# A Computable General Equilibrium (CGE) Approach to Urban Freshwater Planning

Stages 2 and 3: Methodology and Data Requirements

## Report prepared for the Chief Economist Unit, Auckland Council

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The Chief Economist Unit (CEU) at Auckland Council commissioned this study on behalf of the Ministry for Environment (MfE) and provided general oversight of the project. The focus is on the feasibility of incorporating freshwater-quality planning into a sub-regional Computable General Equilibrium (CGE) model.

**This report has been authored by John Kim and peer reviewed by Dr. Adolf Stroombergen.**

**Contact person:** Harshal Chitale
harshal.chitale@aucklandcouncil.govt.nz

**The study has been divided into four stages:**

1. Literature review of Computable General Equilibrium (CGE) models in analysing the impacts on freshwater quality
2. Advice about how to develop the sub-regional housing CGE model to incorporate impacts on freshwater quality
3. Inputs and data requirements to run the CGE model identified in (2), and inputs available
4. Final report and presentation.

**This report focuses on the second and the third stages of the study, where we aim to:**

a) Outline the most appropriate methodology for studying the freshwater-quality issues as identified in the first stage of the study

b) Provide a description of the current sub-regional housing CGE model and how freshwater quality can be incorporated

c) Outline the data requirement including the description of a New Zealand multi-regional social accounting matrix.

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# Executive Summary

## Background

The Chief Economist Unit (CEU) at the Auckland Council commissioned this study on behalf of the Ministry for Environment to assess the feasibility of incorporating freshwater-quality planning into the sub-regional housing Computable General Equilibrium (CGE) model that the CEU is developing.

This study includes: (i) a review of national and international practices of using a CGE model to assess economic impacts of freshwater-quality policy initiatives; (ii) a description of the current sub-regional housing CGE model and how to incorporate a freshwater-quality component; and (iii) an outline of model inputs and data requirements.

## What is a CGE Model?

CGE is a methodology that models the economy and the various inter-relationships between economic sectors. It models decision makers such as consumers, producers and the Government in terms of how they make their choices. Decision makers are assumed to be rational in the sense that their consumption and production decisions aim to maximise their welfare by responding to changes in costs and prices.

CGE models are useful for capturing the effects of a new policy (e.g. freshwater quality standards, tariffs, carbon taxes) or an external shock that affects economic activity (e.g. natural disasters, global market events). The model is able to calculate the impact of this change on the choices and welfare levels of consumers and producers and the consequent effects on the economy as a whole. The impacts on economic activity calculated in a CGE model include direct, indirect and induced impacts.

In addition to how much of a commodity is produced and consumed, the model includes financial flows within the economy (e.g. transfer payments, government revenue and expenditure). The model can then be simulated for different values of parameters set outside the model itself. Such parameters may include different income distributions or policy variables, such as tax and subsidy profiles and water quality standards.

CGE models are used widely within New Zealand and internationally. Many government agencies build and maintain CGE models for economic projections and Economic Impact Assessments (EIA) of policies. These include a high-level New Zealand CGE model built by the Treasury for economic forecasting as well as assessing impacts of trade policies, and a multi-regional transport CGE model built by the New Zealand Transport Agency (NZTA) to assess economic consequences of road outages. Further, CGE models have been used to assess economic impacts associated with greenhouse gas policies.

## Why use CGE models to assess policies about the quality of fresh water?

Internationally, CGE models are widely used to assess the economic implications of freshwater policy initiatives, particularly on economic growth. However, within New Zealand, most EIAs of water policies are use a mix of Cost–Benefit Analysis (CBA) and Input-output (IO) analysis.

CBA and IO do not inherently include an entire economy. In contrast, the CGE model provides a more comprehensive EIA as it simulates a complete economy. Importantly, the supply and demand forces within the CGE model ensure that the economic impacts associated with a policy initiative are not over-estimated, unlike a partial-equilibrium or an IO approach.[1] So the CGE model provides robust economic impact outputs associated with a policy on the quality of fresh water.

The CGE model can show how what we make and consume helps to generate water pollutants within an economy. In addition, the model can include changes in how economic participants behave. One example is when a producer adjusts the way they produce and invest when abatement technology behaviours change following a change in policy. The model also includes detailed financial flows. Specifically, the model can track changes in central and local government finances as a result of a policy.

The model can be used to assess the economic impacts of urban development, planning and growth policies on freshwater quality, and how policy about the quality of fresh water affects the economy. Similarly, the model can include other environmental policies (e.g., greenhouse gas emission) and show feedback effects on freshwater quality, as well as interaction effects between freshwater and environmental policies.

Increases in population[2] and urbanisation[3] change the structure of an economy. Especially for a growing city such as Auckland, these increases can substantially affect freshwater use and quality. Unlike CBA and IO, which cannot assess structural changes in the economy, the CGE model can assess the direction and the magnitude of the structural change and associated freshwater use and quality.

Systems Dynamic Models are sometimes used to study the economic impacts of events such as natural disasters or major policy changes. A particular version of that is used to analyse the impacts of infrastructure outages is essentially a two-region model and not a multi-regional one. It is not a general equilibrium model but tries to mimic one. Whether it does a good job of doing so is an open question. The model can be hard to run and requires the use of experts which can be costly. It is also not as flexible as general equilibrium models and cannot be easily adapted to different contexts or lines of enquiry. A flexible CGE model can likely be developed in the cost it would take to learn to use or get experts to run a systems dynamic model on a repeated basis.

[1] This is illustrated in the paper by Deng et al. (2011)[12]. Using a CGE model, the authors applied a production tax to industries that intensively produce nitrogen and phosphorous emissions. Resulting changes in emission outputs and economic outputs were not a one-to-one relationship; emissions decreased by 1.62 percent while economic output decreased by only 1.08 percent.

[2] Watson and Davies (2011)[60] found that a 50 percent increase in population in Colorado resulted in a 5.7 percent shift in water use from agriculture industry to non-agriculture industry.

[3] Jiang et al. (2014)[20] note that urbanisation in China raises the opportunity cost of water use, and so shifts water use from lower-value and water-intensive agriculture to higher-value livestock farming. Water use and economic output from farming field farming dropped by 11.2 percent and 19.4 percent respectively, while livestock farming increased by 24.6 percent and 17.5 percent respectively.

## Why incorporate freshwater-quality planning into the CEU sub-regional housing CGE model?

A policy initiative in a geographical area can affect not only the area but surrounding areas as well. In addition, policies can affect each area differently and interdependencies between areas cause feedback effects. From a regional policymaking perspective, it is important to understand possible winners and losers of a policy as aggregate metrics will underestimate the magnitude of economic impacts that different groups within a region feel.

The CEU sub-regional CGE model includes inter-spatial relationships within the Auckland region and the rest of New Zealand. Therefore, the model can assess how a policy in a region or a sub-region can affect surrounding regions and identify winners and losers and the sub-regional distribution of the economic impacts of the policy. This can improve our understanding of the spatial distribution of the economic costs and benefits of policies.

The Auckland region consists of multiple Freshwater Management Unit (FMU) areas where each FMU differs in economic activities, land use, and geophysical characteristics. Different characteristics across FMUs lead to distinct economic responses given the same policy on the quality of fresh water. Importantly, a single regional model does not allow for FMU-specific policies and the FMU-specific characteristics are averaged into a regional characteristic.

Incorporating freshwater-quality planning into the CEU sub-regional CGE model at FMU level allows us to model FMU specific characteristics, policies and economic responses. The model has the advantage of capturing inter-FMU feedbacks and reflecting the real world more closely. So it has the potential to provide more robust and disaggregated results and to show the distribution of economic impacts across space for FMU-specific policies on the quality of fresh water. The model also facilitates an analysis of FMU based on the impacts of policy measures at the regional and national levels.

## What are the key concerns about using the CGE model?

The CGE model has major advantages over other EIA methods, yet the model is quite difficult to build and operate. Three key concerns are noted below.

First, the proposed multi-regional CGE model requires a large amount of detailed data. Specifically, robust sub-regional economic and water accounts data is required to build an FMU-level model. Often this is lacking, but data can be calculated numerically and updated when superior data becomes available.

Second, building the CGE model is a highly technical process. New Zealand has only a handful of CGE experts, but some people within our private organisations and academic institutions have CGE experience.

Third, although CGE models are proven to be robust and tested over many years, the model employs strong assumptions. For policies on the quality of fresh water, assumptions such as perfect competition within a market and symmetry of information may not necessarily reflect reality. Yet these assumptions are inherent in most economic models and are handled within the CGE model by designing scenarios around these assumptions.

## How might the CGE model benefit the council's planning initiatives?

There is increasing pressure on land in Auckland due to rapidly growing population. Also, land that is used for housing, industry or agriculture pollutes our freshwater resources and policies that limit freshwater pollution will impose difficult choices on us as we grow. Freshwater policies may impose constraints or make us think hard about the quantity and type of economic activities that can be carried out on our land. A model that can answer questions about how different freshwater management units are affected and how their management via policy in turn affects economic activity across Auckland will be a valuable tool to possess.

The FMU-level, sub-regional CGE model for Auckland Council will potentially enable the council to robustly assess the consequences of policy initiatives focused on freshwater quality. In addition, building the model will develop the capability to assess the economic impact of future policies not only for Auckland but for other New Zealand regions.

# 1 Introduction to this report and purpose of the study

Over the past decade, Auckland has experienced tremendous economic and population growth. Its key consequence has been intensified urbanisation within Auckland. As a result, Auckland Council (the Council) faces policy setting issues that involve balancing growth objectives against consequent environmental externalities that are difficult to quantify. Two key issues the council is facing are housing affordability (Parker, 2015[40]; Torshizian and Chitale, 2016[58]) and how to fund future infrastructure growth and manage urban growth spatially and over time.

The purpose of this study is to understand the potential to expand the scope of the sub-regional Computable General Equilibrium (CGE) model that Auckland Council was proposing to develop, so that it can also account for impacts of freshwater policies under the National Policy Statement for Freshwater Management (NPS-FM) on urban growth and economic development and vice versa.

In particular, this study looks at a particular configuration of a model whose specification incorporates a freshwater-quality management module into a broader CGE modelling framework. We identify some of the key challenges to this exercise and some specific data requirements.

## 1.1 Water as an important natural resource

Water is an important natural resource essential for our society and for the biophysical environment we live in. As with most other public goods, positive externalities of clean water are not fully captured. In addition, as a result of the free-rider problem (when the benefits of a resource are enjoyed without paying for it), people and entities in an economy have little incentive to care for the quality of water. This means, the public sector must intervene to secure clean water supply for society.

The NPS-FM requires regional councils to set objectives for their community consensus about the future role of their water catchments and to set limits.[4] To meet the objectives, the council is required to implement a detailed plan, setting rules and regulations on how to manage fresh water in each region. Yet the economic implications of setting the plan are still unclear and difficult to measure. In particular, expansion of the urban footprint in Auckland may incur considerable mitigation costs in adhering to the NPS-FM. The imposed costs will be a significant burden to the public and the council, potentially causing regional growth that is less than ideal. This stresses the need for tools to analyse the costs of growth and find less costly means of achieving growth.

[4] See the 'About the National Policy Statement for Freshwater Management' web page, Ministry for the Environment. Retrieved on 27 February from www.mfe.govt.nz/fresh-water/national-policy-statement/about-nps

## 1.2 A new model to analyse economic impacts of planning initiatives

The Chief Economist Unit (CEU) of Auckland Council is considering the development a sub-regional housing CGE model to analyse the economic consequences of current policy and planning initiatives within Auckland (with a focus on affordability issues).

One key characteristic of the model being considered for development is that it is a multi-regional model for use also at a sub-regional level. The Auckland region is spatially separated into smaller sub-regions. Specifically, the region is split into sub-regions using Statistics New Zealand (SNZ) 2013 Community Board[5] (CB) boundaries. This allows for a feedback between sub-regions (i.e., CBs), and shows the sub-regional distribution of the economic impacts of policies and planning. Importantly, the model was intended to be able to assess the inter-regional distribution of the economic impacts, winners and losers associated with exogenous shocks and policy settings.

The proposed model could be applied in various scenarios. It has the potential to evaluate the effects of policy interventions on economic outcomes in various sectors within the Auckland region. In addition, the model structure and implementation (e.g., computer codes) could be applied to other spatial definitions (e.g., other regions in New Zealand).

## 1.3 Key advantages of the CGE model over other EIA models

In the literature review conducted in Stage 1 of the study, we found numerous studies supporting the use of CGE models in assessing the economic implications of environmental policy initiatives. We have identified benefits of a sub-regional CGE model and the key advantages that the model has over other Economic Impact Assessment (EIA) methods (i.e., CBA) and Input-output (IO)). Eight key advantages are noted below.

1. Unlike partial equilibrium models (i.e., CBA and IO), CGE models both the supply and demand side for every economic activity. This allows the model to assess the economic consequences of urban development, land-use planning and growth policies on freshwater quality, and on how policy decisions about the quality of fresh water affect the economy and land use.

2. CGE models incorporates price dynamics, where an exogenous shock to the economy affects prices of commodities (which, in turn, affects how people and entities in an economy produce and consume commodities).

3. While the CBA and the IO methods inherently do not include an entire economy, the CGE model simulates a complete economy. As noted above, the model includes physical flows (i.e., production and consumption) and financial flows (i.e., subsidies and transfers) within the economy. This means the model provides a complete picture of the economic consequences associated with a policy.

[5] Community Boards within Auckland are also known collectively as the Auckland Local Board Area. That Area has 21 sub-regions.

4. The model can be used to test the economic impacts of various policies in a standardised setting. This occurs once the underlying structure and formulation [6] of the CGE model is standardised, and the base CGE model is set up. In such tests, it is possible to compare different policies and calculate the opportunity costs (i.e., compare the economic impacts of policy A against policy B).

5. Extending the above point, the CGE model allows for the modelling of the economic consequences of other national and local government policies (e.g., on taxation and on greenhouse gas emission) in conjunction with freshwater policy measures. For example, a CGE model could assess the economic impacts associated with a greenhouse gas policy, and how it affects freshwater quality, to give us a better understanding of the interaction effect between regulating carbon emission and limiting water contaminants.

6. The proposed CEU sub-regional housing CGE model incorporating the management module on freshwater quality is designed to model how both production and consumption activities within an economy help to generate water pollution. In addition, the proposed model incorporates an endogenous abatement module where producers within the economy adjust what they produce and how they behave in response to policy changes. The model can simulate the behaviour of agents within an economy and estimate economic impacts associated with introducing policies with set limits. In particular, the model can be used to test and compare various policies on water quality.

7. Most importantly, the model is multi-regional, where Auckland is spatially separated by the Freshwater Management Units[7] (FMUs) and includes other areas of New Zealand. Each FMU has different economic activities, land use, and geophysical characteristics. Further, different characteristics across FMUs lead to distinct economic responses for the same policy for different FMUs. As such, a simple regional model does not allow for FMU specific policies as the FMU specific characteristics are averaged into regional characteristics.

8. The proposed model includes, for each FMU, specific freshwater-quality issues, water supply, and land use characteristics, and economic activities. The proposed model can run specific policy scenarios for each FMU area. It has the advantage of capturing inter-FMU/inter-regional feedbacks and reflects the real world more closely. It therefore provides more robust results (compared to a regional CGE model) and shows the distribution of economic impacts across space for numerous FMU specific policies about the quality of fresh water. The model also facilitates an analysis of FMU based on the impacts of policy measures at the regional and national levels.

[6] The CEU sub-regional housing CGE model is built in a Mathematical Programming Subsystem for General Equilibrium (MPSGE) programming language. The mathematical complexities of a CGE model increase rapidly with increase in variables, such as more areas and industries. A large CGE model, such as the CEU sub-regional housing model becomes computationally hard to solve. This problem is encountered in the CGE model constructed in a standard Mixed Complementary Problem (MCP) language or other methods, when the model and outputs become unstable. By comparison, the MPSGE is highly robust in dealing with large CGE models.

[7] See sections 2.3 and 3.3.3 for more detail.

## 1.4 Objectives of this report

This report examines two main stages of the study: stages 2 and 3. The two stages involve a detailed feasibility study on incorporating the freshwater planning into a sub-regional Computable General Equilibrium (CGE) model. Outlined below is an excerpt from the original proposal by the Chief Economist Unit (CEU) to the Ministry for the Environment (MfE).

**Stage 2: Advise how the sub-regional CGE model can be developed to incorporate impacts of freshwater quality**

- Describe the potential to incorporate externalities from water quality deterioration into the CEU's proposed CGE framework and how this would be implemented. Comment on the associated risks and issues.
- Advise on a rough development programme, and outline the resource requirements (skills, time, budget etc.) in case the project is progressed to the next stage.

**Stage 3: Inputs required to run a CGE model, and inputs available (gap analysis)**

- Find existing data on freshwater quality for CGE analysis.
- Recommend a research programme to implement CGE model that accounts for impacts on freshwater quality, and outline the data requirement and the value for money of doing so.
- Coarse estimates of further parameters needed for successful application of the CGE model.

## 1.5 Summary of Stage 1: The literature review

In Stage 1 of the study, we conducted a literature review of the existing literature and methodologies with regard to the economic impact of freshwater-quality management using CGE modelling. The literature surveyed for this project mainly concerned whether applying CGE modelling might help us understand the economic impact of environmental policies.

Our review found that work on models specifically focusing on water-quality policies is lacking. Even so, the papers surveyed contained some useful freshwater-economic modules focused on pollution abatement.

A majority of papers surveyed incorporated a separate pollution abatement sector whose 'output' is pollution clean-up. Xie and Saltzman (2000)[61] models pollution taxes, subsidies, and clean-up activities in an integrated economic and environmental CGE model. The services provided by the pollution abatement sector are assumed to be a 'public good' that production sectors can buy so as to comply with environmental regulations, and the government can buy.

Dellink, Hofkes, Ierland and Verbruggen (2004) [10] offer more details about abatement technologies and the costs of abating pollution. Among the multiple pollutants specified in paper by Dellink et al., water quality is measured primarily by nutrient loadings of nitrogen and phosphorus. The Cass-Koopmans-Ramsey type model takes pollution as a necessary environmental input into the production process. The supply of abatement goods is modelled through a separate producer, and the government sets environmental policy by limiting the number of tradeable pollution permits it issues.

Bohringer and Loschel (2006) [4] also endogenise pollution control by creation of clean-up sectors and modelling pollutant directly into production. Further, it specifies a wage curve depicting the inverse relationship between the level of wages and the rate of unemployment. Brouwer, Hofkes and Linderhof (2008) [6] include substitution elasticities between labour, capital, and emissions to water in the sector production function. A static CGE model is built and the results are downscaled to river-basin level. The producers buy emission rights and invest in abatement technologies. The model explicitly distinguishes between abatable and unabatable pollution.

Deng, Zhao, Wu, Lu and Dai (2011)[12] have built another multi-regional environmental CGE model. They specifically look into the nitrogen and phosphorus emissions in China and its impact on economic growth. An alternative approach outlined in the literature survey is to model multiple types and uses of water. Luckmann, Grethe, McDonal, Orlov and Siddig (2013) [28] allow for substitution and price differentiation in the production and use of different water qualities. Water production is represented as a separate, independent activity with a specific cost structure. Different cost structures are implemented by the imposition of policy instruments such as taxes and subsidies. Also, some limitations of CGE modelling on sustainability are outlined. Scrieciu (2006) [43] comments that the CGE models are too primitive to capture most environmental concerns.

In New Zealand, most EIAs of water policies were conducted using a combination of CBA and IO approach and, at time of writing this report, no completed studies focused on water policies using a CGE approach. Several studies used a partial-equilibrium approach focusing on farm systems. Even so, we did find two CGE studies currently under way by Environment Southland, and research project funded by the Ministry of Business, Innovation and Employment (MBIE) and led by GNS Science—a Crown Research Institute (CRI).

In particular, one key objective of the former study is to build CGE modelling capacity within the council so that, in future, it can do its own EIAs using the CGE model.

