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# The Economic Cost of Quality Defects

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Funded from the Building Research Levy

NZIER

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# Authorship

This paper was prepared at NZIER by Michael Bealing and Laëtitia Leroy de Morel.

The assistance of Sarah Spring is gratefully acknowledged.

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This paper was prepared at NZIER by Michael Bealing and Laëtitia Leroy de Morel.



## Reference

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## Abstract

Our aim was to estimate the costs of quality defects in residential construction in New Zealand and the benefits of eliminating them. Using a computable general equilibrium model of the economy we considered the direct costs to the construction industry and the flow-on effects to the rest of the economy. The scope was limited to quality defects discovered during construction. The impacts of quality defects were rework costs, crowding out effects, increased construction costs and decreased housing affordability. We estimated the economic cost of quality defects to be $2.5 billion per year. Households would have $1.4 million additional income available to spend on goods and services, which would increase aggregate living standards.



## Keywords

Computable general equilibrium; quality, defect, housing, residential, construction, productivity

## Acknowledgements

This research was funded by the Building Research Levy.

# Key points

Our aim in this research was to estimate the costs of quality defects in residential construction in New Zealand and the benefits of eliminating them. As part of this, we considered the direct costs to the construction industry and the flow-on effects to the rest of the economy.

## Quality defects are common, and there are many causes

Page (2015) found that 96% of new houses studied had compliance defects. The causes of defects are multifaceted and include:

- poor workmanship
- poor design
- faulty materials
- building errors
- procedural errors
- poor coordination between trades.

The prevalence of quality defects is widespread. The scenarios consider the benefits of complete elimination of defects. Completely eliminating defects may not be realistic. Our scenarios are designed to estimate what's at stake of the construction industry and the economy.

## The impacts of quality defects are wide ranging

The impacts of quality defects in new residential construction were found to be:

- increased demand for rework, which crowded out new work
- increased demand for materials, including imported materials
- incentives to price in rework, increasing construction costs and decreasing affordability.

The benefits of working towards eliminating quality defects include:

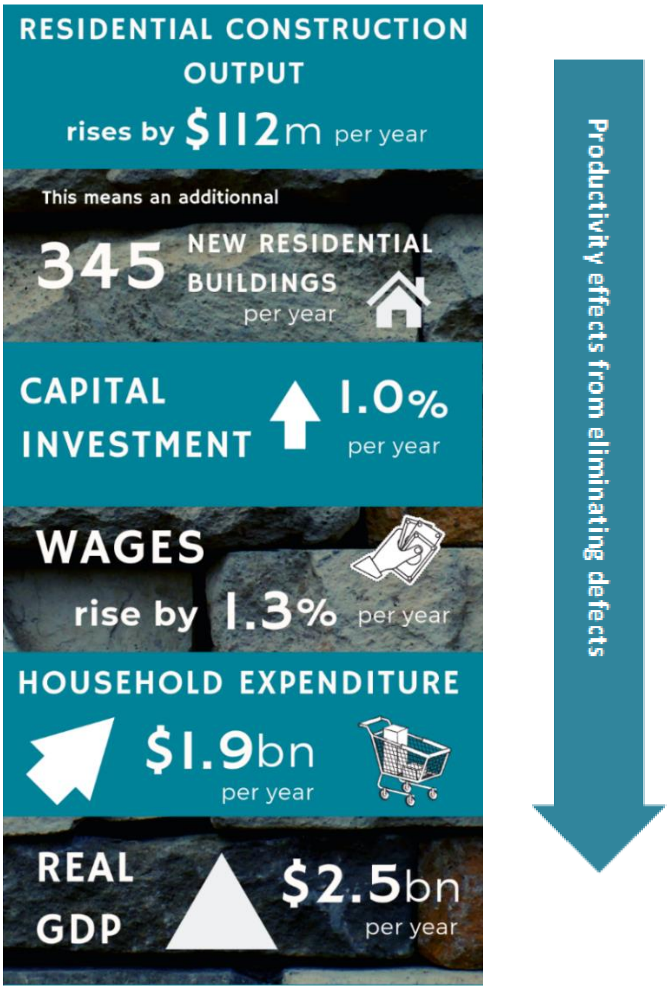
- improved productivity and profitability
- labour and capital become available for other uses
- housing supply increases without additional builders
- the pressure on specialist trades is reduced
- resources used in rework could be redirected to activities that support economic growth
- overall, wellbeing is enhanced for the construction industry, consumers and society.

## Our conservative estimates indicate the economic cost of quality defects is $2.5 billion per year.

Eliminating quality issues would improve the productivity and performance of residential construction in New Zealand. Eliminating defects would release opportunities for additional consumption and economic growth. Residential construction output would increase by $112 million annually, and capital investment across the economy would increase by 1% annually. The productivity improvement in residential construction would lead to a 1.3% increase in wages throughout the economy.

The results show that economy-wide effects of an increase in productivity would see New Zealand's GDP rise by $2.5 billion, as the industry's overall costs of production decrease. Households would have $1.4 million additional income available to spend on goods and services, which would increase aggregate living standards.

**Figure 1 New Zealand economy benefits from quality improvements in residential construction and construction services**




**Source: NZIER**

## There’s plenty of scope for further research

The scope included quality defects that are discovered during the construction of new residential housing in New Zealand. Quality was defined as compliance with the New Zealand Building Code at the time of construction. To ensure that the research was manageable, the following were deemed out of scope:

- Alterations and maintenance
- Non-residential construction
- Undiscovered defects
- Leaky buildings
- Earthquake remedial work.

These issues are all important areas for future research and were only ruled out of scope due to normal constraints on a research project. The approach taken in this research has set the foundation for further exploration.

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# 1. Objectives and scope

Our aim in this research was to estimate the costs of quality defects in residential construction in New Zealand and the benefits of eliminating them. As part of this, we considered the direct costs to the construction industry and the indirect effects on productivity and the supply of housing.

## 1.1. Scope

We began with an open mind about the cost of quality defects. Narrowing the scope too early would limit the consideration of the costs of quality defects in housing. We drew on the literature to define defects, the costs of defects and the effects of defects.

Our research was primarily a desktop exercise drawing on literature, industry sources and existing datasets to develop the estimates of the costs of quality defects. Primary data gathering was out of scope for this research. The scope included quality defects that we discovered during the construction of new residential housing in New Zealand.

Quality was defined as compliance with the New Zealand Building Code at the time of construction.

To ensure that the research was manageable, the following were deemed out of scope:

- Alterations and maintenance
- Non-residential construction
- Undiscovered defects
- Leaky buildings
- Earthquake remedial work.

These issues are all important areas for future research and were only ruled out of scope due to normal constraints on a research project. The approach taken in this research has set the foundation of further exploration.

Rework to address quality issues is an opportunity cost for the construction industry because the rework crowds out other work and diminishes the potential margin for the builder.

## 1.2. Research approach

We used a top-down approach to assess the economic costs of quality defects in residential construction. This approach helped us to understand the scale of the costs in the absence of detailed data required to complete a bottom-up assessment.

The research involved a multistage approach to build the most comprehensive picture possible in the first formal study of the economic costs of quality defects in residential construction. Each stage is outlined below.

### Stage 1: Literature review

We undertook a comprehensive review of the local and international literature on the cost of quality defects in residential construction.

We explored definitions of quality thoroughly at the outset of the project because it is the pivotal keystone for the research.

## Stage 2: Structure of the residential construction sector

We investigated the structure of the residential construction industry to facilitate analysis of the economic cost of quality issues in New Zealand.

The data we used came from Statistics New Zealand including:

- 2013 Input-Output tables, published in 2017 and updated to 2018 using the latest National Accounts available at the time
- Gross domestic product tables by industry
- Employment by industry for the Business Demography Statistics

## Stage 3: Initial estimates of the cost of quality defects

We developed an initial estimate of the economic cost of quality defects based on the combination of the findings from stages 1 and 2. The initial estimated cost of quality defects built on the literature review and quantified the direct and indirect costs of quality defects.

## Stage 4: Testing the initial findings with a panel of industry leaders

We tested the initial findings with a panel of industry leaders to seek their views on:

- how well the findings align with their experiences in the field
- any gaps in the findings
- opportunities to address those gaps.

## Stage 5: Refining the estimates based on feedback

Based on the feedback from the panel, we refined the analysis to ensure the insights from industry leaders were embedded in the findings so that they flow through to the reports and knowledge-transfer mechanisms.

## Stage 6: Identifying the effects of quality defects on construction productivity and supply of housing

Rework to address quality issues is an opportunity cost for the construction industry because the rework crowds out other work and diminishes the potential margin for the builder. Once we estimated the direct economic cost(s) of the quality issues, we investigated the indirect effects: how the elimination of quality issues could support an improvement in construction productivity and an increase in the supply of housing.

We used a computable general equilibrium model to estimate the flow-on impacts of quality defects on other industries and the overall economy.

This stage was critical for developing the value add of this research project because it transforms the findings from a narrative around costs to the evidence of the potential benefits that could be generated by eliminating quality issues. The results from this stage provide a foundation for developing the business cases for initiatives for eliminating quality issues in construction.

# 2. Literature review

The literature review was the foundation of our research. From the results, we distilled themes, evidence and data to develop the inputs for the quantitative analysis.

## 2.1. Literature review approach

The literature review was intentionally broad. It included material from:

- peer-reviewed journals
- books
- industry research (for example, BRANZ study reports)
- industry websites and publications
- consultancy reports
- government research.

The literature review covered domestic and international sources. The relevance and applicability of international sources was carefully considered. Building standards, materials and environmental conditions vary from country to country, so international findings are not always relevant for residential construction in New Zealand.

Nevertheless, the issue of quality defects in residential construction is a common issue for many countries.

The aims of the literature review were to:

- catalogue the definitions of quality construction and quality defects
- describe the nature of quality defects in New Zealand and the similarities or differences to quality issues overseas
- establish the factors that influence the cost of quality defects
- document any known case studies of the costs of quality defects (for example, leaky buildings)
- identify the key themes in the literature on three levels: firm, industry and economy-wide.

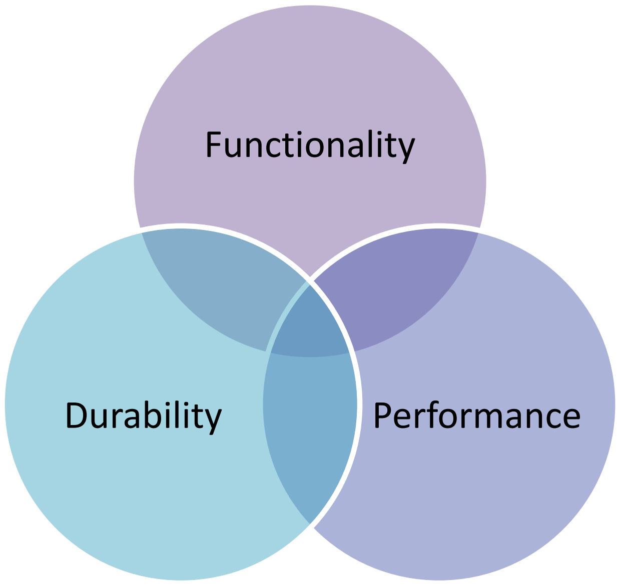
The literature review was structured around answering the following key questions:

- What is quality in the context of residential construction in New Zealand?
- What are construction quality defects?
- What causes defects?
- What is the prevalence of defects in New Zealand?
- What is the cost/effect of defects at a project and industry level?
- What are the wider economic, environmental or social effects of defects?

