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The economic impact of increased irrigation

A dynamic Computable General Equilibrium analysis of increased irrigation in New Zealand

Final Report to Ministry of Agriculture and Forestry

9 November 2010

About NZIER

NZIER is a specialist consulting firm that uses applied economic research and analysis to provide a wide range of strategic advice to clients in the public and private sectors, throughout New Zealand and Australia, and further afield.

NZIER is also known for its long-established Quarterly Survey of Business Opinion and Quarterly Predictions.

Our aim is to be the premier centre of applied economic research in New Zealand. We pride ourselves on our reputation for independence and delivering quality analysis in the right form, and at the right time, for our clients. We ensure quality through teamwork on individual projects, critical review at internal seminars, and by peer review at various stages through a project by a senior staff member otherwise not involved in the project.

NZIER was established in 1958.

Authorship

Prepared by:	Dr Bill Kaye-Blake, Chris Schilling, James Zuccollo
Quality approved by:	John Ballingall
Date:	6/05/2011 12:31 p.m.
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Acknowledgements:	Expert agricultural advisory group including Andy MacFarlane, Hugh Eaton, Grant Pechey, Ian Millner, Simon Harris, Nick Dalgety Gillian Mangin, Darran Austin, Kevin Steel and Richard Lynch. Treasury Infrastructure representative Dieter Katz.

8 Halswell St, Thorndon
P O Box 3479, Wellington
Tel: +64 4 472 1880
Fax: +64 4 472 1211
econ@nzier.org.nz
www.nzier.org.nz

Key points

Modelling an increase in irrigation

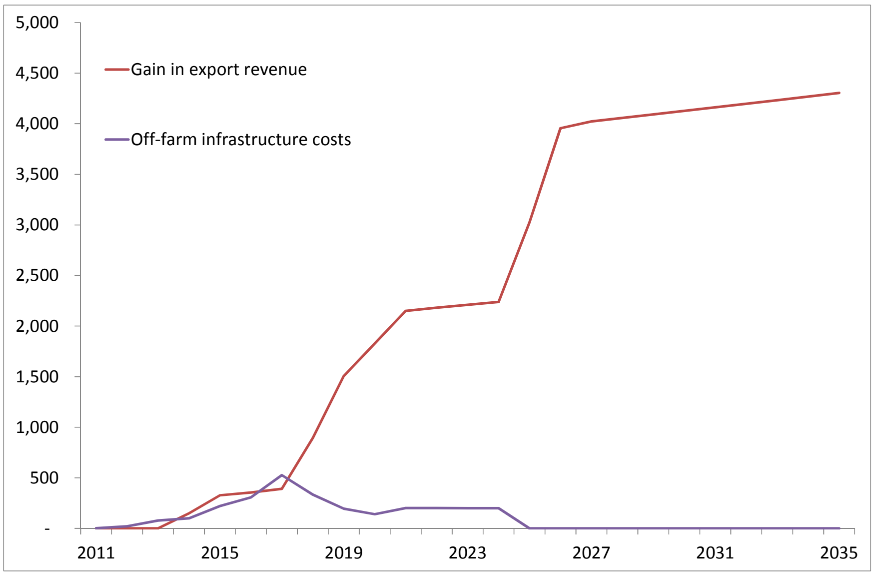
- NZIER have been commissioned by MAF to estimate the economic impact on 'NZ Inc' of 14 irrigation schemes that will deliver an increase in irrigation area of 347,000 hectares, predominantly in the Canterbury and Hawkes Bay regions.
- The increase in irrigation impacts the economy in three key ways: first, there is an increase in off-farm capital infrastructure costs; second, there is an increase in on-farm capital costs, and third, there is an increase in agricultural production due to a move towards irrigated agriculture.
- We developed the following assumptions with MAF and industry experts:
  - Off-farm infrastructure costs will peak at $527 million in 2017, and cost in total $2.7 billion. This is financed through government borrowing at seven per cent interest per annum, and repaid in five years upon completion of the last irrigation scheme.
  - Amortised annual on-farm infrastructure costs are estimated at 37 per cent of the irrigated farm gross revenue[1].
  - Land-use change generates a net revenue gain of approximately $6,000 per hectare in Canterbury and $1,300 per hectare in Hawkes Bay at the farm-gate. The increased agricultural output is processed and exported at the world market price. By 2035, irrigation has increased agricultural exports by $4 billion, in real 2010 prices (i.e., inflation removed). This would be a significant increase on the $23 billion in agricultural and horticultural exports from New Zealand in 2008-09[2].

[1] This is the total percentage of capital costs for the irrigated farm sector excluding any capital already utilised within the non-irrigated sector. The net capital percentage, deducting existing capital, is 25%.

[2] Export figure obtained from www.maf.govt.nz/statistics/international-trade/, accessed 9 November 2010.

Figure 1 Costs of off-farm infrastructure and gains in export revenue

$NZ million



Source: NZIER

- We employ NZIER's MONASH-NZ dynamic CGE model of the New Zealand economy to evaluate the impact of the above shocks on the wider 'NZ Inc'. CGE modelling, in contrast to cost-benefit analysis, explicitly considers impacts on exchange rates, net foreign liabilities and the current account balance, as well as the impacts on factor prices and indirect impacts on other industries. This is particularly important when considering large export shocks such as this.

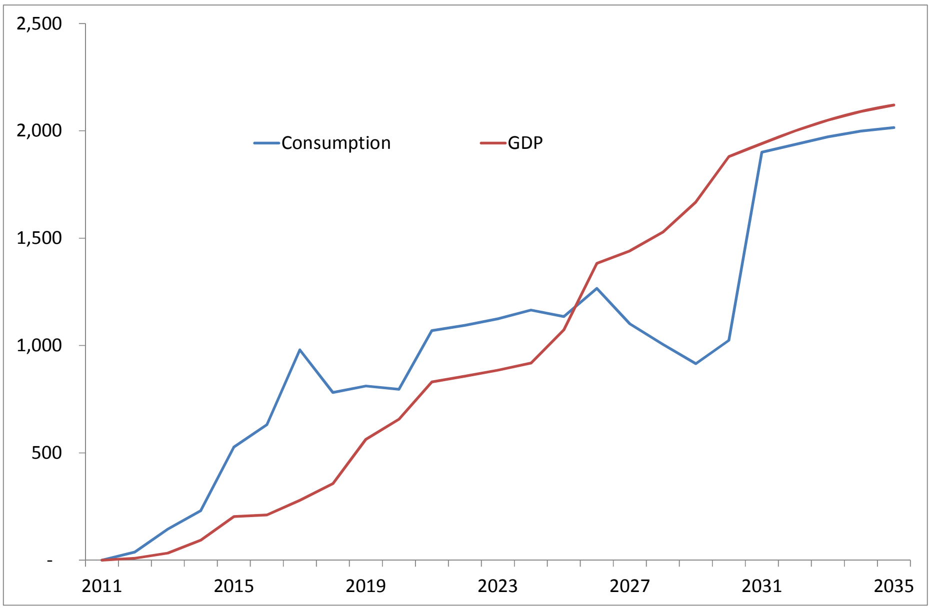
Impact on 'NZ Inc'

We use GDP and consumption figures to summarise the impacts of the economic changes. GDP measures total production in the economy. Consumption is GDP less repayments of overseas borrowing and the opportunity cost of investment, and measures how much money is available for New Zealand consumers to spend. We find that the increased irrigation:

- Increases 2035 GDP by 0.8% over what it otherwise would have been.
- Increases consumption in 2035 by $2 billion.
- Over 25 years, generates a present value consumption gain of $8 billion.
- Creates a fall in consumption between 2025 and 2030 to pay for the offshore borrowing for the off-farm infrastructure investment.

Figure 2 Economic gains resulting from increased irrigation

$NZ million



Source: NZIER

Sector breakdown

- The gains accrue predominantly to the farm sector. The farm sector gains from becoming more productive. Irrigation makes water available to farmers who combine it with existing land and increased capital to produce greater value output.
- The off-farm processing industry expands in line with the farm sector. The sector increases its size relative to other parts of the economy. In addition, it pays higher-than-average wages and returns to capital to attract resources from other sectors.
- In the rest of the economy, there are positive and negative impacts. There are positive flow-on effects to industries that supply agriculture and processing sectors, and to industries that rely on household expenditure. There are negative flow-on effects as the expanding agricultural sectors draw resources away from other sectors, pushing up prices for factors and intermediates. These dynamic adjustments of capital and labour take place over time, rather than as instant reallocation of resources. The net impact on the economy outside the agriculture and processing sectors is somewhat negative.

Impact on foreign liabilities

- The increased agricultural exports leads to a currency appreciation, as overseas consumers demand New Zealand dollars to pay for the increased exports. A stronger New Zealand currency reduces the local-currency value of interest repayments on our foreign debt.
- Despite foreign debt increasing as investment flows into the farm and processing sectors, New Zealand’s net foreign liabilities to GDP ratio improves marginally over the 25 years out to 2035. This is analogous to an increase in foreign direct

investment in New Zealand. The growth in GDP allows us to fund increased overseas borrowings which grows the domestic capital stock.

Robustness of results

We completed sensitivity testing of the key parameters and assumptions to test the robustness of results. We find that:

- Reducing the returns to irrigation by 20 per cent (for example, assuming lower yields or prices for dairying) has a relatively direct negative impact on the net present consumption gains which fall by around $2 billion (25 per cent). The productivity gains that irrigation unlocks are the key drivers of the overall results. As that gain decreases, so too does the NZ Inc. benefit of investing in irrigation schemes.
- Excluding the Lees Valley (120,000 hectares) and Wairarapa Stages 1-3 (total of 30,000 hectares) from the analysis reduces net present consumption gain by about $2.5 billion.
- Increasing off-farm capital costs by 25 per cent has a relatively minor impact on the NZ Inc net present consumption results (-$100 million). The increased debt costs are small relative to the gain in productivity unlocked by irrigation.
- Wholly funding the on-farm infrastructure investment from domestic sources (rather than ~60 per cent) reduces the net present consumption benefit to NZ Inc by around $1.5 billion (-20 per cent), as funding is diverted to savings and investment rather than current consumption.

The sensitivity analysis suggests the key results are robust to reasonable changes in our input assumptions. We conclude that on balance the irrigation schemes as modelled here provide a significant positive benefit to NZ Inc.

Contents

Appendices

Figures

Tables

1. Introduction

1.1 What we were asked to do

This project seeks to estimate the national 'NZ Inc' economic impacts of increasing irrigation in Canterbury, Wairarapa, Waimea and Hawkes Bay by a total of 347,000 hectares.