In summary, we have found numerous cases supporting the use of CGE models to assess economic implications of water quality and other environmental policy initiatives in Auckland.[8] A review of the international literature revealed that CGE models are widely used to help assess the economic implications of environmental policies, particularly those related to economic growth and water quality. The studies on water quality we reviewed were conducted fairly recently, and we noted a growing interest in the issue of water quality.

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[8] Importantly, some studies raised concerns about strong assumptions, such as perfect competition and symmetric information, required within the CGE model. However, these assumptions are inherent in most economic models, and can be offset by designing scenarios and the study around these assumptions.

## 1.6 Outline of the rest of this report

The rest of this report is organised in three stages.

Stage 2 proposes the most suitable model to incorporate freshwater-quality issues into the sub-regional housing CGE model

Stage 3 discusses the data requirements, with a focus on how the Social Accounting Matrices (SAM) are built

Stage 4 provides the report's summary and conclusions.

# 2 Framework of the Computable General Equilibrium model

CGE modelling has the distinct advantage of capturing inter-related markets and secondary (indirect and induced) impacts in evaluating the net economic effects of policies to the economy. To understand the economic impacts associated with setting limits for the quality of fresh water, the proposed CEU sub-regional CGE can be modified to incorporate freshwater quality as an endogenous factor within the model.

This section starts off with subsection 2.1, which outlines important considerations when developing the sub-regional CGE model. Subsection 2.2 describes the housing module within the CGE model. Subsection 2.3 outlines the management module for freshwater quality within a CGE model framework. Subsection 2.4 provides functional specifications of the sub-regional housing CGE model. Subsection 2.5 then describes how the policy instrument for managing freshwater quality is incorporated into the CGE model outlined in subsection 2.4. Finally, subsection 2.6 outlines a possible development programme of the CEU sub-regional housing CGE model for managing freshwater quality.

## 2.1 Key considerations in developing the sub-regional CGE model

Auckland consists of a large urban area, has more than 1.6 million people and contributes to more than a third of New Zealand's GDP. The region has considerable spatial variations in economic and demographic profiles as well as geographical characteristics. These variations cause sub-regions to respond differently to exogenous factors, such as policy changes, economic growth and population changes. In conducting an Economic Impact Assessment (EIA), it is important to analyse not only aggregated regional impacts but how each sub-region is affected and the magnitude of variations within it. For regional policymaking, it is important to understand possible winners or losers of exogenous policy shocks within a region, as aggregate metrics are likely to underestimate the magnitude of economic impacts felt by different members (spatially separated in this example) within a region.

To address this issue, the CEU's proposed CGE framework is a sub-regional CGE model—a multi-regional CGE model with the Auckland region spatially separated into CB-level sub-regions. This allows for feedback between sub-regions and shows sub-regional distribution of the economic impacts. Subsequently, the proposed CGE model for freshwater quality is a sub-regional, multi-regional CGE model. As noted earlier, geophysical and economic characteristics across Auckland vary significantly. As such, channels of water pollution within Auckland will differ spatially.

The proposed model will consist of sub-regions separated by FMUs within Auckland, and consist of regions in the rest of New Zealand. This allows the CGE model to incorporate spatial variations in pollution channels between different FMUs and report FMU-level economic impacts and responses by agents within the economy from the initiatives for setting freshwater-quality limits. Further, the model allows for heterogeneous policies to be applied across the FMUs, where these policies can be set based on differing pollution characteristics of each FMU. This allows for more detailed evaluation of policies and for optimisation of costs and benefits of achieving the target.

Theoretically, a generic multi-regional CGE model framework[9] consists of spatially explicit economies but contains the same agents (e.g., government, household and enterprise), class of industries (e.g., horticulture, dairy farming and manufacturing) and commodities (e.g., raw milk, automobile and insurance). Each region in the model follows similar, if not identical, mathematical formulations. The differences in regional economic responses are driven by varying regional factor (e.g., labour and capital) costs and commodity prices, where regional factor costs are determined by supply of regional employment and available capital. The commodity prices are mostly determined by regional differences in production methods and transportation costs.

Building a realistic and rationally sound sub-regional multi-regional CGE model is more complicated as forces that drive the regional differences in a generic multi-regional model (e.g., transport costs between regions) do not apply strongly within a region. For example, in a generic multi-regional CGE model, the main constraint restricting the size of an economy may be the total labour force available in the region.

In the short run, and given the size of the labour force is fixed, the only way to increase a region's labour force is through people coming from other regions to live and be employed there. In reality, the labour force and people in general do not immigrate easily between regions other than for economic reasons. In economics, this phenomenon is termed "sticky labour force mobility" and is modelled within the multi-regional CGE model through a mathematical function describing the trade-off between the negative utilities from moving between regions against the positive utilities (such as higher wages) from moving.

Yet, in a sub-regional CGE model, people do not need to move between the sub-regions to ensure economic growth in the sub-region and to participate in other sub-regions economic activities. For example, a person living in West Auckland does not have to move to central Auckland for a job. In addition, commodity and factor prices, and parameters driving the CGE model framework, are unlikely to vary enough to cause differences between sub-regions. As such, it will be unrealistic to model a sub-regional, multi-regional CGE model using a generic multi-regional CGE model framework.

Alternatively, two possible methods are available to model the sub-regional characteristics.

#### 2.1.1 Method 1: a generic, multi-regional CGE framework

In the first method, the sub-regional CGE model will be formulated using a generic multi-regional CGE framework but can incorporate a regional market for factors of production (e.g., labour and capital). It will use Armington elasticities that are specific to each sub-region to measure commodities within a main region.

[9] The most widely known CGE model using this framework is the Global Trade Analysis Project (GTAP). GTAP is a multi-national global CGE model looking into economics of international trade.

The regional market for factors combines all sub-regional factors and distribute across sub-regions. In effect, factors in a region have identical prices across the sub-regions and can include elasticities that can govern the mobility factor between sub-regions. For example, Auckland can have a single labour market where all sub-regional labour forces gather and are subsequently distributed across the region at the same labour price. But labourers in North Auckland are less likely to work in South Auckland.

Also, by including sub-regional commodity elasticities, sub-regional demand of commodities produced within a region can be tuned to match sub-regional dynamics. For example, a person in North Auckland may value, and so price, a car in south Auckland the same as a person pricing the same type of car on the north shore. Yet the same person may value their hair dressing services in south Auckland differently to the person doing hair dressing on the north shore. The advantage of using this method is that it can include detailed sub-regional production and demand dynamics, such as different sub-regional household types (e.g., income distribution). Even so, including additional market and certain Armington elasticities adds complexities and increases data requirements to the model.

### 2.1.2 Method 2: two regions within a multi-regional model

In the second method, the industries of a region in the CGE model consist of sub-regional industries. In this method, the CGE model only has Auckland and the rest of New Zealand as two regions within a multi-regional CGE model. But industries within Auckland region are subdivided into sub-regional industries. For example, the Auckland dairy industry will be subdivided into North Auckland dairy industry and South Auckland dairy industry.

If required, the method can also include sub-regional agent types within a region (e.g., north Auckland households and south Auckland households). This method is simpler than the first method, as it does not require additional markets. Also, it models trade interactions between sub-regions but does not model differences in sub-regional demands. For example, a person visiting a hair dresser in north Auckland may value, and so price, a hair dresser in north Auckland the same they would value, and so price, a hair dresser in south Auckland.

### 2.1.3 Method 1 as the preferred method

The sub-regional model component of the CEU CGE model is currently being developed and is not at the stage where specifications and methods are decided. Both methods outlined above have distinctive merits. Although the preferred method is the Method 1, computational complexities and extra data requirements may mean that method cannot be applied. Therefore, further research and trial application of both methods is required before building a full sub-regional model.

## 2.2 Sub-regional housing component

Within the current sub-regional CGE model, housing is a commodity consumed by households and is an output from a productive sector. Production function for the housing commodity shares the same functional form as other commodities, but includes the residential land supply as an additional factor of production. Supply of the total available residential land is an exogenous function of the model and set by the council zoning and density rule parameters. A simple policy assessment is possible by changing these parameter values. The actual supply of residential land is an endogenous linear function of the price of residential land and the total available residential land.

Housing demands follow the household utility maximisation function, with a minimum level of housing commodity consumption modelled using a Linear Expenditure System (LES) function. As the labour and population are inter-related in the model, the factor movement between the study areas influences the level of housing commodity demanded within a study area. Currently, the non-economic values of housing (e.g., environment, amenities and location) are not included, as the model assumes that the values are constant parameters and the base is a steady state comprising all of these.

By including freshwater quality into the CGE model, non-economic values related to the freshwater quality can change within the model. For example, an increase in freshwater quality in a sub-region increases the environmental value. This, in turn, increases demand for housing within the sub-region. This process can be modelled using two endogenous functions; (i) an endogenous labour mobility, where the population is a function of non-economic housing values and wage; and (ii) an endogenous housing LES ratio, where the minimum level of housing demand is a linear function of non-economic housing values and population within the sub-region.

It is important to note that, the specification of the sub-regional housing module requires further work. Proposed future extensions to the module include disaggregating the household into multiple types and splitting the housing commodity into different types of housing (e.g., stand-alone and apartments).

## 2.3 The module for managing the quality of fresh water

The proposed CEU sub-regional CGE model is designed to be built as a multi-regional CGE model (in this case, CBs of Auckland and other parts of New Zealand) to allow for separate region/area-specific supply issues, prices, local government policies, and production functions, as well as imperfect factor mobility between regions. Before going into the details of the freshwater-quality management modules, it is important to note that the CGE model incorporating freshwater quality will be spatially separated by the FMUs. This means that the spatial areas of the sub-regional housing CGE model must be re-specified from CBs to FMUs.

This re-specification involves matching the CB boundaries against FMU boundaries and disaggregating/aggregating CBs to match FMU areas. It is important to note that the FMU boundaries follow geophysical characteristics while the CB boundaries follow economic and demographic characteristics. This can potentially cause some FMU areas having no economic rationale to be a sub-region within the CGE model. As such, the total number of sub-regions within the model will depend upon the economic viability of FMU sub-regions, where any FMUs not viable are merged into a surrounding FMU.

Technically, the multi-regional CGE model, which the sub-regional CGE model is classed as, will add origin and destination subscripts to variables and equations. This means that production sectors (i.e., firms), final demand sectors (e.g., government and households), and factors (e.g., labour and capital) may all be specific to each separate region. We will need data that describes the economic links (e.g., inter-regional trade) between the regions for the multi-regional SAM. For example, for each type of commodity in the model, the two-region system will demand a set of two-by-two trade matrices consisting of information about inter-regional imports and exports.

In a CGE framework, the environmental policies could be effectively modelled by incorporating these policies as endogenous factors. Within the framework, pollution is modelled as a by-product of consumption and production. On the production side, a producer's total cost could include pollution related costs from pollutant emission restrictions. This will come in the form of pollution emission taxes, limits, and the cost of removing pollution to comply with environmental quality standards. In effect, the industrial polluters are required to pay compensation to the society for the environmental damage they cause. On the consumption side, the households are required to pay for pollution they incur, such as the tax to treat sewage. This reduces the amount of money they have available for other consumables.

In the limit-setting initiatives for freshwater quality, the water quality will be measured primarily by nutrient loadings of nitrogen and phosphorus, Total Suspended Solids (TSS), and heavy metals (i.e., copper, lead and zinc).[10] Within the CGE freshwater-quality module, the water pollution will be modelled explicitly as a necessary environmental input for the production and utility functions. Therefore, it will include substitution elasticities between labour, capital, intermediate consumption (goods and services used in production activities), and emissions to water from industrial production.

The government could use various policy instruments to set the standard for freshwater quality. Such options may include setting a cap on emission, a pollution tax, and auctioning a restricted number of tradeable pollution permits. The producer has to produce up to a permissible emission level, pay pollution tax, buy emission rights or adhere to the limit-setting policy. In addition, a producer can make investment decisions in abatement technologies or change their production technology to meet the emission limit.

The module can assume no change in production input requirements under the freshwater-quality limit as a benchmark scenario. Or it can feature an abatement technology module to build in detailed changes in the production input requirement as a response to policy shocks. The choice a producer faces, of whether to pay for the pollution or increase their investment on pollution abatement technologies, is endogenised. The abatement cost curve will slope down and represent abatement costs as a function of pollution.

A Constant Elasticity of Substitution (CES) function is estimated to best fit the abatement cost curve. The estimated CES elasticity describes the possibility of substituting between pollution and investing in abatement technologies. It reflects marginal abatement costs, which is how much additional abatement effort is needed to reduce pollution by one extra unit.

The abatement technology can be modelled as a commodity produced by a separate production sector using both intermediate goods and factors of

[10] The measures of water quality depend on the list of public instruments of the local government, and on the available datasets.

production as inputs. All economic agents can invest in the available abatement technologies by buying the abatement technology commodity. So the trade-off is between investing in abatement technologies and reducing economic activity. Simply put, if you reduce economic activity you reduce emissions.

The model will calculate the abatement functions by calibrating the data derived from the abatement cost curves. The function consists of abatable (can be reduced by increasing the input of abatement goods) and unabatable (proportional to output) pollution.

To model the government costs associated with cleaning up water pollution, the model can incorporate a separate water-pollution clean-up module, whose output is the pollution clean-up. The module can be used to test various funding mechanisms for clean-up activities. For example, the module can assume the services to clean up freshwater pollution are a 'public good' that the production sectors buy to comply with environmental regulations, the government buys, or both buy. Households usually have no has demand for services to clean up water pollution.

Lastly, to model degradation of water qualities and its effects on production activities, multiple types of water with different qualities can be directly incorporated into the CGE model. Specifically, the water pollution can reduce the availability of high-quality water as a factor of production and change the input technology for production. This means industries are forced to use sub-optimal production technology, resulting in a lower output of industrial commodities.

In this model, water production is represented as a distribution activity that supplies water to the activities of producing and consuming other commodities. Those activities in turn create water pollution that in turn feeds back into the water production process. This module enables a wide range of simulations focused on freshwater-related policy. For example, local government can assess the cost and benefits of investing in water treatment plants across the whole economy.

Although out of scope for this study, one way to improve the freshwater-quality module would be to allow the environmental parameters to change over time, incorporating the effects of diffusion of abatement technology, innovation, learning effects and exogenous technological progress in pollution efficiency.

The current parameters govern the changes in technical potential for pollution reduction and efficiency improvements in the abatement sector. Subsequently, exogenous parameters drive the development in the abatement possibilities and costs while the diffusion of existing abatement technology is endogenised.

## 2.4 Specification of the sub-regional CGE model with freshwater quality management

The model specified in this section is a CGE model following a standard Arrow-Debreu general equilibrium framework.[11] [12][13] For an illustrative purpose, the

[11] The Arrow-Debreu general equilibrium framework is based on a seminal paper by Kenneth Arrow and Gerard Debreu. The framework forms a basis for most general equilibrium models where, under a set of assumptions (e.g., convexity of consumption and production decisions, and perfect competition) market clearing prices exist (i.e., in an economic system where the amount demand equals the amount supplied).

model described in the next section is simplified as a static, single-region and has a single pollution measure. The full model specification will be a dynamic,[14] multi-regional CGE model containing multiple sources of pollution. The pollution is modelled as an endogenous commodity used for production and consumption activities, and abatement is modelled as an investment to reduce the cost of pollution. Policy instruments can be set exogenously or endogenously within the model. For example, a limit-setting policy that affects the marginal costs of production can enter into the model as an endogenous variable related to the production output level. Further details on incorporating the proposed policy instruments on freshwater management into the CGE model are given in section 2.5 of this report.

In addition, pollution limits can be represented by an emission cap and a pollution tax, where the tax rates are set exogenously. Both can be used at the same time to simulate the policy instruments. Government sets the emission cap and industries adjust their optimal production and abatement technology investment behaviours endogenously.

The pollution tax is explicitly outlined within the model to simulate the optimal trade-off behaviour of those industries that face both emissions costs imposed by the government (in this case, a pollution tax) and voluntary clean-up costs. Specifications of the pollution tax are outlined in section 2.4.3 of this report.

### 2.4.1 How the baseline CGE models prices

The baseline CGE model represents 10 different groups of average prices. These include:

- composite good price
- domestic good prices
- capital input prices
- the domestic prices of imports and exports
- the prices of intermediate inputs
- value-added prices
- the world prices of imports
- exports and output prices.

The capital input prices are set either exogenously or endogenously depending on the model closure. For example, the wage rate can be assumed fully flexible to let the supply of labour equal demand or, alternatively, unemployment can be modelled to represent the labour market supply and demand imbalance.

### 2.4.2 Transforming the output

We assume that each production sector uses intermediate goods along with other factors of production. The industries are assumed to be perfectly competitive. They engage in joint production so that each industry can produce

[12] Currently, the model is programmed in a General Algebraic Modelling System (GAMS) programming language.

[13] The model specification is as outlined in Kim (2013) [23].

[14] Most dynamic CGE models are built using either a recursive (i.e., sequential) approach or an inter-temporal (i.e., across time) approach. The CGE model outlined in this report can be adopted for both approaches. The suitable dynamics within the dynamic CGE model will vary depending on the design of the freshwater-quality scenario.

more than one type of commodity. A commodity from different industries is assumed to be differentiated and therefore not perfectly substitutable. This means that the elasticity of transformation regarding joint production is set relatively inelastic.

The outputs are either consumed domestically or exported, and they follow the Constant Elasticity of Transformation (CET) Armington specification.[15] We assume Constant Returns to Scale (CRS), and the factors of production include labour, capital, land, and water pollution and water quality. These are combined by the CES production function. Intermediate goods are a mix of domestic and imported goods, and are incorporated into production by the Leontief production function. They are assumed to be heterogeneous and follow the CES function. Figure 1 illustrates the production flow.

[15] The CET and Armington specification is explained in further detail in section 2.4.6.

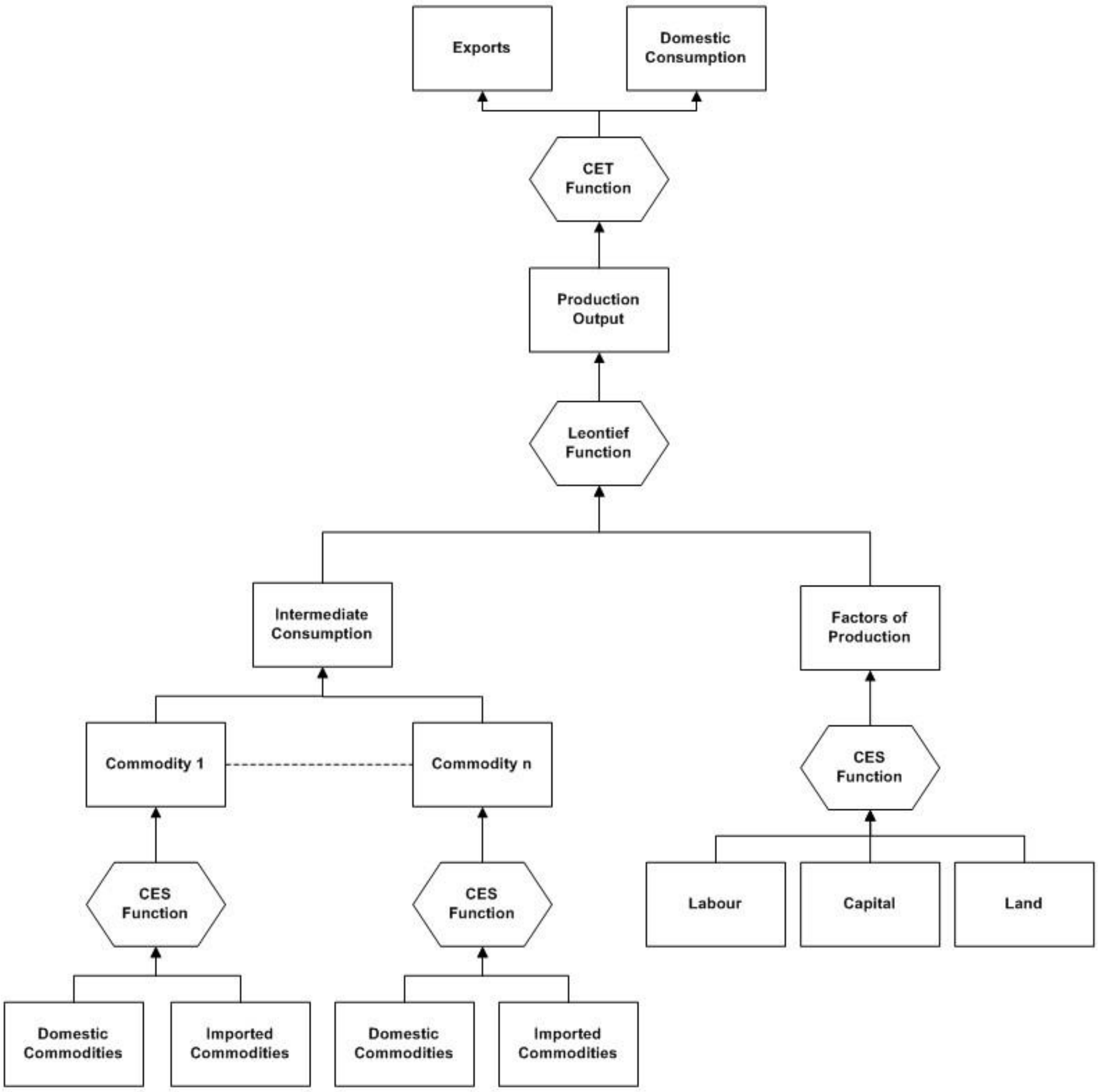


**Figure 1: Production flowchart of the economy**

Figure 1 describes the inputs and outputs of production activities within the CGE model. Inputs, consisting of domestic and imported commodities and factors of production (labour, capital and land), are used to produce outputs that are either exported or consumed domestically.