## 2.2. What is quality?

### Quality has three parameters

**Figure 2 Three parameters of quality**




**Source: Curtis and Gordon (2018)**

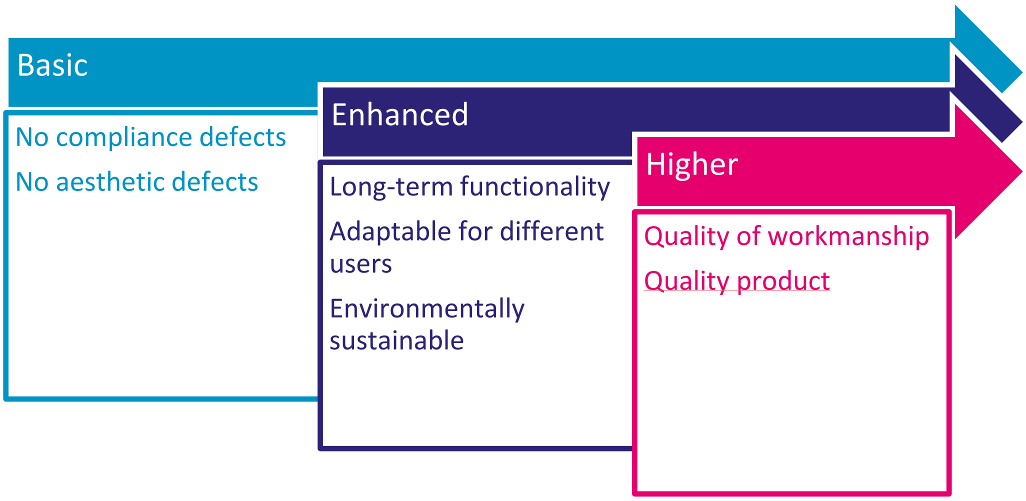
BRANZ authors Curtis and Gordon (2018) define these parameters as follows:

> *1. Functionality: The building meets all of the functional requirements set out in the building contract.*
>
> *2. Durability: The ability of building materials, components and construction methods to satisfy performance and functional requirements of the Building Code for the expected life of the building without a reconstruction or major renovation (or repair).*
>
> *3. Performance: Defined through measurable aspects of the building's design – thermal, structural, seismic, acoustic etc. Performance, as built, must be verified during construction and upon completion of the building process.*

### Quality has three levels

Quality has three levels: basic, enhanced and higher. Basic quality describes a building that meets the Building Code and that the client likes aesthetically. Enhanced quality describes a building that will last in the long term and can meet a client's changing needs (for example, a house for a growing family). Enhanced quality also covers buildings that are energy efficient and water efficient. Higher-quality buildings are defined by opinions about the quality of workmanship and the quality of materials used. These buildings may also have features considered additional to current standards, for example, an above-Code earthquake strength rating or smart lighting.

**Figure 3 Levels of quality**




**Source: Page and Gordon (2017)**

## Most new builds are below basic

New houses often fall short of the basic level of quality due to aesthetic or compliance defects. Surveys show that this is the case in both New Zealand and overseas.

The Building Act 2004 sets out requirements for basic compliance quality.

No independent authority exists to ensure, measure or enforce basic quality. An incomplete set of guidelines is set out in the Ministry of Business, Innovation and Employment (MBIE) guide to tolerances, materials and workmanship in new residential construction (MBIE, 2015).

## Enhanced quality is at the client's discretion (or wallet)

Buildings might meet the enhanced quality level in New Zealand, but this outcome is largely driven by the client-builder-designer relationship. BRANZ found that clients are reluctant to 'lifetime-proof' their building due to a perception of increased costs. Lifetime-proofing residential buildings makes up 0.5% of the build cost (Page & Gordon, 2017).

BRANZ advises user-friendly design to ensure a building stands the test of time. Meeting these user-friendly criteria usually adds ~0.5% to the total construction cost of a new house (Page & Curtis, 2011), while retrofitting may involve costs of 5% for internal changes and another 2.5% for external modifications (Page & Gordon, 2017).

Standards for user-friendly houses specify:

- minimum doorway and hallway widths
- minimum kitchen, bathroom, toilet and bedroom sizes
- sufficient wall strength so handrails can be fitted
- standard heights for power sockets and switches (Page & Curtis, 2011).

The New Zealand Green Building Council estimated that building a house that meets their 6-star rating for sustainability costs 1.5% more than a house that only meets the Building Code (Page & Gordon, 2017).

BRANZ provides advice on achieving a sustainable build though passive design, energy use, heating, ventilation, coatings and so on, but the definition of sustainable design has expanded from minimum negative environmental impact to considering social and economic effects as well (Page & Gordon, 2017).

## The best available measure of high quality may be CONQUAS

BRANZ found no meaningful definitions of high quality in database research. The closest definition considered was "more than a defect-free building" (Eley, 2004, p. 255).

Singapore's Construction Quality Assessment System (CONQUAS)[1] possibly has the best gauge for high quality as it has a sliding scale for assessing building quality. Construction firms often claim high-quality work. These firms argued that high quality is reached through:

- workmanship quality
- builder attitude
- product-based quality
- being award-winning
- being client focused
- quality assurance processes.

[1] https://www.bca.gov.sg/Professionals/IQUAS/conquas_abt.html

### Table 1 Measures of quality

| Indicator | Building type | Process |
|---|---|---|
| KPIs from Construction Excellence in New Zealand | All | The KPIs are collated from surveys of construction clients, contractors, subcontractors and consultants, covering issues such as client satisfaction, profitability, safety and environmental protection. |
| Construction Quality Assessment System (CONQUAS) | Residential | Building is independently assessed and scored based on structural, architectural, mechanical and engineering work. Scores are made publicly available. |
| UK Housing Quality Indicator | Residential (large-scale developments) | Independent assessment scores housing based on location, visual impact, routes/traffic movement, house size, layout, noise/natural light, adaptability, accessibility, sustainability and performance in us. |
| UK Design Quality Indicator | Non-residential | Client sets standards with designers and contractors<br>Independent assessment. |
| Post-occupancy evaluation | Non-residential | Stakeholder walkthrough interviews. |

**Source: Page & Gordon (2017)**

## 2.3. What are defects?

Atkinson (1987) defines construction failures and defects. A failure is a departure from good practice. A defect, on the other hand, is a shortfall in performance, which manifests itself once the building is operational. For the purpose of this study, we are interested in failures and defects. When we use the term defects, we include both defects and failures.

Page (2015) distinguished between the following two types of defects:

- **Compliance defects**: failure to meet the requirements of the Building Code, including issues of weathertightness, cladding and framing etc.
- **Quality and appearance defects**: visible defects on final inspection including insulation installation, bowed walls, seals and nail head popping.

Both types of defects are relevant to the economic cost of quality defects.

## 2.4. What causes defects?

BRANZ conducted inspections and assessed houses for defects and their causes (Page & Gordon, 2017). They then asked builders about what they thought were the key inhibiting factors to them producing quality work. The results are shown in Table 2.

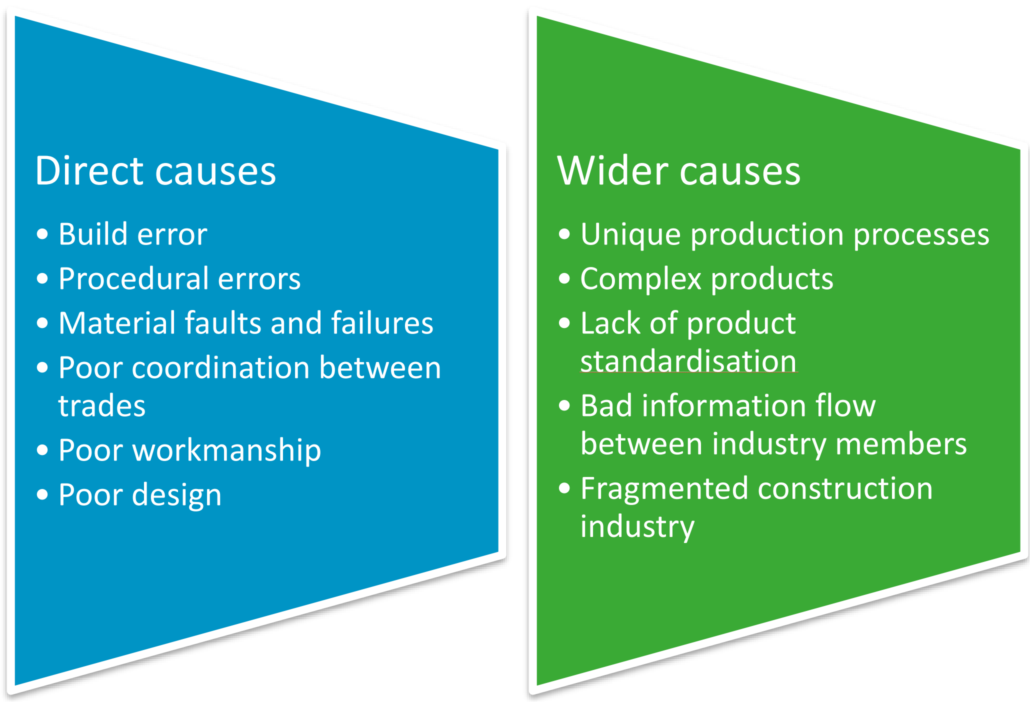
## Table 2 Direct causes of defects

| Cause | Results from BRANZ inspections | Builder opinion of inhibiting factors |
|---|---|---|
| Poor workmanship | 52% | 27% |
| Build error | | 21% |
| Materials | 12% | 7% |
| Subcontractor work/uncoordinated trades | 12% | 8% |
| Poor (or incomplete) design | 12% | 22% |
| Construction methods | 12% | 14% |

**Source: Page (2015)**

BRANZ's summary of international literature by (Wardle & Duncan, 2017) found that defect causes were as shown in Figure 4 below.

## Figure 4 Common causes of defects




**Source: Wardle and Duncan (2017)**

## Building inspectors improve work quality

Building inspectors find more defects than clients and their builders. Building inspection can help rectify defects before they become a long-term problem (Gordon & Curtis, 2018).

## Still a challenge to ensure basic quality

The impacts of labour shortage are being felt. More builders are not adequately trained or supervised, and more mistakes are happening. As a result, whether a building meets the basic level of quality is not guaranteed.

Labour shortages and high build rates also mean that building inspections are falling behind. Delayed or no inspections mean that builders are not easily brought back to remedy any defects. Clients also show an unwillingness to pay for building inspections, even though inspectors are more likely than the clients themselves to find building compliance defects early on. Inspectors are not interested in the cosmetic finish.

## The quality of consent documentation could improve

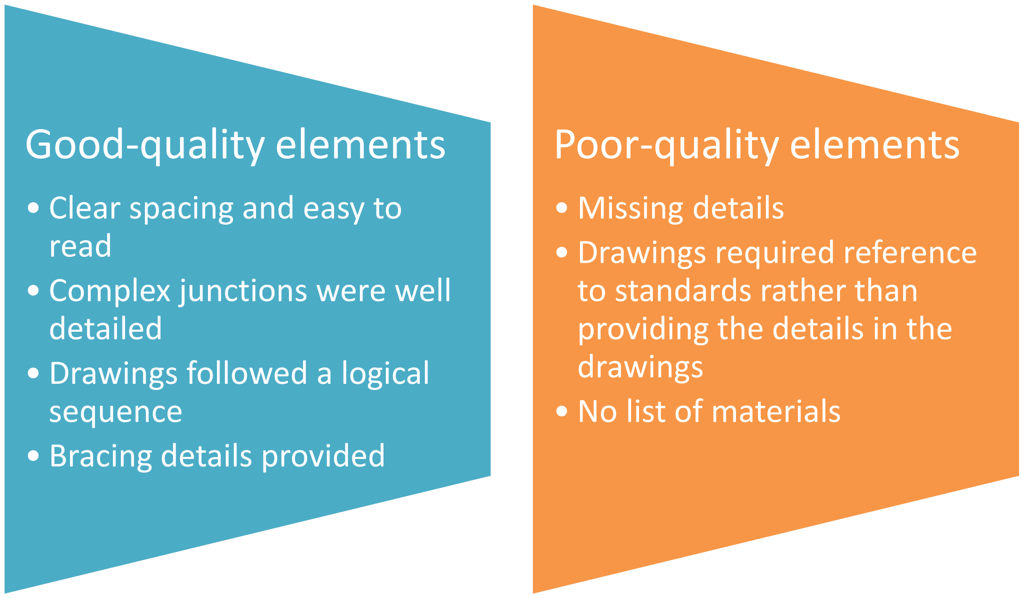
Consent documentation is part of the construction process. From a total quality management perspective, the quality of the consent documentation is integral to delivering a quality final product. Total quality management is defined by Pfeifer (2002) as an organisation-wide management approach centred on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction and benefits to the organisation and society.