Significant off-farm capital investment is required to provide the irrigation water. Once water is flowing, land-use change from non-irrigated to irrigated will deliver gains in agricultural production, however require extra on-farm capital investment in irrigation systems. The task of this project is to estimate the impact of these changes on the national economy. The Ministry of Agriculture and Forestry (MAF) asked for this analysis to be completed using a Computable General Equilibrium (CGE) model which captures the flow-on impacts of the increased irrigation across the wider economy.

This project does not attempt to quantify the environmental, social or regional impacts of the irrigation schemes. Similarly, we do not attempt to investigate the relative merits of public versus private sector funding of the schemes.

1.2 How we conducted the analysis

The core of the research is the MONASH-NZ dynamic CGE model of the New Zealand economy. CGE modelling is a highly-respected and well-developed technique that has a rich history for assessing policy, national and industry questions. The MONASH-NZ model was developed in close collaboration with the Centre of Policy Studies at Monash University, a global leader in building and applying CGE models. It captures the various inter-linkages between sectors, as well as their links to households (via the labour market), the government sector, capital markets and the global economy (via imports and exports). This contrasts with partial equilibrium methods such as Cost Benefit Analysis, which consider only direct impacts on an industry or firm.

To model the economic impact of increasing irrigation, we required detailed data on:

- Off-farm capital costs for each scheme
- Industry structure (including the on-farm capital cost component) of the irrigated agricultural sector
- Estimated change in land-use and agricultural production as a result of irrigation
- Timing of the schemes.

The MAF provided detailed off-farm capital costs, timing and expected irrigation areas for each scheme. MAF and agricultural industry experts from Hawkes Bay and Canterbury provided farm-level information and estimates of changes to the land-use as a result of irrigation.

We converted this information into ‘shocks’ for the model which we used to estimate the national impacts of irrigation.

2. Background on irrigation

2.1 The vision for water

Water is a natural resource. Importantly, it is 'a finite but renewable resource' (Regional Affairs Committee, 2010, p. 4). Because it is a limited resource, it has to be allocated amongst potential uses or users. Discussions of how to manage the potential conflicts have led to several vision statements for water management.

One such vision comes from the Canterbury Water Management Strategy:

> *To enable present and future generations to gain the greatest social, economic, recreational and cultural benefits from our water resources within an environmentally sustainable framework.*

Other similar visions substitute 'environmental' for 'recreational'.

The Ministry for the Environment offered a more succinct vision: 'The Government wants to ensure that fresh water contributes to New Zealand's economic growth and environmental integrity' (p. 1).

These visions recognise that water has many uses, and recognise the trade-offs across these uses or across generations. This is how economic analysis can help: a central topic in economics is allocation of scarce resources amongst competing uses.

2.2 Water and infrastructure

Water by itself is largely unavailable for people to use. For drinking, cooking, and domestic uses, water gets piped into houses. For agricultural or industrial uses, water is diverted from its natural location in rivers and aquifers to the farm or factory. For recreational uses, water may be brought to users, as in public swimming pools. Alternatively, access may be created so that users can access the water, such as roads built to access lakes or streams.

Thus, infrastructure is necessary for water to be useful, and water or access to it must be managed.

The New Zealand National Infrastructure Plan (2010) clearly sets out the goals of infrastructure in general, and also discusses rural irrigation. Infrastructure policy is clearly focused on productivity growth and high levels of employment. The Government is of the view that poor infrastructure is 'holding New Zealand back' (p. 3), and therefore needs improvement.

However, appropriate infrastructure spending requires careful consideration. The overarching message from Treasury is that infrastructure decisions should be made based on cost-benefit analysis (Treasury, 2009). Projects that do not sufficiently contribute to national benefit should not be undertaken.

The Land and Water Forum (2010) expressed both the desire for infrastructure and the need to 'get it right':

> *Because such infrastructure is long-lived, it needs to be done well the first time, and therefore needs to be thought of strategically. Developed in the right place and with the right incentives, it can facilitate economic growth, produce energy savings, reduce contamination of waterbodies, and allow the replenishment of aquifers and the restoration of streams.(150, p. 40)*

2.3 Water in five dimensions

Before we can decide whether we are getting water and its infrastructure right, we have to decide what we want to accomplish. For New Zealand policy, the core concepts are summarised in the Local Government Act of 2002 (Saunders and Dalziel, 2004) and have been further developed. The impacts of policy should be considered along five dimensions: cultural, ecological, economic, social, and governance.

There are clear echoes of these dimensions and the Local Government Act in water policy. The Canterbury Water Management Strategy (2009, pp. 6-7) lists many features of a successful water strategy, with elements drawn from all five dimensions. It further (p. 89) sets out the region's water assets in a table whose headings are Social, Economic, Environmental, and Cultural. The Strategy addresses these different dimensions. For example, it indicates the current water use is creating environmental pressure and that water issues are important to Ngāi Tahu (p. 5).

At the national level, Government policy is also linked to these dimensions. The Minister for the Environment, the Hon Nick Smith, addressed these dimensions in a speech of 8 June 2009. In setting out the agenda for fresh water reform, he summarised the Government's reform agenda with five points:

- Linkages between economic and environmental policies
- Collaborative environmental governance
- Leadership role of the central government
- Scientific and technical underpinnings of policies
- Enhanced role for Maori.

The Cabinet paper released at the same time stated:

> *The aim is to get the "best value" for society from New Zealand's water resources, now and in the future. The concept of "best value" needs to be determined by looking across economic, environmental, social and cultural dimensions, and by weighing up individual, local and national interests (Office of the Ministry for the Environment and Office of the Ministry of Agriculture and Forestry, 2009, 20).*

2.4 The economic dimension

This report focuses on the economic dimension of water. Specifically, it focuses on the economic contribution that increased irrigation could make. Making more water available for irrigation will require increased management of water resources and increased infrastructure.

The Treasury paper on infrastructure (2009) provided a brief history of rural water infrastructure in New Zealand. It stated that there were over 500,000 hectares of irrigated land in New Zealand in 2000, about 350,000 hectares of which were in Canterbury (p. 54). The National Infrastructure Plan updated those figures to 2009, when there were an estimated 550,000 hectares of irrigated land. Much of the irrigation was initially built with public resources, but now has been privatised.

Access to water creates an economic benefit because it allows agriculture to be more productive. Farmers are able to produce more commodities and high-valued produce. The increased control over water availability also reduces the impacts of droughts. As a result, farmers are a major beneficiary of irrigation schemes.

Because major benefits of water infrastructure accrue to private individuals, Treasury stated that 'funding for additional projects needs to come from the private sector' (2009, p. 12). This position fits with the general user-pays approach of the New Zealand government.

However, there are arguments for not leaving provision of irrigation infrastructure to private interests. Treasury suggested that potentially economically viable projects may not be built, for several reasons. These included planning issues, failure to co-ordinate stakeholders, and lack of finance due to uncertainty (Treasury, 2009, p. 57). The National Infrastructure Plan repeated many of the same points (2010, p. 128).

These are well-known economic issues that can lead to difficulties with the private sector providing a specific good or service. For example, where a large number of people needs to be co-ordinated, the cost of co-ordination through discussions and contracting can be larger than the economic benefit created. Public provision can overcome the co-ordination costs.

Both governmental and non-governmental bodies recognise these issues around irrigation. The Land and Water Forum, for example, suggested that public financing may be appropriate for irrigation projects (160). Treasury acknowledged that, although users of irrigation should be charged (2009, p. 14), there could be a role for government in clearing the way for appropriate schemes (2009, p. 8-9). In particular, the central government can support science and technology and planning and proposals through the Sustainable Farming Foundation and the Community Irrigation Fund.

2.5 Potential economic contribution

Irrigation can create economic value by increasing agricultural production. The agricultural sector has made water a focus. The Primary Sector Water Partnership, including Fonterra, the Foundation for Arable Research, Beef and Lamb NZ, and Federated Farmers, has stated that it wants to promote both production and the environment.

The Government is keen to see irrigation schemes move forward (National Infrastructure Plan, 2010, p. 128). The Government has indicated in a number of documents that it is willing to support irrigation that is economically beneficial. This support could take the form of removing planning or legislative hurdles; providing co-ordination of stakeholders; and potentially becoming involved in financing. The key, however, is that projects must be shown to be economically beneficial (National Infrastructure Plan, 2010, p. 128). In addition, the direct beneficiaries of irrigation would still be expected to contribute to paying for irrigation (Treasury, 2009).

The issue facing Government, and the subject of this research, is understanding the potential economic contribution of irrigation at the national level. Irrigation is expected to lead to increased output from the agricultural sector. However, the economic impacts could accrue more widely in New Zealand, and could justify government involvement.

Careful economic analysis is therefore required. Once the economic impacts are established, the Government can decide its appropriate role in developing irrigation infrastructure.

3. Proposed irrigation schemes

3.1 Schemes in the analysis

We consider 14 proposed schemes that will irrigate a total of 347,000 hectares across Canterbury (270,000 hectares), Hawkes Bay (41,000 hectares) and the Wairarapa (30,000 hectares) and Waimea (6,000 hectares). The schemes are considered most likely to be implemented by MAF.

3.2 Timeline for the schemes

The schemes are planned to be implemented over the next 15 years according to Table 1.

Table 1 Irrigation schemes

Scheme	Area (Ha)	First water flows
Waimea East	6,000	2014
Te Pirita Irrigation Ltd - (CPW Stage 1)	6,000	2013
TrustPower Coleridge Stage 1 (includes CPW Stage 2)	20,000	2013
Hawkes Bay Ruataniwha Stage 1	17,000	2015
Hawkes Bay Ngaruroro	10,000	2016
Hunter Downs	40,000	2017
TrustPower Coleridge Stage 2 (provides CPW Stage 3)	42,000	2017
Hawkes Bay Tutaekuri	8,000	2018
Hurunui - Waiau New Option	42,000	2019
Hawkes Bay Ruataniwha Stage 2	6,000	2019
Lees Valley	120,000	2022
Wairarapa Stage 1	14,000	2018
Wairarapa Stage 2	8,000	2022
Wairarapa Stage 3	8,000	2024

Source: MAF

4. Method for this analysis

4.1 CGE modelling

4.1.1 What MONASH-NZ does

The MONASH-NZ dynamic CGE model contains information on 131 industries and 210 commodities in its basic form. CGE modelling is a highly-respected and well-developed technique that has a rich history for assessing policy, regional and industry questions. Our model was developed in close collaboration with the Centre of Policy Studies at Monash University, a global leader in building and applying CGE models. It captures the various inter-linkages between sectors, as well as their links to households (via the labour market), the government sector, capital markets and the global economy (via imports and exports).