Each industry solves the profit maximisation problem with zero economic profit. The equation that demonstrates the industry's optimisation problem for a firm (*j*) is:

$$\max_{x_{ij}^P, x_{ij}^U} \quad (\sum_{i=1}^{C} p_i^P x_{ij}^P) - (p_L L_j + p_K K_j + \sum_{i=1}^{C} p_i^D x_{ij}^U + tp_j + Z_j + Zp_j + PTAX_j + PCOST_j)$$

subject to $f(x_{ij}^U) \geq x_{ij}^P$,

where $p^P_i$ is a producer's price of good *i*

$p^D_i$ is the domestic price of a good *i*

$x^P_{ij}$ is the production output of good *i*

$p_L$ and $p_K$ are price of labour and capital respectively

$L_j$ and $K_j$ are labour and capital used in production respectively

$x^U_i$ is the production use of good *i*; the production tax is $tp_j$

subsidy is $Z_j$

subsidy for pollution abatement is *Zp*.

firm level pollution tax is $PTAX_j$

pollution abatement costs is $PCOST_j$.

The first bracket in the above function represents revenue, which is the total cash inflow from product sales. The second bracket represents total costs which comprises of value-added, spending on intermediate inputs based on the fixed input-output coefficients, production taxes, production subsidy, pollution abatement subsidy, pollution emissions taxes, and pollution abatement costs. The last two components are affected by pollution intensities, pollution clean-up rates and absorption rates and prices. If included, the prices of pollution abatement services and abatement commodity productions are defined in the same way as product prices.

Industry's production technology is specified by the function $f(x^U_{ij})$. Given production technology, **a** > **0**, the equation that presents the Leontief production function is:

$$f(x^U_{ij}) = \min\left(\frac{1}{a^U_{0j}}CES(K_j, L_j), \frac{x^U_{1j}}{a^U_{1j}}, \ldots, \frac{x^U_{PEj}}{a^U_{PEj}}, \frac{x^U_{PAj}}{a^U_{PAj}}, \ldots, \frac{x^U_{Cj}}{a^U_{Cj}}\right)$$

Constant ratio of intermediate goods and factors of production is required in Leontief production function. $x^U_{ij}$ is commodity *i* required for industry *j* and $a^U_{ij}$ is technological coefficient for commodity *i* in industry *j*. Also $CES(K_j, L_j)$ represents capital and labour requirements. One intermediate commodity is the pollution emission $x^U_{PEj}$, and pollution abatement $x^U_{PAj}$.

The factor of production follows the CES specifications as:

$$CES(K_j, L_j) = \left[\phi_j\left(\frac{K_j}{\overline{K}_j}\right)^{\frac{\delta-1}{\delta}} + (1-\phi_j)\left(\frac{L_j}{\overline{L}_j}\right)^{\frac{\delta-1}{\delta}}\right]^{\frac{\delta}{(\delta-1)}}$$

where $\phi_j$ is capital[16] to labour ratio in industry *j*; $\delta$ is the elasticity of substitution; $K_j$ and $L_j$ are capital and labour used in production respectively; and $K_j$ and $L_j$ are baseline capital and labour used in production respectively.

### 2.4.3 Modelling pollution

In this model, pollution is modelled as the by-product of production and consumption process. Pollutants are treated as part of the production and consumption by each agent. That is, some of the industries indicated in the above output section are engaged in producing pollution clean-up services. The price of the services is incorporated into the commodity prices through the production process.

Pollutants are produced by industries as one of the outputs that are then entered into the production process as intermediate goods. The pollutants also enter the household consumption process as one of the commodities. Consequently, the marginal cost of production is raised through abatement expenditure and tax payments, which raise the market price.

The pollution equations include those that define the pollution emission taxes ($PTAX_j$) and pollution-abatement costs ($PCOST_j$) by industry *j*.

$$PTAX_j = ptrh_j SO_j (1 - CLR) impl_j$$

The former equation indicates that pollution emission tax ($PTAX_j$) is a function of industrial outputs ($SO_j$)[17], pollution emission tax rates (*ptr*), pollution intensities ($h_j$), and pollution clean-up rates (*CLR*). Depending on the policy instrument used, the pollution emission tax can be set to zero to simulate no emissions tax. We must note that the initial data rarely fit into this equation. This is because of the difficulty in collecting pollution taxes and measurement errors and because a discrepancy often occurs between the planned pollution emission tax and the actual tax collection.

To address this issue, we introduce an adjustment factor ($impl_j$) into the equation. These unitless adjustment factors can be estimated by calibrating this equation to base year data. The differentiation of pollution clean-up rates across sectors can be considered by using the industry specific factor. This is otherwise ignored when using the economy-wide average clean-up rate (*CLR*). Polluting firms have abatement cost functions and determine the level of abatement activity by equating the marginal cost of abatement activity to the tax rate of emissions. A trade-off between investing in the abatement technology and reducing the economic activity emerges. To meet the imposed emission restrictions, you can simply reduce the amount of output produced.

$$PCOST_j = PASh_j SO_j CLRadj_j$$

We see in the latter equation that the pollution-abatement costs ($PCOST_j$) by industries and by pollutants are a function of total industrial outputs ($SO_j$), pollution intensities ($h_j$), pollution cleaning rates (*CLR*), and the prices of pollution-abatement services (*PAS*). We derive the abatement cost of a production sector from the amount of pollutants abated, i.e., ($d_{,i}SO_jCLR$), times

[16] This model has two types of capital: land and other capital.

[17] Alternatively, the pollution emission tax can be a function of the pollution commodity *XP*.

the price of pollution clean-up (*PAS*). The dollar is the unit used for both sides of the equation.

### 2.4.4 Demand for commodities

Demand for commodities comprises household consumption demand, government consumption demand, export demand, intermediate inputs, investment demand, and inventory. The household consumption activity emits pollution, represented here by consumption of the pollution commodity.

(i) Households: Households are the main supplier of labour to productive industries and the main consumer of produced commodities. They receive wage and transfers from other agents and spend their income on commodity consumption, savings and payments to other agents. Household commodities demand depends on maximising the utility of their CES utility function subject to income constraint. Households consume both domestic and imported goods and each domestic commodity *i* is assumed to be not identical to the imported commodity *i* using the CES function.

Figure 2 illustrates the household demand and supply flow.

A household's disposable income function is specified as:

$$y_H = (1-t_h)\,(CoEH + GOSH + eh + gh + rowh) - (he + hg + hrow + hs + PTAX_H)$$

The above equation describes the disposable income of a household where the left bracket is income and the right bracket is expenditure except commodity consumption. The household receives *CoEH*, compensation for labour (*GOSH*), their share of the capital return and transfer payments from enterprise (*eh*), government (*gh*), and rest of the world (ROW) (*rowh*). Total income is taxed at $t_h$ rate. Household expenditures are transfer payments to enterprise (*he*), government (*hg*), ROW (*hrow*), savings (*hs*), and household pollution tax ($PTAX_H$). Household savings are assumed to be exogenous and do not affect consumption decisions.[18]

The problem of maximising utility for households is set out in Figure 2 below.

[18] We could incorporate a waste disposal services as a lump-sum transfer from each household to the local government.

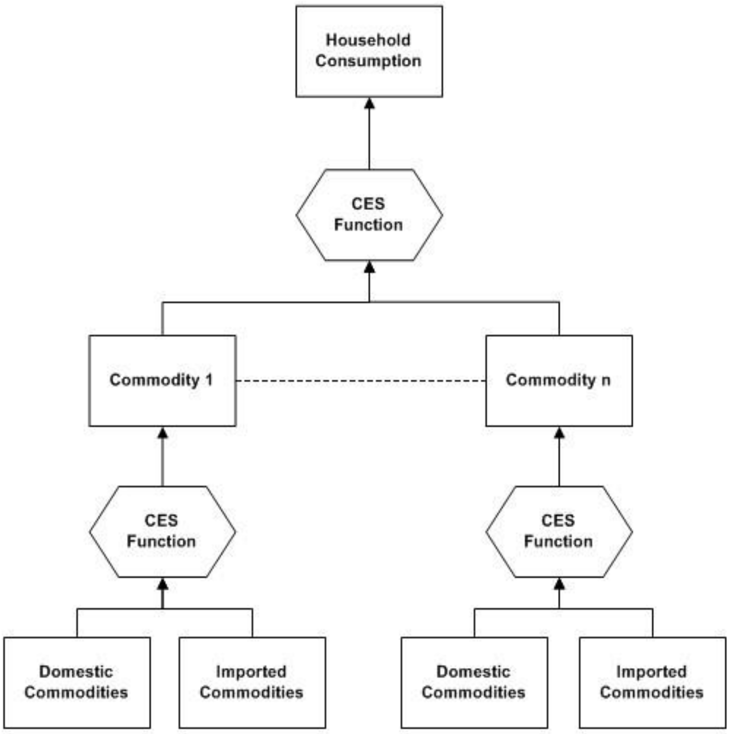


**Figure 2: Household consumption chart of the economy**

Figure 2 describes household consumption patterns within the CGE model. Domestic and imported commodities are consumed to maximise household utilities subject to budget constraints.

$$\max_{x} \quad u^H(x_i^H)$$

$$\text{subject to} \quad \sum_{i=1}^{C} p_i^D x_i^H = y_H$$

Households face consumption decision where utility is maximised subject to its budget constraint. The commodity consumption $x^H_i$ is made at the domestic price levels $p^D_i$ and the total commodities consumption equals the disposable income described in equation i. The household utility function $u^H(x^H_i)$ is a CES function:

$$u^H(x_i^H) = \left[\sum_{i=1}^{C} (a_i^H)^{\frac{1}{\sigma}} (x_i^H)^{\frac{(\sigma-1)}{\sigma}}\right]^{\frac{\sigma}{(\sigma-1)}}$$

where $\sigma$ is elasticity of substitution and $a_i^H$ is the share of good *i*. Commodities become more substitutable as $\sigma \to \infty$ and become complements as $\sigma \to 0$.

The household demand function for commodities is:

$$x_k^H = \frac{a_k^H y_H}{(p_k^D)^\sigma \left[\sum_{i=1}^{C} a_i^H (p_i^D)^{(1-\sigma)}\right]}$$

Household demand for commodity $x_k$, where $k \neq i$, depends on the domestic price of the commodity *j*, the average price of all other goods, and the elasticity of substitution $\sigma$.

(ii) Government: Government takes two forms: central government and local government. The main source of income for both forms of government is tax revenue from other agents. The government also consumes commodities, provides transfers to households and subsidises industries.[19] The government's consumption pattern is assumed to be a fixed and facing Leontief utility function. Government balances its budget: this is modelled by final commodity consumption being restricted by its budget. Government consumes domestic and imported commodities. Figure 3 illustrates the government demand and supply flow.

The government's disposable income is summarised as:

$$y_G + gh + sg =$$

$$(TI + PTAX + GOSG + eg + hg) - \left(\sum_{j=1}^{J} Z_j + \sum_{j=1}^{J} Zp_j + grow\right)$$

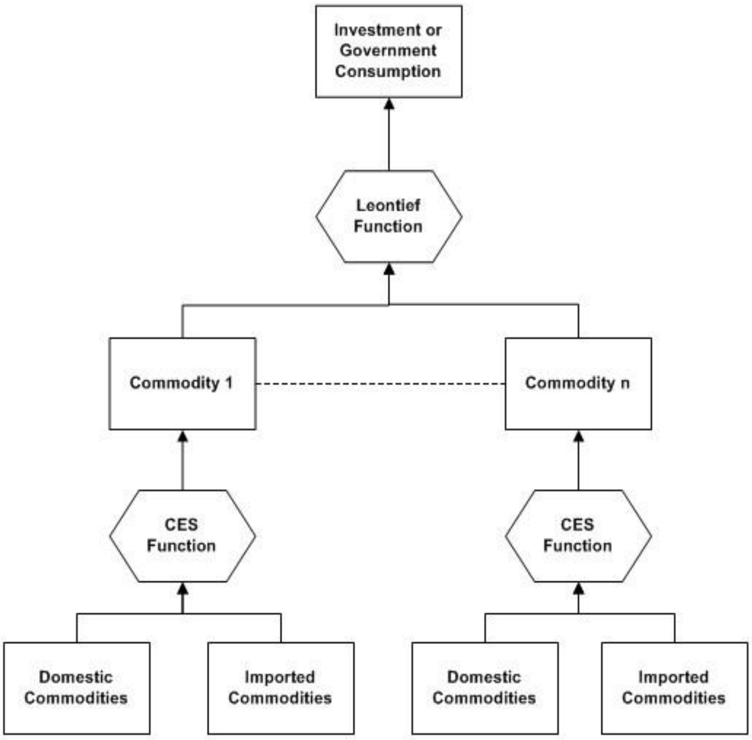


**Figure 3: Investment/government flowchart of the economy**

[19] Subsidy payments are negligible in New Zealand, according to SAM outlined in section 3 of this report.

Figure 3 describes the government consumption and the investment patterns within the CGE model. Both government and investment consume domestic and imported commodities subject to budget constraints.

It is the difference between total income (left bracket) and spending commitments (right bracket). Total income is the sum of total tax income *TI*, total pollution emission tax income (*PTAX*), returns from government capital endowment (*GOSG*), and transfers from enterprise (*eg*) and household (*hg*). Government obligatory expenditures are the sum of the subsidies to industry ($j$, $Z_j$), subsidies to industries for pollution abatement ($Zp_j$); and transfers to ROW (*grow*). Government non-obligatory expenditures are government commodity consumption ($y_G$), transfers to household (*gh*), and government savings (*sg*).

Similar to the household, the government faces a constrained optimisation problem as:

$$\max_x \quad u^G(x_i^G)$$

$$\text{subject to} \quad \sum_{i=1}^{C} p_i^D x_i^G = y_G$$

Government maximises its utility subject to its budget constraints. The commodity consumption ($x_i^G$) at the domestic price levels ($p_i^D$) equals the government disposable income ($y_G$).

The Government has a Leontief utility function specified as below.

$$u^G = \min\left(\frac{x_1^G}{a_1^G}, \ldots, \frac{x_i^G}{a_i^G}, \ldots, \frac{x_C^G}{a_C^G}\right)$$

The Government's utility exhibits Leontief functional form, where $x_i^G$ is government commodity consumption of good ($i$) and ($a^G{}_i$) is the proportion of government commodity ($i$) consumption to total government commodity consumption. Some commodities consumed by the government will comprise the pollution clean-up services and the pollution emission sector.

(iii) Enterprise: Enterprise is endowed with capital and capital rents from industries and receives payments from households and overseas in the form of transfer. The enterprise income is taxed and a fixed amount is invested as savings. Enterprise is a non-productive entity and only engages in a redistributive role. Therefore, enterprise does not consume commodities and transfers the remaining income to other agents of the economy.

The enterprise income and expenditure function is summarised as:

$$eh + eg + erow = (1 - te)(GOSE + he + rowe) - es$$

Enterprise receives capital income (*GOSE*) and receives transfer payments from households (*he*) and from ROW (*rowe*). The total enterprise income is taxed at rate (*te*) and investment (*es*) is made as savings. The remaining income is paid to households (*eh*), government (*eg*), and ROW (*erow*).

It is important to note that the flows by the enterprise can be redistributed to other agents. In this situation the enterprise is removed from the CGE model, reducing the model's complexity.

(iv) Savings and investment: In this model, investment and savings are assumed to be exogenous. Therefore, unless the investment tax rate or savings rate changes, the investment does not change.[20] Savings are received from enterprise, household, government and ROW, and are taxed. The after-tax savings are invested in commodities. The utility from consumption is characterised as a Leontief function. Similar to all other commodity consumption, domestic and imported commodities exist and exhibit CES functional form. Investment flow is depicted in Figure 3.

The equation that illustrates the savings and investment (of disposable income) function is:

$$y_{IS} = (1 - t_{IS})(es + hs + gs + rows)$$

Savings are received from enterprise (*es*), household (*hs*), government (*gs*), and ROW (*rows*). Total savings are taxed at rate ($t_{IS}$).

The investment and savings optimisation problem is:

$$\max_{x} \quad u^{IS}(x_i^{IS})$$
$$\text{subject to} \quad \sum_{i=1}^{C} p_i^D x_i^{IS} = y_{IS}$$

Investment consumption utility is maximised subject to the investment budget constraint. The commodity consumption ($x_i^{IS}$) is made at the domestic price levels ($p_i^D$), and the total value of the consumption equals the disposable income ($y_{IS}$).

Similar to the government, investment and savings exhibit a Leontief utility function as:

$$u^{IS} = \min\left(\frac{x_1^{IS}}{a_1^{IS}}, \ldots, \frac{x_i^{IS}}{a_i^{IS}}, \ldots, \frac{x_C^{IS}}{a_C^{IS}}\right),$$

where, $x^{IS}_i$ is investment commodity consumption of good (*i*) and ($a^{IS}_i$) is the ratio of investment commodity (*i*) to total investment. Some pollution clean-up services will receive investment, as will the pollution emission sector.

[20] Investment and savings play important roles in changes in the capital stock within the economy. In this model, the capital stock is endogenised, where the level of capital stock depends on the relative change in the investment. That is, the model does not have an industry-specific capital stock. Rather, that stock is mobile between industries. This assumption is used to reduce model complexities.

### 2.4.5 The relationship between household income and tax

Household income comes from the sale of people's labour, net of paying income tax to the government. The household also receives environmental compensation from firms and household subsidy payments from the government. Each level of consumption requires some mix of pollution emission or pollution clean-up services. Central and local governments have several sources of income, and central government receives tax income from the pollution emission, the income tax revenue from the households, indirect tax, and tariffs.