Page (2016) reviewed the consent documentation of 52 houses. He found that 85% of the documents had positive aspects but 30% of the documents had elements of poor quality documentation.[2] When Page asked inspectors to score the quality of the document where 1 represents very poor quality and 5 represents very good quality, the average quality score was 3.4. Figure 5 is a summary of the good-quality and poor-quality elements in documents.

Page also found that, for 26% of the inspections, the builder in charge of the site was not a licensed building practitioner (LBP). LBPs are building practitioners who have been assessed as competent to carry out building work essential to the structure or weathertightness of residential buildings (see https://www.lbp.govt.nz/). This raises questions about how day-to-day quality is being managed on site.

[2] Documents can have elements of good and poor quality; therefore, percentages don't add up to 100%.

**Figure 5 Summary of good-quality and poor-quality elements in documents**




**Source: Page (2016)**

# 2.5. The prevalence of defects

## Defects are common in New Zealand

BRANZ has conducted a series of annual surveys about the quality of construction in new houses. These reports provide some of the most detailed information on the prevalence and nature of construction quality defects in New Zealand. This information was a valuable input to our research. A notable limitation of the BRANZ studies was the small sample sizes, which is probably a factor in the results varying from year to year. This was managed using the range of results from the surveys to inform the prevalence ranges in the quantitative analysis.

## Prevalence

Page (2015) reported the findings of the new house construction quality survey in 2014. As previously discussed, Page considered two types of defects:

- Compliance defects, which are failures to meet the requirements of the Building Code.
- Quality and appearance defects, which are largely cosmetic.

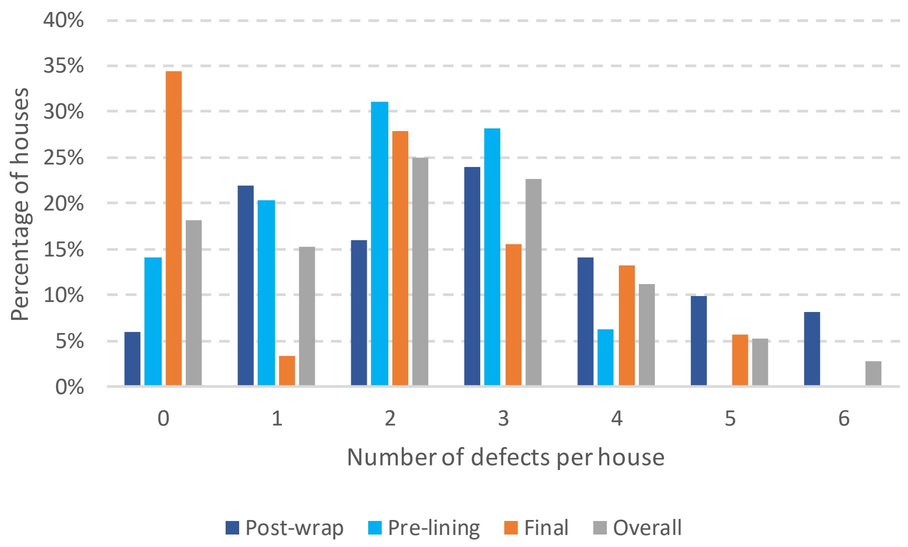
The number of defects were surveyed at three stages of the construction process being:

- post-wrap
- pre-lining
- final inspection.

Figure 6 shows the distribution of compliance defects by construction stage. The results show that:

- the prevalence of defects is generally decreasing as construction progresses
- 96% of new houses surveyed have a compliance defect at the first inspection point
- by the final inspection, 66% have compliance defects
- on average, the new houses surveyed had 2.2 compliance defects and thereby did not meet the requirements of the Building Code.

## Figure 6 Compliance defects in new houses



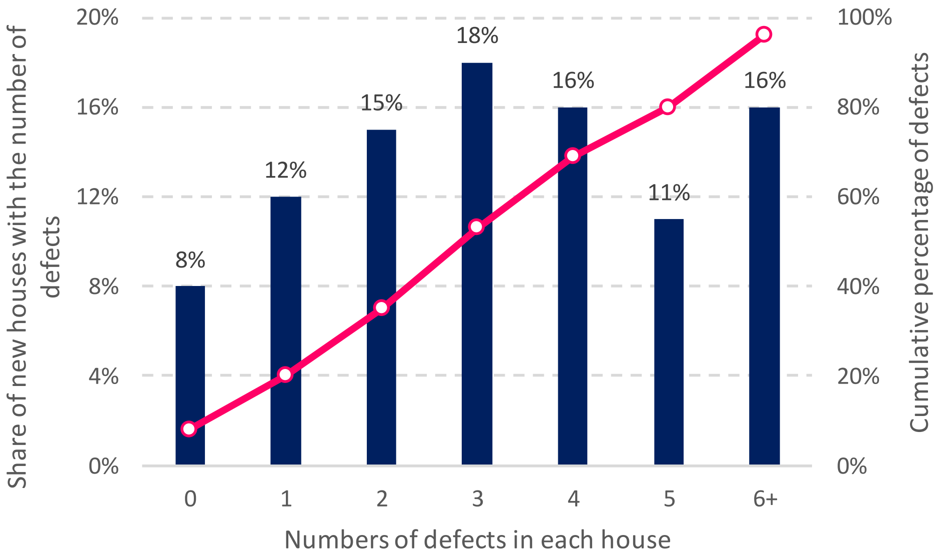

**Source: Based on Page (2015)**

These results raise questions about whether the compliance defects are resolved following the final inspection. If they are not, the impacts could grow and emerge at some point in the future as in the case of leaky buildings.

Figure 7 shows the share of the new houses in the 2014 new house construction quality survey by the number of quality and appearance defects. Overall, 92% of houses had one or more quality and appearance defects. Around half the houses surveyed had more than three defects, and 16% of houses had six or more defects.

### Figure 7 Quality and appearence defects at final inspection

Based on a survey of 225 new houses – cumulative percentages do not sum to 100% due to rounding in the source publication




**Source: Page (2015)**

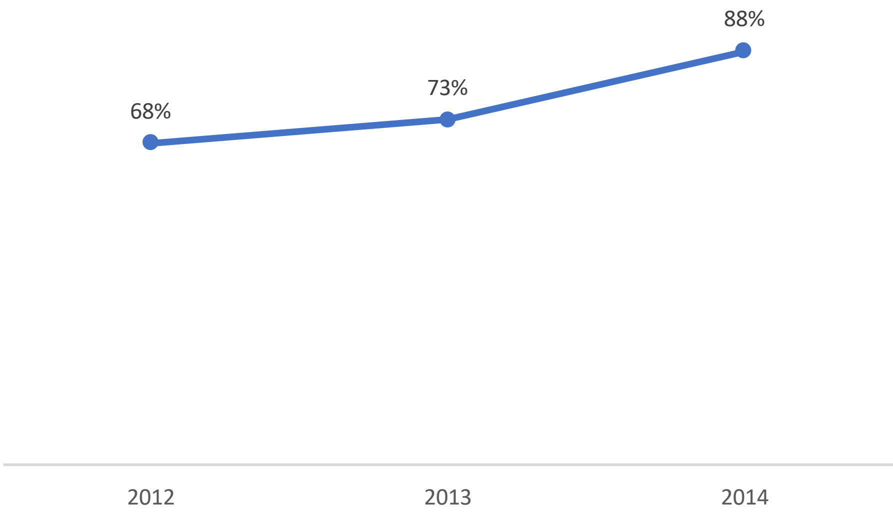
## Call-backs to do repairs

The rate of builders being called back by owners of new homes to do repairs following handover is an indication of the presence of quality defects and the frequency of the opportunity costs from defects. Figure 8 shows the call-back rate to do repairs from 2012 to 2014. The results show that:

- call-backs are very common
- the frequency of owners calling back the builder to do repairs has increased.

**Figure 8 Call-backs to do repair in new houses**

Percentage of owners surveyed that called back the builder to do repairs




**Source: Curtis (2015)**

## 2.6. The costs of quality defects

Our literature search also looked at material on the costs of quality defects. The keywords and phrases used in the literature search included but were not limited to:

- cost of rework
- cost of quality
- cost of poor quality
- cost of construction failures
- cost of defects in construction.

Hall and Tomkins (2001) found the costs of quality defects were 5.8% of the contract value in the United Kingdom.

Love and Li (2000) conducted case studies of the costs of rework in residential and industrial construction in Australia. They estimated the cost of rework in residential and industrial construction to be 3.15% and 2.40% of the contract value, respectively.

Love (2002) reviewed the rework costs from 161 Australian construction projects. The average direct and indirect rework costs were found to be 6.4% and 5.6% of the contract value, respectively.

Mills, Love and Williams (2009) estimated the cost of rectifying residential construction defects. They found the average costs of rectifying a defect was 4.1% of the project contract value. They also found that the costs ranged from 3.0% to 11.2% of the contract value.

## 2.7. Effects of housing quality

Construction quality has wide-ranging and long-lasting financial, economic and environmental effects.

Construction defects affect the financial performance of the residential construction industry because the costs of quality defects can fall on builders, eating into their project earnings.

The economic effects of construction quality defects include a range of costs. The economics costs of quality defects include the financial effects on building firms and flow-on effects to related industries such as construction service specialists. Rectifying quality defects involves opportunity costs in time and materials and reduces the productivity of residential construction in terms of the contribution to the supply of housing.

The effects of construction quality defects can spill beyond the building industry and property owners. Insurance companies and sometimes governments end up bearing part of the cost of quality defects. This has been the case for leaky buildings, with PricewaterhouseCoopers (2009) estimating this to have cost NZ$11.3 billion. Table 3 below shows how that cost was borne by property owners, councils, builders and the government.

### Table 3 Distribution of costs

| Entity | Share of the cost |
|---|---|
| Owners | 69% |
| Councils | 25% |
| Third parties including builders | 4% |
| Government | 2% |

**Source: PricewaterhouseCoopers (2009)**

### Environmental costs and benefits of housing quality

The quality of the construction can deliver environmental benefits through reducing environmental harms arising from:

- construction materials
- construction methods – energy efficiency, construction waste management
- construction outcomes – energy savings, material leaching and waste materials.

# 3. The construction industry

Statistics NZ divides the construction industry into four sub-industries:

- **Residential construction**: includes house construction – mainly building and builders.
- **Non-residential construction**: includes commercial and vertical building for non-residential purposes.
- **Heavy and civil construction**: includes public infrastructure, roads, bridges and railways.
- **Construction services:** includes a wide range of specialist trades such as roofing, plumbing, electrical, air conditioning, earthworks and landscaping.

Table 4 shows the economic output of each sub-industry based on Statistics NZ's input-output tables and NZIER adjustments using the national accounts from Statistics NZ for 2018.

### Table 4 Economic output in the construction industry

2018

| Sub-industry | Economic output |
|---|---|
| Residential construction | $10.55 billion |
| Non-residential construction | $6.76 billion |
| Heavy and civil construction | $14.06 billion |
| Construction services | $19.68 billion |

**Source: NZIER**

For the purpose of this study, we are interested in the economic outputs associated with residential construction. This includes the output from construction specialists in construction services. The complete industry classification of the construction industry is shown in Table 5.

## Table 5 Construction industry composition

| Construction industry |
| --- |
| Residential Building Construction |
| House Construction |
| Other Residential Building Construction |
| Non-Residential Building Construction |
| Non-Residential Building Construction |
| Heavy and Civil Engineering Construction |
| Road and Bridge Construction |
| Other Heavy and Civil Engineering Construction |
| Construction Services |
| Land Development and Subdivision |
| Site Preparation Services |
| Concreting Services |
| Bricklaying Services |
| Roofing Services |
| Structural Steel Erection Services |
| Plumbing Services |
| Electrical Services |
| Air Conditioning and Heating Services |
| Fire and Security Alarm Installation Services |
| Other Building Installation Services |
| Plastering and Ceiling Services |
| Carpentry Services |
| Tiling and Carpeting Services |
| Painting and Decorating Services |
| Glazing Services |
| Landscape Construction Services |
| Hire of Construction Machinery with Operator |
| Other Construction Services not elsewhere classified |

**Source: Australian and New Zealand Standard Industrial Classification (ANZSIC)[3]**

We estimate that 40–50% of construction services are related to residential construction based on the available information on the interaction between construction services and residential construction in Statistics NZ's supply and use tables.