The agricultural sector interacts with the rest of the economy by generating exports and employment, using intermediate inputs such as fertilizer, and competing for use of land, labour and investment. In order to get a sense of how the New Zealand economy as a whole might be impacted by irrigation schemes that allow for large scale production changes within the agricultural sector, we need to use an economic model that takes these interactions into account. We use NZIER's dynamic Computable General Equilibrium (CGE) model of the New Zealand economy to evaluate the impacts of both the construction of capital infrastructure required for the irrigation schemes, and the expected agricultural production changes. More detail about the model is provided in Appendix A .

4.1.2 Advantages of CGE modelling

Our dynamic CGE model is a more robust framework than alternative approaches for estimating the contribution of the irrigation schemes to the New Zealand economy. The most commonly used alternatives are input-output (IO) or 'multiplier' analysis and Cost-Benefit Analysis (CBA). Both of these methodologies typically do not consider:

- Macroeconomic impacts on exchange rates, net foreign liabilities and the current account balance. These are particularly important for analysis such as this where all of the extra production is exported, and explicitly captured within CGE modelling.
- Economy dynamics. The MONASH-NZ dynamic CGE model explicitly models how employment and wages respond to labour demands (assumption of sticky-wages in the short-run), investment responds to rates of return, and how New Zealand's net investment/savings imbalance increases or decreases net foreign liabilities. Neither CBA or IO analysis consider these dynamics.

CBA analysis is limited by an inability to consider wider flow-on effects:

- As a partial equilibrium tool, CBA does not consider impacts on factor prices, nor the flow-on effects to other industries. These are important when considering wider economic impacts to supplying industries, households and industries that rely on household expenditure, competing industries and the government sector.

IO multiplier analysis by contrast can capture the indirect linkages between industries, but fails to consider the opportunity cost of resources or impacts on factor prices:

- Multiplier analysis assumes that resources (land, labour, capital, energy, intermediate inputs) are available in unlimited quantities for the expansion of a sector. It does not consider how those resources might otherwise have been used in the economy – their opportunity cost. Similarly, it assumes that wage rates do not change as the demand for labour rises or falls, and that the prices of intermediate goods such as transport and business services do not change in response to shifts in demand. In reality, if there is additional demand for workers in the agricultural sector, this will place upward pressure on wages across the economy.

Multiplier analysis therefore tends to vastly overstate the economic impacts of changes in demand in a specific sector. These unrealistically large impacts are thus not particularly informative for policy makers or firms. Cost-Benefit Analysis by contrast tends not to consider how an industry or project impacts on the wider economy.

CGE models are by definition general (covering the whole economy) and explicitly address both resource allocation and relative price shifts. This allows for a more credible, richer analysis of economic contribution. See Appendix B for further discussion.

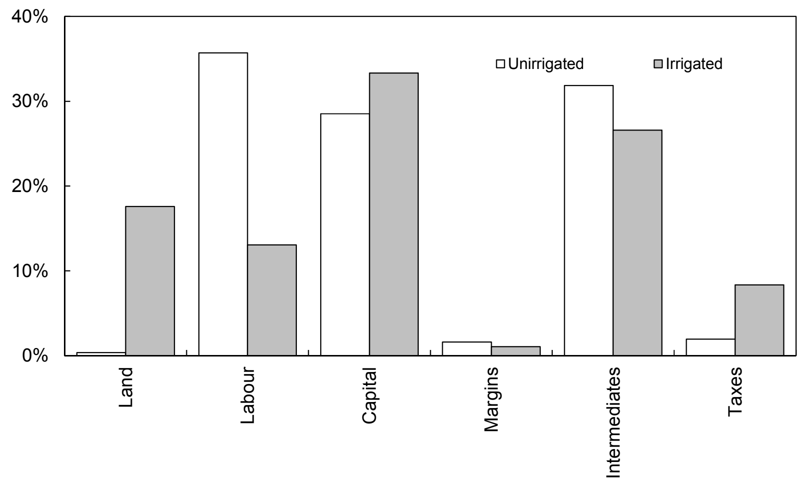
4.2 Tailoring the model database

We tailor the model for this analysis by modifying the database. The irrigation schemes will lead to a change in land-use and a change to the structure of the agricultural sectors within the irrigation area. As the first water flows from the irrigation schemes, the new irrigated sector expands while the unirrigated sector contracts. By specifically splitting out these industries, we can more accurately account for the flow-on impacts on upstream sectors, and the increased demand for on-farm irrigation capital for the irrigated sector.

To do this, we create a new farming industry that is representative of the irrigated sector. Figure 3 indicates the industry structures of irrigated and unirrigated agriculture, and the differences between the two. The irrigated and non-irrigated sectors make different use of the inputs to production: land, labour, capital, and intermediate goods (e.g., fertiliser, seed, electricity). For example, on a percentage basis, labour costs are a larger portion of production costs for unirrigated farms than irrigated farms, whereas the reverse is true for capital costs. By tailoring the model database, we take account of the different input structures for the two types of agriculture.

Figure 3 Industry structure

Per cent of total costs



Source: NZIER

4.3 Developing the simulations

We use the CGE model to compare a world with the irrigation schemes against a world without the schemes. For the baseline economy without the schemes, we use NZIER's Quarterly Predictions to project the economy forward 25 years. In the following sections we calculate the differences that the irrigation scheme imposes on the economy. First, there is the increase in off-farm capital infrastructure costs. The simulations include only the capital cost of off-farm irrigation, not its on-going operating costs. Second, there is in the increase in on-farm capital costs, and third, there is the increase in agricultural production due to a move towards irrigated agriculture.

We explain the simulation development for each of these in the following sections.

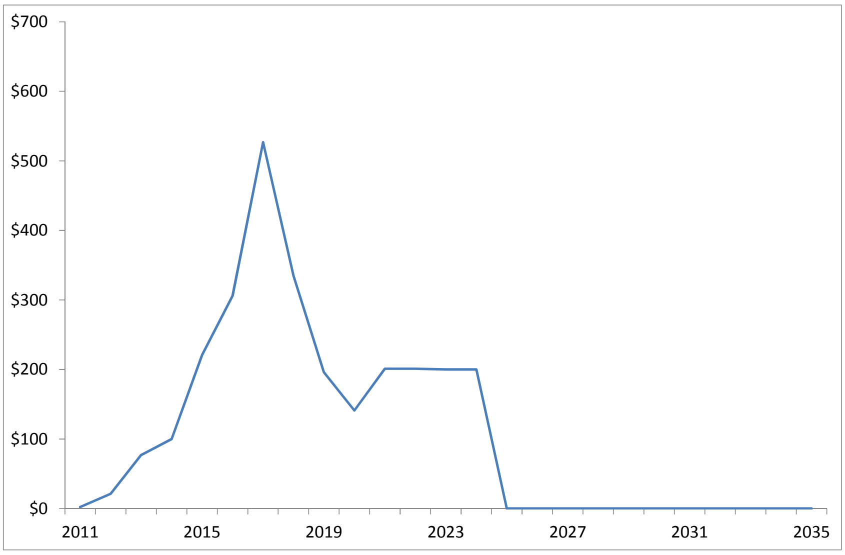
4.3.1 Capital impacts of irrigation

a) Off-farm infrastructure

We model the off-farm infrastructure as capital expenditure in non-residential construction. The costs peak in 2017 at $527 million, and total $2.7 billion across all schemes. With the dynamic model, we are able to explicitly impose these shocks into the economy each year as per Figure 4. The expenditure is financed through offshore borrowing which is paid back in five years after completion of the last irrigation scheme. Interest is paid on the foreign debt at 7 per cent per annum.

Figure 4 Off-farm infrastructure costs

$NZ million



Source: MAF

b) On-farm infrastructure costs

The on-farm infrastructure costs are calculated by taking an average of the capital costs across all land types weighted by land area, from farm budgets provided by MacFarlane Rural Business Ltd. They are incorporated into the structure of the agricultural industries as amortised annual capital payments[1]. Once amortised and included in farm budgets as a capital expenditure, on-farm irrigation costs account for around 37 per cent of the farm industry's gross output[2]. For the sector to expand, it

[1] Amortised over 20 years at 10 per cent. The 20 year period was chosen to be representative of the lifespan of an average irrigation system.

[2] This is the total percentage of capital costs for the irrigated farm sector excluding any capital already utilised within the non-irrigated sector. The net capital percentage, deducting already existing capital, is 25%.

must invest in on-farm capital. This can be financed from both domestic and overseas markets.

Table 2 On-farm irrigation costs

Costs in NZ$, area in hectares

	Land area converted	Total capital cost over all land converted	20yr amortised annual cost
Dairy	148,000	4,906,510,800	$576,316,918
Mixed livestock (50% irrigated)	111,000	813,036,150	$95,498,921
Arable & process crop (irrigated)	92,500	1,271,875,000	$149,393,960
Arable (unirrigated)	24,050	76,960,000	$9,039,693
Dairy support (part irrigated)	109,150	835,543,250	$98,142,597
Horticulture	14,800	820,445,161	$96,369,181
Total	499,500	8,724,370,361	$1,024,761,269

Source: Macfarlane Rural Business Ltd, NZIER

4.3.2 Increased agricultural production

Irrigation provides water for farming, which can allow land to be more productive. To model the impact of irrigation on agricultural production, we needed estimates of the increase in productivity. We worked with experts in the rural sector, including agricultural consultants and MAF personnel, to estimate the change in agriculture from irrigation.

The irrigation schemes being assessed are in two areas of New Zealand: Canterbury and Hawkes Bay. Current agriculture production is different in these regions, and would be affected differently by irrigation. The impacts were therefore estimated separately.

a) Canterbury

The data for Canterbury were provided by MacFarlane Rural Business Ltd. The data provided included farm budgets for different types of farms, with information on production quantities, gross revenues, production costs, and capital costs. The pre-irrigation situation was assumed to be a dryland sheep farm producing sheep, wool, wheat, and barley. With irrigation, the land was assumed to convert to several different types of well-managed and highly productive farms:

- dairy

- mixed sheep and cropping
- arable and process crops
- dairy support
- horticulture.

All farms produce more than one commodity. Because the change in farm types did not map one-to-one onto commodities, the irrigated area was treated as an aggregate of all the farm types. Table 3 provides the data used for modelling the irrigated area. It provides the value of production before and after irrigation. The figures provided MacFarlane Rural Business Ltd were based on an irrigated area of 370,000 hectares and an additional area of impact due to increased dairy support farming on dryland farms, for a total area of impact of 499,500 hectares. Note that the 370,000 hectares used here is greater than the expected irrigated area associated with the schemes in this project, however it is used to calculate the per hectare impact of irrigation. We then apply this to the 270,000 hectares in Canterbury covered by the schemes in this project.