### 2.4.6 Trade with the rest of the world

We differentiate the domestic goods supplied to the domestic market from the goods for trade and treat them as imperfect substitutes. Without this assumption, either domestic or imported commodities with the lowest price will be consumed. Similarly, the commodities will be sold either entirely domestically or entirely exported depending on which market offers higher price. This result is due to price being the main determinant of demand in CGE models. To model consumption of domestically produced and imported commodities, a CES type function that aggregates imports and domestic sales into a composite good is used. The sectoral output is defined as a CET function combining exports and domestic sales of output. World market prices are exogenously given and the Armington approach illustrates reactions on the markets to changes in domestic prices.[21] The balance of payment constraint (warranted through flexible exchange rate) incorporates the benchmark trade surplus or deficit.

The equation that provides the CET export function is:

$$x_i^P = \left[\gamma_i (x_i^X)^{\frac{(\rho_x - 1)}{\rho_x}} + (1-\gamma_i)(x_i^D)^{\frac{(\rho_x - 1)}{\rho_x}}\right]^{\frac{\rho_x}{(\rho_x - 1)}}$$

Domestic commodity production output ($x^P{}_i$) of commodity ($i$) is allocated to exports ($x^X{}_i$), and domestic consumption ($x^D{}_i$), as dictated by CET elasticity ($\rho_x$) and share ($\gamma_i$). Similar to household CES function, commodities become more substitutable as $\rho_x \rightarrow \infty$ and become complements as $\rho_x \rightarrow 0$.

The export and domestic ratio function is given by this equation:

$$\frac{x_i^X}{x_i^D} = \left[\frac{(1-\gamma_i)}{\gamma_i}\frac{p_i^X}{p_i^D}\right]^{\frac{\rho_x}{(\rho_x - 1)}-1}$$

The optimal ratio between exports and domestic sale is given by export price ($p^X{}_i$) and domestic price ($p^D{}_i$) of commodity ($i$).

The CES import function is specified as:

[21] The Armington model assumes that a type of commodity produced by an economy is an imperfect substitute of the same type of commodity produced by a different economy. This leads to consumers demanding the commodity from both economies and optimising their consumption patterns based on the price difference between the commodity from different economies and the magnitude of imperfect substitutability between the commodity. For example, imported vehicles from Japan and Germany are perceived as different but substitutable. As such, both are consumed despite the price difference.

$$x_i^C = \left[\tau_i (x_i^M)^{\frac{-(\rho_m - 1)}{\rho_m}} + (1-\tau_i)(x_i^D)^{\frac{-(\rho_m - 1)}{\rho_m}}\right]^{\frac{-\rho_m}{(\rho_m - 1)}}$$

Domestic commodity consumption ($x^C{}_i$) of commodity ($i$) comes from either imports ($x^M{}_i$) or domestic output ($x^D{}_i$), depending on CES elasticity ($\rho_m$) and share ($\tau_i$). Similar to the household CES and export CET function, commodities increasingly become substitutes as $\rho_m \to \infty$ and become complements as $\rho_m \to$

0.

The import and domestic ratio is given by:

$$\frac{x_i^M}{x_i^D} = \left[\frac{\tau_i}{(1-\tau_i)} \frac{p_i^D}{p_i^M}\right]^{\frac{\rho_m}{(\rho_m - 1)} + 1}$$

Similar to exports, the optimal ratio between imports and domestic commodities is given by import price ($p_i^M$), and domestic price ($p_i^D$) of commodity ($i$).

### 2.4.7 Market clearing and model closure

Equilibrium conditions have demand and supply of goods equal to each other as is the case for the demand and supply of factors of production. Market clearing equations describe this. The model has short-run and long-run macro closures. Using an appropriate closure rule is very important as different closure rules give very different results. To be consistent with most other CGE models, the closure rule used in this report follows the standard neo-classical, short-run and long-run definition. Consequently, we closely follow the MONASH/ORANI model.

The main assumptions are that, in the short-run, the total amount of capital and wage rate are exogenous and fixed. Yet the return to capital and the total amount of labour are endogenously determined within the model. Under the long-run closure rule, the total combined amount of capital and wage rate are taken to be endogenous while the return to capital and the total amount of labour are exogenous and fixed. Therefore, the model behaves differently in the short run than in the long run.

Changes in any exogenous variables will be zero unless exogenous shocks are introduced. Conversely, this means that any variables that we can introduce exogenous shocks into will be exogenous variables. Important exogenous variables in the model are tax rate, production technology, and savings rate.

### 2.4.8 Numerical specification of the model

To correctly specify the parameters of the model, the calibration approach is adopted. The SAM approach is taken to adopt a consistent database for calibration. We extend the traditional SAM to include regional information when we build a multi-regional SAM based on the national SAM. This allows us to capture the inter-regional transactions and contributions of each agent. The data that forms the basis of the SAM will be obtained from the latest supply-use tables and national accounts published by Statistics New Zealand. The numerical specifications of the model and how the SAM is built are discussed in greater detail in section 3 of this report.

## 2.5 Incorporating the policy instruments for managing the quality of fresh water

The CGE model outlined in the previous section can be used to assess the economic impacts of implementing various freshwater policy instruments. Further, the model specifications are flexible and can be easily modified to suit other types of policy instruments (e.g., setting limits for carbon emissions). Even so, as the CGE model contains vast amounts of variables and links within the economic system, each policy instrument is likely to have a different method of application into the CGE model.

Broadly, as noted earlier, the instruments can be applied within the model by changing exogenous variables and/or setting up endogenous variables depending on how the instrument affects the economic system. Therefore, setting up the model for an economic impact assessment of an instrument policy requires a preliminary assessment of how the instrument affects the economy.

For input into this study, the Auckland Council Research and Evaluation Unit (RIMU) provided a list of freshwater instruments for economic modelling (see Appendix A to this report). Broadly, the three types of instrument options are spatial, non-spatial and consents/permits, while four instruments adhere to the NPS-FM. The next subsection outlines examples of how to apply two[22]non-spatial instruments that adhere to the NPS-FM and how to apply a hypothetical social value instrument into the CGE model.

### 2.5.1 Freshwater limits

Under the policy instrument on freshwater limits, available freshwater is constrained to meet the objective of good-quality fresh water. It is important to note that the instrument is not a direct cap on the available fresh water within the economy as the pollutant emission levels are different depending on the industry or consumer who uses it. As such, the constraint will change the composition of the industrial outputs as well as consumption compared to the base case. In addition, investment in abatement technology can alter the ratio of pollutant emissions to output from different sectors of the economy.

Therefore, the limit of freshwater quality, or total pollutant emission levels within the CGE framework, is set as an exogenous variable that limits the production of the pollution commodity. That is, assuming a plentiful supply of fresh water, total emissions must be less than equal to a set limit. This constraint enters into the CGE model as:

$$\sum x_P \leq FL$$

where, $x_P$ is a pollutant emission good ($P$) and $FL$ is an exogenous freshwater quantity limit measured in quantity of pollutant emission goods.

In addition, if the model includes fresh water as a factor of production, the quantity of fresh water supplied enters into the model as an endogenous variable that is a function of the former exogenous variable $FL$. Specifically, $FWS$

[22] Two instruments were excluded: (i) spatial instrument involves setting up a Freshwater management Unit (FMU); and (ii) in-stream value is the instrument that defines the limit settings for freshwater quality.

is a variable of an endogenous supply of total fresh water subject to a constraint $x_P$ which equals *FL*.

### 2.5.2 Prioritising how fresh water is allocated

In the policy instrument 'freshwater allocation in order of priority', the how fresh water is allocated is based on a priority of: (i) health and wellbeing requirements for humans and animals; then (ii) economic, technical and dynamic efficiency, and emergency shortage. Specifically, the priority of each freshwater user in the economy is based on the priority target in turn, where the user with a higher priority is allocated before the user with a lower priority. This can be modelled within the CGE model using a set of constraints:

$$\sum FW_1 \leq FWS_1,$$

$$\sum FW_u \leq FWS_u = FWS_{u-1} - \sum FW_{u-1}$$

where $u$ is the order of priority (1 being the highest priority) allocated to all freshwater users, ($FW_u$) is a quantity of fresh water used by the prioritised users ($u$), and $FWS_u$ is the total freshwater quantity available to those users ($u$).

### 2.5.3 Incorporating social value into the model

Social value instruments in freshwater management can specifically consider community, cultural, traditional Māori uses, environmental and aesthetics values. Although economic values drive the CGE model, the non-economic values can be included in the model once those values are converted into the monetary (ie, numerical) values used within the model. In turn, these values can be included directly in the utility maximisation function, where the model calculates the optimal trade-off level between economic and non-economic values.

Suppose the non-economic values are mainly considered by households. The household utility maximisation problem is then set out as:

$$\max_{x,SV} \quad u^H(x_i^H, SV)$$

$$\text{subject to} \quad \sum_{i=1}^{C} p_i^D x_i^H = y_H, and\ SV(x_P)$$

In this example, households face a consumption decision where utility is a function of consumption of commodities and social value (*SV*). The decision is now a maximisation problem subject to its budget constraints and the *SV*, which is a function of $x_P$.

## 2.6 Development programme for building an integrated model

To adhere to the National Policy Statement for Freshwater Management (NPS-FM), Auckland Council is undertaking research to understand the channels of water pollution and measure quantities of pollutants emitted within the region. The models used within the research are based on freshwater models, and researchers were interested in incorporating the CGE model and, in particular, building an integrated model. Such models may answer a detailed spatial level economic and physical consequences associated with limit setting policies and significantly increase the depth of the research currently undertaken. As far as the author is aware, there are two water management researches[23] undertaken in New Zealand which involves building an integrated model with a CGE based economic module.

Even so, building an integrated model is an enormous undertaking where substantial time and expert inputs from relevant fields are required. In addition, researchers within the council indicated a CGE model, such as the one proposed here, can be used beyond the freshwater management studies currently undertaken. But any future research should adhere to other aspects of the National Policy Statements.

In light of this, the proposed CGE model should have future use in mind and must be able to be integrated into other models. At this stage it is not feasible to build a development programme for a CGE model meeting the requirements noted above. This is because outlining such a programme would require an extensive scoping study involving various potential council users of the model.

Broadly, the development process for the CGE model focused on freshwater quality will have three major stages.[24]

1. **Build the modules for use within the CGE model**: The main objective of this stage is to build modules to be used within the CGE model, where those modules simulate emission channels as a consequence of production. This includes abatement and consumption activities within the economy. We were unable to find any research within New Zealand on a water quality model being endogenously integrated into an economic model. We expect that developing the water quality module will take a large share of resources (time and people).

2. **Modify and update the CEU sub-regional housing to:** This stage involves modifying and updating the specifications of the current CEU sub-regional housing CGE model to accommodate the module built in the first stage. The key tasks in this stage are to identify and specify the sub-regional areas, production sectors, and economic agents that the CGE model will model. Subsequently, appropriate SAM corresponding to the specification needs to be built.

   Finally in this stage, the model formulation and mathematical functions of CEU sub-regional housing CGE model will be modified to match the identified specification. The challenging aspect of this stage is to build the underlying SAM, as this involves intensive data mining. The data required to build an accurate sub-regional, level-based economic database (i.e., SAM)

[23] (1) Southland Regional Council is developing an integrated CGE model to assess the economic implications of water allocation and limit-setting initiatives in the Southland region. Further information is in Stage 1 of this report. (2) Smart Models for Aquifer Characterisation is a multi-year research programme funded by the Ministry of Business, Innovation and Employment. In that programme, ground and surface water models, a land-use model, and a CGE-based economic model are integrated to support decisions on risk. The key focus of the research is to develop a simple model design that is easily incorporated into decision making. The research is co-funded by Environment Southland, Environment Waikato and the Greater Wellington Regional Council.

[24] An important part of a research programme is a feasibility and scoping study. This part is normally included as a first stage of a research programme. However, this study forms part of the feasibility and scoping study for the proposed study and so the development programme in this report does not include a separate feasibility and scoping study.

to be used within the CGE model is lacking. Even at the regional level, only a small amount of data is available to test in the technical estimation methods needed to build SAM. Section 3 of this report includes a detailed technical methodology for building SAM.

3. **Incorporate the CGE model with the modules for managing freshwater quality:** The key tasks in this stage are to integrate the CGE model built in stage 2 with the modules built in stage 1, to calibrate the model, and to test the robustness of the results. Such a calibration exercise (where the model is tested and fitted against real-world data) makes the model more reliable and the results more robust.

   In addition, the estimation and testing of economic model parameters (e.g., elasticities used within the CGE function) will be run alongside the calibration process. Finally, the final output will be promoted in workshops and conferences, with a written technical document and practitioner's guide.

We estimate the programme will take about 12 months, with each stage taking about 4 months.. The time needed depends on the availability of council staff and, from consulting with the council, we expect the full study will involve an initial scoping study and then modification of the CGE model when required.

### 2.6.1 The four groups within the project team

The programme's project team has four major groups.

1. A **Technical Advisory Group** (TAG) is expected to provide broad advice to, and assist with, the overall direction of the project. This will ensure the final outcome of the programme aligns with the requirements of the council and other local and central government agencies.

2. A **management group** will assist a research team during the project, by liaising with different departments within the council, TAG and the peer reviewer. It will also help to run workshops and participate in promoting the programme. The management team is also expected to take part within TAG.

3. A **peer reviewer** will be heavily involved throughout the project, helping with technical aspects of the proposed model. This will ensure that any problems are addressed early in the project. Each stage has six major peer review points (in two steps). The technical methods will be specified and peer reviewed at the start of each stage. The final output of each stage will be peer reviewed at the end of that stage.

4. A **research team** will be responsible for conducting the programme. Although it is expected that the development process will be straightforward, implementing and testing the robustness of the freshwater-quality module will require substantial technical expertise. In particular, the proposed model includes endogenous freshwater-quality modules not previously undertaken in New Zealand.

   Compared to researchers with skills in other economic impact assessment methods, (i.e., CBA and IO), considerably fewer researchers within New Zealand have skills in the CGE model. So the biggest barrier to the development process will be acquiring skilled CGE practitioners capable of building and implementing the freshwater-quality module.

### 2.6.2 The project's Five key deliverables

The development programme has five key deliverables.

1. **The module for managing the quality of fresh water:** The modules built in Stage 1 will be able to model channels of water pollutant emissions in economic production, consumption, and abatement. Auckland Council can apply these modules, as can other local councils, into an economic model used to calculate the quantity of pollutant emissions from the economy. In addition, the modules can be modified to measure pollutants other than water.

2. **The generic CGE model:** Stage 2 will involve building a generic multi-regional CGE model capable of handling regional and sub-regional spatial areas. Although, at first, this model will be used for the Auckland region, it can be run for other regions. In addition, the generic structure of the model will allow easy implementation to future policy studies and to any economic module within an integrated model (e.g., the EIA of setting limits for carbon emissions).

3. **CGE model for managing the quality of fresh water:** The CGE model to assess economic implications of the water quality limit setting initiatives will be created. This model can be used as a stand-alone tool or as a part of integrated model.

4. **Technical documentation and a practitioner's guide:** Key outputs of the development programme will be technical documentation and a practitioner's guide. The technical documentation will provide full technical details on the methodology, procedures and data used within the programme. It is envisioned that the researchers will be able to use the document to develop similar models in the future. The practitioner's guide will provide details on how to use the built model and guidelines on how to use the CGE model to conduct EIAs.

5. **Workshops and presentations:** Workshops on the built model will be run within the council and in other government agencies to promote and inform researchers. The project's research team will also participate in conferences and present the model to inform wider audiences throughout New Zealand.

### 2.6.3 Risks to completing the project successfully

The development programme faces several possible risks.

1. **Technical complexity of the model:** The CGE model and freshwater-quality modelling proposed in this study is at the cutting edge of economic EIA. As such, building the model is highly technical and the research team will most likely face technical difficulties during the development programme. As noted above, New Zealand has only a handful of CGE experts. Even so, a number of private organisations and academics own

and operate CGE models within New Zealand. As such, technical difficulties can be mitigated by seeking expert advice.

2. **Loss of key members of the research team:** Losing key team members is a well-known risk involved with a long-term research programme such as this. As to the first risk, the technical complexity of the CGE model adds to this second risk as New Zealand has only a limited number of researchers with the necessary skills. Also, the key objective of the development programme is increasing CGE capabilities within the council. The loss of any key member of the research team will hinder us in achieving this objective.

   To mitigate the risk, the CGE model will be based on a standard CGE structure built on a widely used programme code. This ensures that the model is easily transferable and people will not need much time to become familiar with it.

3. **Unavailability of key data to populate and check the model:** The robustness of an applied model depends greatly on having accurate data. Building the CGE model will require detailed regional economic data and sub-regional data. Within New Zealand, the data required to build a detailed regional and sub-regional housing CGE model is lacking. So CGE modellers will use numerical estimation methods to build the underlying data.[25] In addition, water accounts and pollution data for Auckland are still being developed, creating the risk that data is not available before this development programme starts.

   Two actions can mitigate this risk of unavailability risk: use an established method to numerically estimate unavailable data; and then update the data as unavailable data becomes available.

4. **Project scope creep:** As noted earlier, researchers within the council were interested in using the proposed CGE model for various policy issues and in applying the model as an economic module within an integrated model. This means the scope of the development programme may expand to include other issues. This would lead to delays in delivering the model within the set timeframe.

   In response to this risk, the model will be built in two stages: (i) the base CGE model; and (ii) the base CGE model expanded to incorporate the freshwater-quality module.

[25] CGE modellers in New Zealand are not the only modellers to have little available data to build SAM. CGE modellers in most other countries have the same problem. The SAM data construction method outlined in this report also uses numerical estimation methods. See section 3 for further details.

# 3 Stage 3: Gap analysis on data requirements and the value of the study

In general, building a CGE model framework involves analysing the transactions of numerous economic agents.[26] One advantage of the modern CGE modelling based on Johansen (1960)[21] is that it is based on national accounts data publicly available for most countries. The downside of this approach is that the same data used to estimate the parameters to build the model are used to provide the benchmark for the model.

This section discusses the data required to model the sub-regional CGE model with the freshwater module. Subsection 3.1 provides an overview of the data requirements, subsection 3.2 describes New Zealand National Social Accounting Matrices, subsection 3.3 outlines a full data construction methodology, and subsection 3.4 lists the data requirements for incorporating a freshwater module.

## 3.1 Overview of the data requirements

### 3.1.1 Social accounting matrix

Most economic impact analyses involve using some form of economic data in building and estimating parameters for the models. The National Accounts (NAs) [27] prepared by Statistics New Zealand (SNZ) provide a good source of economic data for creating a snapshot of the economy at a given point in time. In addition, other accounts, such as the Household Economic Survey [50], Institutional Sector Accounts (Sector Accounts) [53], Harmonised System for Trade [52], can be used to supplement the NAs to provide a more complete picture of the transactions made by the main agents[28] in an economy.

The economic information contained in the aforementioned tables and accounts noted in the above paragraph can appear in many forms. In applying the CGE modelling, which is the proposed methodology in this report, economic data are best represented in a matrix form. This is because the matrix form can represent the market-clearing concept in an intuitive way. The concept of equilibrium and market clearing is fundamental to most economic modelling. As the equilibrium identities dictate the total supply to equal use or input to output or income to expenditure, the same concept can be applied in summarising the NAs.

In this report, the data requirements to build a comprehensive sub-regional housing model are discussed in the context of the following three matrices that summarise the NAs: (1) the National Social Accounting Matrix (NSAM); (2) the Multiregional Social Accounting Matrix (RSAM); and (3) the Sub-regional Social Accounting Matrix (SSAM).

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[26] A CGE model environment may often involve households, producers, commodities, industries, government and others, which can lead to an estimation of parameters that is data intensive.

[27] Statistics New Zealand follows the convention as set out in the United Nations System of National Accounts (1993)[59].

[28] An agent in the context of CGE modelling means any entity (such as households, governments) engaged in economic activities.

### 3.1.2 Spatial economic data

The main spatial economic dataset used in this analysis is New Zealand Business Frame (BF) [51]. This dataset contains employment by industries in 6 Digit ANZSIC06. The data is used in conjunction with the meshblock data from the 2013 Census (Meshblock 2013). Meshblock 2013 is a geographical division of New Zealand land mass relative to categorical and quantitative variables such as population density and types of land use. Each meshblock in a BF dataset contains industry employment information. The employments are further categorised into New Zealand Employment Counts (EC) and Geographical Units (GU). Our main data of interest is EC.