[3] http://archive.stats.govt.nz/browse_for_stats/industry_sectors/anzsic06-industry-classification.aspx

### Table 6 Estimating the total output for residential construction

$ billions

| | Lower estimate | Central estimate | Upper estimate |
|---|---|---|---|
| Residential share of construction services | 40% | 45% | 50% |
| Residential construction output from construction services | $5.90 | $7.87 | $9.84 |
| Residential construction output | $10.55 | $10.55 | $10.55 |
| Total residential output | $16.46 | $18.43 | $20.39 |

**Source: NZIER**

# 4. Methodology

The methodology for estimating the economic costs of quality defects involves two types of economic analysis:

- **Partial equilibrium analysis**: this considers the direct effects on the market in question and assumes that other markets remain the same (i.e. they do not respond to the change in the market or industry directly being considered).
- **General equilibrium analysis**: this allows the investigation of indirect effects on downstream and upstream markets.

Partial equilibrium analysis is common because it requires much less information than general equilibrium analysis and is easier to undertake. It can be done by using basic spreadsheet calculations making it a practical and relatively cost-effective tool for policy analysis, for example. However, partial equilibrium analysis does not tell us anything about how the rest of the economy might respond to the initial change or shock in one part of the economy. This is where computable general equilibrium (CGE) models are powerful and beneficial.

In this research, we use partial equilibrium analysis to:

- provide insights into the magnitude of the initial impacts from quality defects on the residential construction industry
- estimate the shock to be modelled in the CGE model.

The results of the partial equilibrium analysis feed into the general equilibrium analysis to provide greater insights to the impact of the economic costs of quality defects on the whole economy. The partial equilibrium analysis estimates the effects of quality defects on the costs of construction, including what proportion of the total cost of construction is due to defects. In the general equilibrium analysis, we then model the effect of a productivity improvement from avoiding the cost of defects. This means the economic activity from rectifying the defects is avoided. Therefore, both the output and costs from rectifying defects no longer occur, and the labour and capital are redirected throughout the economy.

## 4.1. Partial equilibrium analysis

Figure 9 shows our approach to estimating the economic costs of defects using a partial equilibrium analysis. The equation is composed of three key elements, which are drawn from the literature review and the analysis of the construction industry. The elements of the equation are:

- the prevalence of the construction defects
- the costs of defects measured in terms of a percentage of the project contract (output) value
- the gross output of the residential construction industry as a measure of total economic value of the sector.

Each of these elements involves a degree of uncertainty and some assumptions. The uncertainty and assumptions are described in the results section of the report.

### Figure 9 Estimating the economic cost of defects using a partial approach


**Source: NZIER**

A partial equilibrium approach is a conventional form of economic analysis. It is used widely, especially for policy analysis, because it is simpler and less data hungry than other approaches. The commonality of the approach allows comparison to other analyses.

There are also well-established limitations to partial equilibrium analysis such as:

- it cannot capture the indirect or flow-on effects to the other parts of the economy
- it tends to overstate the direct impact because the economy is not allowed to adjust.

# 4.2. CGE modelling

## CGE modelling captures the full impact of lesser quality defects in the residential construction industry

We use NZIER's ORANI-NZ CGE model to capture the full impact of an increase in productivity resulting from the adoption of higher quality standards in the residential construction industry. Our model contains 106 industries and 201 commodities based on Statistics NZ's input-output tables 2013, which we have updated to reflect the New Zealand economy in 2018. For more detail on the model, see Appendix A.

CGE models are data driven and are used to capture the effects of a new policy or technology or other external shocks affecting economic activity. They capture the economy-wide effects of changes (shocks in modelling jargon) directly on the affected industry as well as indirectly on supplying industries, competing industries and factor markets (labour and capital). CGE models show the full effect of a change, which includes impacts from indirect effects that aren't immediately obvious. The cumulative impact of indirect effects can outweigh the direct effect of a change.

CGE models also estimate the effect of a shock on macroeconomic variables such as GDP, employment, wages and trade.

CGE models are a powerful tool, allowing economists to explore empirically many issues on which econometrics or multiplier analysis would be unusable. For these reasons, CGE models have become widely used internationally (for example, by OECD, IMF, World Bank) for economic impact analysis.

## Why do we prefer CGE over multipliers?

Multiplier studies[4] are popular for economic impact analysis as they are relatively simple and produce appealing big figures. However, they are based on several assumptions, which requires them to be interpreted and considered with considerable care.

Key caveats include that multiplier studies:

- do not consider the impacts of policy changes on the price of goods, services, intermediate inputs, labour (wages) and capital
- assume that land, labour and capital are available in unlimited quantities and at no additional cost to firms
- cannot consider the opportunity cost of using additional resources in one industry on the rest of the economy – there are almost never any losers (i.e. contracting industries) in multiplier studies.

Because of these assumptions, multipliers overestimate the impacts of a change in a particular industry on the rest of the economy. Both MBIE and Treasury have highlighted the inherent flaws in using multiplier studies for serious economic analysis.[5] NZIER no longer offers multiplier-based analysis to our clients as they no longer align with our independence and reputation for delivering high-quality data-driven analysis.

For all these reasons, we prefer to use CGE models.

A CGE model provides an estimation of opportunity costs (between action and inaction) and winners and losers. Resources are limited. It also considers price impacts of shocks and can capture linkages between industries as well as flow-on effects.

NZIER's CGE models are highly regarded amongst government agencies with whom we have worked to conduct policy analysis or sectoral impact studies. This includes MBIE, Treasury, the Ministry of Foreign Affairs and Trade, the Ministry for Primary Industries and the Ministry for the Environment.

## How do CGE models work?

A CGE model consists of equations that describe model variables. It also uses detailed data on the structure of the economy that is consistent with these model equations.

This data provides a snapshot of the economy in a particular year, which is used as a starting point for a baseline or business as usual (BAU) against which to compare policy simulations or economic changes.

4 Also known as input-output studies.

5 For an overview of these weaknesses, see Treasury (2015), MBIE (2013) and Gretton (2013), which clearly state that multipliers overstate economic impacts and thus lack credibility for economic analysis. In Treasury's words: "Unless there is significant unemployment of people with the requisite skills, it is therefore likely that multiplier effects do not exist."

The model data is linked together through a set of equations that capture how the economy evolves over time in response to a shock. These equations, which are based on the economic theory of general equilibrium, ensure supply and demand for goods, services and factors of production in the economy are balanced and determine how firms and households react in response to changes in incentives.

Most CGE models are written and solved in a specific software system, usually GAMS[6] or GEMPACK.[7]

In any CGE model, we must choose what is to be determined within the model (the endogenous variables) and what is to be considered external to the model (the exogenous variables). A CGE model is just a way of explaining the endogenous variables in terms of the exogenous variables.

Where we draw the line between endogenous and exogenous variables and which ones can vary or have to remain fixed depends on a number of factors, including the purpose for which the model simulations are to be used. The choice that we make is called the model closure.

Determining the closure is a key part of any modelling exercise, and it is very important that the modeller be transparent about what is a result of the modelling and what has been imposed by assumption via the closure.

The difference between the initial and the new equilibrium can then be analysed to determine the effect of the shock on a range of economic indicators, such as GDP, employment, wages and living standards.

## NZIER's CGE model ORANI-NZ

NZIER's ORANI-NZ[8] model is a top-down model of the New Zealand economy.

ORANI-NZ is based on the latest Statistics NZ's input-output table that identifies the structure of the industries involved. It contains information on 106 industries, 201 commodities and 15 regions. It therefore offers a unique capability to highlight the role of higher quality in residential construction and services in the New Zealand economy.

Figure 10 shows how the model captures the complex and multidirectional flows between the various actors of the national economy and how they interact with the rest of the world. More technical details on the model are available upon request.

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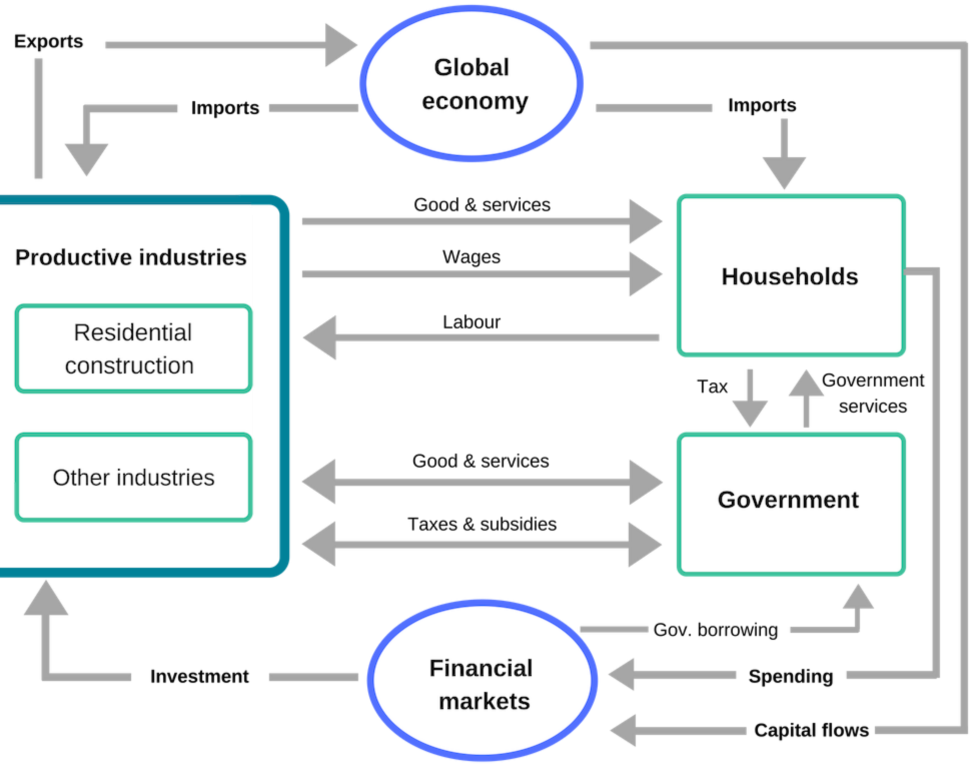
6 General Algebraic Modelling System: https://www.gams.com/

7 General Equilibrium Modelling Package: https://www.copsmodels.com/gempack.htm

8 ORANI-NZ was developed at NZIER based on the original Australian ORANI model created by Professor Mark Horridge of the Centre of Policy Studies, Victoria University, Melbourne, Australia (http://www.copsmodels.com/oranig.htm). NZIER maintains close connections with the Centre, ensuring that our modelling techniques reflect international best practice.

## Figure 10 Our CGE model represents the circular flows between all the agents and activities in the economy




Source: NZIER

# 4.3. Scenario design

Table 7 below presents the three positive shocks on productivity in the residential construction and construction services industries. In effect, we are asking the model to determine how the national economy will adjust to an increase in productivity in these two industries in a way that uses the national economy resources most efficiently to return all markets to equilibrium. Further details on the three scenarios can be found in Appendix A.3.

## Table 7 Summary of productivity shocks

| Industry | Variable | Low scenario | Central scenario | High scenario |
|---|---|---|---|---|
| Residential construction | Prevalence of defects | 85% | 90% | 95% |
| | Average costs of defects | 3% | 6% | 9% |
| | **Cost factor (shock CGE)** | **2.6%** | **5.4%** | **8.6%** |
| Construction services | Residential share of construction services | 40% | 45% | 50% |
| | **Cost factor (shock CGE)** | **1.0%** | **2.4%** | **4.3%** |

Source: NZIER

The scenarios consider the benefits of complete elimination of the productivity effects. Completely eliminating defects may not be realistic. Our scenarios are designed to estimate what's at stake for the construction industry and the economy.