Starting with the pre-irrigation figures, Table 3 uses the data for 370,000 hectares, and then increases the figures to account for the full area of impact. The final column for the pre-irrigation situation indicates that $436 million of sheep and arable farming would be displaced by irrigation. The post-irrigation columns provide the figures for the production that would happen on that area. By value, about half the production would be dairying, the next largest commodity would be grain and pulses (including vegetable seeds), and other commodities would also be produced.

The net impact of irrigating 370,000 hectares in Canterbury, including the added production from non-irrigated land, was estimated to be $2.43 billion in added farm-gate production. Per hectare of irrigated land, the increase is $6,028. Most of this increased production comes from the irrigated area. A small part of the increase comes indirectly from increased production on unirrigated land, which shifts from poorly performing sheep farming to more-productive dairy support.

Table 3 Production change in Canterbury from irrigation

Gross revenue

Commodity	Pre-irrigation --- For 370,000 ha --- Production ($000) (1)	Less stock purchases ($000) (1)	Total ($000) (1)	For 499,500 ha A Total ($K)	Post-irrigation --- For 499,500 ha --- Production ($000) (1)	Less stock purchases ($000) (1)	B Total ($000) (1)	Net impact (B-A) ($000)	Net impact per irrigated ha (2)
Sheep	$188,836	-$3,415	$185,421	$250,318	$235,441	-$105,026	$130,415	-$119,903	-$324
Wool	$31,979		$31,979	$43,172	$14,095		$14,095	-$29,077	-$79
Cattle			$0	$0	$59,914	-$5,550	$54,364	$54,364	$147
Milk			$0	$0	$1,312,669		$1,312,669	$1,312,669	$3,548
Grain and Pulse	$95,403		$95,403	$128,794	$750,421		$750,421	$621,627	$1,680
Small seeds			$0	$0	$111,443		$111,443	$111,443	$301
Miscellaneous	$10,626		$10,626	$14,345	$293,750		$293,750	$279,405	$755
Total	$326,844	-$3,415	$323,429	$436,629	$2,777,733	-$110,576	$2,667,157	$2,230,528	$6,028

Notes: (1) Source: MRB, Farm financial models with and without irrigation, October 2010.

(2) Calculated as the net impact on the regional hectares divided by the number of irrigated hectares (370,000).

Source: NZIER

Table 4 Production change in Hawkes Bay from irrigation

Gross revenue

Farm type	Pre-irrigation: Percent of area	Pre-irrigation: Production per hectare	Pre-irrigation: Description	Post-irrigation: Percent of area	Post-irrigation: Production per hectare	Post-irrigation: Description
Dairy - irrigated	4.0%	$7,150	1300 kgMS/ha at $5.50/kg	20.0%	$7,150	1300 kgMS/ha at $5.50/kg
Sheep	25.0%	$960	$80 per SU and 12 SU/ha	20.0%	$1,600	$80 per SU and 20 SU/ha
Beef	32.0%	$2,292	$191 per SU and 12 SU/ha	20.0%	$3,820	$191 per SU and 20 SU/ha
Dairy support	2.0%	$0		10.0%	$0	
Cropping	35.0%	$2,000	$400/t and 5t/ha	20.0%	$2,800	$400/t and 7t/ha
Horticulture - irrigated	2.0%	$2,520	$420/t and 6t/ha processing peas	10.0%	$2,520	(1)
Total	100.0%			100.0%		
Weighted average production ($/ha)		$2,010			$3,326	
Impact of irrigation per hectare	$1,316					

Sources: NZIER, Nick Dalgety.

b) Hawkes Bay

The impacts for Hawkes Bay were calculated using a different method. We consulted with agricultural consultants and MAF personnel to obtain estimates of the current land use in Hawkes Bay and how it would change with irrigation. The information we obtained is provided in Table 4. The information included the percentage of land that would be used to produce each of the commodities shown, and the production per hectare of the land with and without irrigation. The base information used to produce the production figures are also given in the table.

Table 4 captures two sources of change from irrigation: improved productivity and change in commodity produced. In the pre-irrigation situation, the area has about one-third of production in cropping and beef each, and another quarter in sheep. The rest contains small percentages of dairy, dairy support, and horticulture. Post-irrigation, land use is expected to shift in 20% each of dairy, sheep, beef, and cropping, with 10% in dairy support and horticulture. In addition, sheep and beef farms are expected to carry more stock units, and cropping is expected to yield more.

We have calculated weighted averages for the area before and after irrigation, multiplying the production per hectare by the percentage of the area in the commodity. We calculated that the irrigated area would go from producing $2,010 per hectare to producing $3,326 per hectare, an increase of $1,316 per hectare.

The increase in production in Hawkes Bay is much lower than the gain in Canterbury. We believe that this reflects two things. First, the pre-irrigation scenario in Hawkes Bay was more productive that in Canterbury. Our information from agricultural consultants suggested that the productivity of unirrigated land is higher in Hawkes Bay than Canterbury. Secondly, the two figures were produced with different methods. The Canterbury figures were produced with farm financial and production budgets, and were estimated to represent the experience of actual farms. Importantly, farms were engaged in co-production of several commodities. The Hawkes Bay figures, by contrast, were estimated by applying representative production figures to land areas producing single commodities. The difference between the Canterbury and Hawkes Bay figures is both a result of the reality of farming in the two areas and an artefact of the method of analysis.

The impacts for this analysis on 'NZ Inc' are that the Hawkes Bay contribution is likely to be an underestimate. However the understatement is not material for the nationwide assessment of irrigation because the Hawkes Bay area is only 20% of the total planned irrigation area.

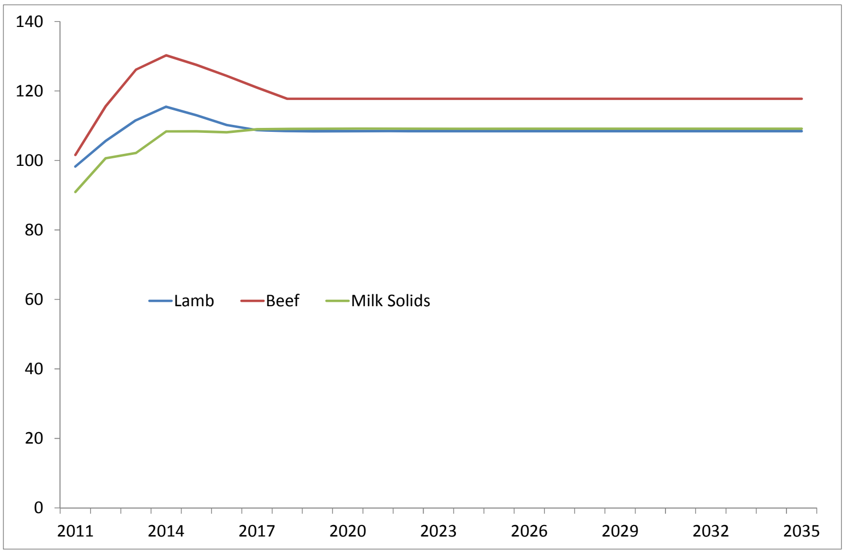
c) Price projections

In the previous sections, we calculated the net gross revenue gain from irrigation. The calculations are based on 2010 price and yield assumptions. We must also consider how the net revenue gain from irrigation changes over the next 25 years due to price and yield growth.

MAF provided real price projections for the key agricultural commodities out to 2020. For the periods after that, and for commodities where no price projections are available, we assume constant real prices.

Figure 5 Commodity price projections

Real price index (2010 = 100)



Source: MAF, NZIER

d) Yield projections

MAF provided yield growth trends for the key agricultural commodities from 1990 to 2025. We use the average values for growth in yields. Where no information was available, we assumed 0.5 per cent annual growth. These yield projections were used for both the irrigated and unirrigated areas[1].

Table 5 Yield growth

Average per annum 1990-2025

Commodity	Growth
Sheep	0.9%
Beef	0.6%
Dairy	1.1%
All other	0.5%

Source: MAF, NZIER

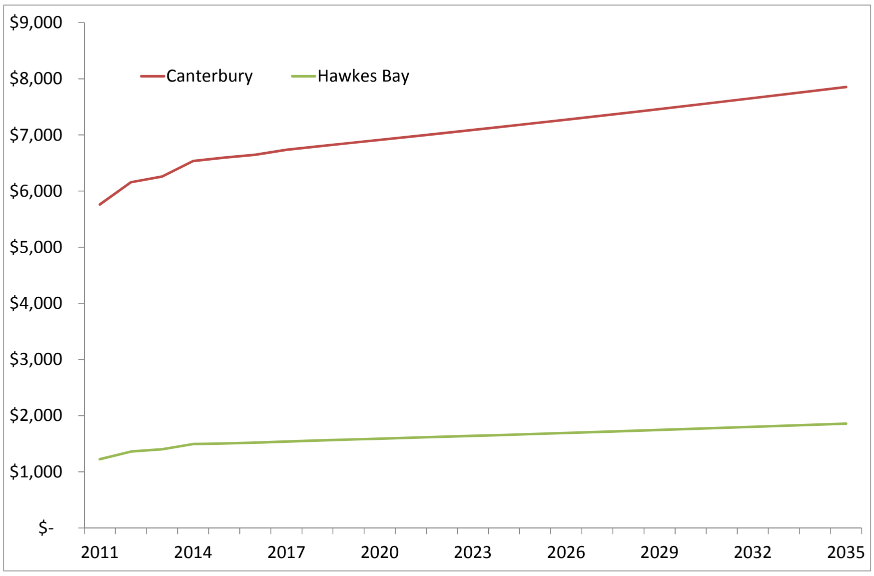
e) Summary of change in agricultural production

Combining the 2010 base year gross revenue gains with the expected price and yield projections, we calculate the expected marginal gross revenue change per hectare from irrigation.

[1] To put this growth in the context of the New Zealand economy, we note that Statistics New Zealand (2010) found that agriculture's productivity growth was higher than most other sectors of the economy.

Figure 6 Marginal gross revenue per hectare gains from irrigation

$NZ, farm-gate.