The dataset can be further aggregated into:

- 6 Digit ANZSIC Classifications into 106 Supply and Use table industries
- Meshblock 2013 area into FMUs and the ROW.

Aggregation of the dataset is possible as the original dataset contained more than 40,000 meshblocks and 500 industry classifications. That dataset is too detailed for our purpose. So each land area of interest will be FMU areas within Auckland and ROW, which contains ECs by 106 industries from the Supply and Use table.

## 3.2 New Zealand National Social Accounting Matrices

The use of SAMs in economic impact analyses is well-supported in literature and is the main source of data for CGE modelling. Even so, building a SAM can be costly due to the substantial time and effort required to obtain and analyse the appropriate economic data. Accordingly, few examples of SAMs are built for New Zealand at the national and regional levels. One early example of updating the New Zealand SAM is featured in Zhang et al. (2008)[63]. In the report, the authors created the National Supply-Use Table for 2003 based on the 2003 NAs and the existing 2002-2003 National Supply-Use Table (NSUT).

The NSAM and RSAM are then built based on the NSUT and the regionalised NSUT. The report well demonstrates the substantial effort required to produce an update of SAMs. The same set of NSUT published for the 2002–2003 year has been used in other studies. Most notably, a series of studies published by private consulting firms, the New Zealand Institute of Economic Research (NZIER) and Infometrics use the 2002–2003 NSUT to evaluate the impact of carbon emission trading schemes in New Zealand.[29] [30]

A more recent example of NSAM and RSAM built for the New Zealand economy is presented in Smith et al. (2015) [44] where the authors extend the approach

[29] Seven studies, published by Infometrics (2007, 2008) [19], NZIER (2008) [37], NZIER and Infometrics (2009, 2011) [38], [39], Landcare Research (2008) [13] and Lennox and van Nieuwkoop (2010) [26], apply the 2002–2003 NSUT in a CGE setting to study the impact of carbon emission trading schemes in New Zealand.

[30] We were not able to obtain information on the detailed mathematical formulation used for the CGE models and the underlying SAMs that NZIER and Infometrics use. This report assumes that, given the models that NZIER use are mainly based on the MONASH/ORANI specification their SAM would be built like the Australian SAM. However, it is unclear how the differences in treating and disclosing data from SNZ and its Australian counterpart are accounted. It is also unclear how differences in the transactional characteristics of industry sectors between the two countries are accounted.

outlined in Zhang et al. (2008) [63] to build the updated NSAM and RSAM using the 2006–2007 NSUT. Robson (2012) [42] provides a description of a prototype RSAM for 25 industry types and 5 regions in New Zealand. In the context of managing the quality of fresh water at the regional level, Market Economics has been involved in two separate studies using the CGE model framework.

The first study is Southland Regional Council's integrated CGE model to assess the economic implications for the Southland region of water allocation and initiatives that set limits.[31]

The second study is Smart Models for Aquifer Management as part of a multi-year MBIE funded research programme, where groundwater and surface water models, land use model, and a CGE based economic model are integrated to support decision making based on risk.

Although numerous RSAMs are created by research organisations throughout New Zealand, it is hard to know whether these will be available for council to use. As such, the next section of the report outlines a detailed method of building NSAM, RSAM and sub-regional SAM. Broadly, the method is a mix of methodology used by Market Economics Ltd and The Enormous Regional Model (TERM) database construction methodology outlined in the paper by Mark Horridge from the Centre of Policy Studies (CoPS), based at Victoria University in Melbourne.

## 3.3 Building the social accounting matrices for the sub-regional model

The sub-regional housing model will be based on the latest NSUT available from SNZ. The latest tables that SNZ released in April 2016 are based on the 2013 financial year. The NSUT outlines the input requirements, final input demand and the final output production by 106 industries of 201 commodities. The 2013 NSUT will form the basis for building the NSAM, along with the RSAM and SSAM.

Other data sources, such as the New Zealand Census and AgriBase, will be used to supplement the requirement for employment and population data.

This section briefly discusses the main components and data requirements for building each SAM.

### 3.3.1 The 2013 National Social Accounting Matrix

The 2013 NSAM will be based on the data contained within the 2013 NSUT. The NSAM will condense the information from the 106 industries and 201 commodities contained in the 2013 NSUT. The condensed matrix will focus on industries, commodities, labour and capital[32] as factors of production, an enterprise, a household, local and central government, direct and indirect taxes, savings/investment and ROW.

An example of NSAM is illustrated in Figure4. As shown in the example, NSAM features the main economic agents, their income and expenditure activities and the total value of those activities. The economic agents modelled in the NSAM are

[31] See Stage 1 of this report for further information about Southland Regional Council's initiative.
[32] Capital will contain physical capital and land as its two main components, and so incorporate the land use information into the sub-regional housing model.

listed along the first row and again, along the first column. The agents modelled in this particular NSAM include commodities (*j* = 1,...,*C*), industries (*i* = 1,...,*I*), factors of production, a household, an enterprise, the central and local governments (*g* = 1,...,*G*), taxes, savings and ROW.

The rows of the matrix indicate the income side of the activities. Correspondingly, the columns indicate the expenditure. For example, the total value of the commodities supplied is indicated by the commodity row and is the sum of **U**, the intermediate consumption, the household consumption (**hc)**, the government consumption (**GC)**, the savings used as investment in production (**s**) and the commodity export to ROW (**x**). The corresponding expenditure related to commodities is indicated by the elements along the commodity column, which is the sum of **S**, the domestic supply of commodities and the value of imports (**IM**). The income and expenditure of the other economic agents, such as within NSAM, producers, enterprise, household, and the government can be interpreted the same way from the NSAM.

Under the market-clearing conditions, the income will equate to the expenditure for each economic agent in the NSAM.

For example, under the market-clearing conditions, the final demand for commodities ($\gamma$) will equal the total supply ($\gamma'$). Similarly, the value of the total domestic production ($\mu$) will equal the cost of production ($\mu'$).

The nine income and expenditure components of the NSAM are summarised briefly below.

1. Commodity: The final demand ($\gamma$) and supply ($\gamma'$) for commodities are characterised by the following two equations for each commodity (*i*):

$$\gamma_i = \sum_{j=1}^{I} u_{ij} + hc_i + \sum_{g=1}^{G} g_{ig} + s_i + x_i$$

$$\gamma_i' = \sum_{j=1}^{I} s_{ij} + IM_i$$

   Under the market-clearing conditions, $\gamma_i = \gamma'_{i'}$ is used for all *i =i'*.

2. Production : Each industry (*j*) involved in producing commodities (*i*) produces the total output ($\mu_j$) in producer prices, as characterised by:

$$\mu_j = \sum_{i=1}^{C} s_{ij}$$

   The value of this production must equate to the cost of production ($\mu'_j$), and this is the sum of the elements in the column corresponding to industries. In particular, the cost of production for industry (*j*) includes the intermediate consumption, **U** used as materials, the payments made for the factors of production, compensation of employees (*CoE*) for the labour input and the gross operating surplus (*GOS*) as return for capital and the payment of tax on production (**TY**). The equation that summarises the cost is:

$$\mu'_j = \sum_{i=1}^{C} u_{ij} + CoE_j + GOS_j + \sum_{t=1}^{T} TY_{tj}$$

3. Factors of production (**f**): The total payments made to compensate the labour and capital input into the production are denoted $l$ and $k$. The total factor income for labour is equal to the total compensation of employees *CoE*, while the total factor income for capital is equal to the total gross operating surplus *GOS*. On the expenditure side, the total factor expenditure for labour ($\epsilon'_l$) and capital ($\epsilon'_k$) comprise these components:

$$\epsilon'_l = CoEH + CoERoW$$

$$\epsilon'_k = GOSE + GOSH + \sum_{g=1}^{G} GOSG_g$$

   The total labour factor expenditure is the sum of the payments to the households for providing their labour, *CoEH* and the labour income generated from the domestic production but paid to ROW (*CoERoW*). As our model has a representative household, the total labour factor payment across all households is the same as the labour factor payment to our representative household.

   The total capital factor expenditure is the sum of the payments made to the enterprise, *GOSE* (the portion of the gross operating surplus paid to the enterprise), the household, *GOSH* and the Government (*GOSG*).

4. Enterprise: The total enterprise income denoted $\pi$ is the sum of *GOSE* and transfer payments made by the household to enterprise (*he*) and the transfers from the ROW (*rowe*):

$$\pi = GOSE + he = rowe$$

   The total enterprise income has to equal the total enterprise expenditure ($\pi'$), which comprises the transfers made by enterprise to the household (*eh*), the Government (*eg*), the ROW (*erow*), the direct tax payments (*te*) and the enterprise saving (*es*). The equation that summarises the components of the enterprise expenditure is:

$$\pi' = eh + \sum_{g=1}^{G} eg_g + \sum_{t=1}^{T} te_t + es + erow$$

5. Household: The total income for household ($\rho$) is made up from the payments for labour (*CoEH*), capital (*GOSH*), transfers from enterprise (*eh*), the Government (*gh*) and from ROW (*rowh*). The household income is summarised as:

$$\rho = CoEH + GOSH + \sum_{g=1}^{G} gh_g + rowh$$

The income ($\rho$) should equal the total household expenditure ($\rho'$), which is made up of consumption of commodities (**hc**), transfers made to enterprise (*he*), tax payments (**th**), savings (*hs*) and transfers made to ROW (*hrow*):

$$\rho' = \sum_{i=1}^{C} hc_i + he + \sum_{t=1}^{T} th_t + hs + hrow$$

6. Government: Central and local government are modelled. The income for government comes from tax (**GTI**), transfers from enterprise (*eg*) and household (*hg*) and the Government's gross operating surplus (*GOSG*).

   Government expenditure items include commodity consumption (**GC**), tax payment (**TG**), transfers to the household (*gh*), ROW (*grow*) and savings.

   The total income for Government ($\theta$) must equal the expenditure ($\theta'$):

$$\theta_g = GOSG_g + eg_g + hg_g + \sum_{t=1}^{T} GTI_{gt}$$

$$\theta'_g = \sum_{i=1}^{C} GC_{gi} + gh_g + \sum_{t=1}^{T} TG_{tg} + gs_g + grow_g$$

7. Tax: Tax takes two forms: direct tax and indirect tax. Direct tax is mainly income tax from household, and enterprise and investment. Indirect tax is mainly GST and customs duty. On the expenditure side, all tax revenues collected ($\tau'$) become the government's tax income. That is, $\tau'$ equals **GTI**. The equation that characterises the total tax income ($\tau$) is:

$$\tau = \sum_{j=1}^{I} TY_j + \sum_{j=1}^{I} PTAX_j + te + th + \sum_{g=1}^{G} TG_g + ti + tx$$

   Indirect tax related to production (**TY**) includes GST and other taxes on product subsidies. *te* and *th* each denote income taxes of enterprise and household and also (in the case of the household), the GST on consumption. **PTAX** denotes the total pollution emission tax from industries; **TG** denotes the direct and indirect tax payment from central government. *ti* is the indirect tax paid on gross capital formation, while *tx* is the income tax and export duty.

8. Savings and investment: The savings or the gross capital formation ($\sigma$) consists of savings made by enterprise (*es*), household (*hs*), the Government (*gs*) and from ROW (*rows*). Balancing this savings input, the investments are made into commodity production as *s* (gross, fixed-capital formation and changes in inventory), and the associated investment tax *ti* is paid to the government. The equations that summarise the savings input ($\sigma$) and the investment output ($\sigma'$) are:

$$\sigma = es + hs + \sum_{g=1}^{G} gs_g + rows$$

$$\sigma' = \sum_{i=1}^{C} s_i + \sum_{t=1}^{T} ti_t$$

9. Rest of the world (ROW): The total foreign outlays ($\phi$) consist of payments for imported commodities (**IM**), the factor income paid for domestic production (*CoERoW*), and transfers made from enterprise (*erow*), household (*hrow*) and the Government (*grow*). The total foreign earnings ($\phi'$) from ROW include the earnings from exports (**x**), transfers from ROW to enterprise (*rowe*) and household (*rowh*), the tax payments, (**tx**) and the savings by ROW (*rows*). Under the market-clearing conditions, the total foreign outlays must equal the total earnings:

$$\phi = \sum_{i=1}^{C} IM_i + CoERoW + erow + hrow + \sum_{g=1}^{G} grow_i$$

$$\phi' = \sum_{i=1}^{C} x_i + rowe + rowh + \sum_{t=1}^{T} tx_t + rows$$

| | Commodity c=1,…,C | Industry i=1,…,I | Factors of production f=k,l | | Enterprises | Households | Governments g=d,ll | Taxes t=1,…,T | Savings - Investment | Rest of World | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Labour | Capital | | | | | | | |
| Commodity c=1,…,C | | U Use (Intermediate Consumption) | | | | hc Household Final Consumption Expenditure | GC Government Final Consumption Expenditure | | s Investment (Changes in Inventories and GFCF) | x Exports | Gross Com Supply |
| Industry i=1,…,I | S Supply (Domestic) | | | | | | | | | | Doestic Production |
| Factors of production f=k,l: Labour | | CoE | | | | | | | | | Total Factor Income (Labour) |
| Factors of production f=k,l: Capital | | GOS | | | | | | | | | Total Factor Income (Capital) |
| Enterprises | | | | GOSE Gross Operating Surplus of Enterprises | | he Household Transfers to Enterprise | | | | rowe Overseas Transfers to Enterprise | Enterprises Income |
| Households | | | CoEH Labour Factor Income for Households | GOSH Gross Operating Surplus of Households | eh Enterprise Transfers to Household | hh Household Transfers to Itself | gh Government Transfers to Household | | | rowh Overseas Transfers to Household | Hhlds Income |
| Governments g=d,ll | | | | GOSG Gross Operating Surplus of Governments | eg Enterprise Transfers to Govt | hg Household Transfers to Government | gg Government Transfers to Itself | GTI Govt Tax Income | | | Govts Income |
| Taxes t=1,…,T | | TY Tax (Indirect taxes GST on Prod + Other Taxes on Prod-Subsidies) | | | te Taxes (Direct Enterprise Taxes) | th Tax (Direct Income+Indirect GST on Cons+other) | TG Tax (Direct Income Taxes+Indirect GST on Consumption) | | ti Tax (Investment) | tx Tax (Export Taxes and Income Taxes) | Total Taxes |
| Savings - Investment | | | | | es Enterprise Saving | hs Household Saving | gs Government Saving | | | rows Overseas Savings | Total Saving |
| Rest of World | IM Imports | | CoERoW Labour Factor Income for Rest of World | | erow Enterprise Transfers to the RoW | hrow Household Transfers to the RoW | grow Government Transfers to the RoW | | | | Total Foreign Outlays |
| Total | Gross Com Inputs | Cost of Production | Total Factor Expenditure (Labour) | Total Factor Expenditure (Capital) | Enterprises Expenditures | Hhlds Expenditures | Govts Expenditures | Total Taxes | Total Investment | Total Foreign Earning | |

**Figure 4: Structure of National Social Accounting Matrix**

**Data requirements for the National Social Accounting Matrix**

The primary data source for NSAM is a national-level, input-output table. The latest available NSUT (published for the 2013 financial year) and the 2013 NAs will be used to build the 2013 NSAM. The main data sources are:

- the National Supply Use (Input Output) Table for the year ended 2013

  [48]

- Statistics New Zealand's National Accounts (Income and Expenditure) for the year ended 2013 [55].

To use the NSUT when building the NSAM, the total supply of each commodity in the NSUT must equal the total use. Also, the total income of each industry must equal the total expenditure. The row totals and the column totals differ slightly for the tables published by SNZ. An optimisation method is used to reduce the difference within the target range before we can apply it to build the NSAM.[33]

The other data source required for building the NSAM is a series of tables published as part of SNZ'S National Accounts (Income and Expenditure). The following 13 tables are included in the Income and Expenditure account.

**Table 1: National Accounts Income and Expenditure**

| | |
|---|---|
| Table 2.1 | Producer enterprises sector accounts |
| Table 2.2 | Private corporate producer enterprises and producer boards sector accounts |
| Table 2.3 | Private non-corporate producer enterprises sector accounts |
| Table 2.4 | Central government enterprises sector accounts |
| Table 2.5 | Local government enterprises sector accounts |
| Table 2.6 | Financial intermediaries sector accounts |
| Table 2.7 | General government sector accounts |
| Table 2.8 | Central government sector accounts |
| Table 2.9 | Local government sector accounts |
| Table 2.10 | Private non-profit organisations serving households sector accounts |

[33] One commonly used method to balance the income and expenditure totals is a 'least squares' optimisation method. This method minimises the squared difference between the total and the target value subject to the identified income and expenditure constraint. See Smith et al. (2015) [44] for further detail.

| | |
|---|---|
| Table 2.11 | Households sector accounts |
| Table 2.12 | Household final consumption expenditure |
| Table 2.13 | Rest of world sector accounts |

The complete set of data sources for each NSAM account is available in the Data Sources for NSAM at Appendix B of this report.

### 3.3.2 The multi-regional Social Accounting Matrix

A regional-level SUT is required to build an RSAM. Ideally, the regional SUT should be built from the ground up and based on information obtained from each region. However, as detailed regional data is lacking, most RSAM are built by regionalising a national-level SUT using various estimation methods.

The basic idea behind the estimation approach is to assume that the regional account is a proportion of the national account. In addition, the regional accounts should sum up to the national account in a given year. For example, the regional supply ($S^r$) can be estimated by $\alpha S$, where $\alpha$ denotes a coefficient that gives the regional share of the national output and $S$ is the total national output. In other words, say if Auckland is attributable for one quarter of the national financial and banking services, then Auckland's regional supply of financial and banking services is estimated to be one quarter of the national supply.

In practice, estimating this share coefficient can be difficult due to regional data constraints. Further, the classification of the national output into 106 industries and 201 commodities within the SUT framework means that some commodities grouped together may differ greatly in how they are traded between regions.

In our report, we investigate the construction of RSUT and RSAM based on the 2013 NSUT and the Regional Gross Domestic Production (RGDP)[54] accounts published by SNZ.[34]

#### Constructing the regional supply-use table

In this report, we outline the process of regionalising the NSUT into 15 regions as defined in the RGDP accounts by SNZ. The following steps summarise the main processes of building a RSUT.

1. Regional supply ($\mathbf{S^r}$): The regional share of national supply of commodity $i$ for industry $j$ within region $r$ is given by this equation:

$$S^r_{i,j} = o^r_j S_{i,j}$$

[34] Where available, more detailed regional data is incorporated to improve the estimates of share coefficients. This may involve a non-numerical approach of making manual (possibly subjective) adjustments based on additional research.

The coefficient for the regional share of output ($o^r_j$)[35] can be estimated using a number of different variables.[36] Using the RGDP will restrict our industry to 18 industry groupings, and other variables are considered to proxy the regional share of output. One such proxy is the number of employees engaged in a particular industry within a region. This information, obtained from SNZ's BF Employee Count (EC) data, provides the employments by the ANZSIC06 industries. The values of national-industry outputs for ANZSIC06 industries are from SNZ's Annual Enterprise Survey.

We use $v_j$ to denote the value of regional output for ANZSIC06 industry $j$. Then, let $\sum_j^J v_j$ denote the total industry output for ANZSIC06 industries matched to one of 106 industries.[37] The regional share of the industry output is then estimated as:

$$o_j^r = \sum_j^J v_j \frac{EC_{r,j}}{\sum_{r=1}^R EC_{r,j}}$$

Using the above regional share of industry output produces the first estimates of regional supply.[38] These estimates can be further refined by aggregating to the RGDP 18-industry level and minimising the difference between the value-added portion of the first estimates and the RGDP output levels.