## 4.4. Analysing the modelling results

Our analysis of the modelling results is systematic as we track the impacts as they flow through the economy.

We first look at the **direct impacts** on the residential construction and construction services industries to see how these two industries respond to increased productivity.

We then analyse the **flow-on or indirect impacts** on other industries. We split the indirect impacts into the following industry categories:

- **Supplying industries:** industries that supply intermediate inputs are likely to be negatively affected by cost savings in residential construction and construction services industries. These are industries such as wood manufacturing or fabricated metal product.
- **Household expenditure industries:** industries that households spend money on are likely to be positively affected from the increased income that comes through higher employment and wages and the increased returns to capital from productivity increase in residential construction and construction services industries.
- **Competing industries:** industries that compete for resources (such as labour and capital) with the residential construction and construction services industries.

We also examined the **economy-wide effects** that flow logically from the direct and indirect impacts. We focus on macroeconomic variables such as employment, GDP, welfare (private and public consumption) measures, trade and investment.

# 5. Results

We now present the results of the partial and general equilibrium analyses.

## 5.1. Estimating the cost of quality defects (partial equilibrium)

Table 8 contains the scenario input variables. They are based on the literature review and the construction industry analysis

### Table 8 Scenario inputs

| Variable | Central | Lower bound | Upper bound |
|---|---|---|---|
| Prevalence of defects | 90% | 85% | 95% |
| Average costs of defects | 6% | 3% | 9% |
| Cost factor | 2.6% | 5.4% | 8.6% |
| Output of the residential construction industry | $18.43 billion | $16.46 billion | $20.39 billion |

**Source: NZIER**

These assumptions were made in the estimation of the costs of residential construction defects:

- The prevalence of quality defects in non-new house construction is the same as in new house construction.
- International estimates of the costs of residential construction quality defects are applicable to New Zealand.
- Findings from earlier years are applicable to the construction industry in 2018.

The results for the lower, central and upper scenarios are shown in Table 9.

### Table 9 Partial equilibrium analysis

| Scenario | Cost of quality defects |
|---|---|
| Lower estimate | $420 million |
| Central estimate | $995 million |
| Upper estimate | $1,744 million |

**Source: NZIER**

## 5.2. Wider economic effects (general equilibrium)

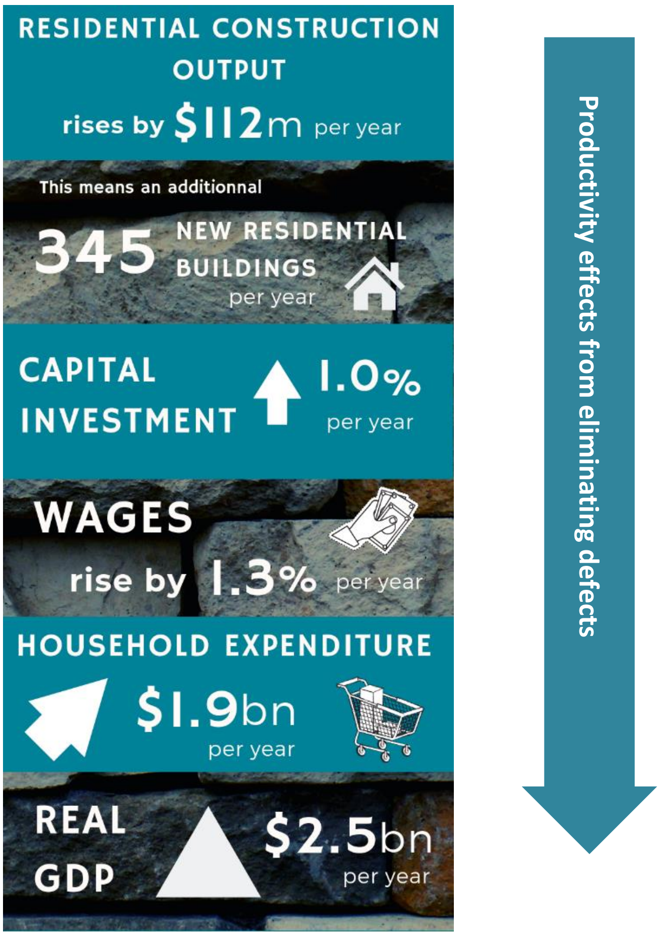
The macroeconomic impacts for the central scenario are discussed in this section. Results from the sensitivity scenarios can be found in Appendix B.

Eliminating quality issues would improve the productivity and performance of residential construction in New Zealand, by releasing opportunities for additional consumption and economic growth. Residential construction output would increase by $112 million annually, and capital investment across the economy would increase by 1% annually.

The productivity improvement in residential construction would lead to a 1.3% increase in wages throughout the economy. Households would better off and increasing spending in other parts of the economy.

The results show that economy-wide effects of an increase in productivity would see New Zealand's GDP rise by $2.5 billion, as the industry's overall costs of production decrease. Households would have $1.4 million additional income available to spend on goods and services, which would increase aggregate living standards.

**Figure 11 New Zealand economy benefits from quality improvements in residential construction and construction services**




**Source: NZIER**

### 5.2.1. Direct impacts on the residential construction industry

Table 10 presents the direct impact on outputs from increased productivity in residential construction and construction services industries.

The productivity improvement has a positive effect on the residential building construction industry. The productivity improvement increases residential construction output by $112 million (1.1%) under the central scenario. This equates to an additional 345 new residential buildings per year on average.[9]

There are two effects on construction services due to the interaction between residential construction, non-residential and heavy construction, which all compete for resources from the construction services industry.

Currently rectifying the defects generates activity for the construction services industry. Therefore, avoiding work from rectifying defects means demand for construction services decreases. In the first effect, capital and labour in construction services is reallocated away from the residential work and towards non-residential and heavy construction.

Then the increase in residential construction output attracts capital and labour from non-residential and heavy construction, which results in a decrease in output for these two industries. This is the second effect.

Overall output in construction services decrease by $138 million (see Table 10) as the industry provides services to the three competing industries that make up the construction sector: residential, non-residential and heavy construction.

**Table 10 Impacts on residential building construction and construction services outputs**

Changes from baseline (2018)

| Industries | Productivity increase | | | | | |
|---|---|---|---|---|---|---|
| | Low scenario | | Central scenario | | High scenario | |
| | % change | Level ($m) | % change | Level ($m) | % change | Level ($m) |
| **Residential construction** | 0.50% | $53 | **1.10%** | **$112** | 1.83% | $181 |
| **Construction services** | -0.36% | -$70 | **-0.71%** | **-$138** | -1.05% | -$202 |
| **Net effects** | -0.07% | -$17 | **-0.11%** | **-$26** | -0.09% | -$21 |

Source: NZIER

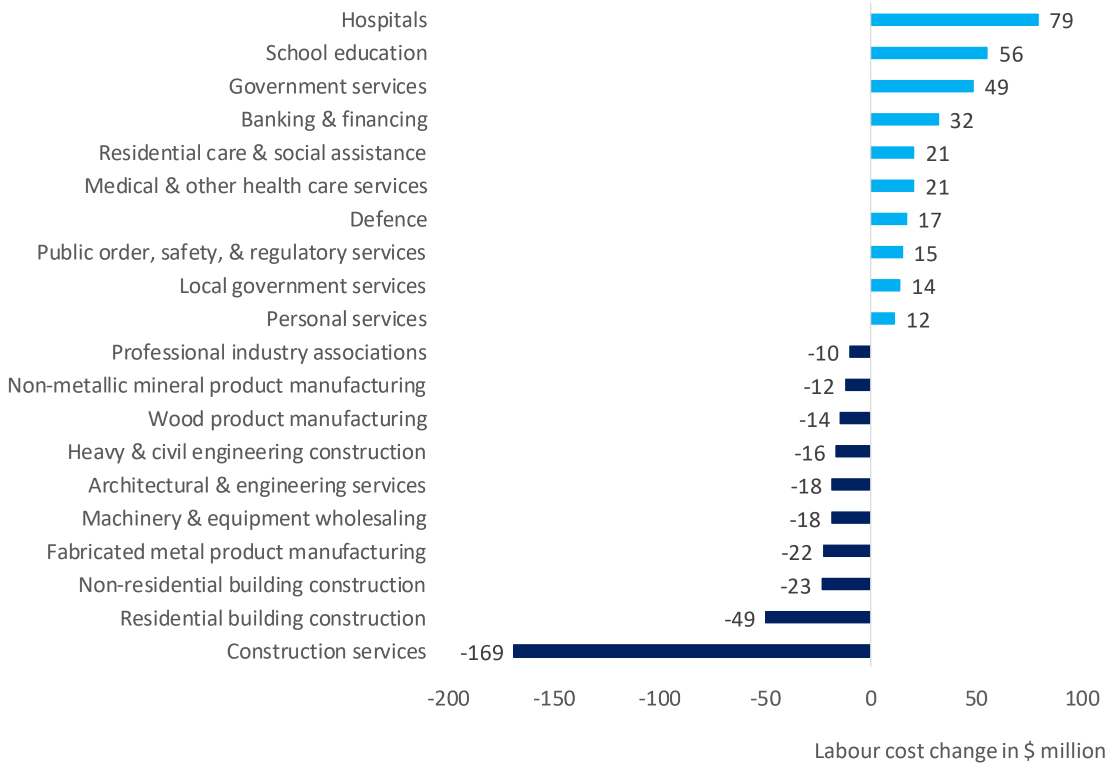
9 Based on 31,251 building consents issued for all dwellings in 2018 and assuming that 99% of these consents go through. https://www.stats.govt.nz/information-releases/building-consents-issued-january-2019

## 5.2.2. Labour is reallocated across industries

With higher productivity in the residential construction industry, labour relocates away from residential building construction and construction services into other industries that are labour intensive and offer higher wages, such as the service industries. Figure 12 shows the reallocation of labour across construction industries following an increase in productivity in the residential construction industry.

**Figure 12 Labour costs decrease in construction industries**

Changes from baseline (2018) in $ millions (central scenario) – selected industries




**Source: NZIER**

## 5.2.3. National industry outputs expand with the flow-on effects

Table 11 presents the flow-on effects on selected top industries that benefit the most from a productivity increase in the residential construction industry. The overall effect is that economic output increases by $2.5 billion in 2018.

The indirect effects of increased productivity in residential construction and construction services industries are widespread across other industries within the economy (see Table 11).

## Table 11 Flow-on effects on selected top industries

Changes from baseline (2018) in $ millions (central scenario) – selected industries

| Industries | Industry type | Central scenario | |
|---|---|---|---|
| | | % | $ millions |
| Banking and financing; financial asset investing | Competing industries | 1.4% | $183 |
| Central government administration services | | 1.5% | $109 |
| Electricity generation and on-selling | | 0.7% | $84 |
| School education | | 1.0% | $81 |
| Telecommunications services | | 0.7% | $68 |
| Non-residential property operation | | 0.6% | $65 |
| Dairy product manufacturing | | 0.3% | $50 |
| Food and beverage services | | 0.5% | $41 |
| Defence | | 1.5% | $35 |
| Local government administration services | | 1.5% | $31 |
| Heavy and civil engineering construction | Competing/ downstream industries | -0.3% | -$35 |
| Non-residential building construction | | -2.5% | -$166 |
| Owner-occupied property operation | Household expenditure industries | 3.3% | $780 |
| Residential property operation | | 2.1% | $228 |
| Hospitals | | 1.1% | $122 |
| Medical and other health care services | | 1.2% | $114 |
| Residential care services and social assistance | | 0.7% | $35 |
| Beverage and tobacco product manufacturing | | 0.7% | $34 |
| Personal services; domestic household staff | | 1.4% | $33 |
| Supermarket and grocery stores | | 0.8% | $32 |
| Real estate services | | 0.2% | $10 |
| Scientific, architectural, and engineering services | Supporting industries (downstream and supplying) | -0.1% | -$14 |
| Machinery and equipment wholesaling | | -0.4% | -$27 |
| Non-metallic mineral product manufacturing | | -1.5% | -$43 |
| Wood product manufacturing | | -1.0% | -$53 |
| Fabricated metal product manufacturing | | -1.3% | -$77 |
| **New Zealand industry outputs** | | **0.4%** | **$2,618** |

Source: NZIER

**Supplying (or upstream) industries** process the basic or raw materials (sand, wood logs, glass etc.) into intermediary products (cement, wood panels etc), which are then supplied by the residential construction and residential construction services.