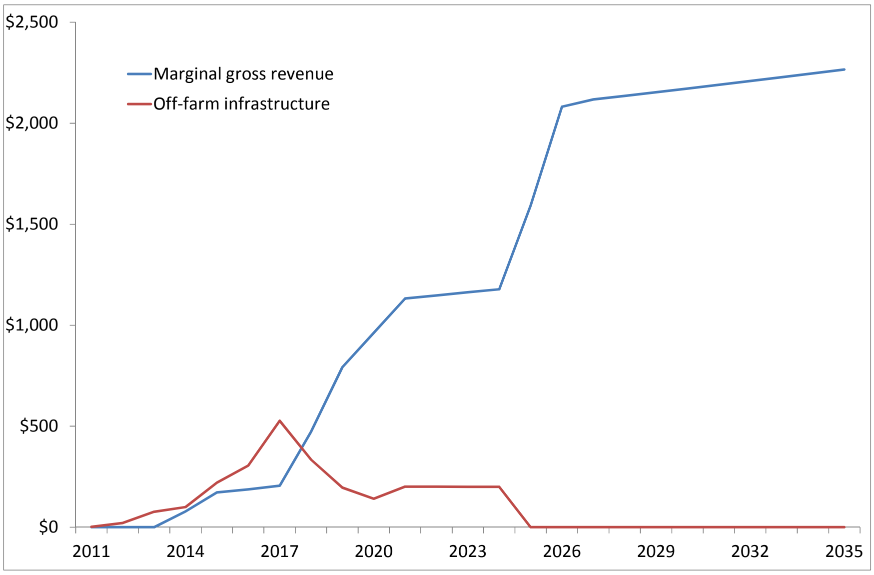
Source: NZIER, various.

We apply the marginal gross revenue changes to the hectares that become irrigated as the schemes are implemented as per the schedule in Table 1. We assume it takes 2 years to transition to full irrigation production for all crops except horticulture, which takes 4 years, as per data from MAF and the expert agricultural consultants.

By 2026 when all schemes are fully operational across the full 347,000 hectares, the irrigation schemes generate an extra $2.1 billion (in real, 2010 dollars) each year in agricultural production at the farm-gate. For comparison, 2010 dairy production was 1,435 million kgs of milk solids at a payout of $6.10 per kg, for a total farmgate revenue of $8.75 billion (Ministry of Agriculture and Forestry, 2010). Figure 7 shows the increase in revenue and the off-farm infrastructure costs out to 2035.

Figure 7 Marginal gross revenue gains from irrigation

$NZ millions, farm-gate.



Source: NZIER

f) Exports

The shocks we developed above are at the farm-gate. That farm production is then processed in meat and wool processing industries before being exported.

The nature of the agricultural processing industry is such that the outputs from the farm gate comprise only 50 per cent of the total export output value. This means that the extra $2.1 billion a year in agricultural farm production generates around $4 billion in exports of processed goods. These values represent the change in gross output within the sectors due to irrigation, not their contribution to GDP or consumption. We assume that all of the extra processed production is exported at the world market price.

5. Results

The impact of the irrigation schemes on 'NZ Inc' can be measured a number of different ways. One widely used measure is **Gross Domestic Product (GDP)**, which is the sum of all value created in the economy per year. Our reporting includes GDP impacts from irrigation.

Although GDP is a widely used and valid metric, it does not provide the best measure of the schemes' net benefit to New Zealand. To measure net benefit, **total consumption** is the critical metric to consider from a 'NZ Inc' perspective. It measures the amount of income available to New Zealanders to spend on goods and services. It starts with GDP, which measures the production in the economy, and then subtracts the repayment of overseas debt and the opportunity cost of investment. We make these adjustments because:

- the repayment of offshore debt to finance the off-farm infrastructure reduces the amount of income available for consumption
- the opportunity cost of capital investment must be paid to make capital available for uses such as on-farm irrigation equipment and processing infrastructure. These are costs in the sense that the finances used to fund them cannot be consumed. However in our model, any savings-investment imbalance is offset by an increase in net foreign liabilities, with an associated increase in foreign interest repayments. We believe this is an appropriate representation of international finance markets.

The impact of export growth can be explained by considering GDP from either a consumption or a production perspective:

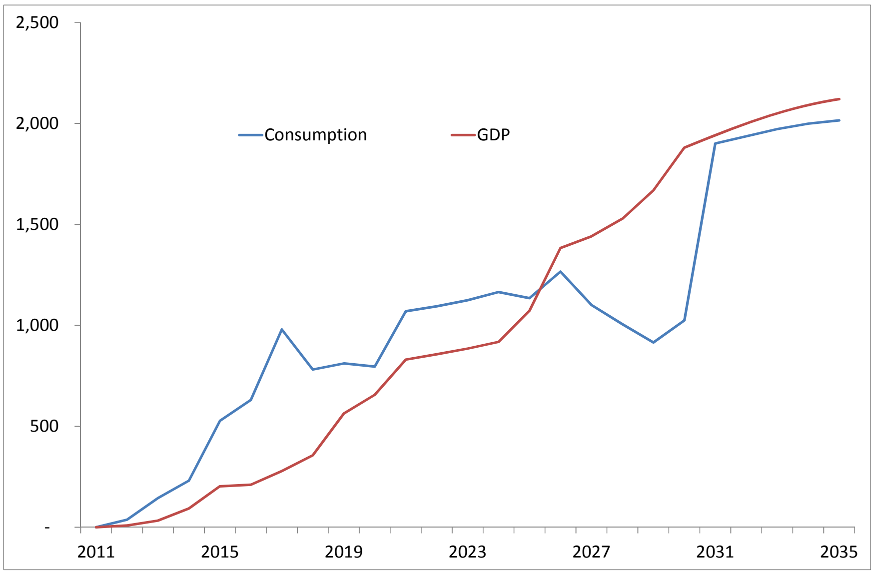
(i) GDP is the sum of the value of expenditure on goods and services made in New Zealand and exports are a component of that expenditure, so a change in exports directly affects the level of GDP. The change in exports will then have flow-on effects on other parts of the economy, as we describe in more detail below.

(ii) GDP is also the sum of the value of resources utilised in the economy. Increased agricultural exports are generated by gains in productivity. Greater productivity allows the same land and labour resources – albeit with higher capital requirements – to generate greater value, so GDP increases as productivity rises. Thus we expect export growth to have a direct impact on GDP and, in the long run, a positive impact.

5.1 Macroeconomic results

We present the key macroeconomic results in Figure 8.

Figure 8 Central scenario
$NZ million



Source: NZIER

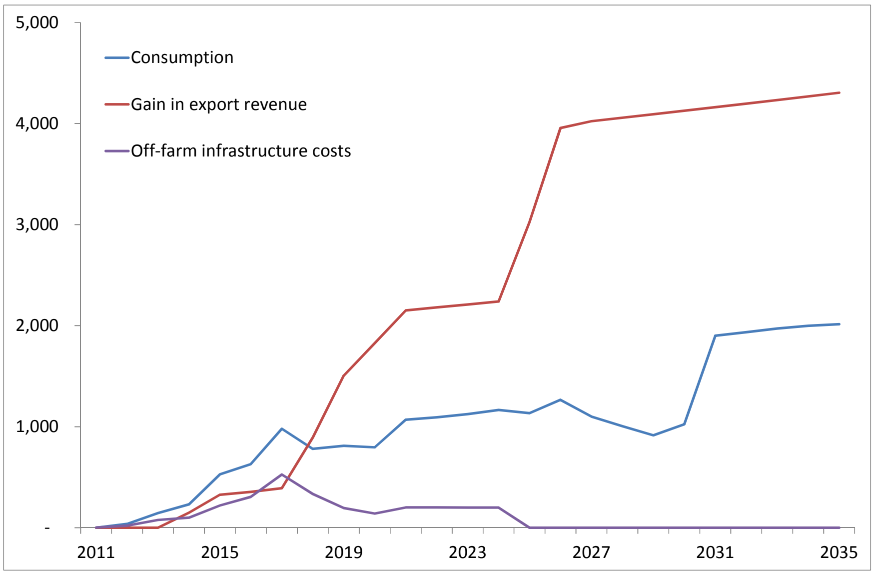
We find that the irrigation scheme delivers significant gains to the economy:

- Consumption by 2035 is around $2 billion greater than if the irrigation schemes have not been implemented.
- The drop in consumption between 2025 and 2030 is due to the repayment of the offshore borrowing for the off-farm infrastructure investment.
- Over 25 years, we find a net present consumption gain of $8 billion.
- GDP by 2035 is around $2.1 billion or 0.8% higher than it otherwise would have been.

To put the results in perspective, we can plot the gains relative to the off-farm infrastructure costs and the gains in export revenue due to the increased irrigation. The gains to consumption are a function of the large increases in agricultural production unlocked by irrigation. By 2026 when all schemes have been implemented, the extra production is worth $2.1 billion a year at the farm-gate, and almost $4 billion a year in exports. Relative to the gains in agricultural production, the off-farm infrastructure costs are small (Figure 9).

Figure 9 Comparison of costs, export revenue and consumption

$NZ million



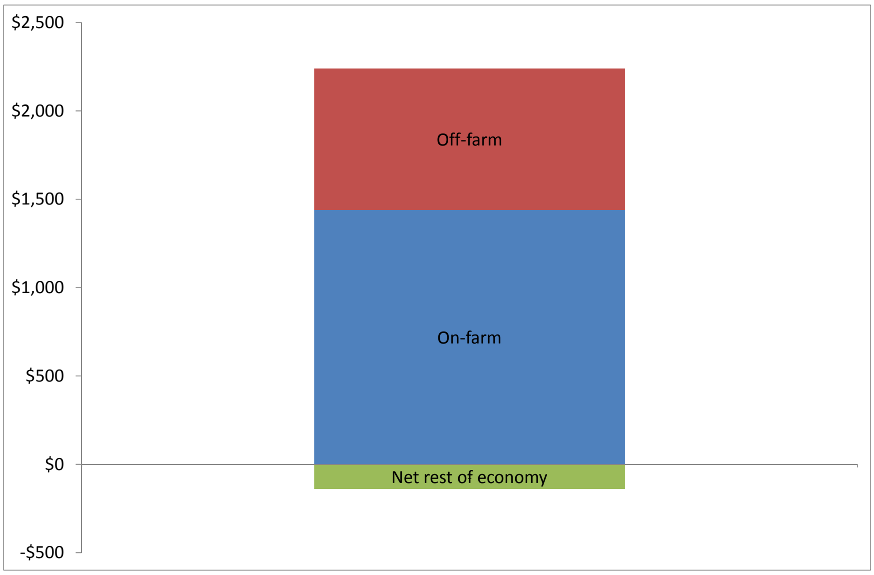
Source: NZIER

5.2 Sector results

The majority of the gains in GDP come through gains in agricultural production at the farm level. This has flow-on downstream effects on the processing sector.

Figure 10 Breakdown of results

2035 GDP split



Source: NZIER

The farm sector gains from becoming more productive. Irrigation makes water available to farmers who combine it with existing land and increased capital to produce greater value output. One source of the economic gain is that a new resource is available for economic production. Using an otherwise unutilised resource to create additional value results in a factor productivity gain that necessarily benefits the sector and the wider economy.

The off-farm processing industry expands in line with the farm sector. Together these industries draw resources away from other sectors in the economy, pushing up prices for factors and intermediates.