2. Regional factor payments ($\mathbf{f_l^r}$, $\mathbf{f_k^r}$) and production taxes ($\mathbf{TY^r}$): The regional labour factor payments or $CoE^r$ is estimated as the labour share of the regional value-add (GDP). Similarly, the regional capital factor payments or $GOS^r$ is estimated as the capital share of the regional GDP.

   For this we use the estimates of regional supply ($S^r$), which is aggregated to concord with 15 region and 18 industry RGDP data. We denote $r$ to be one region from 15 regions and $j'$ to be one industry out of 18 in RGDP. One SUT 106 industry is denoted as $j$.

   The regional value-added data for region $r$ and industry $j'$ obtained from RGDP are denoted as $VA^r_{j'}$, while $\mu^r_{j'}$ denotes the regional total supply from the same industry.

   The national value-add from the NSUT is denoted as $VA_j$, the national labour factor payments as $CoE_j$, and the national capital factor payments as $GOS_j$ (as in the NSAM described earlier).

---

[35] For notational convenience, the superscript $r$ is used to denote the region and as an exponent term throughout the report. When a superscript is used as an exponent term, according to the mathematical convention it will be specifically mentioned.

[36] One straightforward way to get this coefficient is to use the RGDP data to estimate the regional share for each industry, and then allocate this share to different commodities using the household final demand share (later defined as $DS_i$). This will ensure that the regional GDP for each industry together totals up the national GDP data. With our specification of the CRS production technology, it is reasonable to use the regional share of the value-added input to proxy the regional output.

[37] The 2013 NSUT publishes the concordance table for matching ANZSIC06 industries to SUT industries. Unfortunately, due to data restraints, the estimation of the share coefficient will involve matching the SUT commodities and industries to different sets of regional data.

[38] As mentioned, this regional output share estimate is just one possible proxy of many. For example, Smith et al. (2015) [44] incorporated the productivity of employees by using the mean income for the employed within a particular industry and region.

The labour and capital factor payments are then estimated using these two equations:

$$CoE_j^r = v_{j'} o_{j'}^r \frac{VA_{j'}^r}{\mu_{j'}^r} \frac{CoE_j}{VA_j}$$

$$GOS_j^r = v_{j'} o_{j'}^r \frac{VA_{j'}^r}{\mu_{j'}^r} \frac{GOS_j}{VA_j}$$

In both equations, the term $v_{j'} o_{j'}^r$ is the regional supply of industry *j'* in region *r* and $\frac{VA_{j'}^r}{\mu_{j'}^r}$ denotes the value-added portion of the total regional output by industry *j'*. Finally, $\frac{CoE_j}{VA_j}$ is the labour share of the national value added and $\frac{GOS_j}{VA_j}$ is the capital share of the national value added.

The product taxes, $\mathbf{TY^r}$ can be estimated once the commodity consumption accounts are estimated in steps (3) to (9).[39]

3. Regional intermediate consumption ($\mathbf{U^r}$): The estimate of regional intermediate consumption ($\mathbf{U^r}$) is derived in a number of stages. As in step 1 above, the first estimates are produced and then refined depending on what data is available. The regional intermediate consumption is categorised into two types of commodities: the use of domestic commodity ($u^{D,r}_{i,j}$) and imported commodities ($u^{M,r}_{i,j}$). The following share coefficients are defined for estimating regional commodity use:

$$\text{(i)}\ D_{i,j} = \frac{u_{i,j}^D}{\mu'_j - VA_j}$$

$$\text{(ii)}\ M_{i,j} = \frac{u_{i,j}^{IM}}{\mu'_j - VA_j}$$

Here, the terms $u_{i,j}^D$, $u_{i,j}^{IM}$ respectively denote the total national use of domestic commodity *i* by industry *j* and the total national use of imported commodity *i* by industry *j*. The total national cost of production for industry *j* is denoted as $\mu'_j$, while $VA_j$ denotes the total national value-added portion of the cost. That is, $VA_j = CoE_j + GOS_j + \sum_{i=1}^{T} TY_{i,j}$.

Using the above share coefficients, an estimate of domestic commodity use $u_{i,j}^{D,r}$ in production for industry *j* in region *r* is:

$$u_{i,j}^{D,r} = D_{i,j}(\mu'^r_j - VA_j^r)$$

Similarly, an estimate of imported commodity use in production for industry *j* in region *r* is:

$$u_{i,j}^{M,r} = M_{i,j}(\mu'^r_j - VA_j^r)$$

[39] Product taxes are conventionally linked to commodities and not industry accounts as in NSUT. It is possible to estimate the regional share of product taxes for each industry in the same way as the regional industry supply. Here, the product taxes are estimated using the estimates from the commodity account.

While no further adjustment is required for the estimates of imported commodity use, the estimates of other commodity accounts derived in steps 4 to 7 below can help to further refine the domestic commodity use in production.

4. Regional household consumption ($\mathbf{hc^r}$): The regional household consumption is estimated using a coefficient calculated as the region's total household income as a proportion of the total national household income. This is based on an assumption that those regions with higher household income consume higher shares of the national consumption. The following equations illustrate the derivation:

$$hc_i^{D,r} = H^r hc_i^D$$

$$hc_i^{M,r} = H^r hc_i^M$$

The NSUT provides the value of $hc^D_i$, the total national household consumption of commodities produced domestically, while $hc^M_i$ is the total national household consumption of imported commodities. The household income share coefficient, $H^r$ is calculated as:

$$H^r = \frac{\text{Total household income in region r}}{\text{Total household income in NZ}}$$

Both the regional household income and the total national household income can be sourced from SNZ's New Zealand Income Survey.

5. Regional investment in commodity ($\mathbf{s^r}$): As for regional household consumption of commodities, the regional investment into commodities can be estimated using the household income share coefficient ($H^r$). Again, this is based on the assumption that those regions with a higher household income invest higher shares of the national commodity consumption. Both the regional investment in domestic consumption and the imports are calculated as:

$$s_i^{D,r} = H^r s_i^D$$

$$s_i^{M,r} = H^r s_i^M$$

Both the investment in domestic consumption and imports data are available from NSUT.

6. Regional government consumption ($\mathbf{GC^r}$): For government $g$'s consumption of commodity $i$ in region $r$, the appropriate share coefficient for each region is considered proportional to the regional population. That is, the higher the population in a particular region, the higher the government spending on consumption for that region.

This coefficient denoted as $P^r$ is calculated as:

$$P^r = \frac{\text{Total population in region r}}{\text{Total New Zealand population}}$$

The regional population data are available from the RGDP.

The equations that summarise the regional government spending on commodities are:

$$GC_{i,g}^{D,r} = P^r GC_{i,g}^{D}$$

$$GC_{i,g}^{M,r} = P^r GC_{i,g}^{M}$$

7. Regional share of imports from ROW (**IM$^r$**): The total regional share of imports from ROW is the sum of imported commodity consumption accounts. That is, for each commodity *k* in the *IM* account, which corresponds to the *i*th commodity in the commodity accounts, the following equation estimates the regional share of imports:

$$IM_k^r = \sum_{j=1}^{I} u_{i,j}^{M,r} + hc_i^{M,r} + \sum_{g=1}^{G} GC_{i,g}^{M,r} + s_i^{M,r}$$

8. Regional share of international export (**x$^r$**): The international export of commodities account is analysed in two groups of commodities: (1) tourism export ($x^{T,r}$); and (2) other general commodity export ($x^{G,r}$).

   (i) Tourism export: The data on international tourist consumption information is available from SNZ's Tourism Satellite Account (TSA) [49]. The TSA provides the consumption of 14 tourism-related products and 9 tourism-characteristic products. These are matched to the SUT 201-commodity types using the household consumption demand shares (*DS*) calculated as:

$$DS_i = \frac{hc_i}{\sum_i^C hc_i}$$

   The demand for the matched products allocated to the NSUT commodity groups using *DS* coefficients are denoted as $x^T$.

   For the matched products, the total national spend by international tourists is allocated to each region using the regional shares ($T^r$)

$$T^r = \frac{\text{Total international visitor spend in region r}}{\text{Total international visitor spend in New Zealand}}$$

   How much international and domestic visitors spend on tourism products in 31 regions is available from MBIE's Monthly Regional Tourism Estimates. [32]

   The regional international tourism export ($x^{T,r}{}_i$) is then estimated by the equation:

$$x_i^{T,r} = T^r x_i^T$$

(ii) Other general commodity export: The values of remaining export commodities for region $r$ are denoted as $x^{G,r}$. The export of general commodities by region $r$ is calculated as the regional share of the national general commodity export ($x - x^T$).

The appropriate regional share of the national general commodity export ($GX^r$) for given industry $j$, commodity $i$, and government $g$ is calculated as:

$$GX_i^r = \frac{(\sum_{j=1}^{I} S_{j,i}^r - x_i^{T,r}) - (\sum_{j=1}^{I} u_{i,j}^{D,r} + hc_i^{D,r} + \sum_{g=1}^{G} GC_{i,g}^{D,r} + s_i^{D,r})}{\sum_{r=1}^{R}((\sum_{j=1}^{I} S_{j,i}^r - x_i^{T,r}) - (\sum_{j=1}^{I} u_{i,j}^{D,r} + hc_i^{D,r} + \sum_{g=1}^{G} GC_{i,g}^{D,r} + s_i^{D,r}))}$$

The first bracketed term in the numerator ($\sum_{j=1}^{I} S_{j,i}^r - x_i^{T,r}$) denotes the total regional supply of commodity $i$ not used for tourism export. The second bracketed term ($\sum_{j=1}^{I} u_{i,j}^{D,r} + hc_i^{D,r} + \sum_{g=1}^{G} GC_{i,g}^{D,r} + s_i^{D,r}$) denotes the total regional domestic consumption of that commodity. Together, the numerator estimates the regional net supply of the commodity for general export. The denominator is the national net supply of the commodity for general export.

The regional general export of commodity $i$ is therefore:

$$x_i^{G,r} = GX_i^r(x_i - x_i^T).$$

The regional international export of commodity $i$ is the sum of the tourism export ($x_i^{T,r}$) and the general export ($x_i^{G,r}$):

$$x_i^r = x_i^{T,r} + x_i^{G,r}$$

9. Inter-regional export ($\mathbf{y_X^r}$) and inter-regional import ($\mathbf{y_M^r}$):

A region's export to another region is an import to the destination region, and, as such, this framework only needs to derive one trade flow between regions.

For each commodity $i$ from the 201 commodity groups within NSUT, it needs to be determined whether or not the commodity will have inter-regional trade.

For example, certain types of local government services such as waste disposal are not likely to be traded inter-regionally. Other types of services may be tourism export to inter-regional visitors (that is, domestic visitors). These trades will have to be estimated using the tourism specific accounts.

The following steps outline the different methodologies used to estimate inter-regional trade.

(1) Local consumption-only commodities: The inter-regional trade is denoted by $y_i^{r,s}$ for region $r$'s export of commodity $i$ to region $s$, and the following holds for all: $r \neq s$, $y_i^{r,s} = y_i^{s,r} = 0$.

(2) Inter-regional tourism: For the 14 tourism-related products and 9 tourism-characteristic products, TSA provides the spend by domestic visitors. As for the estimation of international tourism export, the tourism products (as defined in TSA) are matched to NSUT 201-commodity using the household demand shares ($DS_i$). To estimate the inter-regional tourism ($y_T^{r,s}$), the values used are:

$$TS_i^D = \text{Total tourism spend on commodity } i \text{ by domestic visitors}$$

$$DT^{r,s} = \frac{\text{Domestic tourism spend in region r by visitors from region s}}{\text{Total tourism spend in region r by all domestic visitors}}$$

The inter-regional tourism is then estimated as:

$$y_{T,i}^{r,s} = DT^{r,s} TS_i^D$$

(3) National supplier commodity: For commodities (such as electricity) that all users trade off the national grid, it is appropriate to estimate the region's export to other regions as its share of total national production of that commodity.[40] One example would be if the Waikato region produces one-quarter of the total electricity, and then the region exports one-quarter of its national electricity output to all other regions. Other examples of national supplier commodities include the central government services, such as civil construction and military services.

(4) All other commodities: The inter-regional trade for all other commodities are estimated using the Gravity Model method as outlined in Smith et al. (2015) [44]. Initially developed to model international trade flows, the model has been applied in Input-Output and SUT analyses to model inter-regional trade flows. The basic specification of the inter-regional trade ($y_i^{r,s}$) is as a function of the supply of commodity *i* by the exporting region, the use of that commodity by the importing region, and the trade impedance factor denoted as *q*. The inter-regional trade is then estimated as:

$$y_i^{r,s} = \frac{IS_i^r + IU_i^s q_i^{r,s}}{\sum_{r=1}^{R} \sum_{s=1}^{S} IS_i^r + IU_i^s q_i^{r,s}} IS_i ,$$

where:

(i) $IS_i^r = \sum_{j=1}^{I} S_{j,i}^r - x_i^r$ denotes the region *r*'s total domestic supply of *i*

(ii) $IS_i = \sum_{j=1}^{I} S_{j,i} - x_i$ denotes the total domestic supply of *i* by all regions

[40] Calculating a regional share of electricity import and export is difficult due to the uniqueness of the operation mechanism of the electricity market. As such, we have opted to use a simple approach. Alternatively, the Gravity Model method as outlined in Smith et al. (2015) [44] can be used.

(iii) $IU_i^s = \sum_{j=1}^{I} u_{i,j}^{D,s} + hc_i^{D,s} + \sum_{g=1}^{G} GC_{i,g}^{D,s} + s_i^{D,s}$ denotes region *s*'s total use of that commodity.

Given the pre-determined levels of supply and use of commodity *i*, the impedance factor *q* determines the extent to which the commodity will be traded between the regions.

Smith et al. (2015) [44] specifies two different types of *q* factor depending on the commodity group. For physical commodities, the factor is calculated using the freight transport flows.[41] For other types of commodities and services, the factor is calculated using the credit and debit-card transaction data.[42]

The equations that provide the two specifications for *q* factor are:

$$q_i^{r,s} = \frac{\text{freight}_k^{r,s}}{\sum_s \text{freight}_k^{r,s} + \sum_r \text{freight}_k^{r,s}},$$

where *k* denotes the commodity from the freight study to which SUT commodity *i* is matched:

$$q_i^{r,s} = \frac{\text{trans}_l^{r,s}}{\sum_s \text{trans}_l^{r,s} + \sum_r \text{trans}_l^{r,s}},$$

and where *k* denotes the commodity from the transaction data to which SUT commodity *i* is matched.

To ensure that the estimates for inter-regional trade are consistent with the equilibrium identities, the least squares optimisation method is used to produce estimates that satisfy the following constraints:

(i) $\sum_s y_i^{r,s} = \sum_{j=1}^{I} S_{j,i}^{r} - x_i^r$

(ii) $\sum_r y_i^{r,s} = \sum_{j=1}^{I} u_{i,j}^{D,s} + hc_i^{D,s} + \sum_{g=1}^{G} GC_{i,g}^{D,s} + s_i^{D,s}$

The first constraint ensures that the total trade of commodity *i* from a region (*r*) equals the total production of that commodity from that particular region. The second constraint ensures that the total trade of commodity *i* into a region (*s*) equals the total use within that region of the commodity.

(5) Kronenberg Regionalisation Method: Kronenberg (2009) [24] demonstrated a method in which the same type of commodities are imported and exported at the same time. This allows for differentiation in commodities categorised under the same SUT commodity groups.

[41] The freight data is obtained from the National Freight Demand Study conducted by Richard Paling Consulting (2008) [41].

[42] The transaction data is obtained from Bank of New Zealand (BNZ)'s MarketView data.

The method is applied to the remaining set of commodities, which mainly comprise services, using the process outlined in Smith et al. (2015)[44] and Kronenberg (2009) [24].

For the application of the model, a coefficient called $HET_i$ is defined to denote the level of heterogeneity among all commodities grouped under one category. This coefficient is estimated as:

$$HET_i = \frac{x_i + IM_i + |x_i + IM_i|}{\gamma_i' + \gamma_i}$$

The term $x_i + IM_i$ is the balance of export and import of commodity *i*, and $\gamma$ and $\gamma'$ are the national use and production of *i* as defined in section 3.3.1 of this report. The heterogeneity coefficient is therefore estimated by the extent that the commodity is traded across international markets relative to its total domestic supply and use. All import, export and supply data are available from the NSUT.

The level of *cross-hauling* or simultaneous import and export of a commodity is denoted as $CH_i^r$, and estimated as:

$$CH_i^r = HET_i(IS_i^r + IU_i^r),$$

where the terms $IS_i^r$ and $IU_i^r$ are as defined earlier. Therefore, the level of *cross-hauling* is the total sum of domestic supply and use of a given commodity in a region, scaled by how much products under the same commodity category differ. This specification allows $CH_i^r$ to increase in proportion to the increase in both the supply and use of the commodity, but a less-than-proportional increase if only one of them increases. Also, the more the products differ, the higher the *cross-hauling* between regions.

The total inter-regional import and export of a given commodity *i* and region *r* are then estimated as:

$$y_{Mi}^r = \frac{TV_i^r - (IS_i^r - IU_i^r)}{2}$$
$$y_{Xi}^r = \frac{TV_i^r + (IS_i^r - IU_i^r)}{2},$$

where $(IS_i^r - IU_i^r)$ denotes the net surplus in production of commodity *i* within *r*, and $TV_i^r$ denotes the total value of inter-regional trade in commodity *i* for *r*, calculated as:

$$TV_i^r = |(IS_i^r - IU_i^r)| + CH_i^r$$

Finally, the estimate of inter-regional trade of commodity *i* for all possible destination regions is calculated using the trade share coefficient $TR^{r,s}$ as:

$$y_i^{r,s} = y_{Xi}^r + TR^{r,s},$$

where

$$TR^{r,s} = \frac{sales^{r,s}}{\sum_s sales^{r,s}} \quad s \neq r$$

The trade share coefficients are estimated using the MarketView data on total sales by agents within region *r* to agents within region *s*, denoted as $sales^{r,s}$.

**Balancing the RSUT**

As mentioned earlier, the estimates derived in the above steps can be further refined to ensure that the RSUT meets the market-clearing conditions.

In particular, the total supply of commodity *i* in region *r* has to equal the total use of that commodity in that region:

Using the estimates from the above steps, $\overline{U}^r$, $\overline{hc}^r$, $\overline{GC}^r$, $\overline{s}^r$, $\overline{IM}^r$, $\overline{y}^{r,s}$, $\overline{x}^r$ (the over-line indicates that they are estimates), the final estimates can be obtained by using the balance equation.

Using the estimates, the total supply of commodity *i* in region *r*, $S_i^r$ and total use, $U_i^r$ can be estimated as:

$$\overline{S}_i^r = \sum_{j=1}^{I} \overline{S}_{j,i}^r + \sum_{s=1}^{R} \overline{y}_i^{s,r} + \overline{IM}_i^r$$

$$\overline{U}_i^r = \sum_{j=1}^{I} \overline{u}_{i,j}^r + \overline{hc}_i^r + \sum_{g=1}^{G} \overline{GC}_{i,g}^r + \overline{s}_i^r + \sum_{s}^{R} \overline{y}_i^{r,s}$$

The final use of commodity *i* in region *r* by industry *j* is then estimated by using the least squares optimisation method:[43]

$$u_{i,j}^r = \overline{u}_{i,j}^r \frac{\overline{S}_i^r}{\overline{U}_i^r}$$

When the market-clearing condition is held, $S_i^r = U_i^r$ and $u_{i,j}^r = \overline{u}_{i,j}^r$.

The constrained optimisation equation is specified to reduce the squared deviation of the estimate from the final target subject to the above market-clearing constraint.

**Constructing the RSAM**

For a given region (*r*), a RSAM is essentially of the same structure as the NSAM.[44] The additional agent, the rest of New Zealand (RoNZ), represents the transactions with the other regions in New Zealand. A number of components

[43] Alternatively, a RAS (bi-proportional fitting method) can be used to estimate the final use of commodities. Although both methods (optimisation and RAS) have a chance of producing an illogical solution, the RAS method is more prone to producing an out-of-equilibrium or an illogical solution.