Supplying industries, whose outputs depend on the demand from the residential construction and residential construction services, are likely to be negatively affected by cost savings in residential construction and construction services industries, including:

- fabricated metal product outputs decrease by $77 million (1.3%)
- wood manufacturing outputs decrease by $53 million (1.0%).

**Household expenditure industries** that households spend money on are likely to be positively affected from the increased income that comes through higher employment and wages, and the increased returns to capital from productivity increase in residential construction and construction services industries. Outputs increase for:

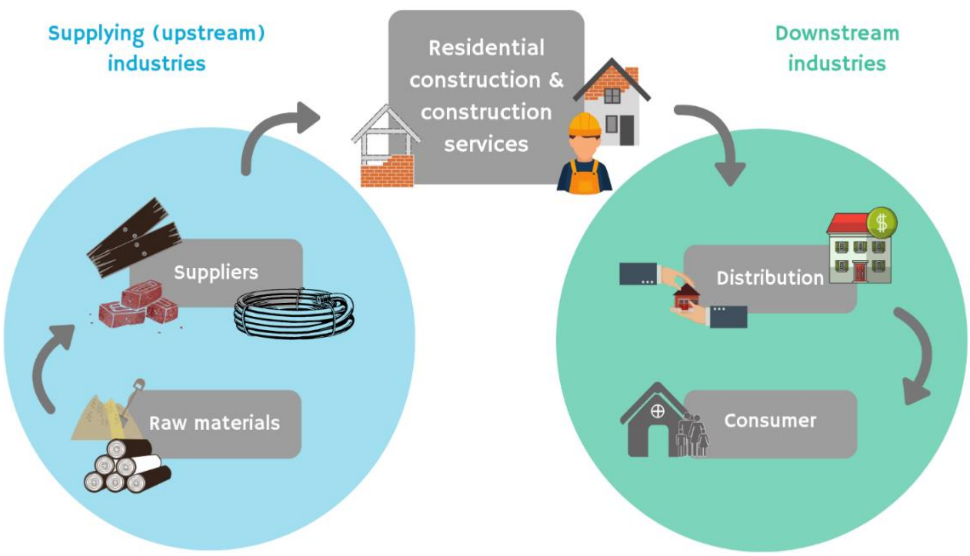
- owner-occupied property operations ($780 million or 3.3%)
- residential property operation industries ($228 million or 2.1%)
- real estate services ($10 million or 0.2%).

**Competing industries** that compete for resources (such as labour and capital) with the residential construction and construction services industries are expected to be positively affected by cost savings in these two industries. This is especially the case for:

- banking and financing industry ($183 million or 1.4%)
- other service industries such as central government administration services ($109 million or 1.5%)
- school education ($81 million or 1.0%)
- telecommunication services ($68 million or 0.75%).

Figure 13 presents the linkages between the supplying and downstream industries of the residential construction and construction services industries.

## Figure 13 Supplying (upstream) and downstream industries




Source: NZIER

### 5.2.4. Real imports of supporting industries fall

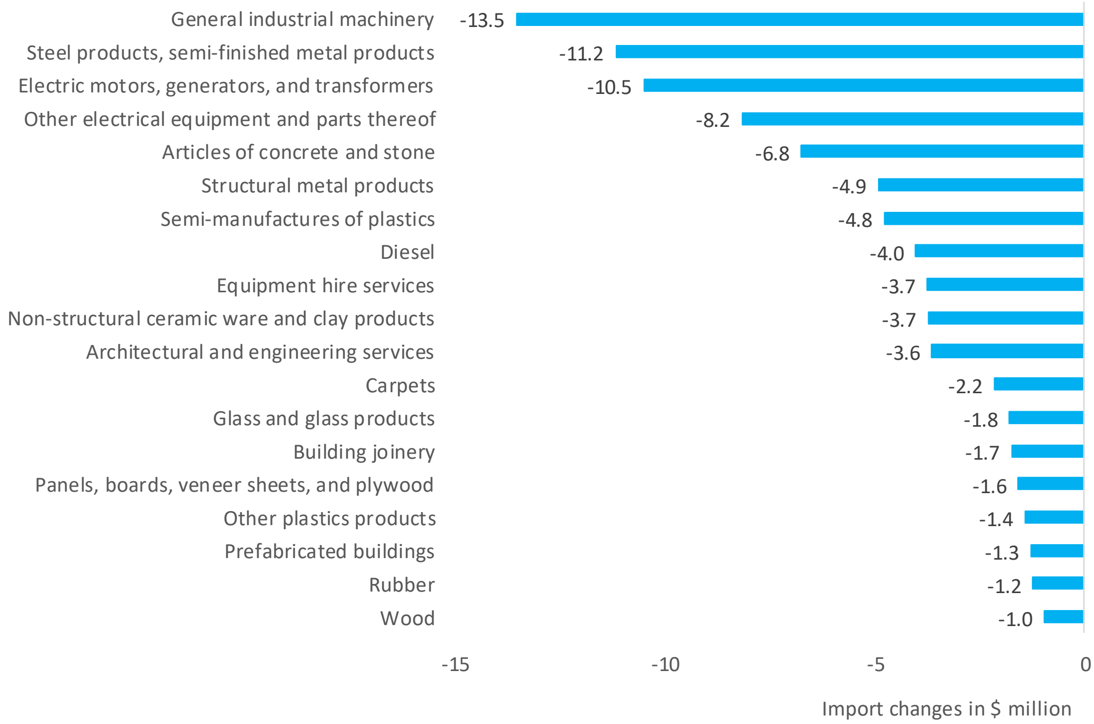
Figure 14 presents the effects of productivity increases in residential construction and construction services industries on imports of supporting industries.

Under the central scenario, national real imports rise by $121 million (0.16%) with the growth in GDP.

At the industry level, imports are reduced for commodities mainly used by the residential construction and construction services industries, representing the cost savings from the reduced demand for imports needed to rectify construction defects. In comparison, imports of growing industries (services, agriculture, food and accommodation) are rising to respond to the increased household demand, as shown in Table 17 in Appendix B.

**Figure 14 Import effects of higher productivity on supporting industries**

Change in real imports from baseline (2018) central scenario ($ millions)




**Source: NZIER**

### 5.2.5. Household consumption and wages increase

Table 12 presents the impacts of a productivity increase in residential construction and construction services on household spending and wages.

As a result of higher productivity, the marginal value of labour rises, which leads to an increase of real wages. Real household consumption increases, which drives the growth in industry outputs.

**Table 12 Impacts on household consumption and wages**

Change in output from baseline (2018) in $ millions and percent, in real terms

| Indicator | Productivity increase | | | | | |
|---|---|---|---|---|---|---|
| | Low | | Central | | High | |
| | % change | Level ($m) | % change | Level ($m) | % change | Level ($m) |
| Household consumption | 0.53% | $646 | 1.18% | $1,444 | 1.96% | $2,407 |
| Wages | 0.58% | NA | 1.30% | NA | 2.17% | NA |

**Source: NZIER**

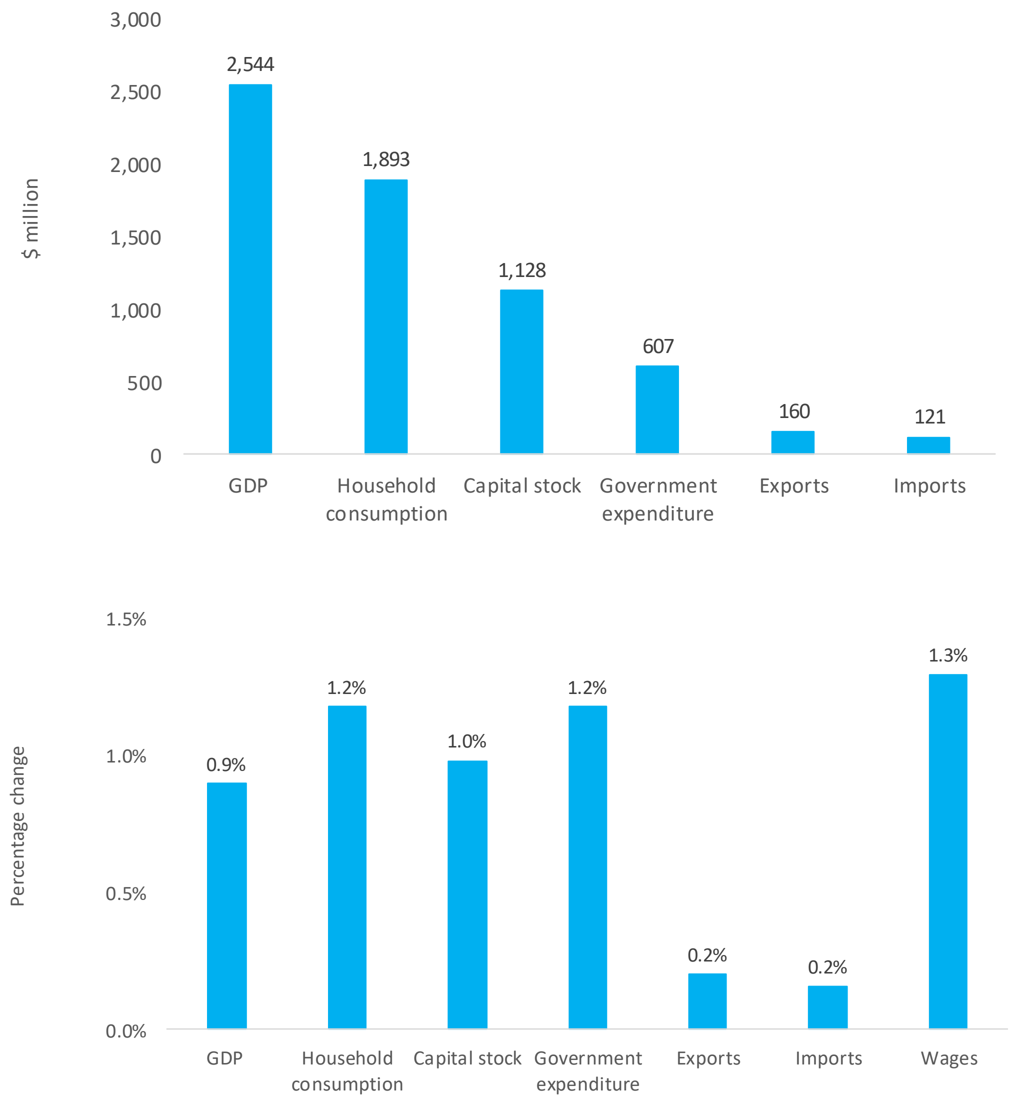
### 5.2.6. New Zealand's GDP increases by $2.5 billion

Figure 15 shows the macroeconomic impacts of a productivity increase (decrease in quality defects) in residential construction and services under the central scenario.

As the cost of construction decreases with higher productivity, economic activity grows and real GDP rises by 0.9% (or $2.5 billion). The volume of exports increases by 0.2% or $160 million as New Zealand exporters become marginally more internationally competitive. As the economy expands, the demand for labour rises, which sees real wages increase by 1.3%. Consequently, household incomes increase and real household spending is 1.2% or $1.9 billion higher. Capital increases by $1.1 billion (1.0%).

## Figure 15 National economic impacts following quality improvemnts in residential construction and services

Change in output from baseline (2018) in $ millions (in real terms), central scenario




Note: Our CGE only provides percentage change for wages.

**Source: NZIER**

# 6. Discussion

The research shows that the economic effects of quality defects are not limited to the construction industry. The labour and capital required for the rework caused by the defects discovered during inspections could be utilised in other economic activities.

In this section, we summarise the implication for firms, the construction industry, consumers and the economy.

## 6.1. Implications for firms

Rework is an opportunity cost for firms. Reducing rework improves the profit margin from the construction of new houses. In effect, frequent rework weakens the resilience of firms. As profit margins are squeezed, the residential construction business is left with little cushioning to cope with rainy days.

