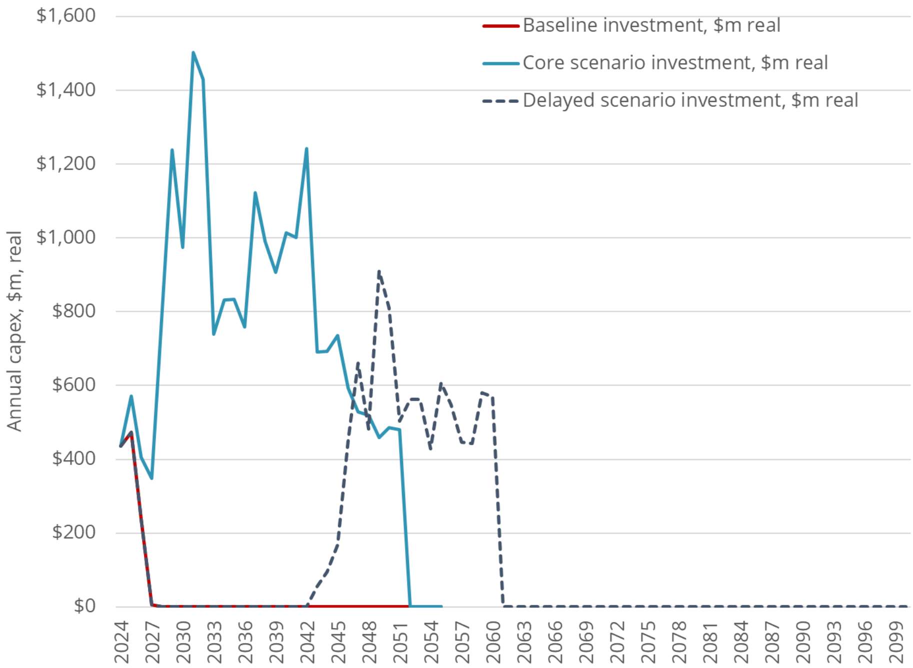
The estimated capital costs of the Delayed scenario are $8.9bn above the baseline scenario and are incurred between 2043 and 2060 (Figure 18). Renewals are $1.5bn above baseline.

The Delayed scenario does not enable as much growth as the Core scenario. This is because the Delayed scenario invests in infrastructure well after the time forecasts estimate that the additional capacity is needed. Investment in capacity significantly lags demand.

As well as enabling demand much later, this lag in investment also results in a lower future demand path for both metro patronage and freight volumes (Figure 19 and Figure 20). This is because we assume that some of the demand that was forecast to be met by rail has been met by other modes of transport.

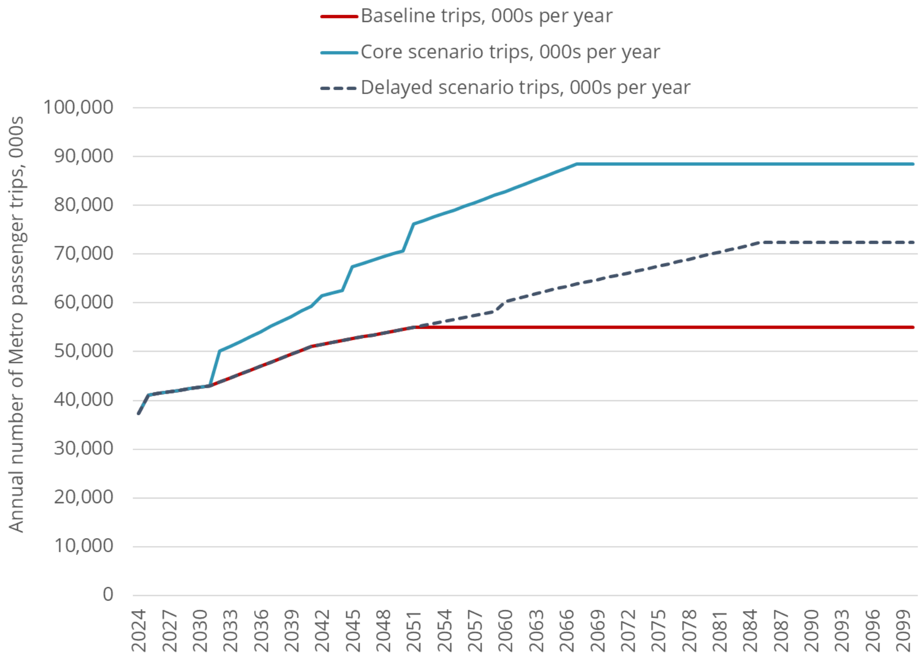
Other rail infrastructure that drives demand in the recommended programme, such as the Crosstown (Avondale-Southdown) rail corridor and all-day express services from Pukekohe, are excluded from the delayed scenario, which also inhibits demand.

FIGURE 18 BASELINE, CORE AND DELAYED SCENARIO CAPITAL COSTS, $M, REAL



SOURCE: KIWIRAIL

FIGURE 19 BASELINE, CORE AND DELAYED SCENARIO PASSENGER VOLUMES



SOURCE: KIWIRAIL

FIGURE 20 BASELINE, CORE AND DELAYED SCENARIO FREIGHT VOLUMES

SOURCE: KIWIRAIL

3.5. Key closure assumptions

In the Core and Delayed scenarios conducted for this report, the policy closure contained a few key blocks of settings:

- Real wages are sticky in the short run, meaning the immediate labour market impacts of rail investment are seen largely through changes in employment. Over time, employment trends back towards baseline and real wages adjust to clear the labour market.
- In the Core scenario the Average Propensity to Save from real Gross National Product is exogenous and the balance of trade is 'open' (i.e. not tied to GDP or to the baseline) between 2025 and 2040. This implies additional overseas borrowing can be accommodated without a large decrease in domestic consumption.[22]

  We then adjust the closure so that more of the investment needs to be funded from the domestic savings pool on the basis that unlimited access to overseas borrowing for 75 years does not seem realistic for an economy of New Zealand's size.[23]
- Population growth, net immigration and land supply growth are exogenous.
- The ETS cap is exogenous and fixed at baseline levels, with the emissions price endogenous.
- Nominal interest rates on government debt are exogenous.
- Total real central government expenditure is exogenous and held at baseline levels, on the basis that this investment is unlikely to influence government spending patterns.
- The nominal exchange rate is exogenous, but the real exchange rate is determined by the model.
- Most industry-specific and commodity-specific technological change and preference variables are exogenous.

Alternative assumptions about the path of the balance of payments can influence welfare results in particular. These can be explored in future work as required.

[22] If domestic savings are insufficient to meet investment demand, the trade balance must adjust to accommodate it. This could be via importing the excess demand for capital goods over and above savings (importing foreigners' savings, in effect), reducing exports and reallocating those resources to investment, or a combination of the two.

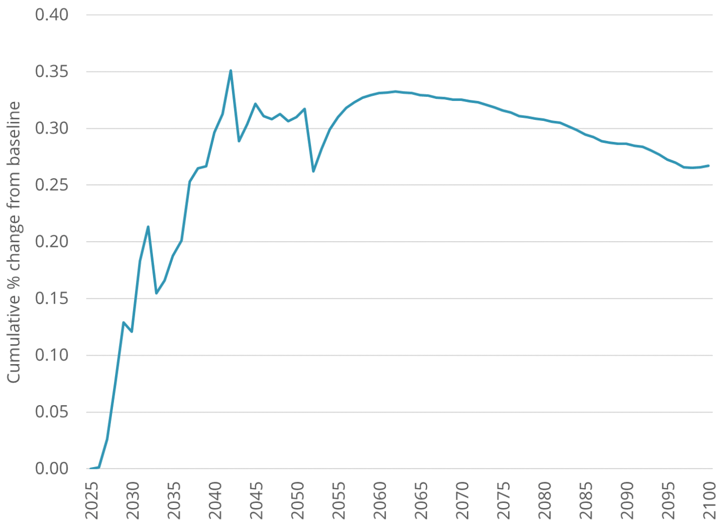
[23] In the Delayed scenario we move this closure swap out to 2059 to reflect the later start date for the construction phase of the investment programme.

4. Macroeconomic results

The Core scenario investment would lift real GDP by $6.6bn by 2100

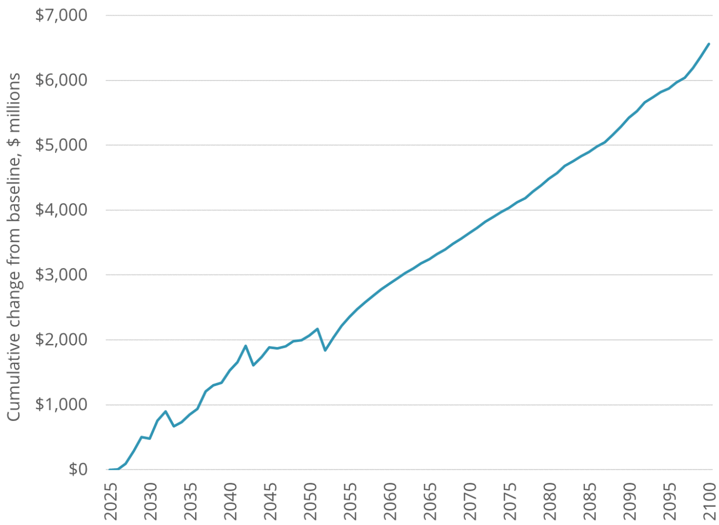
The Core rail investment programme lifts national real GDP by 0.35% above baseline by 2042. As the construction impulse moderates and transitions from capital expenditure to more renewals and maintenance, the GDP effects ease to around 0.32% above baseline by 2075 and 0.27% by 2100. In dollar terms, this equates to an additional $1.9 billion, $4.0 billion and $6.6 billion respectively.[24] GDP remains above baseline throughout the projection period.

FIGURE 21 CORE SCENARIO REAL GDP IMPACTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 22 CORE SCENARIO REAL GDP IMPACTS, $ CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

[24] Note baseline GDP increases over time, so the % changes are from a higher base as we move out towards 2100.

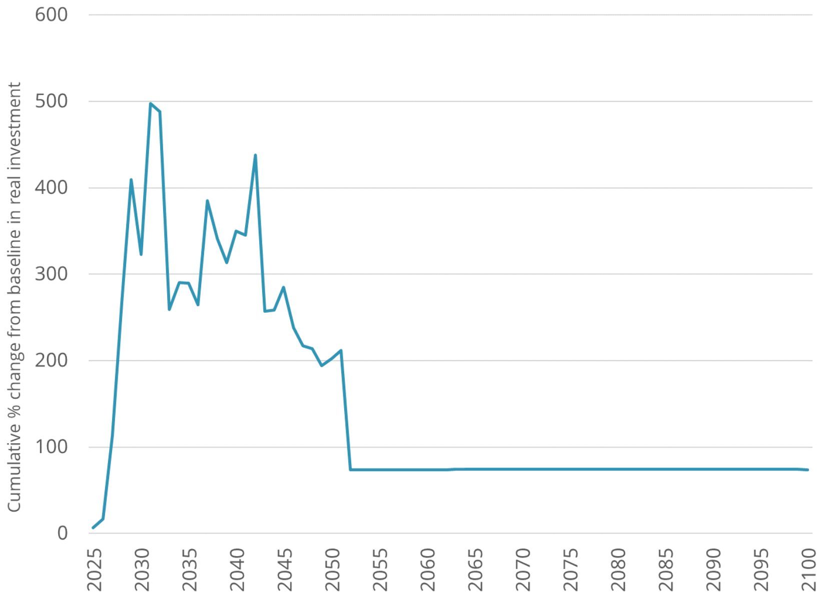
These GDP impacts take into account the cost of the programme, so can be thought of as its additional economic impacts *over and above* its costs.

The shape of the GDP impacts over time reflects the nature of the shocks occurring in each phase. The initial boost is from the construction phase. Once that impulse eases off in the 2050s, the renewals and maintenance programme plays a larger role in lifting GDP above the baseline, albeit at a slightly lower level. In addition, there are productivity improvements associated with a more reliable and efficient rail network in Auckland once it is completed and operational.

The rail programme investment boosts the national capital stock

Figure 23 shows the Core investment scenario growth in rail sector investment relative to the baseline. These are large shocks in a single industry. Even after the construction phase ceases around 2050, the renewals and maintenance programme ensures rail investment continues to grow around 75% above baseline over the second half of the century.

FIGURE 23 CORE SCENARIO RAIL SECTOR INVESTMENT, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

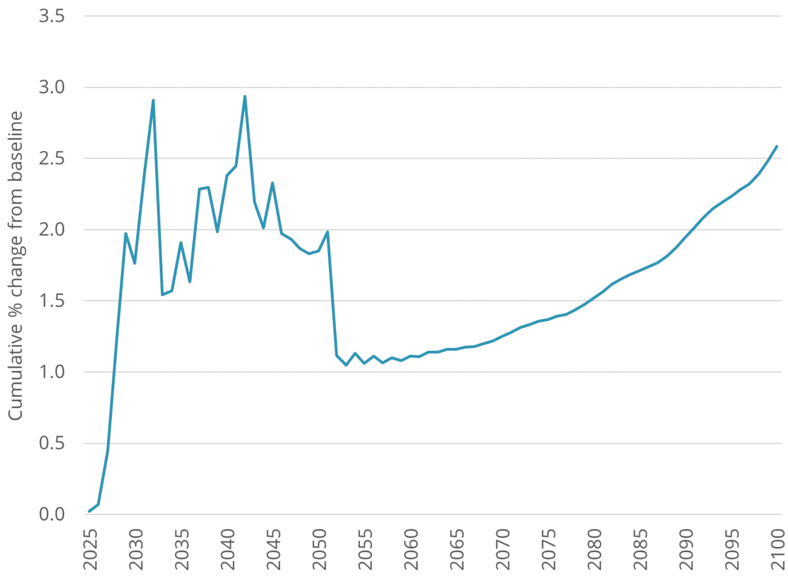
The positive GDP impact reported above is driven primarily by the expansion of the national capital stock (even though it all occurs in Auckland). Economy-wide investment rises by 2.9% above baseline by 2042 before the construction phase impacts ease after 2050.

But there are crowding out impacts as other industries compete for investment resources

The extent of the crowding out impacts can be seen in Figure 31 on page 27. The additional Core rail investment programme capital expenditure is $21.2 billion, plus an additional $12.8 billion of renewals and maintenance (essentially depreciation).