The crowding out of other industries does not occur instantly. The labour market model assumes sticky wages in the short term. In the presence of sticky wages, there are short-run gains in employment. In our model, a labour market shock takes five years to be fully translated into a wage shock[2]. Capital, by contrast is fixed in the short term. As the farm sector expands, the increased demand for capital pushes up the rate of return, inducing investment. Layman (2004) notes: 'the crowding out, through a reduction in capital in other industries, does not occur instantly, but occurs over time as the capital stock of other industries is allowed to depreciate without replacement investment.'

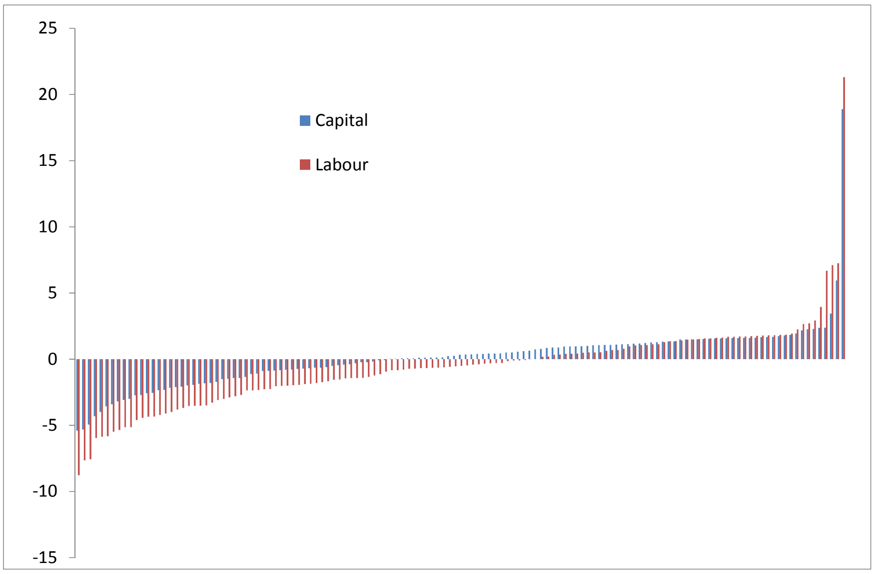
[2] This is consistent with the Reserve Bank of New Zealand's modelling – see Benes et al (2009).

Figure 11 shows the 2035 capital and labour changes for the 131 industries in the model. In the presence of a productivity shock, and with investment in the farming sector outpacing depreciation in other sectors, there is a positive long run gain in capital stocks. Conversely, labour supply in the long term is exogenous: gains in one industry are offset by losses in another.

In addition to the competition for resources, an exchange rate appreciation driven by increased demand for agricultural exports also negatively impacts other exporters. Thus not all the gains to the farm and processing sector are net gains to 'NZ Inc'.

Figure 11 Capital and labour changes for 131 industries

2035, per cent change versus baseline



Source: NZIER

However Figure 11 also shows there are positive flow-on impacts to some sectors of the economy:

- **Supplying industries** – industries that supply the farm and processing sectors with intermediate inputs are likely to benefit from the growth in these sectors. These are industries such as agricultural services and the fertilizer industry.
- **Household expenditure industries** – industries that households spend money on are likely to benefit from increased income that comes through higher employment and wages, and increased returns to capital from a growing agricultural sector.
- **Government industries** – industries that rely on government funding are positively impacted by a stronger economy and bigger tax takes, as this increases the money available for the government to spend.

Considering all of these flow-on effects, the rest of the economy suffers a small net negative impact.

The impacts on factor prices, and the flow-on effects to other industries are an important part of the economic analysis of the impact of increased irrigation.

Modelling these impacts requires a general equilibrium approach. Partial equilibrium approaches such as CBA are unable to capture these impacts.

5.3 Foreign debt and current account results

Important macroeconomic impacts that a general equilibrium analysis captures include the impact on exchange rates, net foreign liabilities and the current account balance. These are particularly important for analysis such as this where all of the extra production is exported. We find that:

- The increased demand for agricultural exports leads to a currency appreciation. A stronger New Zealand currency reduces the local-currency value of interest repayments on our foreign debt.
- Despite foreign debt increasing as investment flows into the farm and processing sectors, New Zealand's net foreign liabilities to GDP ratio improves marginally over the 25 years out to 2035. This is analogous to an increase in foreign direct investment in New Zealand. The growth in GDP allows us to fund increased overseas borrowings which grows the domestic capital stock.

5.4 Sensitivity analysis

We consider the robustness of the results to a number of key input parameters into the modelling, specifically:

- returns to irrigation
- the number of implemented schemes
- the off-farm capital costs.

We also consider the impact if all on-farm irrigation costs had to be domestically funded.

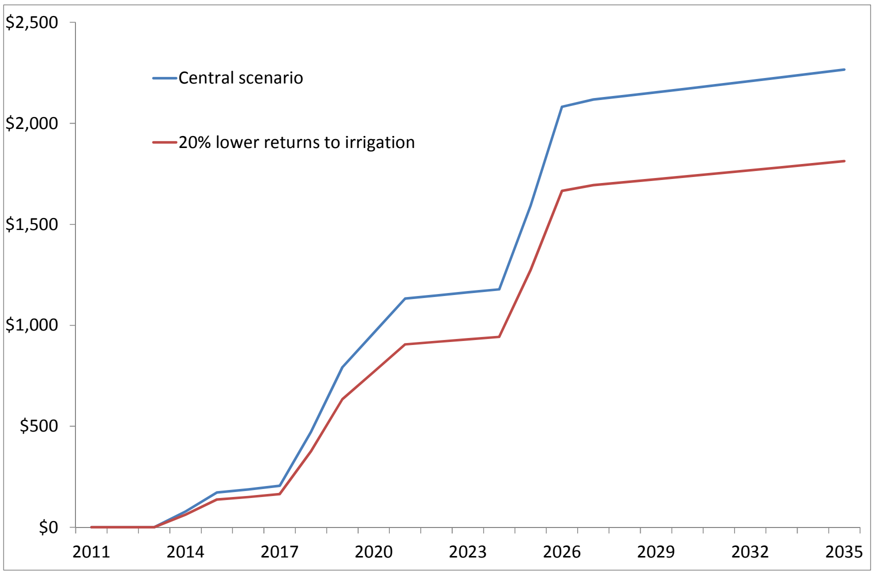
5.4.1 Commodity revenues

a) Sensitivity development

The revenue earned by newly-irrigated land depends on productivity and commodity prices. The farm budgets used to develop the model inputs were based on assumptions regarding productivity and prices. We did a sensitivity test by assuming lower total revenue for the irrigated sector. Lower commodity prices or yields (particularly for dairy) will lower the gains available from converting to irrigation. We consider a sensitivity of 20 per cent lower gains from irrigation per hectare. This would be a significant reduction. For example, milk solids would need to fall from $5.50/kg to $4.40/kg, or yields would need to fall from $1,600 MS kg/ha to 1,280 MS kg/ha.

Figure 12 Marginal gross revenue gains from irrigation

$NZ millions, farm-gate.

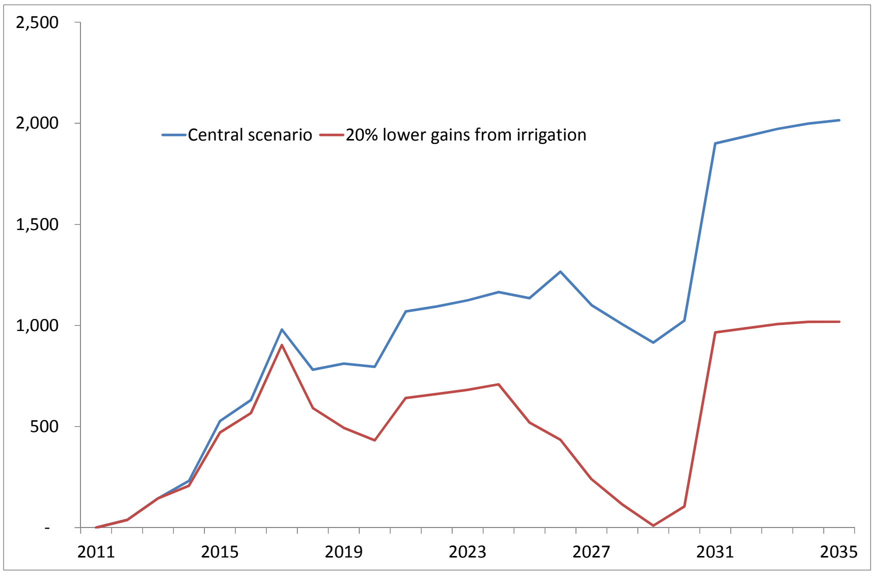


Source: NZIER

b) Results

Reducing the returns to irrigation by 20 per cent has a relatively direct negative impact on the net present gains which fall by around $2 billion (25 per cent).

Figure 13 20% lower gains from irrigation
Consumption, $NZ million



Source: NZIER

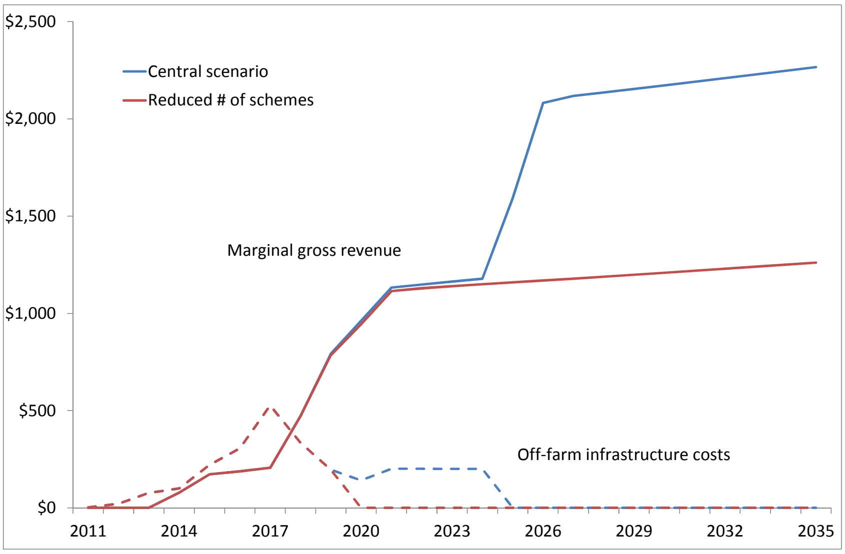
5.4.2 Number of schemes that are implemented

a) Sensitivity development

There is uncertainty surrounding the total number of schemes that will be implemented. We consider a scenario in which four of the 14 schemes are excluded from the analysis. The excluded schemes are Lees Valley (120,000 hectares), and the Wairarapa Stages 1-3 (total of 30,000 hectares). This reduces the total area of the irrigation schemes from 347,000 to 197,000 hectares (-43 per cent). It also reduces the total off-farm capital expenditure cost from $2.7 billion to $1.6 billion (-42 per cent). Figure 14 compares the farm-gate marginal gross revenue and the off-farm infrastructure costs under the central 14 scheme scenario versus the reduced 10 scheme alternative.