The impact of quality defects on the financial viability of building firms was beyond the scope of this report. That said, the prevalence of quality defects should be considered a potential source of financial pressure for individual firms.

A bottom-up case-by-case review of the impact of quality defects would be needed to understand the role quality defects play in the resilience and sustainability of the residential construction business.

## 6.2. Implications for industry

The prevalence of quality defects means that rework has become the norm for the industry. As a consequence, project managers will be incentivised to price in the cost of rework where they can and spread the costs across several projects. As a result, the cost of construction is increased, and housing affordability of new homes is affected.

Quality defects impede productivity improvements in an industry that has struggled to improve productivity over time.

## 6.3. Implications for the economy

Eliminating quality issues would improve the productivity and performance of residential construction in New Zealand. Eliminating defects would release opportunities for additional consumption and economic growth. Residential construction output would increase by $112 million annually, and capital investment across the economy would increase by 1% annually. The productivity improvement in residential construction would lead to a 1.3% increase in wages throughout the economy.

The results show that economy-wide effects of an increase in productivity would see New Zealand's GDP rise by $2.5 billion, as the industry's overall costs of production decrease. Households would have $1.4 million additional income available to spend on goods and services, which would increase aggregate living standards.

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# Appendix A Overview of ORANI-NZ CGE model

## A.1 CGE modelling

To capture the full effect of the quality defects in residential construction and residential construction services industries, we have used the ORANI-NZ model, one of our suite of computable general equilibrium (CGE) models.

CGE modelling is widely regarded as more robust and providing more credible impact assessments than input-output (multiplier) methodologies.[10]

Multiplier methodologies typically overstate economic impact estimates because they assume that economic resources such as land, labour and capital are infinitely available are never idle or can be reallocated without adjustment costs. They also assume that all prices remain constant, even if demand increases.

In contrast, CGE models are not only driven by prices that respond to changes in supply and demand, they also account for resource constraints and flow-on effects. That is, in a CGE model, there are no "free lunches".

CGE models therefore produce more conservative but more credible economic impacts compared to multiplier methodologies. CGE models are now our preferred method for assessing economic impacts and are used extensively in New Zealand and internationally.

As a commentary by Denniss (2012) noted regarding CGE modelling, "a well-designed model that is used by skilled practitioners to shed light on issues the model was designed to illuminate can make a significant contribution to policy debates and decision making".

Using actual economic data, CGE models estimate how an economy reacts to major projects or changes in policy, technology or other external factors. CGE models are useful whenever we wish to estimate the effect of changes in one part of the economy upon the whole of New Zealand.

In summary, to estimate the effect of some change such as change in the productivity (referred to as a shock), the modeller specifies a starting position for the economy based on data in which supply is equal to demand in all markets (known as being in equilibrium), changes parts of the data to reflect the shock and then, using a highly detailed model of the economy and specialised software, determines what needs to happen to return the economy to a new equilibrium.

To allow the model to achieve a new equilibrium, some aspects of the economy have to remain fixed. These aspects are collectively known as the model closure. Common

[10] See Gretton (2013) for a thorough discussion of what multipliers are, how they are constructed and their shortcomings as tools for assessing economic impacts. We also note that the Australian Bureau of Statistics has ceased to provide multiplier estimates from its input-output tables. https://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/5209.0.55.001Main%20Features4Final%20release%202006-07%20tables

closures, for example, are population and the labour force, the exchange rate, interest rates or export prices.

Determining what should be included in the closure and what should be allowed to vary within the model is a key part of any modelling exercise, and it is very important that the modeller be very transparent about what is a result of the modelling and what has been imposed via the closure.

We detail the specific closures we have used in this model in section A.4 below.

The difference between the old and the new equilibrium can then be analysed to determine the effect of the shock on a range of economic indicators such as GDP, employment, wages and living standards.

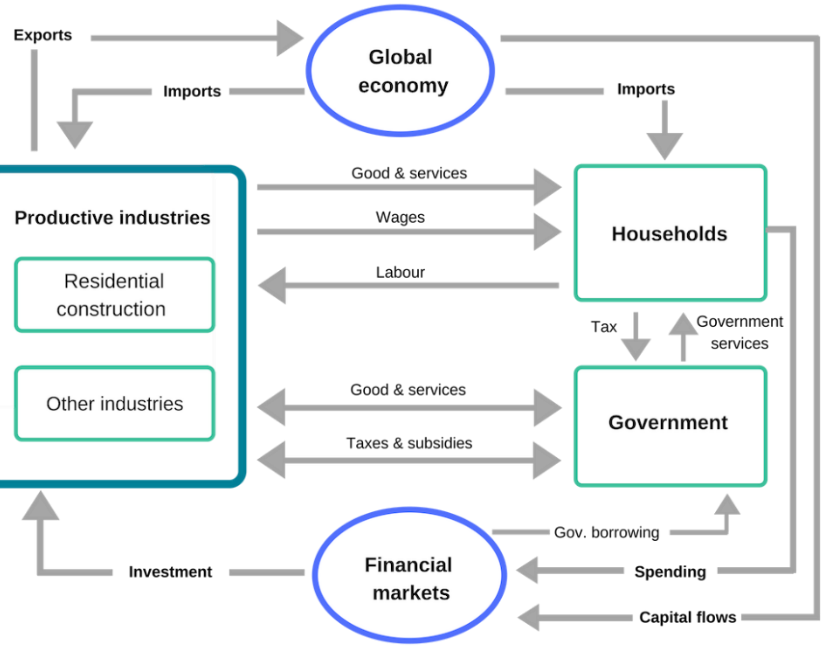
## A.2 Our national CGE model, ORANI-NZ

NZIER's national CGE model, ORANI-NZ, is a top-down model of the New Zealand economy, which begins with components of the economy and sums them up to obtain an aggregate description of the economy.

It is based on Statistics NZ's 2013 input-output tables, which have been updated to reflect the economy in 2018.

A visual representation of ORANI -NZ is shown in Figure 16. It highlights how the model can capture the complex and multidirectional relationships between the various parts in the economy and how they interact with the rest of New Zealand and rest of the world.

**Figure 16 Our CGE model represents the circular flows between all the agents and activities in the economy**




**Source: NZIER**

**Key features** of the model:

- Each industry can produce a number of different commodities.
- Production inputs are intermediate commodities (domestic and imported) and primary factors (labour, land and capital).
- The demand for primary factors and the choice between imported and domestic commodities are determined by constant elasticity of substitution (CES) production nests. This means an increase in price of one input shifts sourcing towards another input.
- Intermediate goods, primary factors and other costs are combined using a Leontief production function. This means the proportion of production inputs is held constant for all levels of output.
- The production mix of each industry is dependent on the relative prices of each commodity. The proportion of output exported or consumed domestically is also dependent on relative prices.
- Policy impacts are often unevenly spread across industries and regions. To capture these heterogeneous effects, the model is extended to include a regional component. A top-down approach is used to decompose national impacts to the regional level, using regional data as weighting.[11]

More technical details on the model are available on request.

The model includes 106 industries and 201 commodities in its standard form.

## A.3 Our modelling approach

### A.3.1 Business as Usual 2018

We wanted to assess the economic impacts of increased productivity in the residential construction and residential construction services industries due to a reduction in quality defects.

Our first step was to develop a baseline or BAU picture of the economy. To do so, we calibrated our model of the national economy to the latest available data from Statistics NZ. This allows us to ensure we correctly benchmark the size of the various industries and gives us a BAU snapshot of the national economy.

### A.3.2 Scenario design

As stated previously, we are interested in estimating the economic contribution of quality defects in residential construction and construction services industries.

We do not explicitly model the timing of the quality improvement in the different residential construction industries but instead analyse a static, long-term scenario that estimates the overall impacts of a reduction in quality defects to the New Zealand economy.

[11] The regions in the model are Northland, Auckland, Waikato, Bay of Plenty, Gisborne, Hawke's Bay, Taranaki, Manawatu-Wanganui, Wellington, Tasman-Nelson, Marlborough, West Coast, Canterbury, Otago, Southland. For the purposes of this analysis, we have split out the Rotorua economy from the Bay of Plenty region and applied our shocks directly to the Rotorua district.

As shown in Table 13, we impose three positive shocks on productivity in the residential construction and construction services industries. In effect, we are asking the model to determine how the national economy will adjust to an increase in productivity in these two industries in a way that uses the national economy resources most efficiently to return all markets to equilibrium.

The construction services industry works across the following three construction sub-industries:

- Residential construction
- Non-residential construction
- Heavy and civil engineering construction.

We looked at the use table from Statistics NZ latest input-output tables to estimate the share of construction services provided to the residential construction industry.

We measured this share at 45%, which became our central scenario, and used 40% and 50% as our low and high scenarios, respectively. We then used these shares to estimate our productivity shocks in the construction services.

### Table 13 Productivity shocks

| Industry | Variable | Low scenario | Central scenario | High scenario |
|---|---|---|---|---|
| **Residential construction** | Prevalence of defects | 85% | 90% | 95% |
| | Average costs of defects | 3% | 6% | 9% |
| | **Cost factor (shock CGE)** | **2.6%** | **5.4%** | **8.6%** |
| **Construction services** | Residential share of construction services | 40% | 45% | 50% |
| | **Cost factor (shock CGE)** | **1.0%** | **2.4%** | **4.3%** |

**Source: NZIER**

## A.4 Closure

As we noted above, in any CGE model, it is important to understand which factors have been allowed to vary and which remain fixed by assumption (also known as exogenous variables). The particular combination of fixed factors is known as the closure.

Table 14 lists the main variables included in the modelling underlying this report.

- National employment is fixed but labour is completely mobile between industries and regions, and real wages adjust to labour market changes. This is consistent with the idea that both the labour force and the rate of employment are, in the long run, determined by mechanisms outside the model.
- Real household and real government expenditures move together to accommodate a fixed balance of trade as a share of GDP. This assumption is made to prevent welfare effects from having unsustainable trade deficit.
- Foreign currency prices of imports are naturally exogenous.

- Rates of return are exogenous, and capital is mobile between industries and regions. This mobility can occur either in the form of machinery etc. being physically moved or capital in one industry/region being allowed to depreciate without replacement while investment builds up the stock of another industry/region.
- Other exogenous variables include rates of production tax, technological coefficients, national population and national labour supply.

**Table 14 Fixed elements of the model**

| Items |
|---|
| Taxes on production |
| Technological change |
| Government demand |
| Gross growth rate of capital |
| Price on capital rental |
| Number of households |
| National population |
| National labour supply |
| Import prices, foreign currency |
| Foreign demand for New Zealand exports |
| Land usage |

Source: NZIER

## A.5 Modelling caveats

As with any economic modelling approach, the technique we have employed has its limitations:

- We have used a productivity shock to represent quality improvements in residential construction and residential construction services industries. This is a simplification of how a reduction in quality defects in these industries will operate.
- We do not explicitly model the timing of the quality improvement in the different residential construction industries but instead analyse a static long-term scenario that estimates the overall impacts of a reduction in quality defects to the New Zealand economy.
- Our CGE model assumes no relocation costs. In reality, relocation will be required to find alternative employment, increasing the time required and other costs to find new work.
- The CGE model is based on Statistics NZ's input-output tables, with decisions based on neoclassical economics. Structural changes to the economy from higher-quality outputs in the residential construction and services industries are therefore not captured in the modelling, nor are any non-competitive market structures.