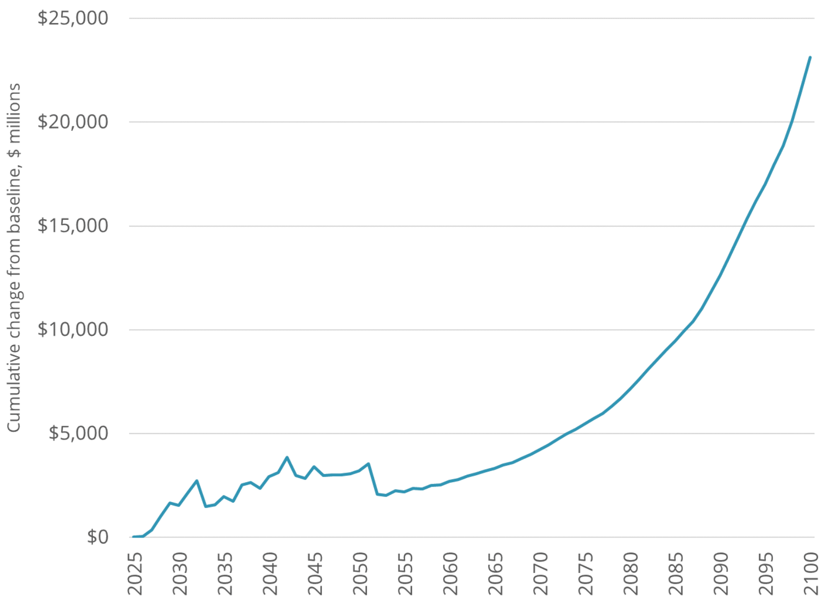
But the economy-wide investment impacts are limited to around $23.1 billion above baseline by 2100, as resources available for the rail investment programme are no longer available for other industries.

FIGURE 24 CORE SCENARIO ECONOMY-WIDE REAL INVESTMENT IMPACTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 25 CORE SCENARIO ECONOMY-WIDE REAL INVESTMENT IMPACTS, $ CHANGE FROM BASELINE



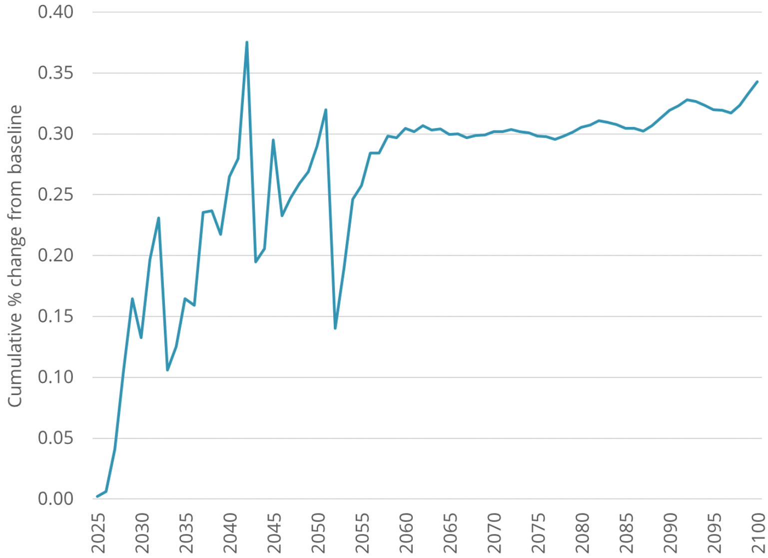
SOURCE: MODELLING RESULTS

A faster growing economy delivers 22,800 extra jobs by 2100

As the economy expands above baseline, so too does the demand for labour. While there is some volatility as the construction phases come onstream and then ease back off, the total number of full time equivalent (FTE) jobs is around 0.3% above baseline across much of the projection period. See Figure 26.

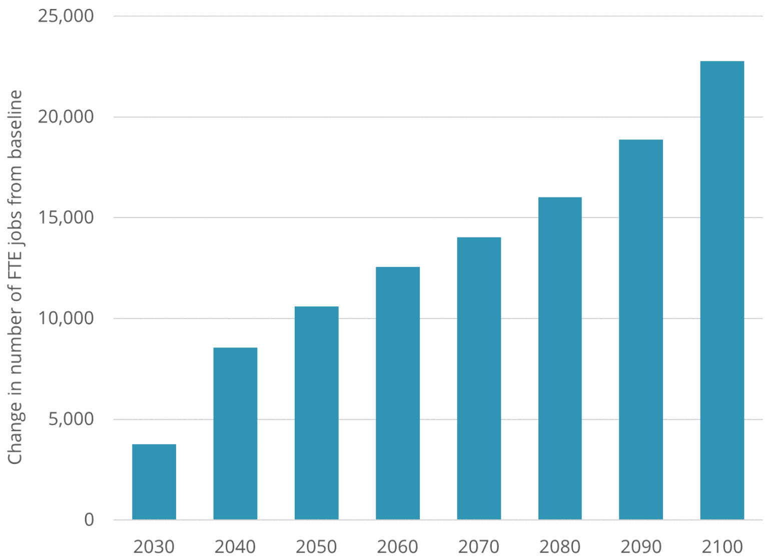
This equates to around 10,600 additional FTE jobs by the end of the construction phase in 2050, and 22,800 additional FTE jobs nationwide by 2100.

FIGURE 26 CORE SCENARIO EMPLOYMENT IMPACTS, FTE JOBS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

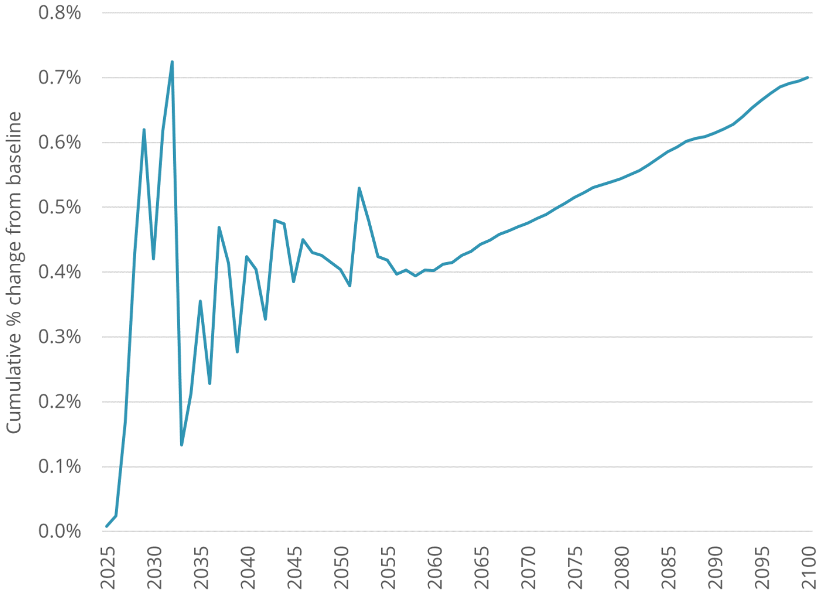
FIGURE 27 CORE SCENARIO EMPLOYMENT IMPACTS, FTE JOBS, LEVELS CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

And average real wages grow above baseline by up to 0.7% during the construction phase

FIGURE 28 CORE SCENARIO REAL WAGE IMPACTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

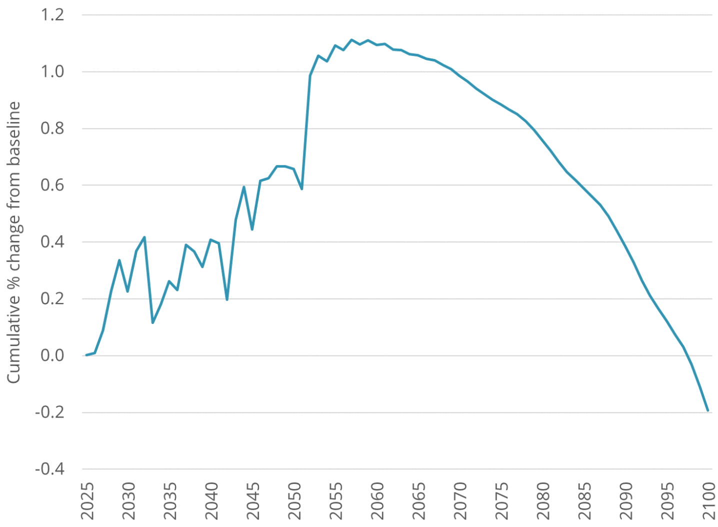
As the demand for labour grows, so too does the average real wage. It shows a similar pattern of ups and downs as employment, but is always above the baseline and peaks at 0.72% in the early 2030s.

As employment and real wages rise, households enjoy $1.9bn more spending by 2050 and $5.3bn more by 2075

With more jobs and higher real wages, household spending rises above baseline out to the late 2080s. Further out, household consumption growth eases and eventually drops below baseline as the repairs and maintenance spending soaks up more domestic savings, reducing income available for household spending.

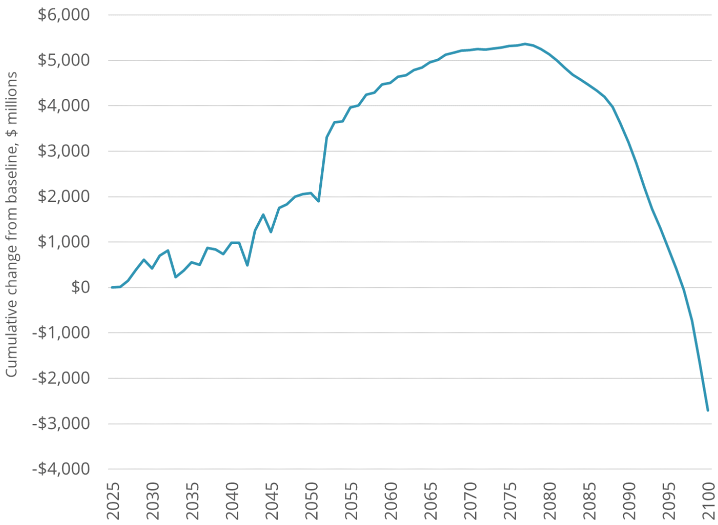
The latter result is partially due to our balance of trade closure choice, whereby investment is initially funded through accessing overseas savings, but over time is instead drawn from the domestic savings pool.

FIGURE 29 CORE SCENARIO REAL HOUSEHOLD SPENDING, % AND $ CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 30 CORE SCENARIO REAL HOUSEHOLD SPENDING, $M CHANGE FROM BASELINE



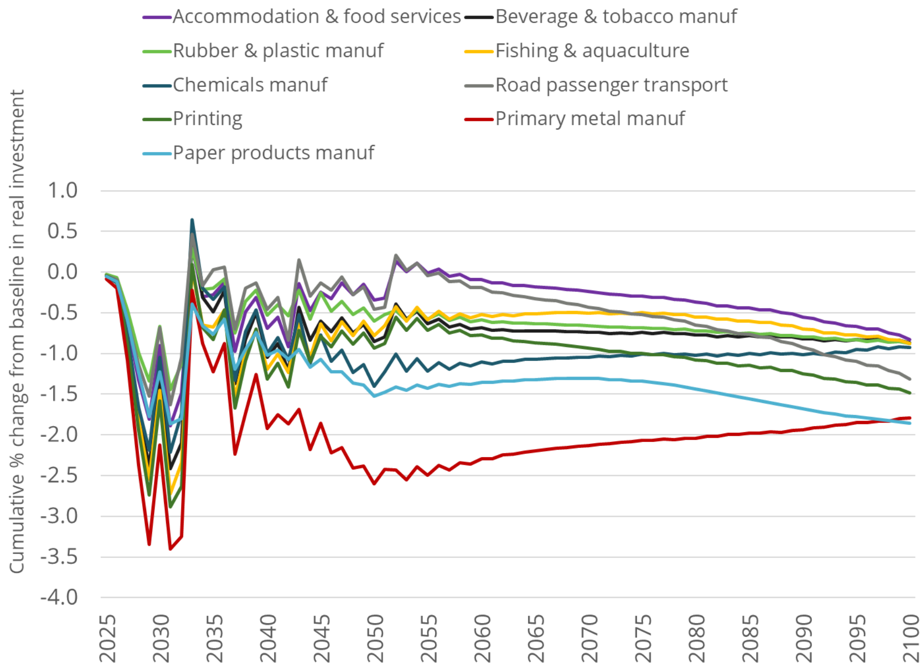
SOURCE: MODELLING RESULTS

The tradable sector faces stronger competition for resources

As the rail investment programme draws more resources towards construction activities, this draws workers and capital away from the export and other capital-intensive sectors – crowding out other investment (Figure 31) and moderating overall growth in economic activity.

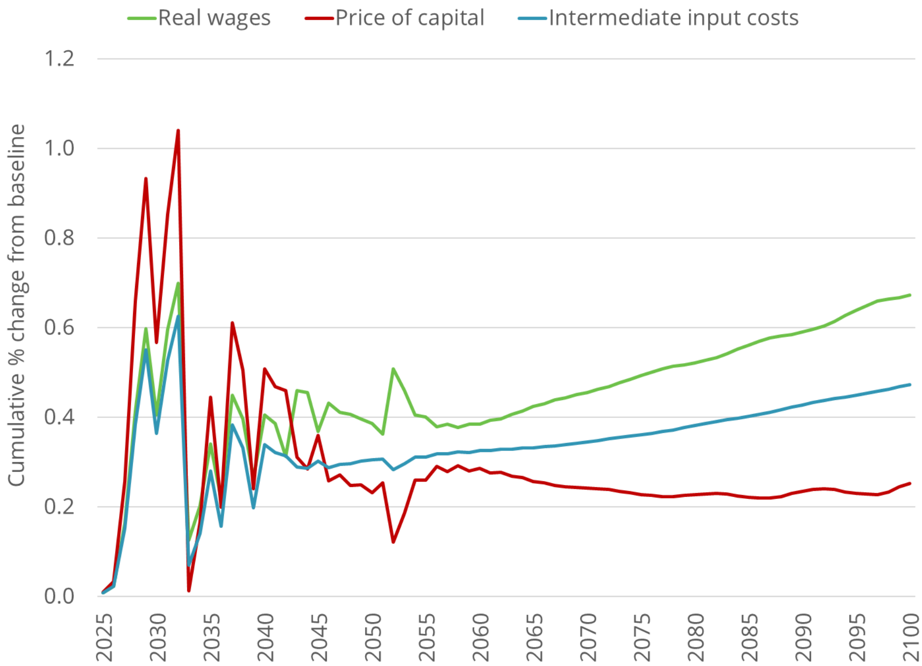
The export sector also faces higher real wage costs (due to the higher demand for labour economy-wide) and capital costs (as the demand for capital surges due to the rail investment during the construction phase). In addition, the cost of intermediate inputs purchased from other parts of the economy rises (Figure 32).