Figure 14 Off-farm infrastructure costs: fewer schemes

$NZ million



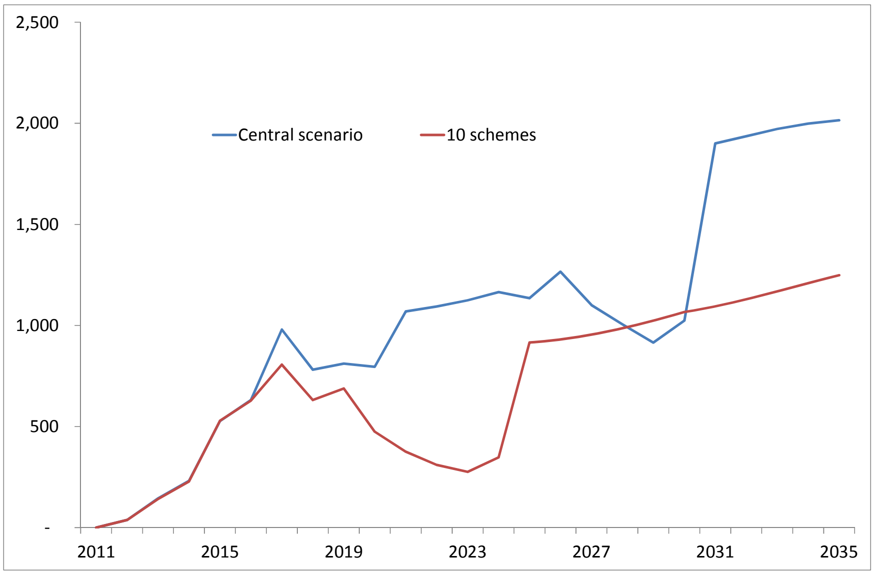
Source: NZIER

b) Results

Reducing the number of schemes reduces the net present consumption gain by about $2.5 billion (-31 per cent). The schemes we eliminate in this sensitivity are schemes with the longest lead time until first water flows: thus in net present value terms they contribute less to the total under the central scenario.

Figure 15 Reduction in number of schemes

Consumption, $NZ million



Source: NZIER

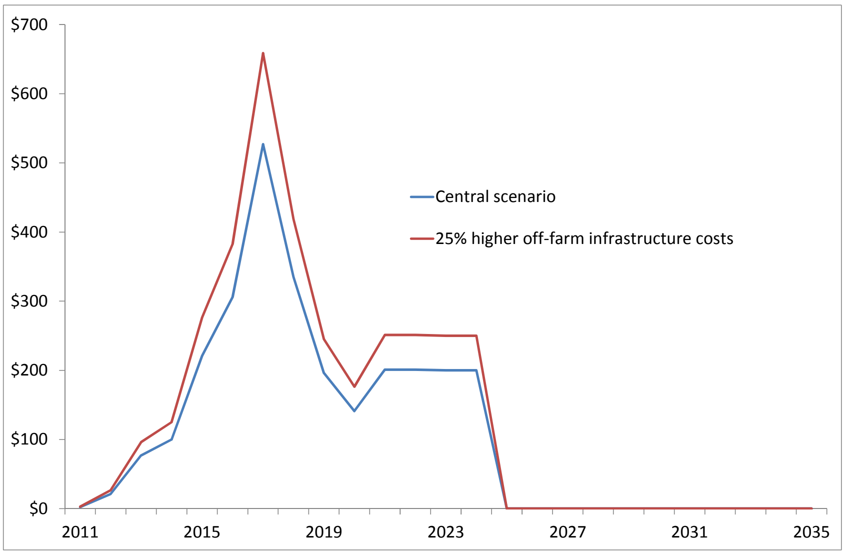
5.4.3 Off-farm capital costs

a) Sensitivity development

The off-farm capital costs are subject to uncertainty. We consider a sensitivity in which these costs are 25 per cent higher than predicted.

Figure 16 Off-farm infrastructure costs: 25% higher capital costs

$NZ million



Source: NZIER

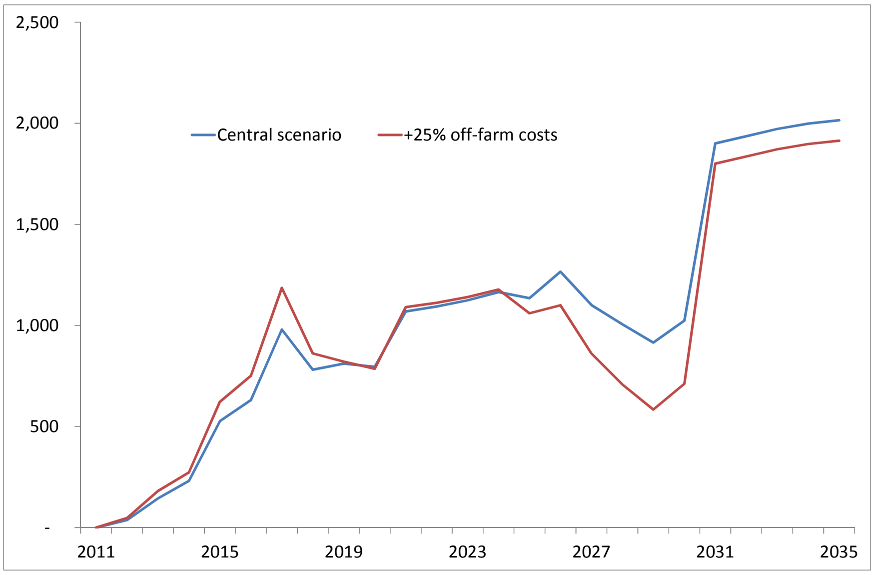
b) Results

A 25 per cent increase in off-farm construction costs creates a larger stimulus into the economy during the construction period. However the off-shore borrowing and associated interest repayments are also increased. A greater reduction in consumption is therefore required between 2025 and 2030 to repay the debt (Figure 17).

The impact on the net present value of consumption is small (~$100 million). This is because the debt costs are small relative to the gain in productivity unlocked by irrigation.

Figure 17 25% higher off-farm costs

Consumption, $NZ million



Source: NZIER

5.4.4 Funding of on-farm infrastructure costs

a) Sensitivity development

New Zealand does not typically save enough to finance our investment demand. We live in an open economy linked to the international goods and services, and financial markets. Our model is representative of this: we export and import goods and services, and any savings-investment imbalance can be offset by an increase in net foreign liabilities, with an associated increase in foreign interest repayments. In the central simulation, around 40 per cent of on-farm infrastructure investment is funded from offshore.

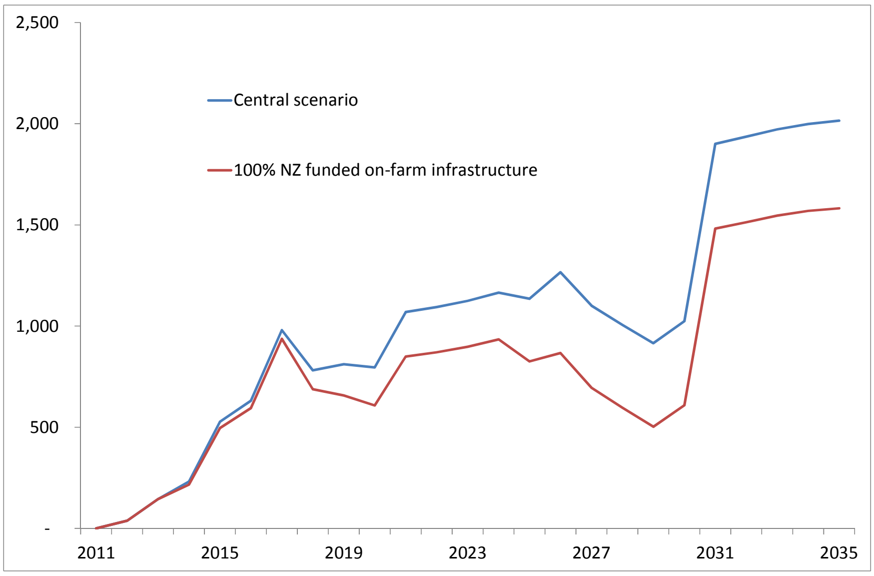
In this sensitivity, we consider the impact if all of the on-farm infrastructure costs had to be wholly domestically financed.

b) Results

Wholly funding the on-farm infrastructure investment reduces the consumption benefit to NZ Inc. by around $1.5 billion (-20 per cent), as funding is diverted to investment rather than being able to consumed.

Figure 18 100% domestically funded on-farm infrastructure

Consumption, $NZ million



Source: NZIER

5.4.5 Summary of sensitivity testing

The modelling results we present here are dependent on the input parameters and assumptions used to calculate them. The changes to the model outputs are consistent with the changes to inputs. The consistency indicates that the model is functioning appropriately.

The results from the sensitivity analysis also suggest that the main modelling findings are robust to reasonable changes in the inputs. We have further confidence in this analysis because the MONASH-NZ dynamic model framework is based on the tried-and-tested MONASH CGE model that has been widely used for policy analysis around the world.

We conclude that on balance the irrigation schemes as modelled here provide a significant positive benefit to NZ Inc.

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Appendix A MONASH-NZ

A.1 Dynamics of the MONASH-NZ model

MONASH-NZ is a recursive dynamic CGE model based on the ORANI-NZ core. It can be thought of as a series of static simulations linked by three dynamic adjustment procedures. Each year's simulation takes the final database of the previous year's simulation as its starting point and applies the current period's shocks. Because the solution for the current period depends only on the previous period's solution and the current period's shocks, it can be solved recursively, rather than having to solve all periods simultaneously. Economists might refer to this sort of model as having adaptive, rather than rational, expectations formation.

In addition to solving a 'static' problem in each period, the MONASH-NZ model improves upon ORANI-NZ simulations by adding three dynamic adjustment processes:

- Labour market adjustment: We assume that wages are sticky in the short run and gradually adjust over time. A mechanism in the model allows employment to first respond to increases in aggregate demand and then return to the NAIRU over time as wages adjust.
- Capital formation: An industry-specific capital accumulation mechanism allows industries to build their stock of capital over time. Capital is generated by investment, which in turn responds to rates of return in each industry.
- Balance of payments adjustment: The model tracks changes in the current account and capital account over time. Changes in net foreign liabilities affect domestic consumption through the level of interest that must be paid to service the foreign debt.