[44] As a consequence, the RSAM includes arbitrary regional measures, such as regional factor payments to ROW. Any regional measures not necessary for the EIA analysis on freshwater quality have been summed and modelled as a national-level measure in the sub-regional CGE model (including the freshwater-quality module).

derived for RSUT are used directly in RSAM. These components include $U^r$, $hc^r$, $GC^r$, $s^r$, $IM^r$, $x^r$, $S^r$, $TY^r$ and $x^{r,s}$.

Other components (such as factors of production and transfer terms) are derived using the appropriate regional proportions obtained from various data sources.

In this section, we explain the derivation of components not directly obtained from the RSUT.

1. Labour Income Accounts: The total factor payments for labour input in region *r* can be allocated to the households within the region, the RoNZ and the ROW.

   The first step in deriving the value of labour income from the RoNZ denoted as $CoE_r^{ronz}$ is to estimate the value of total labour factor income for RoNZ (*CoERoNZ*).

   This can be calculated as the difference between the total national labour factor income, *CoE* (obtained from the NSUT) and the region *r*'s labour factor income ($CoE^r$ from the RSUT).

   That is, $CoERoNZ = CoE - CoE^r$. The following steps demonstrate the derivation of the labour factor income from *r* to ROW ($CoE^r_{row}$), from RoNZ to ROW ($CoE^{ronz}_{row}$), from RoNZ to $r$, $CoE^{ronz}_r$, and then finally from *r* to RoNZ ($CoE^r_{ronz}$).

   (i) $CoE^r_{row}$: The labour factor income from region *r* to ROW is calculated using the regional GDP share of the total national labour income payment to ROW. Implicit, in this estimation is the assumption that the larger the GDP of the region, the larger the factor payments made to ROW. The equation that demonstrates the calculation is:

   $$CoE^r_{row} = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) CoERoW$$

   (ii) $CoE^{ronz}_{row}$: The labour factor income from RoNZ to ROW is estimated by taking the difference between the total labour factor payment to ROW and the region *r*'s share of that payment. Once the region *r*'s payment to ROW is subtracted, the rest of the payments are made by RoNZ. The equation that demonstrates this method is:

   $$CoE^{ronz}_{row} = CoERoW - CoE^r_{row}$$

   The value for $CoE_{row}^r$ is as estimated in the previous step, while *CoERoW* is from NSUT.

   (iii) $CoE_r^{ronz}$: The total labour factor payment from RoNZ into *r* is estimated by using the proportion of people who reside in *r* but commute to RoNZ for work. This coefficient ($c^{s,t}$) denotes the number of people who live in region *s* but who commute to region *t*, and can be calculated using the data from SNZ's Census.[45]

The equation that demonstrates the estimation of $CoE_r^{ronz}$ is:

$$CoE_r^{ronz} = \frac{c^{r,ronz}}{\sum_{s=1}^{R} c^{s,r}}(CoERoNZ - CoE_{row}^{ronz})$$

The bracketed term above indicates the total *CoE* payment from RoNZ that remains within New Zealand.

(iv) $CoE_D^r$: The total factor for income paid from domestic labour from enterprises in *r* to households in region *r* is estimated as:

$$CoE_D^r = \frac{c^{r,r}}{\sum_{s=1}^{R} c^{s,r}}(CoE^r - CoE_{row}^r) + CoE_r^{ronz}$$

The bracketed term indicates the total domestic regional share of labour income, while the last term denotes the labour income paid from RoNZ to *r*.

(v) $CoE_{ronz}^r$: The labour factor payment from businesses in region *r* to the households in RoNZ is estimated by the proportion of people who live in RoNZ but who commute to *r* for work.

$$CoE_{ronz}^r = \frac{c^{ronz,r}}{\sum_{s=1}^{R} c^{s,r}}(CoE^r - CoE_{row}^r) + CoE_r^{ronz}$$

Again, the bracketed term indicates the total domestic regional share of labour income, while the coefficient indicates the share of workers who reside in RoNZ but work in region *r*.

2. Capital Return Accounts: Similar to the labour income accounts, the capital income for a given region *r* can be sourced from other regions within New Zealand and the ROW.

The total capital factor payments to RoNZ are calculated as the difference between the total national payment and the capital payment in region *r*. That is, $GOS^{ronz} = GOS - GOS^r$.

The regional transfer of *GOS* from RoNZ to $r$ is $GOS_r^{ronz}$. This transfer includes the region *r*'s share of enterprises located in RoNZ.

Typically, the *GOSH* comprises the imputed rent from the owner-occupied dwellings and the return from capital investment into enterprises. To separate the return on capital from the enterprises, the income from the owner-occupied dwellings is estimated by the following coefficient $d^r$ as:

$$d^r = \frac{OS_o^r + CoFC_o^r}{OS_o^{NZ} + CoFC_o^{NZ}},$$

where, $OS_o^r$ indicates the gross operating surplus from owner-occupied dwellings in region *r* and $CoFC_o^r$ denotes the consumption of fixed capital

[45] SNZ Census, Usual Residential Areas and Workplace Areas by Main Means of Travel to Work. [47].

in owner-occupied dwellings in $r$. The denominator is the sum of the national total for the two values.

Both values are derived from the RGDP and the SUTs. The national total values are also available from the NAs. We also define the enterprise ownership coefficient, $\epsilon$.

$$\epsilon^{r,s} = \frac{\sum_{k=1}^{100}\left(\sum_{EC=1}^{N} GU_{EC,k}^{r}\left(\frac{EC}{GU}\right)_k^r\left(\frac{GDP}{EC}\right)_k^r\right)k}{\sum_{k=1}^{100}\left(\sum_{EC=1}^{N} GU_{EC,k}^{r}\left(\frac{EC}{GU}\right)_k^r\left(\frac{GDP}{EC}\right)_k^r\right)},$$

where, $EC$ is the full-time equivalent employee count for each enterprise, and $GU$ is a geographical business unit as defined by SNZ's Geographic Unit and Employee Data. The gross domestic product for each region $r$ is denoted as $GDP$ and $k$ denotes the New Zealand enterprise ownership share information (in percentage units) as contained in SNZ's Enterprises and Full-Time Equivalent Persons Engaged by Degree of Overseas Equity and ANZSIC.

The region $r$'s share of gross operating surplus from enterprises in RoNZ ($GOS_r^{ronz}$) is then estimated as:

$$GOS_r^{ronz} = \epsilon^{r,ronz}\left(GOS^{ronz} - (1-d^r)GOSH - GOSG^{ronz}\right),$$

where, $GOS^{ronz}$ is as calculated above, and $GOSG^{ronz}$ is the RoNZ share of the government's gross operating surplus calculated as $GOSG{-}GOSG^r$. The region $r$'s share of enterprises in RoNZ is estimated by $\epsilon^{r,ronz}$.

(i) $GOSE^r$: The gross operating surplus to enterprises in region $r$ is calculated as the sum of total surplus payments from RoNZ and the regional total surplus after deducting the surplus payment to households, government and RoNZ:

$$GOSE^r = GOS^r - d^r GOSH - GOSG^r - GOS_{ronz}^r + GOS_r^{ronz},$$

where, $GOS_{ronz}^r$ is calculated as below.

(ii) $GOS_{ronz}^r$: The surplus payment from $r$ to RoNZ is calculated as:

$$GOS_{ronz}^r = \epsilon^{ronz,r}\left(GOS^r - d^r GOSH - GOSG^r\right)$$

(iii) $GOSH^r$: The regional share of surplus payment to households can be estimated as a proportion of the national surplus payment. That is, $GOSH^r = d^r GOSH$, where $GOSH$ is directly obtained from the NSUT.[46]

(iv) $GOSG^r$: The regional value of the government's share of $GOS$ is calculated by summing the capital income of both central and local government in each region.

$$GOSG_{Gi}^r = GOSG_{Gi}\left(\frac{OS_{Gi}^r + CoFC_{Gi}^r}{OS_{Gi}^{NZ} + CoFC_{Gi}^{NZ}}\right),$$

[46] This estimation can be refined by using the data on residents who usually live in each region, as demonstrated in Smith et al. (2015)[44].

where, $OS_{Gi}{}^{r}$ denotes the government industry *i*'s (*Gi*) gross operating surplus in region *r* and $CoFC_{Gi}{}^{r}$ denotes the government industry *i*'s (*Gi*) consumption of fixed capital in region *r*.

3. Enterprise Account: The household transfers to enterprises for region *r* is calculated using a coefficient that is used to estimate the given region's share of the national enterprise investment and another scalar that indicates RoNZ's share. The total superannuation and pension fund investment services provided by region *r* to *s* can be denoted as $R^{r,s}$. Then $\sum_{s=1}^{R} R^{r,s}$ indicates the total investment services provided from region *r* to all of New Zealand and $\sum_{s\neq r}^{R} R^{r,s}$ indicates the total services provided by *r* to the RoNZ.

   Then the transfers from households in region *r* to enterprises in region *r* are calculated as:

$$he_r^r = he\left(\frac{\text{Pension fund investment in r}}{\text{Pension fund investment in NZ}}\right)\left(\frac{R^{r,r}}{\sum_{r=1}^{R}\sum_{s=1}^{R} R^{r,s}}\right)$$

   The first term and the bracketed term together indicate the regional share of the total household transfers to enterprise, while the last term indicates the region *r*'s share of that transfer.

   (i) $he_r^{ronz}$: The household transfer to enterprises from the households in RoNZ to enterprises in *r*. The equation that illustrates the estimation is:

$$he_r^{ronz} = he\left(1-\frac{\text{Pension fund investment in r}}{\text{Pension fund investment in NZ}}\right)\left(\frac{\sum_{s\neq r}^{R} R^{r,s}}{\sum_{r=1}^{R}\sum_{s=1}^{R} R^{r,s}}\right)$$

   Then the total national household transfer to enterprises in region *r* is the sum of the $he_r^r$ and $he_r^{ronz}$:

$$he_r = he\left(\frac{\sum_{s=1}^{R} R^{r,s}}{\sum_{r=1}^{R}\sum_{s=1}^{R} R^{r,s}}\right)$$

   (ii) $rowe^r$: The transfer from the ROW to enterprises in region *r* is estimated using the regional GDP share:

$$rowe^r = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) rowe$$

   (iii) $eh_r$: The total enterprise transfer to household in region *r* is estimated using the total share of investment held by households in region *r*, denoted by $I^r$. The household investment *I* includes: (1) entrepreneurial income from self-employment or casual and hobby income; (2) property income received from dividends; and (3) property income received from other investments. Including income from any portfolio investment entries. All data are available from SNZ's Household Economic Survey.

The enterprise transfer to household in region *r* is estimated using the equation

$$eh_r = I^r eh$$

Then the enterprise transfer to household in RoNZ is estimated by $(1 - I^r)eh$.

(iv) $eh_r^r$ and $eh_{ronz}^r$: The transfer from enterprises in region *r* to households in region *r* is estimated as:

$$eh_r^r = I^r eh \left( \frac{R^{r,r}}{\sum_{r=1}^{R} \sum_{s=1}^{R} R^{r,s}} \right)$$

The transfer from enterprises in region *r* to households in RoNZ is then similarly estimated as:

$$eh_{ronz}^r = (1 - I^r)eh \left( \frac{\sum_{s \neq r}^{R} R^{r,s}}{\sum_{r=1}^{R} \sum_{s=1}^{R} R^{r,s}} \right)$$

(v) $eg_i^r$: The enterprise transfer to government *i* can be regionalised using the regional GDP share coefficient.

$$eg_i^r = \left( \frac{VA_r}{\sum_{r=1}^{R} VA_r} \right) eg_i$$

(vi) $te^r$: The enterprise tax can be regionalised using the regional share of total enterprise earnings. The regional enterprise income is denoted by $\pi^r$ and can be obtained directly from the RSUT, while the national sum is denoted as $\pi$ and can be obtained from the NSUT.

$$te^r = \left( \frac{\pi^r}{\pi} \right) te$$

(vii) $es^r$: The enterprise savings can be regionalised using the region's share of consumption of fixed capital:

$$es^r = \left( \frac{\sum_i^I CoFCe_i^r}{\sum_i^I CoFCe_i^{NZ}} \right) es \quad ,$$

where, $CoFCe_i^r$ is the consumption of fixed capital by enterprises within region *r* and is estimated by the total regional consumption of fixed capital by industries $CoFC_i^r$, which excludes the residential property ($CoFC_R^r$) and owner-occupied property operations ($CoFC_O^r$).

That is, $CoFCe_i^r = CoFC_i^r - CoFC_R^r - CoFC_O^r$.

(viii) $e_{row}^r$: The enterprise transfer from region *r* to ROW is calculated by using the regional GDP share as:

$$e_{row}^r = \left( \frac{VA_r}{\sum_{r=1}^{R} VA_r} \right) erow$$

4. Household Accounts: The remaining household accounts include the transfers from government, ROW and RoNZ.

(i) $gh^r$: The government transfer to households is regionalised to each region by using the regional share of ACC ($ACC^r$) and social welfare payments (Social $Welfare^r$). Both data are available from the Household Economic Survey. The equation that illustrates the government transfer to households in region *r* is:

$$gh^r = \left(\frac{\text{ACC}^r + \text{Social Welfare}^r}{\text{ACC}^{NZ} + \text{Social Welfare}^{NZ}}\right) gh$$

(ii) $ronzh^r$: The transfer from RoNZ to households in region *r* can be estimated using the regional enterprise shares derived in the capital return accounts:

$$ronzh^r = GOSH_r^{ronz} + eh\left(\frac{\sum_{s\neq r}^{R} R^{r,s}}{\sum_{r=1}^{R}\sum_{s=1}^{R} R^{r,s}}\right) I^r$$

The first term denotes the gross operating surplus payment from RoNZ to households in region *r*, while the second term indicates the transfer from enterprises in RoNZ to the households in region *r*.

(iii) $rowh^r$: The transfer from ROW to households in region *r* is calculated using the household regional foreign income share, denoted as $F^r$:

$$rowh^r = F^r rowh$$

The household regional foreign income share includes: (1) private superannuation and benefits from overseas; (2) overseas pension income; (3) trust, maintenance and irregular overseas income; and (4) interest and dividends from overseas. All data can be obtained from SNZ's Household Economic Survey.

(iv) $hg_i^r$: The household transfer to government can be regionalised using the regional GDP share:

$$hg_i^r = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) hg_i$$

(v) $th^r$: The household tax rate can be regionalised using the share of household income tax and other taxes in region *r*.

$$th^r = \left(\frac{\text{Household Income tax and Other taxes in r}}{\text{Household Income tax and Other taxes in NZ}}\right) th$$

(vi) $hs^r$: Household savings in region *r* are estimated using the household savings and consumption of fixed capital data from the Household Economic Survey.

$$hs^r = \left(\frac{\text{Household savings and CoFC in r}}{\text{Household savings and CoFC in NZ}}\right) hs$$

(vii) *hronz^r^*: The household transfer to RoNZ from region *r* can be estimated as:

$$hronz^r = he\left(\frac{\sum_{s\neq r}^{R} R^{s,r}}{\sum_{r=1}^{R}\sum_{s=1}^{R} R^{r,s}}\right) I^r$$

(viii) *hrow^r^*: The household transfer to ROW is regionalised using the regional GDP share:

$$hrow^r = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) hrow$$

5. Government Accounts: This model assesses two types of government: central and local. For each local government type *g* within region *r*, we can estimate the local government's total indirect tax income ($GTI^r_{g,IT}$) and direct tax income ($GTI^r_{g,DT}$) as:

$$\text{(i)}\ \ GTI^r_{g,IT} = (TY^r_{IT}+PTAX^r_{IT}+te^r_{IT}+th^r_{IT}+TG^r_{IT}+ti^r_{IT}+tx^r_{IT})\left(\frac{GTI_{g,IT}}{\sum_g^G GTI_{g,IT}}\right)$$

$$\text{(ii)}\ \ GTI^r_{g,DT} = (te^r_{DT}+th^r_{DT}+TG^r_{DT}+tx^r_{DT})\left(\frac{GTI_{g,DT}}{\sum_g^G GTI_{g,DT}}\right)$$

(iii) The central government's direct tax income can be regionalised using the regional GDP share as:

$$GTI^r_{CG,DT} = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) \times (\text{Central Government Direct Tax Income})$$

(iv) *gs^r^*: Government savings can be regionalised using the regional share of consumption of fixed capital and the government savings.

$$gs^r = \left(\frac{\text{Government savings and CoFC in r}}{\text{Government savings and CoFC in NZ}}\right) gs$$

(v) *grow^r^*: The government transfer to ROW can be regionalised using the regional GDP share:

$$grow^r = \left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) grow$$

6. Taxes: The remaining tax accounts include the investment tax ($ti^r$) and the export tax ($tx^r$). The regional investment tax can be directly obtained from the RSUT. The regional share of export tax is the sum of taxes on export products ($TY_{EX}^r$) obtained from the RSUT and the export taxes regionalised using the regional GDP share.

   The equation that illustrates this calculation is:

$$tx^r = TY^r_{EX} + \left(\left(\frac{VA_r}{\sum_{r=1}^{R} VA_r}\right) tx\right.$$

7. Savings Accounts: The only remaining RoNZ account is the savings by RoNZ ($ronzs^r$). This can be estimated as the balance of all other transfers between region $r$ and $ronz$. This estimation assumes that all remaining transfers between region $r$ and RoNZ are transfers of capital.

   The savings from ROW ($rows^r$) is regionalised using the regional GDP share.