FIGURE 31 CORE SCENARIO REAL INVESTMENT BY INDUSTRY IMPACTS, % CHANGE FROM BASELINE – SELECTED INDUSTRIES



SOURCE: MODELLING RESULTS

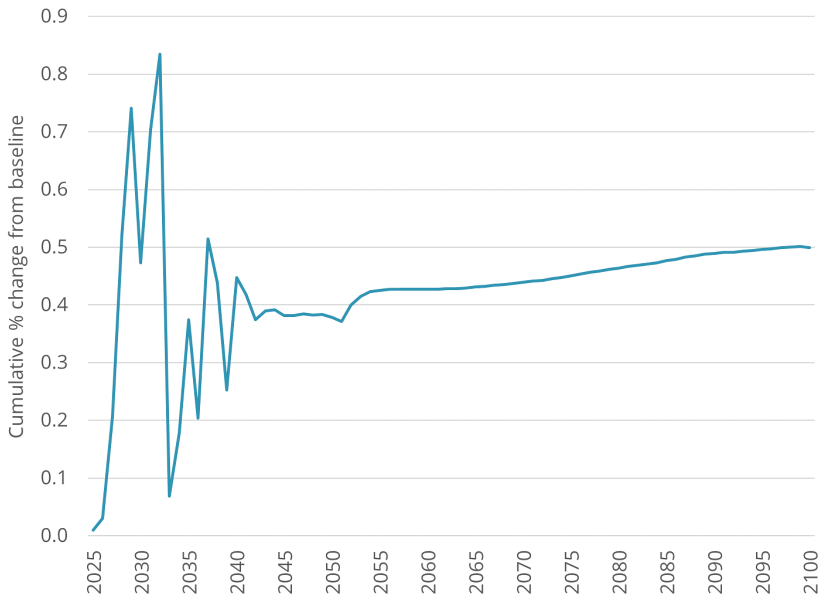
FIGURE 32 CORE SCENARIO ECONOMY-WIDE BUSINESS COSTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

The combination of these effects is to push up production costs, reducing exporters' competitiveness relative to overseas firms. This forces an appreciation of the real exchange rate (Figure 33).

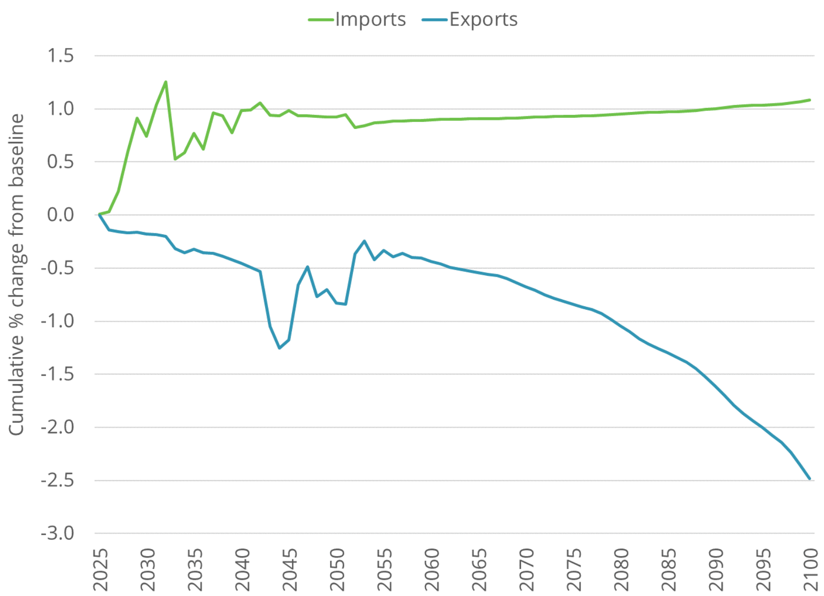
FIGURE 33 CORE SCENARIO REAL EXCHANGE RATE, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

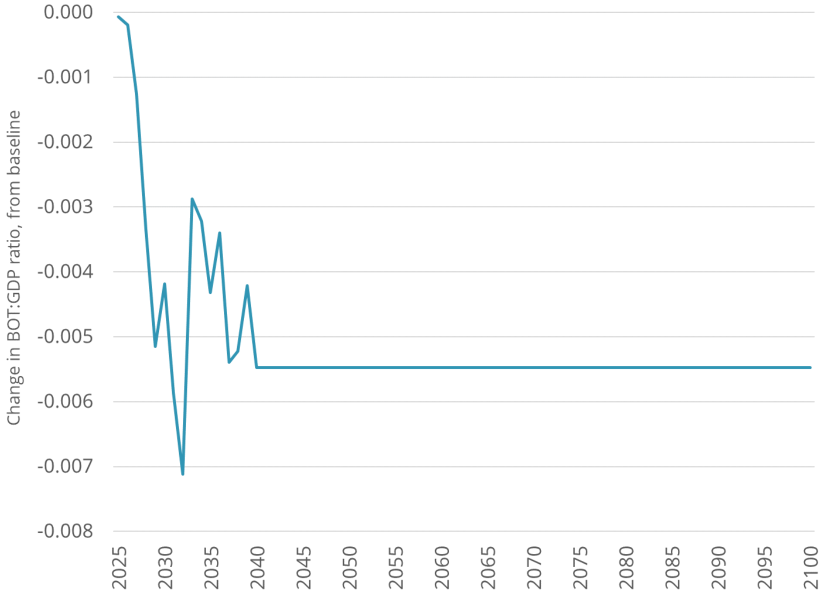
As a result, imports rise above baseline in line with the expanding economy, exports drop below baseline (Figure 34) and the balance of trade deteriorates (Figure 32). The closure swap in 2040 can be seen in Figure 35 – the balance of trade as a ratio to GDP is exogenously held constant from that date, rather than being 'open' so that overseas savings can be accessed.

FIGURE 34 CORE SCENARIO REAL EXPORTS AND IMPORTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 35 CORE SCENARIO CHANGE FROM BASELINE IN RATIO OF BALANCE OF TRADE TO GDP



SOURCE: MODELLING RESULTS

5. Emissions impacts

Total emissions are determined by the ETS emissions cap, so the investment programme does not directly influence that

Given we assume an Emissions Trading Scheme remains in place, there is no change in *total* CO2 emissions between the baseline and Core scenario – this amount is determined administratively by the government, based on the Climate Change Commission's advice.

However, the rail investment programme does lead to shifts in the *nature* of emissions within the cap, across industries, type of transport and region.

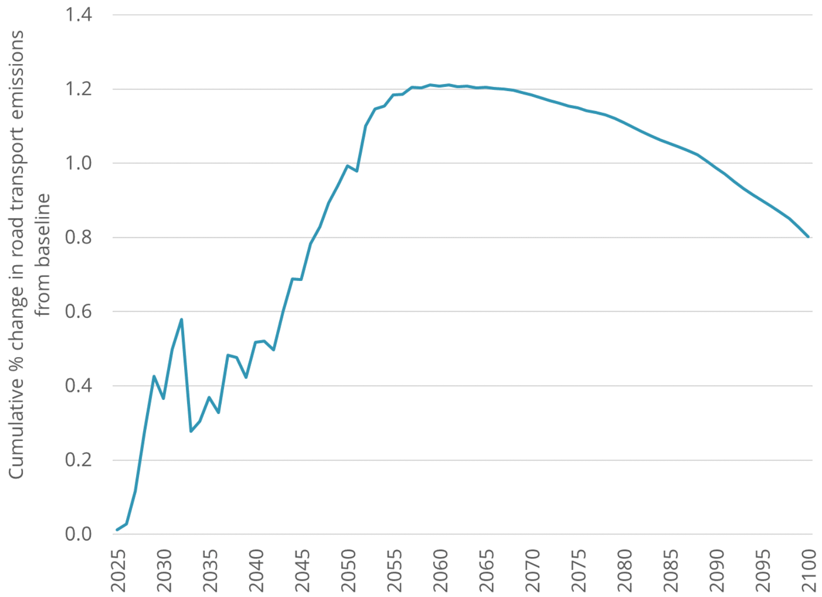
Road transport emissions rise as household incomes grow and the demand for freight expands as the economy grows...

Despite the modal shift from road transport to rail transport facilitated by the investment programme, for both passengers and freight, road transport emissions rise above baseline in our Core scenario (Figure 36).

This may feel counterintuitive, but it's important to remember that the rail investment leads to both income and substitution effects. The economy is growing above the baseline due to the investment programme. More economic activity generally leads to more road freight emissions, and as household incomes rise, they spend more on road transport, in both private vehicles and public transport.

The construction activity associated with the investment programme is also highly transport emissions-intensive.

FIGURE 36 ROAD TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



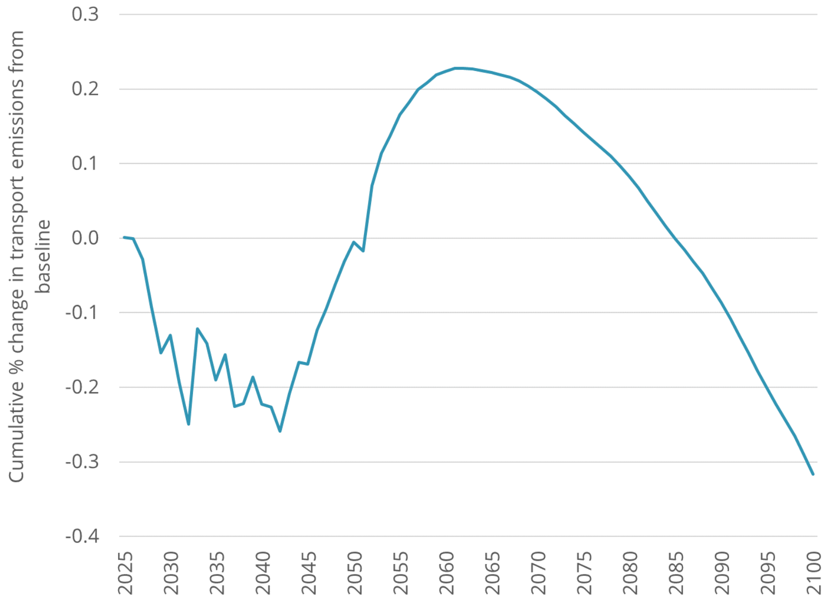
SOURCE: MODELLING RESULTS

…but *total* transport emissions fall in the outyears, reflecting the emissions gains from modal shift

However, these higher road transport emissions are – over time – more than offset by the emissions benefits that the rail investment programme delivers.

Total transport emissions, which includes road, rail, domestic air and sea transport, fall below the baseline by 2085, ending up 0.32% lower than baseline by 2100. This equates to a transport emissions 'saving' of 32.3Kt CO2-e by 2100.[25]

FIGURE 37 CORE SCENARIO ECONOMY-WIDE TOTAL TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

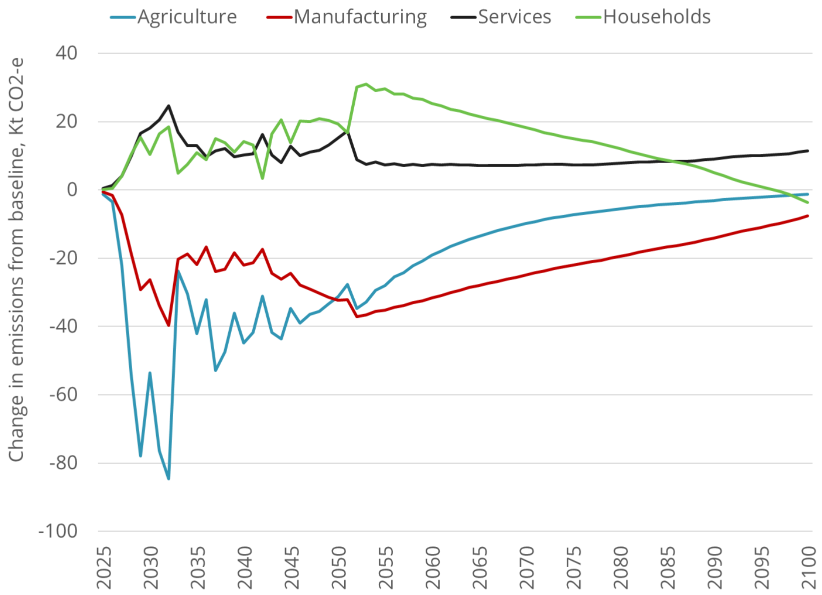
Primary and manufacturing sectors become more emissions-efficient due to the investment programme

The composition of emissions changes across the economy as a result of the investment programme. The primary sector and manufacturing sector, both of which are heavy users of rail freight, see their emissions fall below baseline over time, despite their output growing faster.

Services emissions rise primarily because construction activity is included in this sector. Household emissions grow above baseline for most of the projection period as real wages and employment grow, boosting spending across the economy on goods and services that embody emissions.

[25] Economy-wide CO2 emissions are determined by the ETS cap, which is set exogenously in all scenarios at the baseline level. So the emissions savings in transport will be offset by additional emissions elsewhere in the economy.

FIGURE 38 CORE SCENARIO BROAD SECTOR CHANGE IN EMISSIONS FROM BASELINE, KT CO2-E



SOURCE: MODELLING RESULTS

Overall the economy becomes more emissions efficient

As shown in Figure 21, the Core scenario sees GDP grow above the baseline over the projection period. With economy-wide CO2 emissions fixed at their baseline level, this implies an improvement in the emissions-intensity of GDP.

This indicates the investment programme plays a positive role in supporting the transition to a lower emissions economy: relative to the baseline there is more economic activity occurring but total CO2 emissions hold steady and agricultural emissions decline. (i.e. the emissions-intensity of the economy falls).

6. Regional impacts

6.1. Impacts across regions

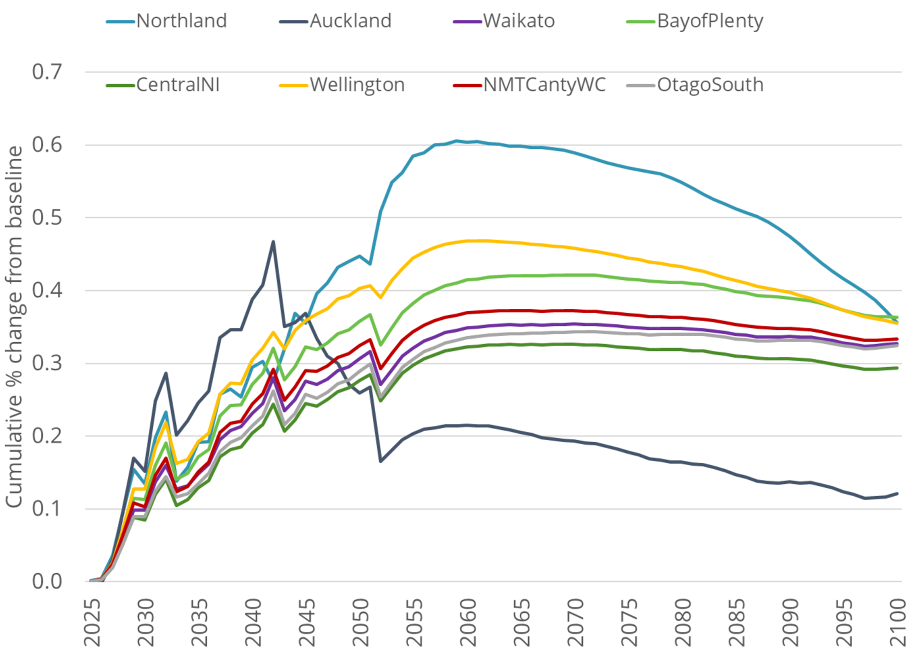
Auckland benefits the most in the first half of the century…

The investment programme leads to additional growth in all regions (Figure 39).