# Appendix B Additional results from CGE modelling

## Table 15 Additional flow-on effects on selected industries

Changes from baseline (2018) in percent and $ millions

| Industries | Industry type | Low | | Central | | High | |
|---|---|---|---|---|---|---|---|
| | | % | $ millions | % | $ millions | % | $ millions |
| Banking and financing; financial asset investing | Competing industries | 0.6% | $82 | 1.4% | $183 | 2.3% | $306 |
| Central government administration services | | 0.7% | $49 | 1.5% | $109 | 2.4% | $182 |
| Electricity generation and on-selling | | 0.3% | $37 | 0.7% | $84 | 1.1% | $140 |
| School education | | 0.5% | $36 | 1.0% | $81 | 1.7% | $136 |
| Telecommunications services | | 0.3% | $30 | 0.7% | $68 | 1.2% | $114 |
| Non-residential property operation | | 0.3% | $29 | 0.6% | $65 | 1.0% | $108 |
| Dairy product manufacturing | | 0.1% | $22 | 0.3% | $50 | 0.4% | $84 |
| Food and beverage services | | 0.2% | $18 | 0.5% | $41 | 0.9% | $68 |
| Defence | | 0.7% | $16 | 1.5% | $35 | 2.5% | $58 |
| Local government administration services | | 0.7% | $14 | 1.5% | $31 | 2.4% | $52 |
| Professional associations | | -0.4% | -$9 | -0.8% | -$20 | -1.4% | -$34 |
| Heavy and civil engineering construction | | -0.1% | -$15 | -0.3% | -$35 | -0.4% | -$60 |
| Non-residential building construction | | -1.2% | -$78 | -2.5% | -$166 | -4.0% | -$264 |
| Owner-occupied property operation | Household-related industries | 1.5% | $353 | 3.3% | $780 | 5.5% | $1,286 |
| Residential property operation | | 0.9% | $102 | 2.1% | $228 | 3.6% | $381 |
| Hospitals | | 0.5% | $55 | 1.1% | $122 | 1.9% | $204 |
| Medical and other health care services | | 0.5% | $51 | 1.2% | $114 | 1.9% | $191 |

| Industries | Industry type | Low | | Central | | High | |
|---|---|---|---|---|---|---|---|
| | | % | $ millions | % | $ millions | % | $ millions |
| Residential care services and social assistance | | 0.3% | $16 | 0.7% | $35 | 1.1% | $59 |
| Beverage and tobacco product manufacturing | | 0.3% | $15 | 0.7% | $34 | 1.2% | $58 |
| Personal services; domestic household staff | | 0.6% | $15 | 1.4% | $33 | 2.3% | $55 |
| Supermarket and grocery stores | | 0.3% | $14 | 0.8% | $32 | 1.3% | $54 |
| Scientific, architectural, and engineering services | Supporting industries (downstream and supplying) | -0.1% | -$8 | -0.1% | -$14 | -0.2% | -$20 |
| Machinery and equipment wholesaling | | -0.2% | -$11 | -0.4% | -$27 | -0.7% | -$47 |
| Non-metallic mineral product manufacturing | | -0.7% | -$20 | -1.5% | -$43 | -2.4% | -$70 |
| Wood product manufacturing | | -0.5% | -$25 | -1.0% | -$53 | -1.6% | -$83 |
| Fabricated metal product manufacturing | | -0.6% | -$36 | -1.3% | -$77 | -2.2% | -$125 |
| **New Zealand industry outputs** | | **0.2%** | **$1,157** | **0.4%** | **$2,618** | **0.7%** | **$4,412** |

**Source: NZIER**

## Table 16 Additional effects on labour costs for selected industries

Changes from baseline (2018) in percent and $ millions

| Industries | Low scenario | | Central scenario | | High scenario | |
|---|---|---|---|---|---|---|
| | $ millions | % | $ millions | % | $ millions | % |
| Residential building construction | -74.2 | -1.55% | -168.8 | -3.51% | -285.5 | -5.92% |
| Construction services | -23.2 | -2.22% | -49.2 | -4.71% | -78.1 | -7.45% |
| Non-residential building construction | -10.6 | -1.23% | -22.7 | -2.63% | -36.5 | -4.22% |
| Machinery and equipment wholesaling | -10.2 | -0.77% | -22.2 | -1.68% | -36.1 | -2.74% |
| Professional industry associations | -7.9 | -0.30% | -18.3 | -0.70% | -31.7 | -1.21% |
| Real estate services | -8.2 | -0.25% | -17.7 | -0.54% | -28.7 | -0.87% |
| Road transport | -7 | -0.22% | -16.1 | -0.49% | -27.4 | -0.84% |

| Industries | Low scenario | | Central scenario | | High scenario | |
|---|---|---|---|---|---|---|
| | $ millions | % | $ millions | % | $ millions | % |
| Architectural and engineering services | -6.4 | -0.60% | -13.8 | -1.28% | -22.1 | -2.05% |
| Fabricated metal product manufacturing | -5.3 | -0.85% | -11.7 | -1.85% | -19.2 | -3.02% |
| Heavy and civil engineering construction | -4.3 | -0.41% | -9.7 | -0.91% | -16.2 | -1.52% |
| Non-metallic mineral product manufacturing | -2.4 | -0.35% | -5.4 | -0.79% | -9.1 | -1.32% |
| Transport equipment manufacturing | -2.4 | -0.11% | -5.3 | -0.25% | -8.7 | -0.40% |
| Mining and quarrying | -2.1 | -0.10% | -4.7 | -0.22% | -7.8 | -0.37% |
| Legal and accounting services | -1.6 | -0.15% | -3.7 | -0.34% | -6.2 | -0.57% |
| Wood product manufacturing | -1.2 | -0.35% | -2.7 | -0.79% | -4.5 | -1.34% |
| Employment and other administrative services | 2.7 | 0.12% | 5.9 | 0.27% | 9.8 | 0.44% |
| Auxiliary finance and insurance services | 2.8 | 0.18% | 6.2 | 0.41% | 10.3 | 0.68% |
| Food and beverage services | 3.3 | 0.13% | 7.3 | 0.29% | 12.1 | 0.47% |
| Supermarket and grocery stores | 3.3 | 0.19% | 7.3 | 0.42% | 12 | 0.70% |
| Preschool education | 4.2 | 0.43% | 9.5 | 0.96% | 15.8 | 1.60% |
| Personal services; domestic household staff | 5.2 | 0.50% | 11.6 | 1.12% | 19.4 | 1.86% |
| Local government administration services | 6.3 | 0.58% | 14.1 | 1.29% | 23.5 | 2.15% |
| Public order, safety, and regulatory services | 6.8 | 0.17% | 15.2 | 0.39% | 25.3 | 0.64% |
| Defence | 7.7 | 0.59% | 17.1 | 1.31% | 28.5 | 2.17% |
| Medical and other health care services | 9.4 | 0.33% | 20.8 | 0.73% | 34.5 | 1.21% |
| Residential care services and social assistance | 9.4 | 0.28% | 20.9 | 0.63% | 34.7 | 1.05% |
| Banking and financing; financial asset investing | 14.5 | 0.40% | 32.2 | 0.88% | 53.5 | 1.46% |
| Central government administration services | 21.8 | 0.62% | 48.8 | 1.38% | 81.4 | 2.30% |
| School education | 24.9 | 0.44% | 55.7 | 0.97% | 92.8 | 1.61% |
| Hospitals | 35.5 | 0.48% | 79.5 | 1.08% | 132.6 | 1.79% |

**Source: NZIER**

## Table 17 Additional effects on imports for selected industries

Changes from baseline (2018) in percent and $ millions

| Industries | % | | | $ millions | | |
|---|---|---|---|---|---|---|
| | Low | Central | High | Low | Central | High |
| General industrial machinery | -0.2% | -0.5% | -0.9% | -6.0 | -13.5 | -22.9 |
| Steel products, semi-finished metal products | -0.4% | -0.9% | -1.5% | -5.1 | -11.2 | -18.2 |
| Electric motors, generators, and transformers | -0.5% | -1.2% | -2.0% | -4.6 | -10.5 | -17.8 |
| Other electrical equipment and parts thereof | -0.3% | -0.8% | -1.3% | -3.6 | -8.2 | -13.9 |
| Articles of concrete and stone | -1.4% | -3.1% | -5.0% | -3.1 | -6.8 | -10.9 |
| Structural metal products | -1.4% | -3.0% | -4.8% | -2.3 | -4.9 | -7.9 |
| Semi-manufactures of plastics | -0.4% | -0.9% | -1.5% | -2.1 | -4.8 | -8.0 |
| Diesel | -0.3% | -0.6% | -1.0% | -1.8 | -4.0 | -6.6 |
| Equipment hire services | -0.3% | -0.6% | -1.0% | -1.6 | -3.7 | -6.4 |
| Non-structural ceramic ware and clay products | -1.0% | -2.0% | -3.1% | -1.8 | -3.7 | -5.9 |
| Architectural and engineering services | -0.5% | -1.0% | -1.6% | -1.7 | -3.6 | -5.9 |
| Carpets | -0.7% | -1.5% | -2.4% | -1.0 | -2.2 | -3.6 |
| Glass and glass products | -0.3% | -0.6% | -1.0% | -0.8 | -1.8 | -3.1 |
| Building joinery | -2.7% | -5.8% | -9.1% | -0.8 | -1.7 | -2.7 |
| Packaged software, tapes, audio, and video records | -0.2% | -0.5% | -0.8% | -0.8 | -1.7 | -2.9 |
| Panels, boards, veneer sheets, and plywood | -1.1% | -2.4% | -3.8% | -0.7 | -1.6 | -2.5 |
| Other plastics products | -0.1% | -0.3% | -0.4% | -0.7 | -1.4 | -2.3 |
| Prefabricated buildings | -2.9% | -6.2% | -9.7% | -0.6 | -1.3 | -2.0 |
| Rubber | -0.2% | -0.6% | -0.9% | -0.6 | -1.2 | -2.0 |
| Sands, pebbles, gravel, clays, stone, and bitumen | -0.6% | -1.3% | -2.2% | -0.4 | -1.0 | -1.6 |
| Wood | -0.4% | -0.9% | -1.5% | -0.5 | -1.0 | -1.5 |
| Food products | 0.2% | 0.4% | 0.6% | 1.6 | 3.6 | 6.1 |
| Television, cameras, and other electronic goods | 0.1% | 0.2% | 0.3% | 1.7 | 3.8 | 6.3 |
| Meal services | 0.4% | 0.8% | 1.4% | 1.9 | 4.3 | 7.1 |
| Other insurance services | 0.2% | 0.5% | 0.8% | 2.0 | 4.5 | 7.6 |
| Accommodation | 0.2% | 0.5% | 0.8% | 2.0 | 4.6 | 7.7 |
| Crude petroleum | 0.0% | 0.1% | 0.1% | 1.9 | 4.8 | 8.8 |

| Industries | % | | | $ millions | | |
|---|---|---|---|---|---|---|
| | Low | Central | High | Low | Central | High |
| Furniture | 0.3% | 0.7% | 1.1% | 2.2 | 4.9 | 8.1 |
| Games and toys | 0.3% | 0.6% | 1.1% | 2.3 | 5.3 | 8.8 |
| Soap and perfumes | 0.3% | 0.6% | 1.0% | 2.4 | 5.4 | 9.0 |
| Computers, parts, and office machinery | 0.1% | 0.3% | 0.5% | 2.8 | 6.3 | 10.7 |
| Intellectual property licensing services | 0.3% | 0.6% | 1.1% | 2.9 | 6.4 | 10.8 |
| Basic chemicals; other paper and paperboard products | 0.2% | 0.4% | 0.6% | 2.9 | 6.5 | 11.1 |
| Other fabricated metal products | 0.3% | 0.6% | 1.0% | 3.1 | 6.6 | 10.7 |
| Petrol | 0.2% | 0.4% | 0.6% | 3.0 | 6.7 | 11.4 |
| Financial intermediation services | 0.5% | 1.1% | 1.8% | 3.8 | 8.5 | 14.0 |
| Clothing and knitted fabrics | 0.2% | 0.5% | 0.9% | 4.9 | 11.1 | 18.5 |
| Pharmaceutical products | 0.4% | 0.8% | 1.3% | 5.0 | 11.3 | 18.8 |
| Motor vehicles, trailers, and semi-trailers; bodies (coachwork) | 0.1% | 0.3% | 0.5% | 7.9 | 17.9 | 30.0 |
| Air passenger transport | 0.3% | 0.7% | 1.1% | 8.2 | 18.5 | 30.9 |
| **Total New Zealand imports** | **0.1%** | **0.2%** | **0.3%** | **53.2** | **121.0** | **204.7** |

**Source: NZIER**