A.2 Database structure

The model is based on a large database containing the value flows of the economy, as per Figure 19. The database defines the initial structure of the economy, which by definition is assumed to be in equilibrium in all markets. The structure of the database is broadly similar to traditional input-output tables; for example commodities may be used as intermediate input for further production, utilised in investment, exported or consumed by households and the government. Industry costs include the cost of intermediates, margins, taxes and primary factor costs for labour, land and capital. As per the accounting identities in input-output tables, the total value sum of producers' input costs (including margins, taxes, returns to factors and other costs) equates to the total value of output production (the 'MAKE' matrix in the database).

The MONASH-NZ model consists of:

- 131 industries
- 210 commodities

- 14 regions
- 1 household
- 24 occupations

The database has been sourced initially from Statistics New Zealand 1995/96 Inter-Industry tables, updated using the subsequently released 2003 Supply and Use tables, and finally ‘up-scaled’ to 2010 levels using latest Statistics New Zealand macroeconomic data.

Figure 19 The MONASH-NZ database

		Absorption Matrix					
		1	2	3	4	5	6
		Producers	Investors	Household	Export	Government	Change in Inventories
	Size	← I →	← I →	← 1 →	← 1 →	← 1 →	← 1 →
Basic Flows	↑ C×S ↓	V1□□S	V□BAS	□□B□S	V4BAS	V5BAS	V6BA□
Margins	↑ C×S×M ↓	V1□AR	V2MAR	V3MAR	V4MAR	□5M□R	n/a
Taxes	↑ C×S ↓	V1□A□	V2TAX	V3TAX	V4TAX	V5TAX	n□a
Labour	↑ O ↓	V1LAB					
Capital	↑ 1 ↓	V1CAP					
Land	↑ 1 ↓	V1LND					
Production Tax	↑ 1 ↓	V1PTX					
Other Costs	↑ 1 ↓	V1OCT					

C = 210 Commodities

I = 131 Industries

S = 2: Domestic, Imported

O = 24 Occupation Types

M = 5 Commodities used as Margins

	Joint Production Matrix
Size	← I →
↑ C ↓	MAKE

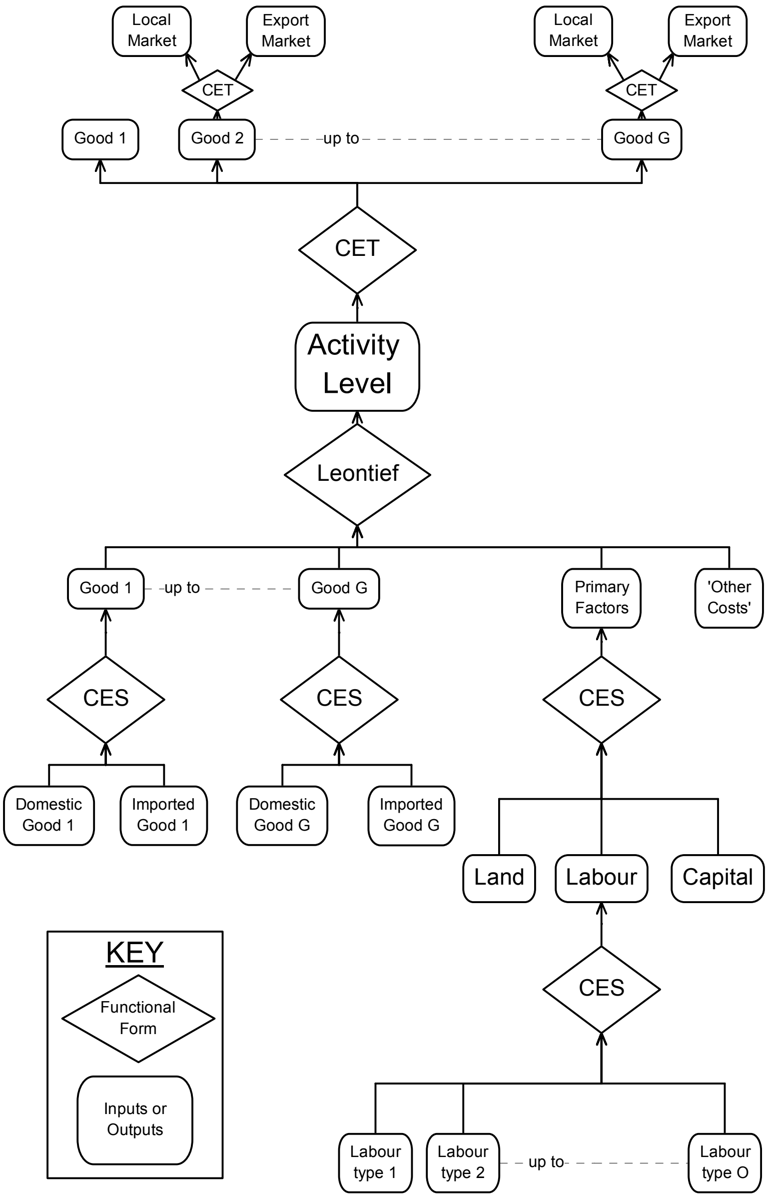
	Import Duty
Size	← 1 →
↑ C ↓	V0TAR

Source: Horridge, 2008b; NZIER

A.3 Production structure (Horridge, 2008)

The production structure of the model is presented in Figure 20. Each industry can produce a number of different commodities. Production inputs are intermediate commodities, both domestic and imported, and primary factors labour, land and capital. Working from bottom to top, we see constant elasticity of substitution (CES) production nests for occupations, primary factors and the choice between imported and domestic commodities. In this case, an increase in price moves sourcing towards another input, for example, if the price of imports increases, more domestic commodities are demanded in the intermediate sourcing CES nest.

Figure 20 Production structure



Source: Horridge, 2008

At the activity level, intermediate goods, primary factors and other costs are combined using a Leontief production function. This means the proportion of production inputs does not change. On the output side, there are two further constant elasticity of transformation (CET)[3] nests. The production mix of each

[3] A CET function is identical to a CES function except that the transformation parameter has the opposite sign (i.e. increasing price increases output in a CET; in a CES, increasing price reduces demand)

industry is dependent on the relative prices of each commodity. Similarly, the export nest determines local and export market shares depending on relative prices.

Appendix B CGE and multiplier analysis

Many studies attempt to quantify the economic contribution of a certain sector or project using input-output (IO) multipliers. This is a technique that NZIER (and many other consultancies) has used in the past.

Despite their popularity, IO models have a number of significant drawbacks.

The primary issue with IO models is that they assume that supply is unconstrained. That is, inputs such as labour, capital and land are always available for expanding a sector. There is no recognition of the reality that resources used in one part of the economy are *not* available for use elsewhere. Labour and capital are unconstrained and available at a constant price in an IO framework. That is important because they are also assumed to be used in fixed proportions. Hence an IO model excludes any consideration of substitutability between factors of production.

Furthermore, since IO models exclude prices, they also assume that supply is perfectly elastic. This means that no matter how much labour (for example) is used, there is no change in wages. The consequence is that they exclude all supply constraints, rigidities and price effects, leading to unrealistically large shifts in resource use and economic activity.

The absence of substitution effects also extends to demand. There is no substitution between different goods as incomes rise. Rather, consumption is assumed to rise linearly with incomes and the proportion of different goods consumed remains constant. In reality, as incomes rise, people tend to buy relatively more luxuries and fewer necessities, and more services (such as tourism).

IO models also exclude a treatment of exports and imports. Imports do not compete with domestic goods and exports are exogenously determined. Neither depends on prices, since relative prices cannot change.

Among the other drawbacks, savings are fixed as a proportion of incomes, so financial markets are not included in the model. Technology is exogenous so technological progress cannot be modelled. This reflects the static nature of the model, which has no dynamic (time) element to it. The lack of explicit dynamics is problematic for a model which seeks to capture the change in industry flows over time.

As a consequence of the limitations outlined above, IO multipliers tend to systematically overestimate the true ripple effects and provide an unjustifiably rosy picture of the economic impacts of a project. This is particularly the case for employment multipliers (Mules, 1999).

IO models are only appropriate for circumstances where there are no supply constraints and demand considerations completely dominate the analysis (Bandara, 1991). This set of circumstances may hold in small regional economies (Dwyer et al, 2005). In such economies factor and commodity flows from outside the region tend to be very free. If the region is small enough then relative prices can safely be regarded as exogenous, which allows IO models to be safely used so long as the assumptions and deficiencies are recognised.

CGE models explicitly address many of the shortcomings in IO analysis. They allow resources to move between sectors in response to a shock, and the demand and supply of goods and factors respond to relative prices. CGE models tend to produce smaller economic impacts than IO models, primarily because they consider the opportunity costs of the expansion (or contraction) of a sector.

It is helpful to consider an illustrative example of how IO multipliers compare to CGE estimates. A comparative assessment of CGE and IO multipliers was carried out for the regional and national impact of the Australian leg of the Formula 1 Grand Prix circuit. The 2005 analysis of the 2000 Grand Prix resulted in the multipliers reported in Table 6.

Table 6 IO vs. CGE multipliers

Multiplier values

	IO model		CGE model	
	Regional	National	Regional	National
Output multiplier	2.2	2.3	1.2	0.9
Value added multiplier	0.8	0.8	0.4	0.3
Employment multiplier	10.2	11.6	6.2	2.5

Source: Dwyer et al (2005)

As expected, the CGE multipliers are far lower than the IO multipliers, primarily due to the price and resource constraints included in the CGE model. The CGE estimates in this study are between 20% and 55% of the IO multipliers. Such differences are not unusual in the literature.

CGE models are a significant improvement on the previous generation of IO models, particularly when estimating the nationwide or regional effects of projects which are likely to have significant price effects. Indeed, CGE modelling has become one of the most widely used tools for economic policy analysis over the past three decades. Today, the leading CGE modelling institutions are the World Bank, the International Food Policy Research Institute (IFPRI) and the Centre of Policy Studies at Monash University (CoPS). Much of the World Bank's economic assessment of trade and environmental impacts is conducted using their LINKAGE and Env-LINKAGE CGE models. CoPS has done extensive work advising the government in Australia using their CGE models.[4] Variants of their models are used in over 400 organisations in over 70 countries.[5]

4 For example, Dixon, Parmenter and Rimmer (2000); Adams et al (1994); Dixon, Picton, and Rimmer (2005), Dixon, Madden, and Peter (1993); Dixon and Rimmer (1999).

5 GEMPACK homepage http://www.monash.edu.au/policy/gempack.htm

The widespread usage and acceptance of CGE results over the last thirty years reinforces the view taken in the literature that it is now the best method available for analysing the impact of economy-wide shocks.