Given all of the capex is directed to Auckland, it benefits the most in the early decades of the projection period, with real regional GDP being 0.47% ($880 million) larger than the baseline in 2042. Further out beyond 2050, the additional investment for the rail programme is funded more by domestic savings than accessing overseas savings. This sees Auckland household spending and exports soften, with an associated easing in GDP gains above the baseline.

See section 6.3 for more discussion of the impacts of the Core scenario programme on the Auckland economy.

FIGURE 39 CORE SCENARIO CHANGE IN REAL REGIONAL GDP FROM BASELINE, %



SOURCE: MODELLING RESULTS

…but a rising Auckland tide lifts all regional boats

Since most regions have strong economic linkages with Auckland (due to import/export trade or the use of Auckland's large business services sector), its additional GDP growth has positive flow-on effects across New Zealand.

The regional outcomes can be summarised as follows:

- **Northland** benefits the most (proportionately) of all regions for much of the projection period. It gains from greater activity at Northport, with rail freight output being 7.3% larger than baseline by 2100. Non-metallic minerals mining, primary processing sectors, construction and professional services all benefit as a result of these links and Auckland's stronger growth. The boost to Auckland's rail investment will draw in construction workers and firms from adjoining regions to meet demand.

- The **Waikato** and **BOP** regions have more moderate increases in economic activity, in part reflecting resources flowing towards Auckland as it grows strongly.

  These regions' mining sectors contract slightly as they struggle to access (and pay higher prices for) construction services that support their activity. However, their dairy manufacturing and meat processing sectors expand above baseline, reflecting improved rail links. These regions' construction sectors, and related industries such as wood products, also gain during the Auckland rail investment phases.

- The **Central North Island**'s reliance on forestry and related downstream sectors sees its economic growth above baseline being fairly modest. Those sectors have less raw material to work with as more logs and wood products are directed towards the construction sector in Auckland and elsewhere. Printing and paper products both contract relative to the baseline as a consequence.

  The beverage manufacturing sector in the region (basically all wine, and all in Hawke's Bay) contracts slightly, due to exchange rate pressures and a higher labour cost base as wages rise. Heavy manufacturing industries, such as rubber and plastic manufacturing and primary metal manufacturing, contract relative to baseline as they compete for capital goods with the Auckland rail industry.

- The additional growth in **Wellington** is largely a result of greater demand from Auckland for construction services, professional and technical service, and media and communication services. That is, Wellington's services firms benefit from Auckland's growth.

- The **Canterbury, West Coast, Nelson, Marlborough and Tasman** composite region grows moderately above baseline. The largest percentage gains come in metal ore and non-metallic minerals mining (due to cheaper road freight costs), construction, wood products, and professional services.

- The **Otago and Southland region** benefits proportionately less due to its distance from Auckland and hence less intensive industry linkages, as well as the composition of its economy:

  - Its important and labour-intensive industries such as tourism, winemaking, and export education suffer a loss in competitiveness from higher real wage costs and a stronger real exchange rate that more than outweighs any improved rail connection benefits.

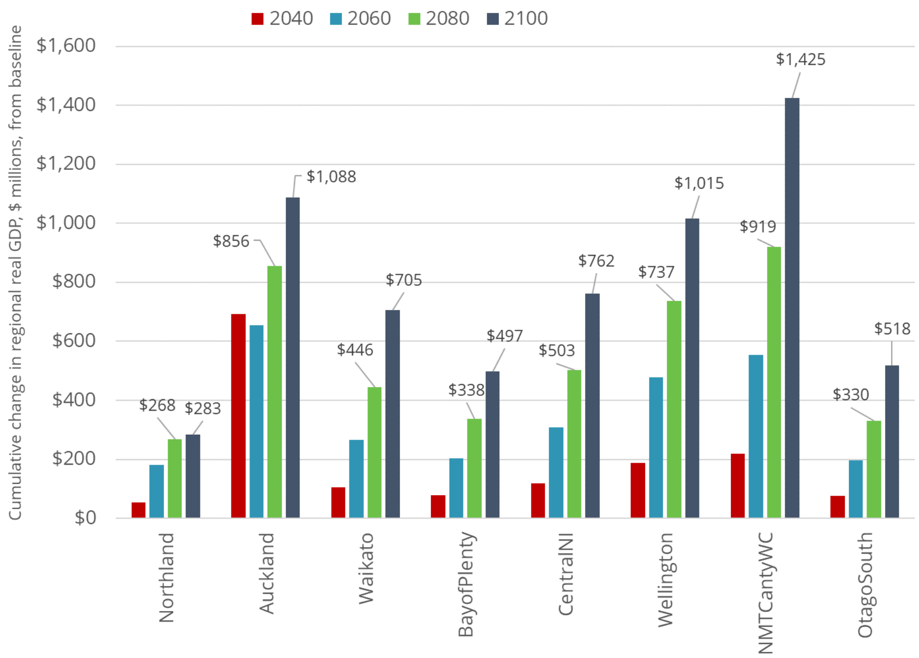
  - Extractive industries such as coal mining face higher capital costs in addition to the stronger real exchange rate, and contract relative to the baseline accordingly.

- Heavy manufacturing, such as primary metal manufacturing, machinery and equipment manufacturing, rubber and plastic manufacturing, and chemicals manufacturing face similar challenges to mining, and contract.

Nevertheless, the Otago and Southland region does grow slightly faster than baseline over the projection period, mainly due to improved meat, dairy and wood processing outcomes.

The change in levels of real regional GDP attributable to the Core scenario rail investment programme is shown in Figure 40.

FIGURE 40 CORE SCENARIO CHANGE IN REAL REGIONAL GDP FROM BASELINE, $ MILLIONS



SOURCE: MODELLING RESULTS

6.2. Regional employment impacts

Auckland’s growth pulls in workers from adjoining regions

Employment grows slightly above the baseline in all regions because of the Core scenario investment.

As the investment programme in Auckland significantly boosts the demand for workers related to rail expansion (construction, technical services, rental equipment, etc.), it attracts workers from nearby regions such as the Waikato, BOP and Northland. As a result, employment in those adjoining regions grows only slowly, relative to the baseline.

FIGURE 41 CORE SCENARIO, LEVELS CHANGE IN REGIONAL FTE EMPLOYMENT FROM BASELINE

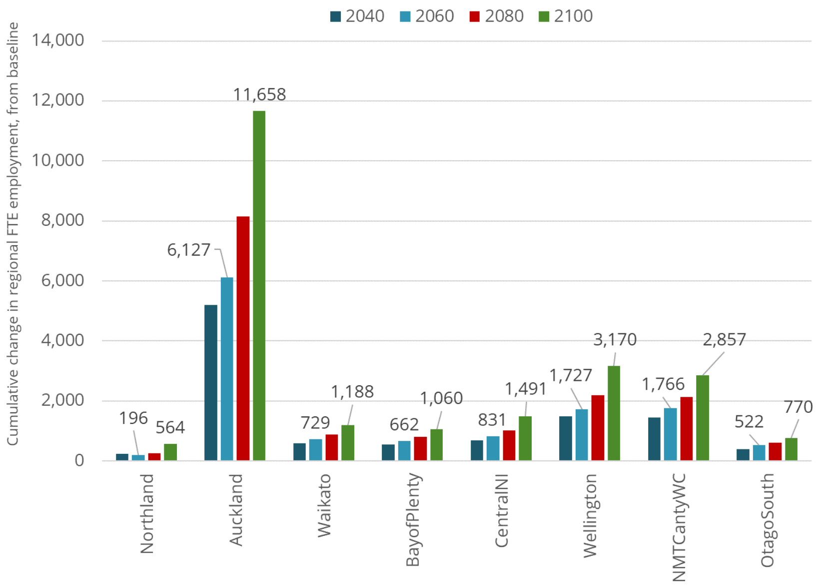
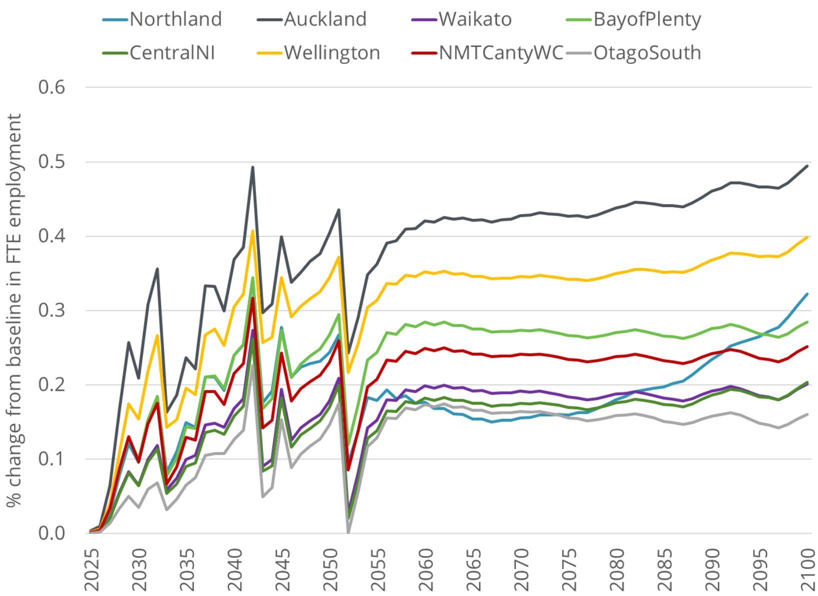


FIGURE 42 CORE SCENARIO, % CHANGE IN REGIONAL FTE EMPLOYMENT FROM BASELINE



SOURCE: MODELLING RESULTS

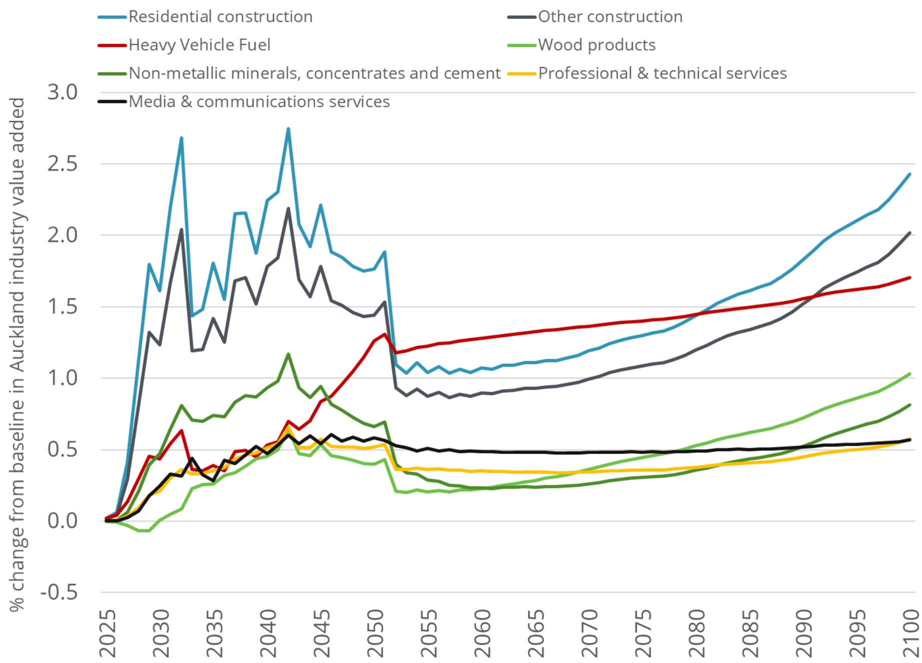
Outside of the Upper North Island, overall employment changes are not proportionately large, apart from in Wellington towards the end of the projection period. The biggest winners in the Wellington job market are construction services, professional and technical services, and retail and wholesale trade (as household incomes rise, Wellingtonians spend more).

We are happy to provide more detail on employment by industry by region as required.

6.3. Auckland industry impacts

The investment programme provides a significant boost to several Auckland industries besides the rail sector

FIGURE 43 CHANGE IN AUCKLAND REGIONAL INDUSTRY VALUE ADDED, %, FROM BASELINE – SELECTED INDUSTRIES



SOURCE: MODELLING RESULTS

Several Auckland industries experience strong output growth above baseline due to the investment programme (Figure 43):

- Auckland rail freight transport (not shown in chart) enjoys huge growth, ending up over twice as large (around 113%) than it would otherwise have been in the baseline by 2100.
- Industries that make the investment programme happen, such as construction and heavy vehicle fuel wholesaling, end up around 1.7-2.4% larger than baseline by 2100. The professional and technical services industry grows by 0.6% above baseline by 2100.
- Construction-supplying industries such as water transport and producers of wood products, cement and other non-metallic minerals also benefit as the construction sector grows.

But others decline slightly as costs rise and the exchange rate appreciates

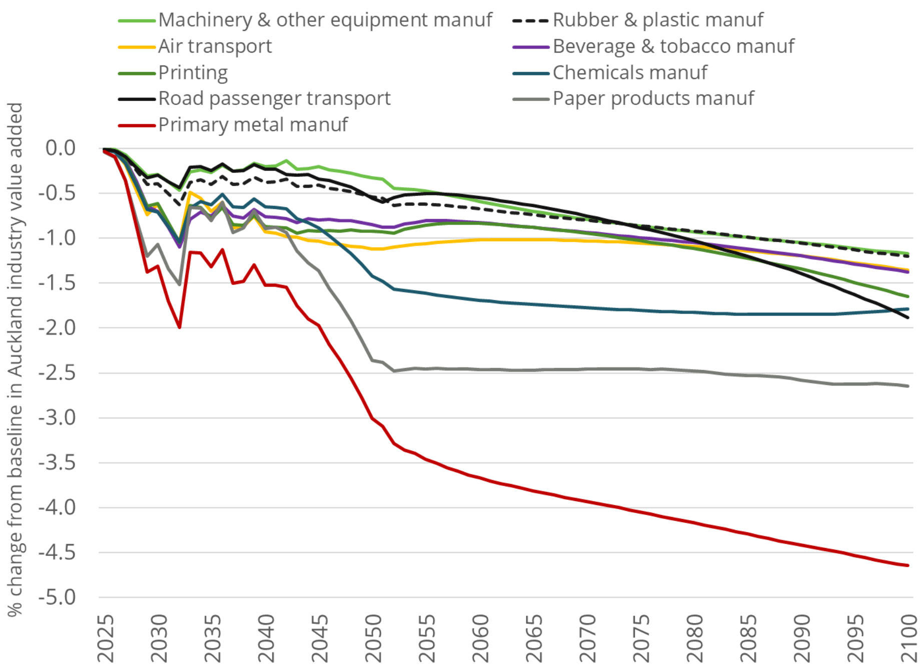
The industries most negatively affected include primary metal manufacturing and chemicals manufacturing (Figure 44). These industries compete for capital and the use of construction services with the investment programme, and are exposed to the exchange rate.

Paper products manufacturing and printing suffer as more of their source material (i.e. logs) get turned into wood products for construction rather than being available for making paper.

Air transport contracts as it faces a stronger exchange rate and higher labour costs.

Road passenger transport drops relative to the baseline as more commuters use the enhanced rail services in Auckland.

FIGURE 44 CHANGE IN AUCKLAND REGIONAL INDUSTRY VALUE ADDED, %, FROM BASELINE – SELECTED INDUSTRIES



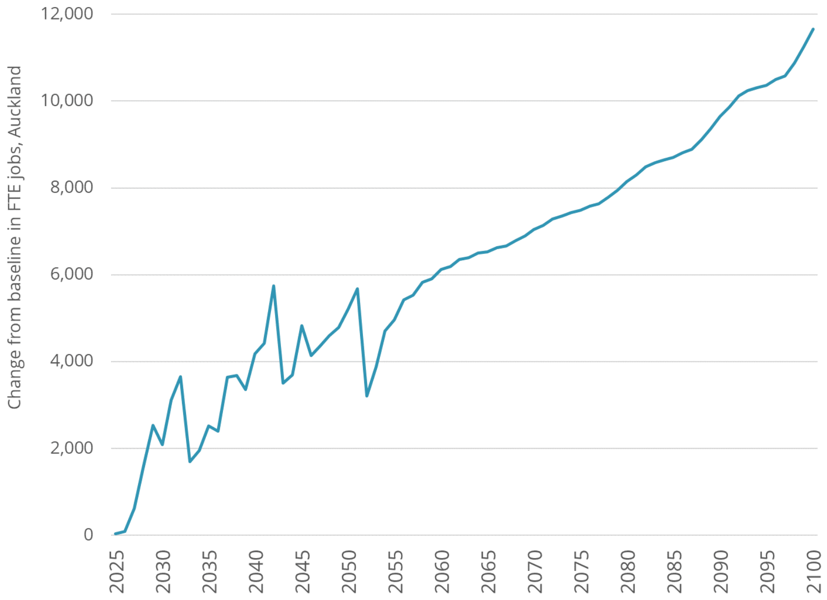
SOURCE: MODELLING RESULTS

Auckland FTEs jobs grow by almost 11,700 above baseline by 2100

Employment in Auckland grows steadily above baseline across the projection period, moving around in line with the rail programme's construction phases and expanded renewals and maintenance spending. FTE employment is over 6,100 higher by 2060, 8,150 higher by 2080 and almost 11,700 higher by 2100 (Figure 45).

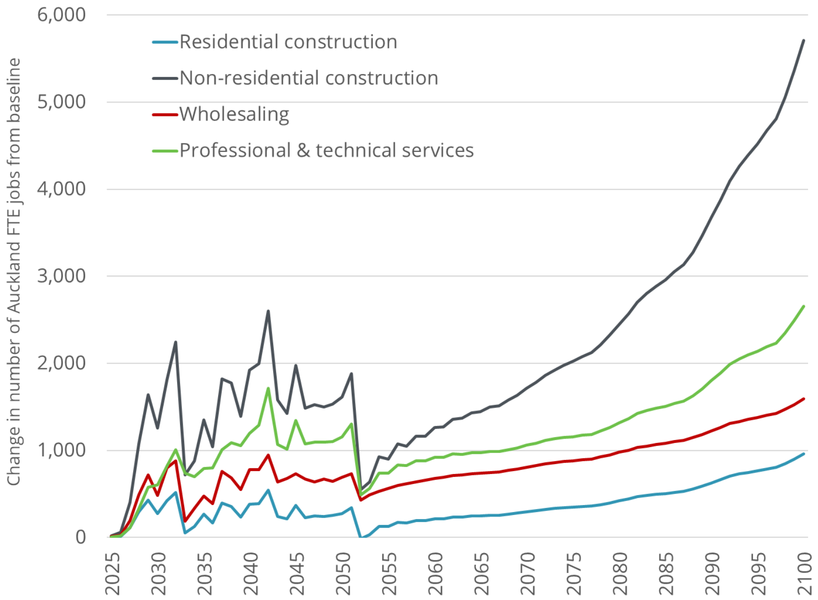
The most significant job gains come in construction services (Figure 46). This highlights the importance of the New Zealand rail construction industry being retained in New Zealand.

FIGURE 45 CHANGE IN AUCKLAND REGIONAL FTE JOBS, FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 46 CHANGE IN AUCKLAND REGIONAL CONSTRUCTION INDUSTRY-RELATED FTE JOBS, FROM BASELINE



SOURCE: MODELLING RESULTS

7. Sensitivity analysis: Delayed investment scenario

The Delayed investment scenario is described in section 3.4. It envisages limited investment in the most congested part of the network (southern corridor) taking place between 2043 and 2060, but no growth investment in any other part of the network. It has an additional capital cost of $8.9 billion relative to the baseline, plus an additional $1.5 billion of renewals and additional maintenance of $4.75 billion, largely after 2050.

In this scenario, the GDP gains follow a similar pattern to those of the Core scenario, but at a lower level and not until after 2043. Real GDP is $1.3 billion above baseline by 2050, $3.0 billion higher by 2075 and $5.0 billion higher by 2100.

FIGURE 47 REAL GDP IMPACTS, % CHANGE FROM BASELINE

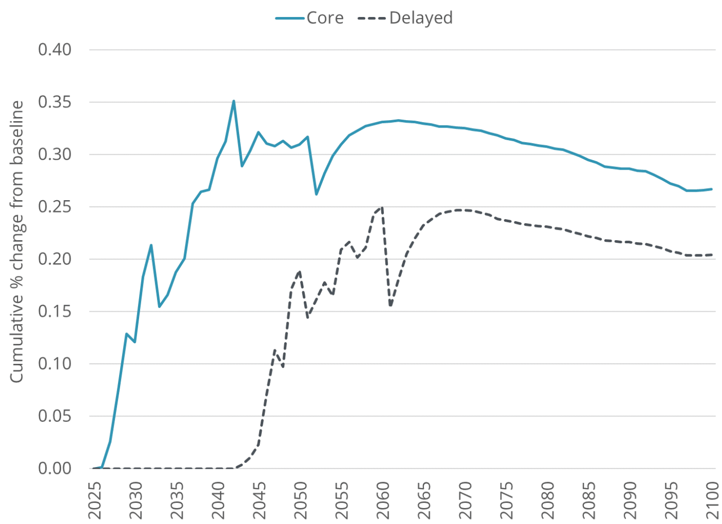
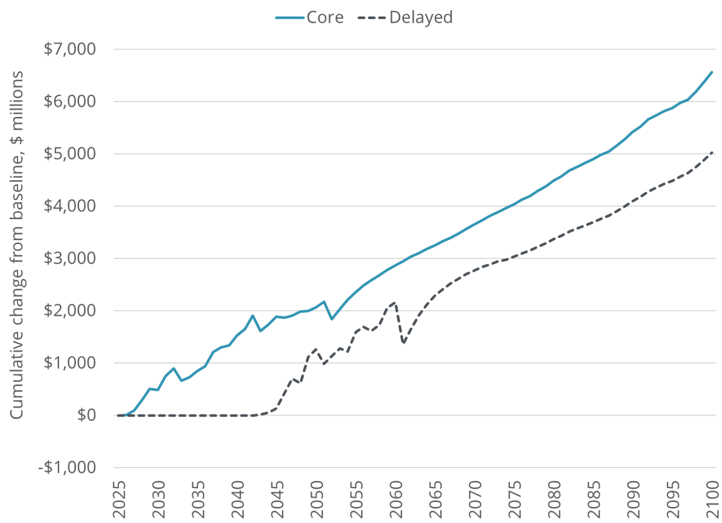


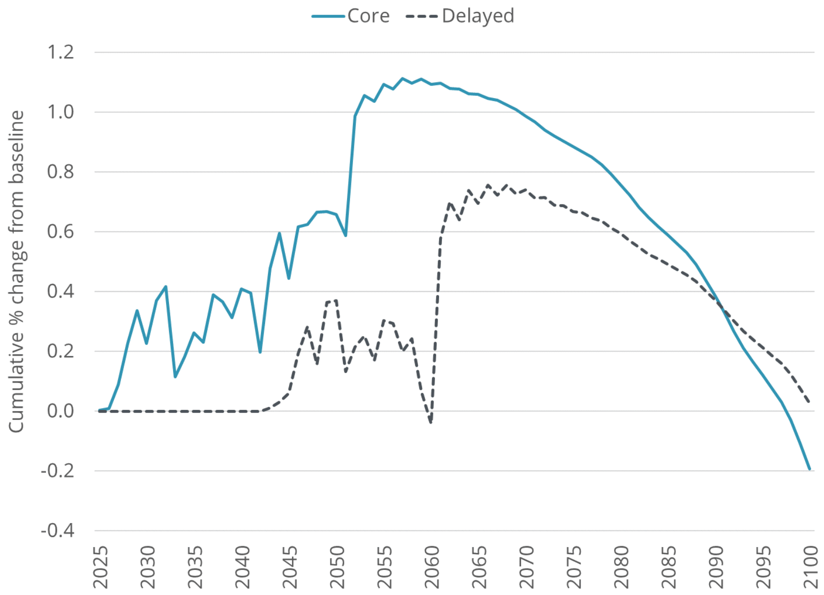
FIGURE 48 REAL GDP IMPACTS, $ MILLIONS CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

Household spending in the Delayed scenario peaks at around 0.75% above baseline by the mid-2060s, before gradually returning to the baseline later in the projection period as more of the investment is funded from domestic savings instead of overseas borrowing.

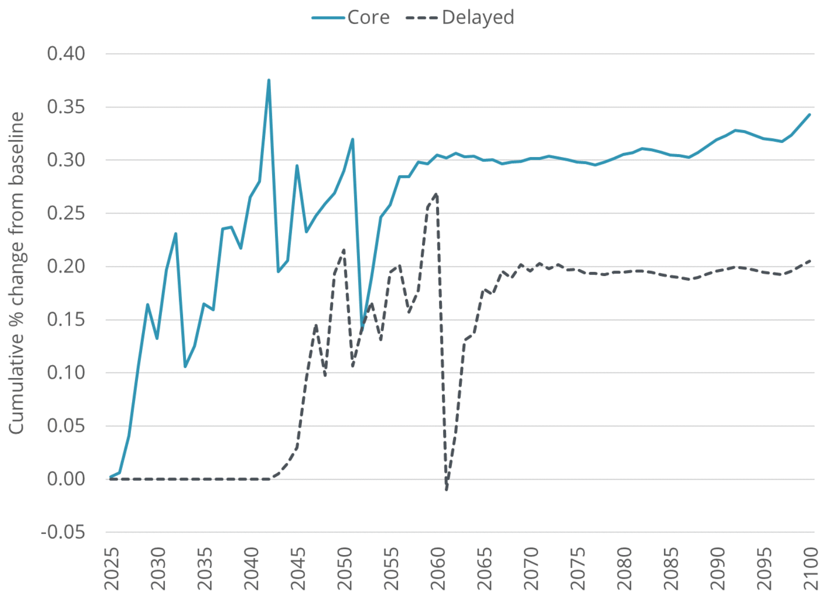
FIGURE 49 REAL HOUSEHOLD SPENDING, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

Employment impacts are more moderate than in the Core scenario, as the initial construction phase is less stimulatory. Nationwide employment peaks at around 0.27% above baseline by 2060, and settles around 0.20% from 2070 onwards.

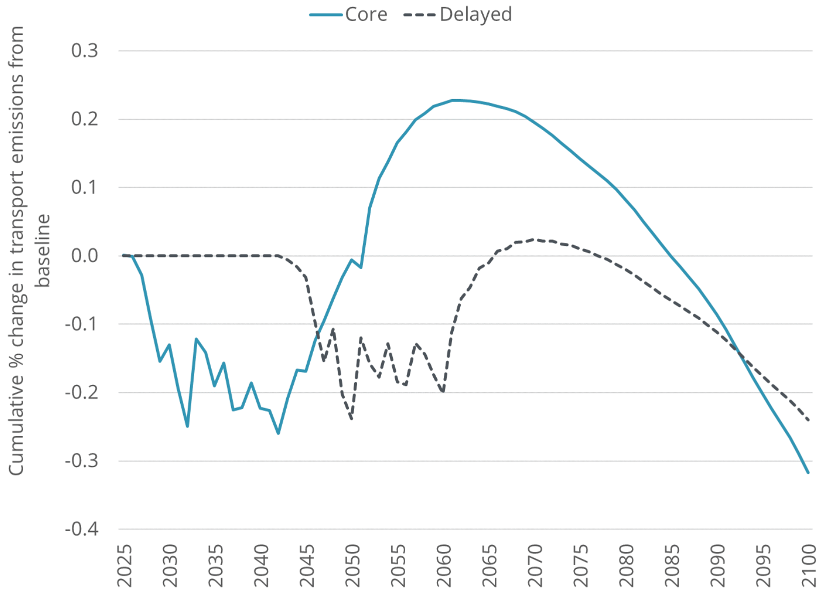
FIGURE 50 FTE EMPLOYMENT, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

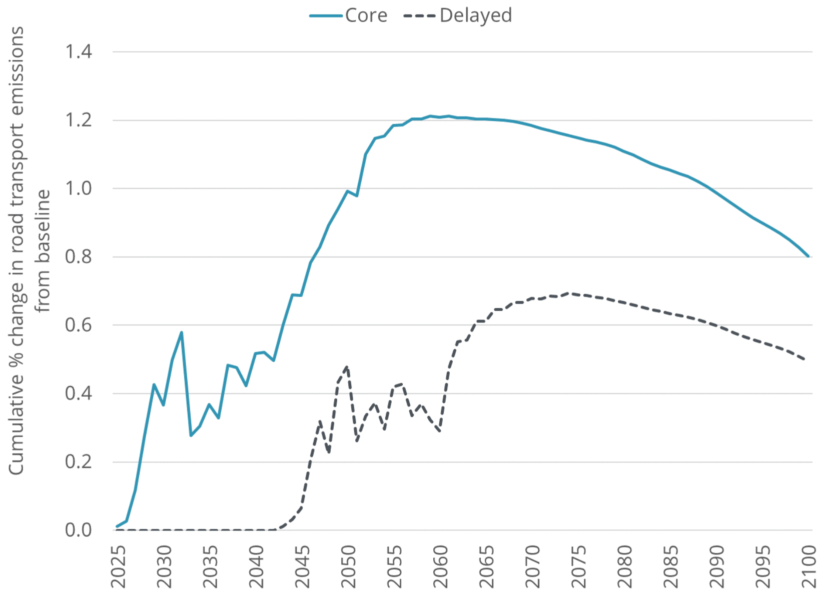
The Delayed scenario also delivers transport emissions savings (Figure 51). With the investment stimulus being smaller than in the Core scenario, the economy expands less and there is a relatively lower increase in demand for road freight and road passenger transport (Figure 52).

FIGURE 51 TOTAL TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 52 ROAD TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

8. Conclusion

This analysis has modelled the economic and emissions impacts of KiwiRail's proposed investment programme.

The Core investment scenario results in the national economy being $6.6 billion larger than in the baseline by 2100. The GDP gains are driven by the construction impulse in the initial investment phase and subsequent productivity gains once the improved and expanded rail network becomes operational. Greater investment in renewals and maintenance also provides an economic boost.

Since our modelling approach takes into account the costs of the investment, this results in a benefit-cost ratio greater than 1.

All regions benefit from the additional investment in Auckland. Northland benefits the most, proportionately, as it benefits from improved rail links and greater activity at Northport.

The proposed rail investment would generate several other social and economic benefits that are challenging to include in a CGE model but should be seen as additional to the quantified estimates we present here. They include safety benefits, time savings for commuters and freight users, improved urban design and liveability, and reduced road and vehicle maintenance for a given amount of economic activity.

The rail investment programme also delivers environmental benefits. With ETS-covered emissions fixed at the baseline level, there are no additional emissions despite the investment generating more economic activity, jobs and incomes. This means the economy becomes more emissions-efficient: fewer emissions are generated per unit of GDP.

Furthermore, overall transport sector emissions fall below the baseline towards the end of the projection period as more freight switches from road to rail. Again, this implies that transport emissions per unit of GDP decline over time.

An alternative Delayed investment scenario has smaller – but still positive – GDP impacts, which occur from the mid-2040s. It too delivers an improvement in the emissions-efficiency of the economy.

A scenario that sees Northport rather than Port of Tauranga take more of the additional freight activity generated by the investment programme delivers slightly larger economic gains than the Core scenario (see Appendix A). The key driver of the larger GDP boost in the Northport scenario is the earlier investment into the Crosstown (Avondale-Southdown) rail corridor, which occurs six years earlier than in the Core scenario.

The overall cost of the Northport scenario is slightly (0.9%) lower than the Core scenario. This, plus slightly higher economic benefits, indicate it would have a higher cost-benefit ratio than the Core scenario.

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Appendix A Northport scenario

Scenario description

The Northport investment programme scenario is based on the recommended Core investment programme scenario, but differs in its assumptions on port activity and hence rail freight requirements.[26]

Rather than all future growth occurring at Port of Tauranga as in the Core scenario, it assumes that future freight growth will also come via Northport.

In this scenario, the package of investment is largely the same as for the recommended programme in the Core scenario. However, the timing of investment changes to accommodate greater freight volumes from Northport. Some new capacity that would otherwise be needed between Westfield and Wiri junctions in the Core scenario is no longer required.

The key differences between this scenario and the Core scenario are as follows:

- **Freight flows** – the Core scenario assumes that traffic through the Ports of Auckland does not grow beyond its 2018 level, with any increases above this diverted to Tauranga. By contrast, the Northport scenario assumes that 40% of the increases that would have been diverted to Tauranga are instead diverted to Northport.
- East-West crosstown (Avondale-Southdown) rail **corridor via Onehunga** – the timing of investment in this corridor has been brought forward in the Northport scenario to open in 2045 (compared to 2051 in the Core scenario). This is driven by increased freight flows from Northport.
- **Fleet, depots and stabling** – some fleet purchases and associated stabling is brought forward in the Northport scenario to align with the timing of the delivery of the Crosstown (Avondale-Southdown) rail corridor.
- **North Island Main Trunk (NIMT) between Westfield Junction and Wiri** – some investment in capacity enhancement between Westfield and Wiri junctions has been removed. This is because, in the Northport scenario, there is less freight on this section of line in comparison to the Core scenario, and more freight on the Crosstown (Avondale-Southdown) rail corridor.

Programme costs

The estimated capital costs of the programme are $19,878 million above the baseline scenario ($1,308m lower than the recommended programme) and are incurred between FY25 and FY51 (Table 2). After accounting for slightly higher capex maintenance and operating costs, the Northport scenario has a total cost 0.9% lower than the Core scenario.

[26] Descriptive material provided by KiwiRail.

TABLE 2 PROGRAMME COSTS FOR NORTHPORT SCENARIO, $M, REAL

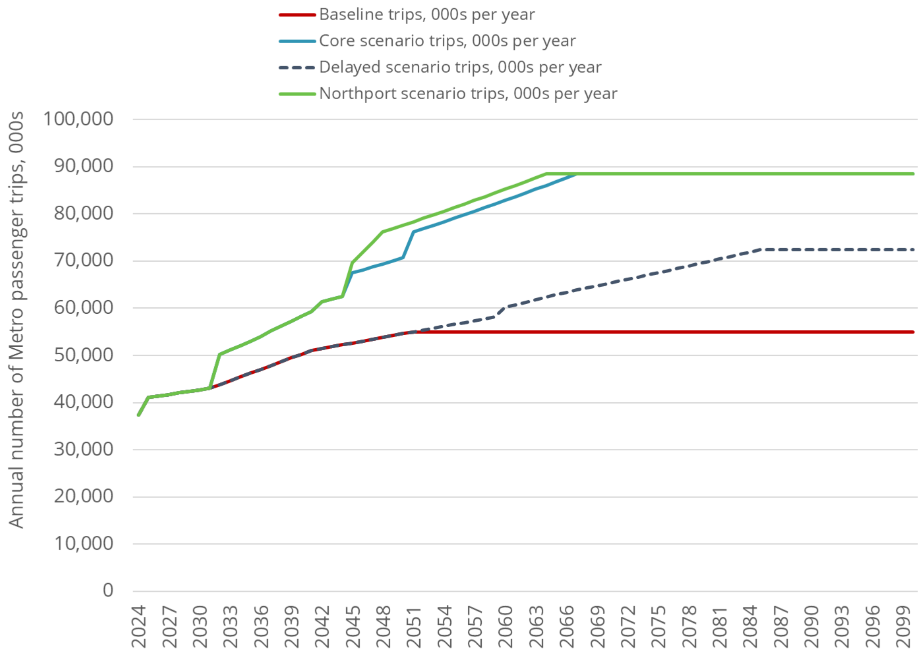
Description	Baseline	Core	Northport	Difference from Baseline	Difference from Core
Capital costs	$1,882	$23,068	$21,760	$19,878	-$1,308
Renewals	$6,283	$8,854	$8,854	$2,571	$0
Capex maintenance	$8,497	$18,711	$18,920	$10,423	$209
Operating costs	$14,120	$32,488	$32,810	$18,690	$322
Total cost (real)	**$30,781**	**$83,121**	**$82,345**	**$51,564**	**-$776**

SOURCE: KIWIRAIL

Impacts on freight and passenger demand

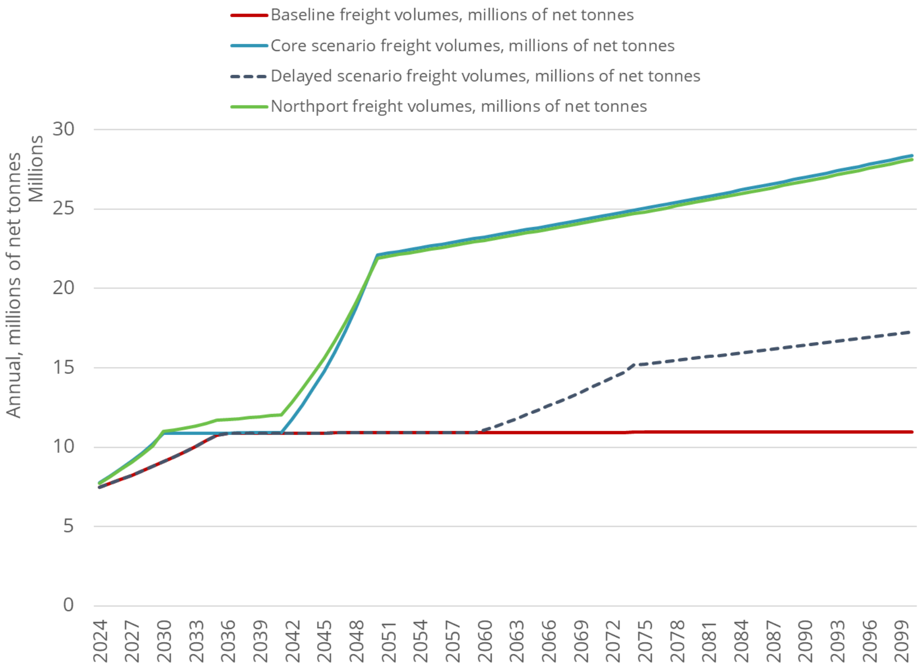
The Northport scenario and the Core scenario enable similar levels of passenger and freight growth. But because the Northport scenario brings forward the Crosstown (Avondale-Southdown) rail corridor, it enables growth earlier than the Core scenario (see Figure 53 and Figure 54 overleaf).

FIGURE 53 SCENARIO PASSENGER VOLUMES



SOURCE: KIWIRAIL

FIGURE 54 SCENARIO FREIGHT VOLUMES

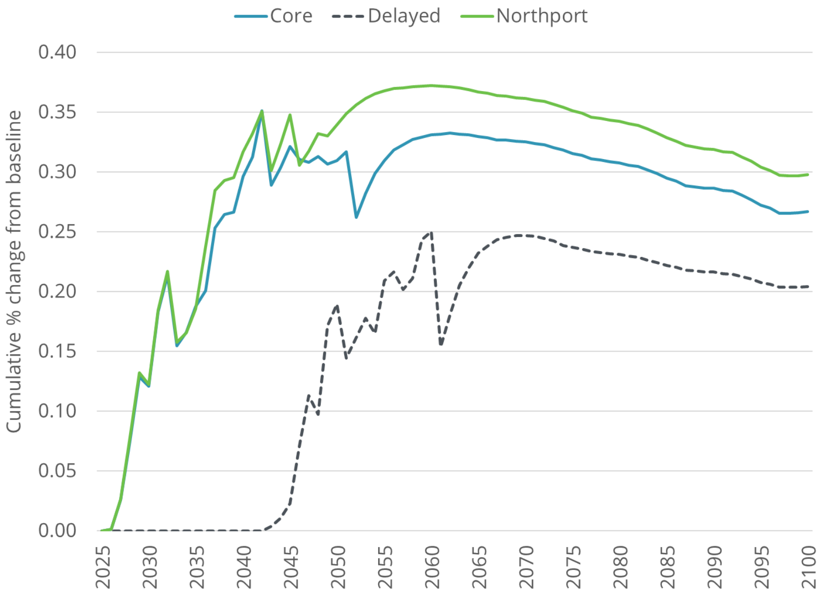


SOURCE: KIWIRAIL

Macroeconomic impacts

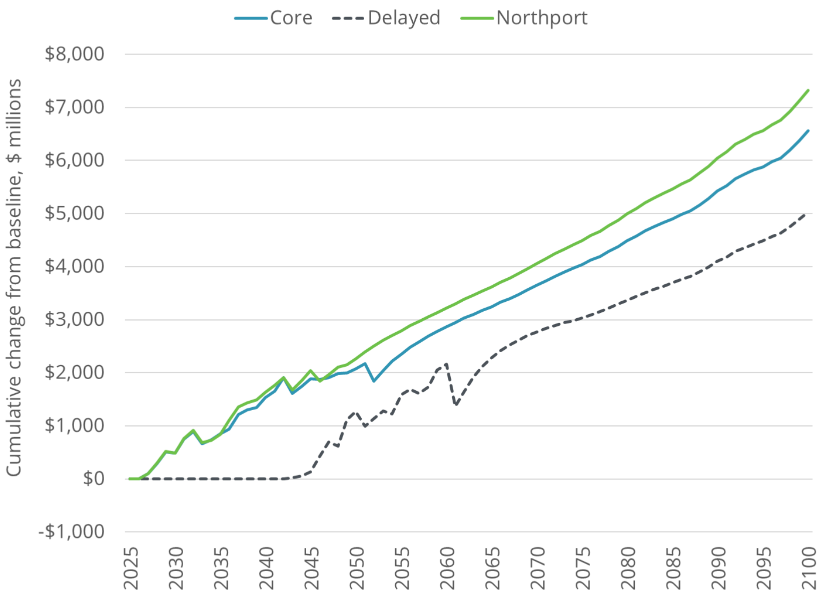
The Northport scenario enables freight and passenger growth slightly earlier than the Core scenario. This, plus a very similar-sized investment size, leads to the economy growing slightly more – and earlier – above the baseline than the Core scenario. The economy peaks at 0.37% above baseline around 2060, compared to 0.33% above baseline for the Core scenario (Figure 55).

FIGURE 55 REAL GDP IMPACTS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

FIGURE 56 REAL GDP IMPACTS, CHANGE FROM BASELINE, $ MILLIONS

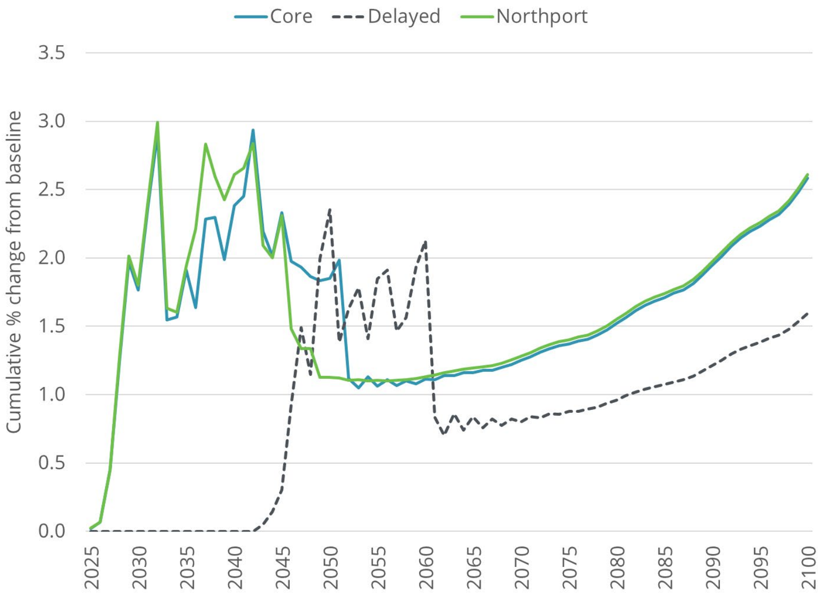


SOURCE: MODELLING RESULTS

In dollar terms (Figure 56), the Northport scenario causes national real GDP to be $3.22 billion above baseline by 2060, compared to $2.88 billion in the Core scenario. By 2100, real GDP in the Northport scenario is $7.32 billion above baseline, around $650 million higher than the Core scenario.

The key driver of the earlier GDP boost is the earlier investment into the Crosstown (Avondale-Southdown) rail corridor, which occurs six years sooner than in the Core scenario (Figure 57).

FIGURE 57 REAL INVESTMENT IMPACTS, % CHANGE FROM BASELINE



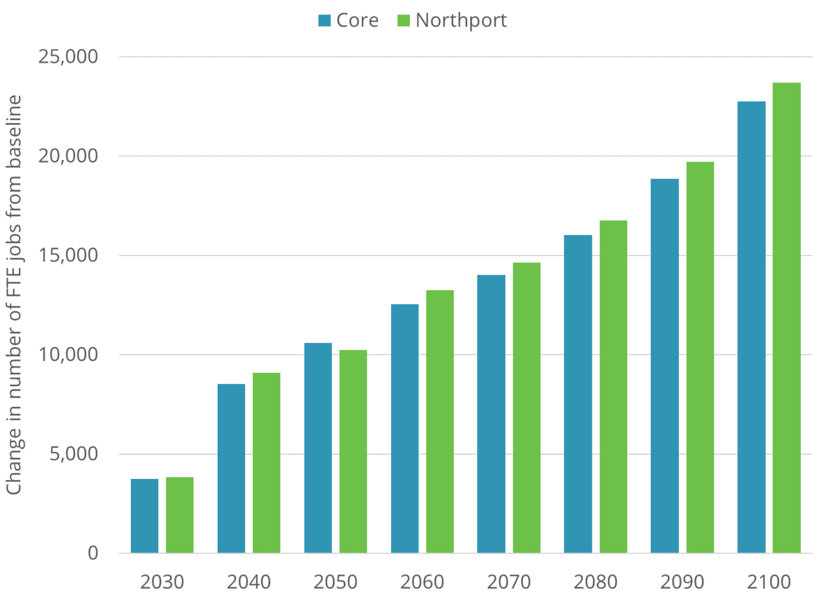
SOURCE: MODELLING RESULTS

The earlier investment activity supports slightly stronger employment growth than in the Core scenario. This can be seen in Figure 58 overleaf. In 2040, the number of FTE jobs nationwide is around 9,100 above baseline in the Northport scenario, compared to around 8,500 in the Core scenario.

The additional freight and passenger activity the Northport investment programme generates once operational pushes the economy to grow faster, which in turns lifts labour demand. By 2100, the Northport scenario would see an additional 23,700 FTE jobs created, around 1,000 more than in the Core scenario.

These additional jobs, plus higher average real wages, support greater household spending. Spending is $5.11 billion above baseline by 2060 in the Northport scenario, compared to $4.51 billion above baseline in the Core scenario.

FIGURE 58 IMPACTS ON NATIONAL FTE EMPLOYMENT, CHANGE FROM BASELINE

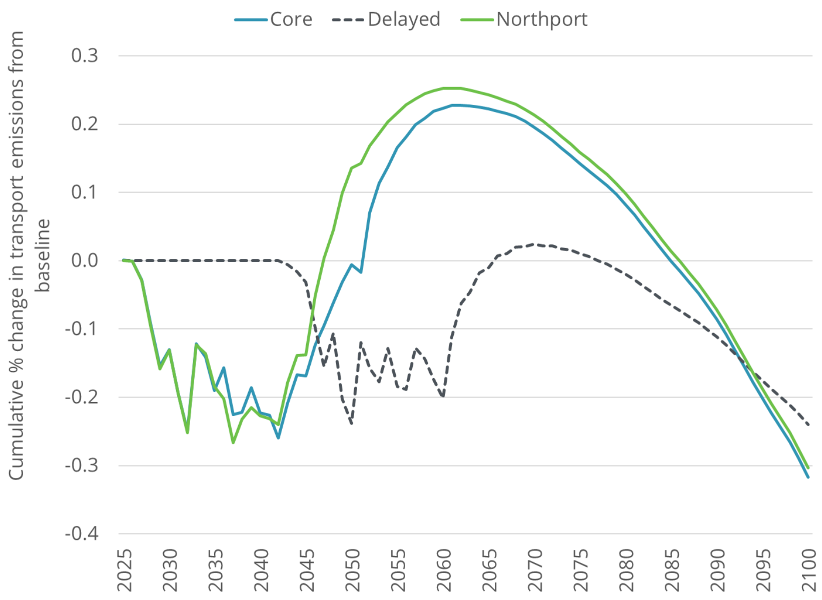


SOURCE: MODELLING RESULTS

The transport emissions impacts of the Northport scenario are slightly higher than in the Core scenario (Figure 59). A faster-growing economy and higher household incomes lift the demand for all types of transport, including road freight and personal vehicles.

However, as with the Core scenario, recall that *total* ETS emissions are fixed between the baseline and Northport scenarios. So we have more economic activity for the same level of emissions, implying an improvement in the emissions-efficiency of the economy.

FIGURE 59 IMPACTS ON TRANSPORT EMISSIONS, % CHANGE FROM BASELINE



SOURCE: MODELLING RESULTS

Regional impacts

The Northport scenario sees Northland's economy do slightly better than in the Core scenario between 2025 and 2060 (see left hand panel of 60). It benefits directly due to more freight activity and indirectly from the spillover effects of Northland firms supplying more goods and services to a faster-growing Auckland regional economy as its freight and passenger volumes lift five years earlier than in the Core scenario.

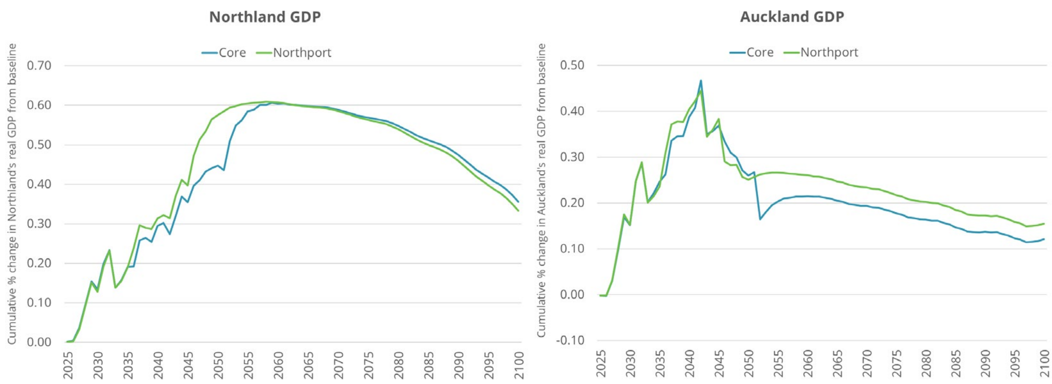
The additional economic activity in Northland in the Northport scenario relative to the Core scenario is not massive in dollar terms (see Figure 61 overleaf). This reflects the fact that once the initial construction boost has ceased, having more freight trains moving through the Northland region to Northport does not in and of itself significantly boost productivity in the region. There may be some extra economies of scale at Northport as throughput rises, and potentially more activity for firms servicing the port, but much of the Northland economy will be largely unaffected.

Past 2060, there is very little difference between the Northland GDP impacts for the Northport and Core scenarios. This is due to the net effect of two opposing forces:

- The additional rail freight activity in Northland, and its related upstream and downstream impacts, pushes up GDP.
- The ongoing strength of the Auckland regional economy (see right hand panel in Figure 60 below) draws resources (labour, capital, etc.) away from neighbouring regions including Northland, which tempers those regions' growth potential.

The differences between the growth tracks for Northland between the two scenarios – especially after 2060 – are immaterial in the context of a 75-year projection period marked by considerable uncertainty around technological change.

FIGURE 60 IMPACTS ON REGIONAL REAL GDP, NORTHLAND AND AUCKLAND, % CHANGE FROM BASELINE

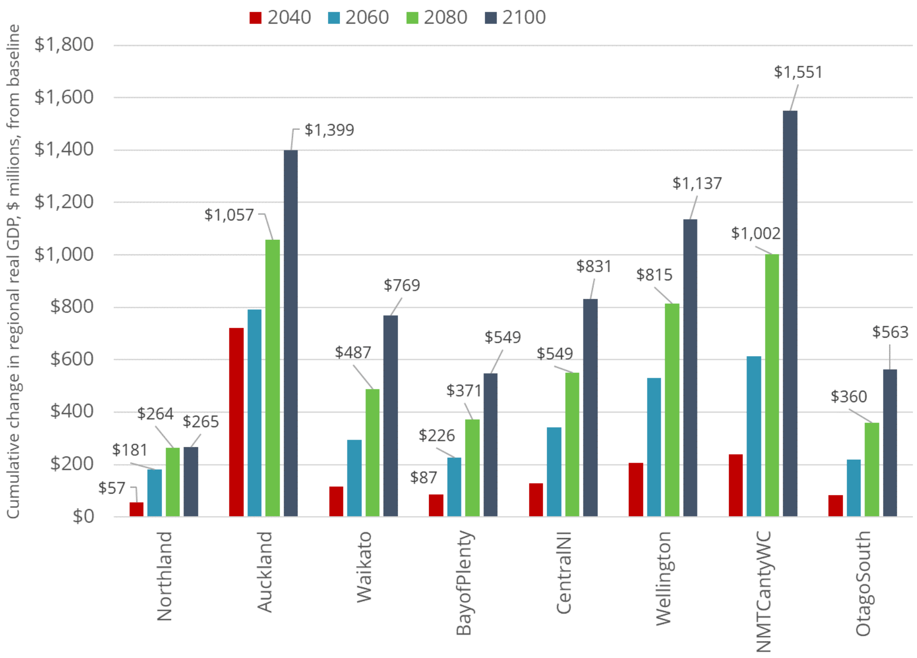


SOURCE: MODELLING RESULTS

Even though the capital investment in Auckland is slightly lower in the Northport scenario than in the Core scenario, Auckland's real GDP grows more above baseline in the Northport scenario than in the Core scenario (compare Figure 62 below with Figure 40 on page 35).

This may feel counter-intuitive, but recall the Northport scenario sees faster freight and passenger growth, earlier, than in the Core scenario. This benefits Auckland's economy both directly and indirectly as other regions grow faster and earlier.

FIGURE 61 NORTHPORT SCENARIO: IMPACTS ON REGIONAL REAL GDP, CHANGE FROM BASELINE, $ MILLIONS



SOURCE: MODELLING RESULTS

Appendix B The MDG CGE model

Introducing MDG-NZ

We use an advanced dynamic CGE model of the New Zealand economy for this project. Titled MDG-NZ, it was built for Sense Partners in late 2019 by Dr Ashley Winston of MacroDyn Group (MDG) LLC, based in Washington DC.

The New Zealand CGE modelling suite is built on the foundation of MDG's path breaking and proven MDG model. MDG incorporates a wide range of policy modelling innovations created for high-profile projects conducted by MDG's team in a range of countries over the last 25 years.

Versions of the MDG modelling framework continue to be used by governments in several countries, and applications have informed key policy reform and other economic matters in many dozens of countries in addition.

MDG-NZ has a lineage that traces back to the MONASH dynamic CGE model developed by the Centre of Policy Studies, then at Monash University, now at Victoria University, Melbourne.[27] Dr Winston implemented several improvements to the MONASH model as a PhD student under the tutelage of Professor Peter Dixon in the late 1990s/early 2000s.

Dr Winston continued developing dynamic CGE models throughout the next two decades, including the USAGE model of the US economy[28] and the FLAGSHIP[29] suite of models for over 20 countries, before building and continually extending the proprietary MDG suite of models from 2015.

MDG-NZ is built and run in the GEMPACK software suite.[30] Technical documentation is under development, and a draft is available from the authors on request.

What is a CGE model?

CGE models are commonly used tools for policy analysis. Such models typically consist of:

1. A **database** that represents an economy in a certain year based on input-output (IO) tables. The database specifies the interactions and relationships between various economic agents including firms, workers, households, the government and overseas markets.

2. Behavioural **parameters** governing agents' responses to relative price changes (e.g. elasticities).[31]

[27] See https://www.copsmodels.com/monmod.htm. Full documentation is in Dixon and Rimmer (2002b).
[28] See https://www.copsmodels.com/usage.htm. Dixon and Rimmer (2002a) has the technical documentation.
[29] See KMPG (2015).
[30] See Horridge et al (2018).
[31] We rely on published studies for elasticity estimates to calibrate MDG-NZ. Elasticities are set at values widely understood to be valid in the modelling community and can be replaced by country- or industry-specific estimates where available for specific projects.

3. A **system of equations** that define the model specification or theory, which is generally based on standard economic assumptions[32], but not necessarily constrained by them (for example, in the always-and-everywhere attainment of equilibrium after shocks are imposed).

From an initial equilibrium where demand equals supply in all factor, final demand and intermediate input markets,[33] the system is then 'shocked' by changing one or more variables that represent a policy change or other change in economic conditions.

By comparing the pre- and post-shock databases, we can then observe the effects of the shock in question in terms of changes to GDP, employment, wages, industry output, etc.

Bringing dynamics into the picture

Static CGE models consider only 'before' and 'after' the policy shock. There is no ability to consider the nature of the adjustment path between equilibria.

A dynamic CGE model allows the user to examine in each intervening period (usually each year) how variables adjust from the time when a shock is implemented to the time when all its effects have worked through the economy (which may be several years).

MDG-NZ contains four key **dynamic mechanisms** that link successive years:

1. The deviation in the real wage rate away from its forecast path in year *t* caused by a policy shock equals the deviation in year *t-1* plus a term reflecting the gap in year *t* between the employment deviation and the deviation in labour supply. That is, real wages deviate from the baseline based on the gap between the changes in the labour supply and employment caused by a policy shock.

   Real wages are sticky in the short term, meaning labour market impacts are felt more through changes in employment. Further out in the projection period, employment gradually returns to the baseline, meaning impacts are more commonly seen through real wage changes.

2. Capital at the start of year *t* equals capital at the end of year *t-1*.

   Capital stock in an industry at the end of year *t* equals the capital stock at the start of year *t,* depreciated at a given rate, plus investment in year *t* for that industry.

   Investment in year *t* for an industry is a function of the expected rate of return (i.e. gross operating surplus) in that industry. The expected rate of return is a function of

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[32] These include, for example, consumers maximise their utility subject to their budget constraints; firms maximise their profits by buying intermediate goods and inputs (labour and capital) and selling outputs to other domestic and international firms, households and government; there is a market for each commodity (goods and intermediates) and in equilibrium market prices are such that demand equals supply in all input and output markets; and under the standard assumption of constant returns to scale firms, earn zero pure profit.
Alternative theoretical specifications can be incorporated where the project dictates it.
[33] This is true in both a theoretical and real-world sense. For example, goods market clear because the macroeconomic accounting used in these models accommodates inventory accumulation (or decumulation), and labour markets allow for structural unemployment and other factors that allow something like a NAIRU to act as the market-clearing condition.

the rental and asset prices of that industry's capital in year *t*, depreciation, taxes on capital, and expected changes in those variables.[34]

3. Net foreign liabilities at the start of year *t* equal net foreign liabilities at the end of year *t-1.* Net foreign liabilities at the end of year *t* equal net foreign liabilities at the start of year *t* plus the current account deficit for year *t.*

   The current account deficit for year *t* is imports less exports plus interest payments for foreign liabilities less exports of royalties, and less net transfers from foreigners to New Zealand residents.

4. Public sector debt at the start of year *t* equals public sector debt at the end of year *t-1*.

   Public sector debt at the end of year *t* equals public sector debt at the start of year *t* plus the public sector deficit for year *t*.

The MDG-NZ model is generally solved in recursive dynamic mode, as this has clear advantages in terms of (for example) realistic behavioural responses that can include errors in expectations.

We can also conduct comparative static analyses of both short- and long-run timeframes, along with (much less frequently) forward-looking or 'rational expectations' dynamic simulations that capture anticipation effects but that impose arguably unrealistic 'clarity of foresight' assumptions on simulation output.

Regional dimensions

We take a 'bottom-up' approach to examining how policy changes affect regional economies. This means we split the national economy into 8 regional economies (see Table 2), which are linked by origin-destination-tagged flows of final goods and services, intermediate goods and services, margins (e.g. transport, wholesale and retail trade), factor payments and labour.

[34] A novel feature of MDG-NZ is the inclusion of "slack capital" capabilities for dynamic projections using nested complementarity relationships. This allows for endogenously determined proportions of productive capital stocks and other "fixed" factors (like land and other natural endowments) to become idle at low rates of return during periods of falling demand. Along with the labour market treatment described above, the modelling suite is capable of more realistic dynamic simulations through the business cycle, tempering a standard dynamic CGE tendency to create unrealistically fast recoveries from downturns in response to low primary factor prices.

TABLE 3 REGIONAL AGGREGATION

Model region name	Regions
Auckland	Auckland
Northland	Northland
Waikato	Waikato
Bay of Plenty	Bay of Plenty
Central NI	Gisborne, Hawke's Bay, Taranaki, Manawatu-Whanganui
Wellington	Wellington
NMT_Canty_WC	Nelson/Tasman, Marlborough, Canterbury, West Coast
Otago_South	Otago, Southland

When a shock is introduced into one or more regions and relative prices change, resources are reallocated within each regional economy's industries and also across regional boundaries.[35]

There is no official input-output data available for New Zealand's regional economies. To create our own regional input-output tables, we start with the 2020 national level input-output table and use business demography data from StatsNZ to apportion (in shares) economic activity by industry across New Zealand's regions. Regional GDP (or Gross Regional Product) is consistent with StatsNZ's official estimates.

In lieu of official data to the contrary, we assume industry cost structures are broadly constant across regions.

The output of any industry within a region is consumed within that region or 'exported' outside of the region to be consumed by end users (including overseas buyers) or as intermediate inputs into other regional industries' production processes. As products move between regions, they attract transport, wholesale and/or retail margins, which are incorporated into purchasers' prices.

Firms seek to minimise production costs for any given level of output. Producer prices are equal to the marginal cost of production in each regional industry. Producer prices differ from purchasers' prices due to the presence of government taxes and margins.

Firms determine their input mix using a nested structure:

- The first nest is a bundle of intermediate inputs and a bundle of primary factor use (land, labour, capital, etc.) using a Leontief (fixed proportions) structure. This means that if output grows by x%, so too does the demand for the bundles of intermediates and factors of production.

[35] See Adams et al (2015) for a technical description of how a bottom-up regional module operates. MDG7-NZ shares many features of the VURM modelling framework, at least structurally, with both originating from the ORANI/MONASH models.

- The second level nest determines the mix of intermediate inputs between domestic inputs and inputs imported from overseas; and the split of primary factors across labour, land and capital.
- The third level nest determines where domestic intermediate inputs come from across the 8 regions. It also combines labour inputs across eight occupation types and different types of capital.

Factors of production are 'sticky' on a regional basis, apart from labour and capital, which can move across regional boundaries based on relative factor prices.

Inter-regional trade flows are determined based on regional industry structure, distance and prices of intermediate inputs and factor prices relative to their national averages. Given purchasers' prices include transport margins (which increase proportionally with distance), firms prefer to use inputs produced closer to their location, ceteris paribus.

Road and rail freight can be substituted for each other in margin demands, based on changes in the relative price of road relative to rail in each region.

Each regional industry faces its own downwards sloping export demand curve, so the only way to export more is to reduce export prices in foreign currency. It can choose whether to sell within its own region, 'export' to other domestic regions or export overseas.

Aggregate household spending is a function of aggregate household disposable income in that region. Households purchase goods and services from within their region and imports from other domestic regions and from overseas.

Regional labour markets can be examined in several ways, depending on the research question being considered. In this report we exogenously set regional labour supplies and unemployment rates and let real wage differentials clear the regional labour market.

Industry aggregation for this project

Our national database usually comprises 140 industries producing 220 goods and services (some industries produce more than product).[36] This allows an enormous degree of richness in designing CGE scenarios and analysing the results.

The trade-off – especially when we are essentially running 8 regional CGE models simultaneously – is the time required to run each dynamic scenario. As such, we aggregate some industries into broader aggregated sectors, reducing the 140 industries down to 72 sectors.

Much of this aggregation involves smaller industries that are less vital for this analysis (e.g. 'Religious services; civil, professional, and other interest groups' or 'Non-store and commission based retailing').

[36] See StatsNZ. 2021. 'National accounts input-output tables: Year ended March 2020'. https://www.stats.govt.nz/information-releases/national-accounts-input-output-tables-year-ended-march-2020/

We keep separated any industries that use rail freight intensively (forestry & logging, horticulture, dairy processing, etc.) or that provide inputs to the rail sector (e.g. construction, basic materials wholesaling, etc.) to ensure we can identify the important flow-on impacts of the proposed rail investments.

We are happy to provide our aggregation schedule on request.

Model closure

The closure of a CGE model refers to the elements that we tell the model about (**exogenous variables**) and those which we want the model to tell us about (**endogenous variables**).

In MDG-NZ the closure is extremely flexible, allowing us to incorporate a wide variety of inputs into simulations depending on the availability of data in a particular country, often including expert speciality forecasts from official or other expert sources.

We can adjust the closure assumptions from year to year, depending on the policy simulations we are considering. There is no need, for example, to assume full employment in all years.

The **deviation or 'policy' simulation** is the run that includes the shocks for the economic or policy experiment itself. The number of shocks can vary from a single shock to dozens or hundreds of shocks.

The results are reported as deviations – that is, as the difference between the baseline rerun results and the policy simulation results for each variable. This enables us to report results that capture only the impact of the experimental shocks themselves.

The policy simulation closure looks much more like a 'standard' economic closure. By this we mean that if we were to write down an economic model's equation in a standard theoretical manner, most of the left-hand side variables would be endogenous in the deviation simulation.[37]

Closure choice, across all simulation types, reflects choices about the economic environment and normally goes beyond a simple assessment of matching exogenous variables with shocks.

A full list of our closure choices for this project is available on request.

[37] There are some exceptions: for example, if a path has been endogenously generated for a certain productivity metric in the forecast, these results might be used as shocks in the deviation simulation if we believe that the nature of the experiment does not lead to additional productivity change. However, sometimes the deviation experiment does require further accommodation of shocks by productivity shifts, in which case we would leave it endogenous and report the difference between the baseline and deviation experiments.

Appendix C Baseline description

Projections timeframe

The major rail investments considered in this study take place between 2025 and 2051. They will generate ongoing benefits for passengers and freight users, plus emissions benefits, for decades to follow.

As such, and at the request of KiwiRail, we have modelled the economic and emissions benefits of the PBC out to 2100.

This introduces several caveats:

- By 2100, the economy is likely to look quite different to what we can realistically imagine now. What New Zealand firms produce and households consume will change over time. We cannot realistically capture such changes beyond a continuation of historical trends.
- Technological change will massively change the way we live, work and travel. For example, road transport is likely to be completely transformed once autonomous vehicles arrive. We do not attempt to forecast when this might happen.
- New Zealand's emissions profile is very hard to project after 2050. Official projections only go to 2050. Beyond this we need to make some simple assumptions about the emissions-intensity of output, technological change in fuel sources, and forestry removals.
- Demographic shifts (i.e. births and deaths) will lead to a rapidly ageing population and declining labour force.[38] This will make immigration policy important. But we can only make broad assumptions about net migration flows based on official population projections.

Economic projections for baseline

The economic baseline represents our best guess of what the economy will look like out to 2100 without the proposed rail investment.

Our standard approach for the baseline is to draw on official forecasts from Treasury. We use:

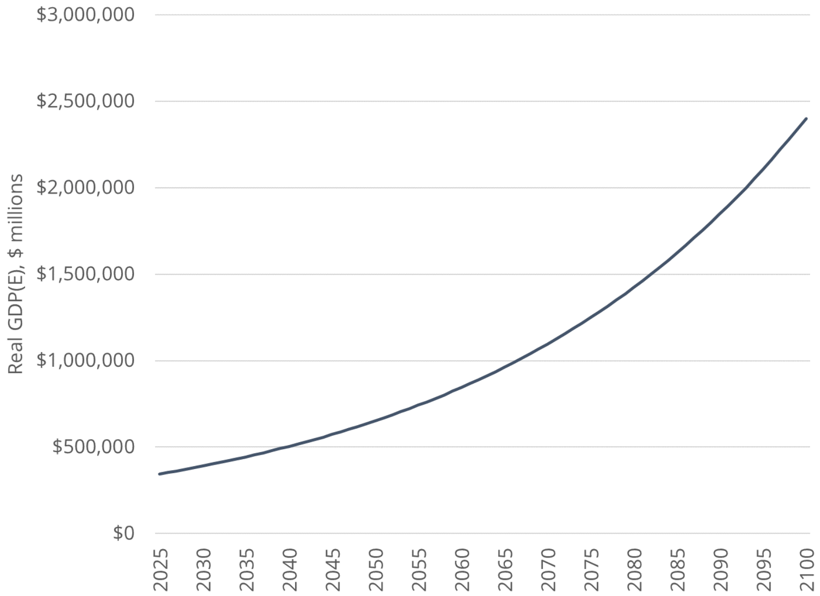
- Treasury's Budget Economic and Fiscal Update for the 2023-2027 period.
- Treasury's Long Term Fiscal Model, last updated in September 2021, for longer term projections out to 2060.

This effectively means we largely accept Treasury's view of the economic world out to 2060 as our baseline, including their and StatsNZ's projections of population growth, labour force growth, productivity, exchange rates, etc.

[38] See Sense Partners (2023).

Beyond 2060, no official economic projections exist, so we make assumptions around population growth, labour force growth and factor productivity to determine aggregate GDP.

FIGURE 62 BASELINE REAL GDP PROJECTIONS



SOURCE: TREASURY (2023); TREASURY (2021); MODELLERS' ESTIMATES

In the baseline, the composition of the economy changes over time in line with historical trends (e.g., growth in the share of personal services as incomes rise; decreases in the share of some manufacturing industries due to automation and global offshoring trends). We use professional judgement to moderate historical trends if they (for example) suggest an industry may cease to exist completely.

The regional economic baselines are consistent with the national macroeconomic projections and industry growth projections. Each region's economic growth is a function of national-level industry growth rates and the share of each industry in the regional economy.

Emissions baseline projections

Projecting emissions out to 2100 is challenging because it requires making multiple assumptions around the pace of emissions-reducing technological change in the absence of any new policies that might incentivise it. For example, we need to think about the likely pace of EV uptake, improvements in combustion engine fuel efficiency, shifts in the electricity generation mix, absorption from forestry sinks, generic emissions-reducing technologies, etc.

Economy-wide greenhouse gas emissions are initially generated from the baseline economic activity by industry projections, using emissions intensity coefficients, along with exogenously imposed energy efficiency improvements that largely reflect historical trends.

We then adjust aggregate gross emissions through technological change parameters to align with the Climate Change Commission's (CCC) 'Current Policy Reference' (CPR) track out to 2050 (CCC, 2022). We trend down agricultural emissions in line with the CPR track.

The baseline also draws on the CCC's projected NZU price for the CPR, at $35 real per unit.

The emissions baseline includes known emissions policies such as the Emissions Trading Scheme (ETS) but does not include 'step change' technologies such as hydrogen energy or electric planes, given uncertainty over their feasibility, effectiveness and timeframes.

Projected forestry removals for our baseline and policy scenarios were provided to us by Climate Forestry Association (CFA) for a previous consulting project.

Beyond 2050, no official projections are publicly available. We assume New Zealand reaches net zero for long-lived gases around 2050 and stays there, such that the remaining carbon dioxide emissions are exactly offset by forestry removals. Biogenic methane emissions are reduced to be broadly consistent with the legislated New Zealand domestic target of a 24-47% reduction from 2017 levels.

Note these emissions projections do not get to net zero of long-lived gases by 2050, largely because the net zero goal will rely on as-yet unannounced policies and technological breakthroughs. This is consistent with the Ministry for the Environment's projections.[39]

To proxy an emissions cap, we hold economy-wide emissions covered by the ETS constant at the baseline level for all scenarios. Emissions are able to move between covered sectors as output expands or contracts in the policy scenarios, but aggregate ETS emissions do not change between the baseline and policy scenario. Agricultural emissions are not constrained.

The emissions price varies to ensure the demand and supply of emissions units balances.

[39] MfE (2022) notes "The projections scenario presented on this webpage assumes only existing policies. These projections do not capture most of the new policies included in New Zealand's first emissions reduction plan (ERP), released in May 2022".

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