The RSAM can be built using the regionalised elements estimated above. An example of RSAM for a given region ($r$) is provided in Figure 5.

| | | Commodity<br>c=1,...,C | Industry<br>i=1,...,I | Factors of production<br>f=k,l | | Enterprises | Households | Governments<br>g=cl,ll | Taxes<br>t=1,...,T | Savings<br>-<br>Investment | Rest of NZ | Rest of World | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Labour | Capital | | | | | | | | |
| Commodity<br>c=1,...,C | | | $U^r$<br>Use (Intermediate Consumption) | | | | $hc^r$<br>Household Final Consumption Expenditure | $GC^r$<br>Government Final Consumption Expenditure | | $s^r$<br>Investment (Changes in Inventories and GFCF) | $Y_x{}^r$<br>Interregional Exports | $x^r$<br>Exports | Gross Com Supply |
| Industry<br>i=1,...,I | | $S^r$<br>Supply (Domestic) | | | | | | | | | | | Doestic Production |
| Factors of production<br>f=k,l | Labour | | $CoE^r$ | | | | | | | | $CoE_{RoNZ}{}^r$<br>Labour income from RoNZ | | Total Factor Income (Labour) |
| | Capital | | $GOS^r$ | | | | | | | | $GOS_{RoNZ}{}^r$<br>GOS from RoNZ | | Total Factor Income (Capital) |
| Enterprises | | | | | $GOSE^r$<br>Gross Operating Surplus of Enterprises | | $he^r$<br>Household Transfers to Enterprise | | | | $ronze^r$<br>RoNZ Transfers to Enterprise | $rowe^r$<br>Overseas Transfers to Enterprise | Enterprises Income |
| Households | | | | $CoEH^r$<br>Labour Factor Income for Households | $GOSH^r$<br>Gross Operating Surplus of Households | $eh^r$<br>Enterprise Transfers to Household | $hh^r$<br>Household Transfers to Itself | $gh^r$<br>Government Transfers to Household | | | $ronzh^r$<br>RoNZ Transfers to Household | $rowh^r$<br>Overseas Transfers to Household | Hhlds Income |
| Governments<br>g=cl,ll | | | | | $GOSG^r$<br>Gross Operating Surplus of Governments | $eg^r$<br>Enterprise Transfers to Govt | $hg^r$<br>Household Transfers to Government | $gg^r$<br>Government Transfers to Itself | $GTI^r$<br>Govt Tax Income | | | | Govts Income |
| Taxes<br>t=1,...,T | | | $TY^r$<br>Tax (Indirect taxes GST on Prod + Other Taxes on Prod-Subsidies) | | | $te^r$<br>Taxes (Direct Enterprise Taxes) | $th^r$<br>Tax (Direct Income+Indirect GST on Cons+other) | $TG^r$<br>Tax (Direct Income Taxes+Indirect GST on Consumption) | | $ti^r$<br>Tax (Investment) | | $tx^r$<br>Tax (Export Taxes and Income Taxes) | Total Taxes |
| Savings<br>-<br>Investment | | | | | | $es^r$<br>Enterprise Saving | $hs^r$<br>Household Saving | $gs^r$<br>Government Saving | | | $ronzs^r$<br>RoNZ Savings | $rows^r$<br>Overseas Savings | Total Saving |
| Rest of NZ | | $Y_m{}^r$<br>Interregional Import | | $CoERoNZ^r$<br>Labour Factor Income for Rest of NZ | $GOSRoNZ^r$<br>Gross Operating Surplus of Rest of NZ | $eronz^r$<br>Enterprise Transfers to the RoNZ | $hronz^r$<br>Household Transfers to the RoNZ | | | | | | Total RoNZ Outlays |
| Rest of World | | $IM^r$<br>Imports | | $CoERoW^r$<br>Labour Factor Income for Rest of World | | $erow^r$<br>Enterprise Transfers to the RoW | $hrow^r$<br>Household Transfers to the RoW | $grow^r$<br>Government Transfers to the RoW | | | | | Total Foreign Outlays |
| Total | | Gross Com Inputs | Cost of Production | Total Factor Expenditure (Labour) | Total Factor Expenditure (Capital) | Enterprises Expenditures | Hhlds Expenditures | Govts Expenditures | Total Taxes | Total Investment | Total RoNZ Earning | Total Foreign Earning | |

**Figure 5: Structure of Regional Social Accounting Matrix**

### 3.3.3 The sub-regional Social Accounting Matrix

The structure of the sub-regional SAM depends on the choice of a sub-regional CGE method outlined in section 2.3. The main difficulty building the sub-regional SAM is the availability of sub-regional data. At the time of writing this report, detailed methods of building the sub-regional SAM are not available. Yet the method chosen is likely to be similar to the RSAM construction method.

Listed below is a possible strategy for building the sub-regional SAM.

- As noted in the spatial economic data section, the most detailed sub-regional data available are SNZ BF and Census. The BF data includes employment by meshblock-level spatial locations and can be used to estimate the industrial production levels of sub-regions and the intermediate consumption associated with those production activities. The Census data includes detailed household information and can be used to estimate household demands for commodities within sub-regions. Together, this helps us to build the sub-regional supply-use tables.

- The broad structure of the sub-regional SAM will be similar to the RSAM, but may include minor, secondary financial flows between agents. Their status is because they may be hard to estimate. For example, all sub-regions within the region (i.e., Auckland Council) have only one local government. Sub-regionalising the local government is unrealistic in this example. Overall, the build method is likely to follow a similar approach used to build the RSAM.

- The sub-regional SAM must be consistent with the regional SAM. For example, the summation of the dairy product outputs of the sub-regions must equal the same output estimated in the RSAM. Once individual components of sub-regional SAMs for all sub-regions are built, each SAM will be matched to the RSAM using a 'least squares constrained' optimisation method. Here, the constraint is such that the summation of individual components of the sub-regional SAM is matched to the corresponding components in the RSAM.

## 3.4 Data requirements for incorporating a freshwater module

Currently, Auckland Council is building the necessary data to meet the NPS-FM. This process includes full water accounting for the Auckland region and water catchment models capable of deriving emission levels from water pollutants. Initial consultation with the council's research team revealed that the current water accounts and pollution data are not suitable for the proposed CGE model. However, the research team confirmed that it is possible to numerically calculate the data to meet the requirements for the CGE model. Subsequently, further collaboration within the council is required.

Below are some of the key issues and observations for each of the freshwater modules, (production, consumption, and abatement).

- Production: Current Auckland Council water accounts and pollution models produce output data at highly aggregated level for the pollution production module. Specifically, the pollution data will be broadly categorised based on activities (e.g., industrial, business) and may not be detailed enough for production-based pollution output in the CGE model (categorised by the ANZSIC06-based 106 industry classifications from the supply-use tables).

Consequently, tracing specific water pollutant quantities to a specific industry classification is difficult. For example, disaggregating the quantities of zinc wastes from an industrial activity to industrial classifications (e.g., chemical manufacturing and basic metal manufacturing) used in the CGE model is very difficult. This difference in how economic activities are categorised arises because the water accounts and pollution model is based primarily on spatial land uses. In contrast, the CGE model is based on monetary data, where it is difficult to categorise the spatial land uses into specific industry classifications. This is because a parcel of land maybe used for multiple uses.[47]

- Consumption: As the outputs from Auckland Council water accounts and pollution model are spatially explicit, water pollution from household consumption for each sub-region may be derived by: (1) calculating the average pollution per population from the residential areas within the sub-region; and then (2) multiplying that average pollution per population by the total sub-region population.

- Abatement: Initial data mining revealed that the data required to build the abatement curve is insufficient. Abatement data for the agricultural industries maybe built using farm-level financial models such as FARMAX. Even so, such models are not available for either the manufacturing sector or service sector, which together make up a large portion of Auckland's economy.

  Consequently, simpler partial equilibrium financial models may be built for each industry. For example, a firm chooses a level of abatement investment to maximise profit based on exogenous factors such as subsidies. In turn, it can collect the data necessary to build abatement curves by running multiple simulation runs of the partial-equilibrium model and varying the exogenous factors.

[47] For example, a multi-storey building in a business section can be used for retail on the ground level and business services on the upper levels.

# 4 Summary and Conclusions

## 4.1 Summary of Stage 2

The CGE model framework introduced in this report is a multi-regional one.

The framework involves modelling the decisions and transactions of households, producers, and central and local government. Each agent in the model faces its own optimisation problem subject to its budget constraints. Households make choices to maximise their welfare subject to their budget constraints while producers maximise their profits subject to their cost constraints. The model outputs the demand and supply and prices of every traded commodity in a state of general equilibrium. This is where all agents are doing the best they can and markets clear (i.e., demand for a commodity equals its supply).

We have incorporated water pollution emission and abatement sectors to into production and consumption processes. The impact of different policy measures (such as changes in tax rate and subsidies) can be examined at national, regional and sub-regional levels.

One main feature (also a challenge) in building the comprehensive sub-regional model is in modelling various sources of freshwater pollution and the effect of policy measures on different regions within the model.

## 4.2 Summary of Stage 3

The sub-regional CGE model examines policy impacts at the national, regional and sub-regional levels. This involves an extensive search for corresponding data at those levels. The detailed data requirements for each level are discussed in section 3 of this report.

In summary, the basis for our national-level supply and use of resources is provided by the 2013 NSUT (Input-Output) table published by SNZ. Correspondingly, the state of the economy is based on the national accounts for the same year. We would use both sets of data to build the NSAM.

We would then regionalise NSAM by incorporating the regional data obtained from RGDP and various other sources. The resulting RSUT and RSAM would capture the transactions of agents for the 15 main regions within New Zealand.

We can then disaggregate the regional level data into the sub-regional level using the FMUs. This step is expected to incur the highest cost for data gathering, as information at a sub-regional level is scarce and difficult to source.

## 4.3 Conclusions

The CEU at Auckland Council is proposing to develop a sub-regional CGE model to assess how current policy and planning initiatives affect economy and land use in Auckland. The key characteristic of the model is that it is multi-regional at a sub-regional level. That is, the model is multi-regional CGE model with the Auckland region, spatially separated into CB level sub-regions. This allows for feedback between sub-regions, as well as between other parts of New Zealand, and shows the sub-regional distribution of the economic impacts. Importantly, the model is able to assess the inter-regional distribution of the economic impacts, winners and losers associated with exogenous shocks and policies.

The model provides a more realistic representation of Auckland's economy[48]than a regional CGE model or partial equilibrium approaches, and can be used to examine a diverse range of policies and EIAs. In addition, the model structure and implementation (eg, by using computer codes) is generalised and can be easily used for other spatial definitions (such as other regions in New Zealand).

### 4.3.1 A summary of how the CGE model assesses freshwater quality

In this report, we identified the CGE model setup for assessing the economic impacts associated with initiatives that set limits for freshwater quality.

We have specified a framework that incorporates: (i) a multi-regional, sub-regional spatial level; (ii) freshwater-quality management module that examines the production and consumption of pollution; and (iii) an abatement technology module that allows for detailed changes in production input requirements in response to exogenous policy shocks.

The proposed CEU sub-regional CGE model incorporating freshwater-quality management is designed to model how water pollutions are generated by both production and consumption activities within an economy. In addition, the model incorporates an endogenous abatement module where producers within the economy adjust their production and investment behaviours in response to policy measures. The model can therefore be used to test and compare the effects various policies on freshwater quality for each FMU at the same time.

The model includes production and consumption (primary) flows as well as accounting and financial (secondary) flows within the economy, and reproduces the behaviour of agents within an economy. Further, the CGE model offers interdependence between agents and regions, represents a complete picture of Auckland's economy, and provides robust, economic impact outputs associated with policies focused on the quality of fresh water.

We can use the model to infer how combinations of freshwater policies for each FMU affect the economy of that FMU as well as the Auckland region and other parts of New Zealand. It is important to note that the model can assess economic consequences of urban development, land-use planning and growth policies about freshwater quality, as well as the reverse (i.e., how policy decisions about freshwater quality affect the economy and land use). Similarly, the model can include non-freshwater policies (e.g., greenhouse gas emissions) faced by the council and show the effects on freshwater quality, as well as interaction effects between freshwater policies and non-freshwater policies.

This study also looked at the sources of data for building the CGE model and identified potential data constraints. We found that, currently, insufficient data is available to build the national and multi-regional CGE model framework. However, the council is currently developing the pollution, abatement and water

[48] For example, a sub-region mainly used as a residential area will show different pollution emission levels and pollutant composition from a mainly industrial area. The approach taken by the sub-regional housing model should be able to match the economic and demographic composition to each sub-region.

account data required for sub-regional housing CGE model to study the impact of pollutant emission and abatement technology. This is required to meet the NPS-FM standards.

#### 4.3.2 The benefits of using an expanded CGE model to assess the implications of both freshwater quality and other economic initiatives

The purpose of this study was to improve our understanding of the potential and challenges if we expand the sub-regional CGE model to account for impacts of freshwater policies on economic growth and development. In addition, the CGE model proposed in this study aims to help us understand the potential economic consequences of policies under NPS-FM.

From this study and the literature review conducted in Stage 1 of the study, we found numerous benefits of using the CGE model to assess the economic implications of both freshwater quality and other environmental policy initiatives. Further, we found that a sub-regional CGE model at FMUs level is required to conduct a robust economic impact analysis of proposed freshwater-quality policies in Auckland. Eight key benefits for developing the model are noted below.

1. CBA methods (mainly analysing primary sectors) and IO methods (without behavioural change) used in EIAs of other regions in New Zealand do not incorporate overall changes in production behaviours. In comparison, the CGE model incorporates price dynamics, where an exogenous shock or a policy change affects prices of commodities. This in turn affects the consumption and production behaviours of the agents within the economy. A key objective of the study is to build a CGE modelling capacity within the council so we can use the CGE model to conduct future EIAs within the council.

2. Despite the wide use of CGE model in assessing economic implications of environmental policies (as evidenced in the international literature), in New Zealand most EIAs of water policies are conducted using a mix of CBA and IO approach. Our review of the international literature showed numerous studies on the EIA of economic growth and water quality. These studies on water quality were completed relatively recently, and we observed a growing interest in this issue.

3. Auckland has different economic structures from the rest of New Zealand. Auckland’s economy is dominated by manufacturing and service industries, while primary industries occupy a relatively small portion of the economy. As manufacturing and services industries are more flexible in changing their production behaviours, any policy initiatives will have a greater impact on these industries. In addition, Auckland has experienced an unprecedented pressure on its infrastructure, such as freshwater supply, as a result of the increase in net migration and general population growth. The proposed CGE model will try to capture these features of the Auckland economy as realistically as possible.

4. Policy initiatives affect demand and the price of underlying factors of production (e.g., labour, capital and land). CGE models can capture this fact. For example, certain policies may lower demand for land from the

production side of the economy. In contrast, the key issue for Auckland is urban intensification and housing, where the availability and the price of land is an important consideration. The CGE model can incorporate both the patterns of household demand for housing land and demand from the production sector for land. Subsequently, we can use the model to analyse potential impacts of freshwater policy initiatives on housing land prices and supply (as well as on other aspects of the economy).

5. CGE models are useful in analysing the impacts of multiple policy initiatives at the same time. As CGE models search for an optimal economic decision for all agents (e.g., production, households, and governments) in the economy, and include both supply and demand side of economic activities by these agents, they are flexible in including different types of exogenous and policy shocks. Instruments that set the limits for freshwater quality affect the economy through various channels, and a CGE model captures this.

   In addition, CGE models can incorporate seemingly unrelated exogenous policy shocks. They can calculate the overall impacts of these policies on the economy and any associated externalities. For example, the models could include water quality and housing policy initiatives to determine the combined impacts on the economy and the environment.

6. The sub-regional CGE model includes inter-spatial relationships within the region and the rest of New Zealand. Therefore, the model can assess how a policy in a region or a sub-region can affect other regions and sub-regions. For example, the effect of reduction in economic output of the Auckland region caused by a freshwater policy will flow on to other areas within New Zealand. Further, the model can identify the sub-regional and inter-regional winners and losers of implementing freshwater-quality policies.

7. The CGE model can assess opportunity costs associated with those policies where a comparison between the economic impacts of different policies meeting the limits is possible. Typically, a CGE model includes a base case economic scenario (i.e., business as usual). The base case is used as a benchmark and compared against outputs resulting from exogenous shocks and policy scenarios. As such, the model can use changes in outputs against a benchmark for each scenario to compare different policies. Building a comprehensive sub-regional housing CGE model framework for Auckland will not only enable the council to develop the capability to study the impact of various policy implications within Auckland. It will also contribute to studying other regions in New Zealand.

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# Appendix A Freshwater Instruments for Economic Modelling

| Spatial | | | |
|---|---|---|---|
| **Option** | **Description** | **Articulation** | **Effects** |
| Freshwater Management Unit (FMU) | A water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes | NPSFM requirement<br>Spatial management | No effect on cost of development |
| High-use Aquifer Management Areas Overlay | Areas with highly allocated aquifers, providing water to users as well as major source of stream flow; already under the pressure of use and may be further degraded over time due to the high potential for development | Water quantity<br>Water quality<br>Spatial management | Not eligible for 5m3/day permitted activity water takes – water takes require resource consent and assessment. |
| Quality-sensitive Aquifer Management Areas Overlay | Areas with aquifers that are shallow and unconfined; susceptible to pollution from surface sources such as excess fertiliser application or discharges of contaminants such as stormwater or sewage | Water quantity<br>Spatial management | No additional rules apply. Overlay applies objectives and policies where this could be an issue for discharges and management of bores. |
| High-use Stream Management Areas Overlay | Area with streams that are under pressure from demands to take water or use water | Water quantity<br>Spatial management | Takes of 20-100m3/day discretionary rather than restricted discretionary activity in overlay. Takes from municipal supply dams not permitted. Overlay applies objectives and policies for managing demand for water and ecological values in highly allocated streams |
| Natural Stream Management Areas Overlay | Areas with river and stream reaches with high natural character and high ecological values | Water quantity<br>Water quality<br>Spatial management | A range of uses and activities require consent, assessment and protection including works in streams, takes use damming and diversion, land disturbance and vegetation management. |
| Natural Lake Management Areas Overlay | Areas with natural lakes located in rural areas | Water quantity<br>Water quality<br>Spatial management | A range of uses and activities require consent, assessment and protection including takes use, damming and diversion, land disturbance and vegetation management. |
| Urban Lake Management Areas Overlay | Specific to Lake Pupuke and Western Springs Lake only | Water quality<br>Spatial management | A range of uses and activities require consent, assessment and protection including lakes structures and land disturbance |
| Water Supply Management Areas Overlay | Areas comprised of catchments that are mainly in public ownership surrounding municipal water supply infrastructure. Specific to the Hunua Ranges, Hays Creek, Riverhead Forest and the Waitakere Ranges. | Water quantity<br>Water quality<br>Spatial management | A range of uses and activities require consent, assessment and protection including discharges, water takes and use, damming and diversions, works in streams and lakes, land disturbance and vegetation management. |
| Wetland Management Areas Overlay | Areas with significant wetlands listed in Schedule 1 Wetland Management Areas Schedule. The overlay provisions protect wetlands from the adverse effects of discharges, water takes, wetland drainage, invasive pest species and their physical disturbance | Water quantity<br>Water quality<br>Ecology<br>Spatial management | A range of uses and activities require consent, assessment and protection including discharges, takes, drainage, land disturbance and vegetation management. |
| Significant Ecological Areas Overlay | Areas of significant indigenous vegetation or significant habitats of indigenous fauna located either on land, marine or in freshwater environments | Ecology<br>Spatial management | Vegetation management, land disturbance, infrastructure and Coastal Plan consent requirements and protections. |
| River and stream minimum flow and availability Appendix 2 | Specifies minimum flow and availability of water for each specific river or stream | Water quantity<br>Spatial management | Water quantity control<br>No effect on cost of development |
| Aquifer water availabilities and levels Appendix 3 | Specifies availability of water for each specific aquifer | Water quantity<br>Spatial management | Water quantity control<br>No effect on cost of development |
| Stormwater Management Area Flow 1 and 2 Overlay (SMAF 1 and SMAF 2) | Areas with an applied set of requirements for the development and redevelopment of impervious areas. SMAF1 discharges to streams with high current or potential value that are sensitive to increased stormwater flows and have relatively low levels of existing impervious area. SMAF2 discharges to streams with moderate to high current and potential values and sensitivity to stormwater flow and with generally higher levels of existing impervious area within the sub-catchment | Treatment devices<br>Water quantity<br>Discharge volume and content/concentration<br>Spatial management | Higher development costs due to more stringent rule control, cost neutral |

| Non-Spatial | | | |
|---|---|---|---|
| **Option** | **Description** | **Articulation** | |
| Macroinvertebrate Community Index (MCI) | The assessment of macroinvertebrate specie abundance and diversity to assess stream health<br><br>https://www.mfe.govt.nz/sites/default/files/mci-user-guide-may07.pdf | Ecology<br>Water quality | Measures general water quality and habitat quality, using the guideline values to inform the management of water quality required. |
| Stream Ecological Valuation (SEV) | The assessment of hydraulic, biogeochemical, habitat provision and biodiversity provision for quantifying ecological functions and values of streams. | Water quality<br>Ecology | A stream ecosystem valuation system to inform resource management decisions, catchment planning or state of the environment monitoring. |
| At-Source-Treatment | Manage stormwater as close to the source as possible | Treatment devices<br>Discharge volume and content/concentration<br>Discharge location | Higher development costs due to more stringent rule controls |
| On-site waste water treatment | Treatment of domestic wastewater and return it to the environment within the site of generation | Treatment devices<br>Discharge volume and content/concentration<br>Discharge location | Higher development costs due to more stringent rule controls |
| Integrated Stormwater Management Approach | Use of stormwater as a resource to improve the health of urban waterways, provide green corridors, recreation spaces and improve amenity for the community.<br><br>Water Sensitive Design for Stormwater - Auckland Design Manual GD04 | Landscape and features<br>Treatment devices<br>Discharge volume and content/concentration<br>Discharge location<br>Risk<br>Flooding | Design process for housing developments that take into consideration of land use planning and development at complementary scales including region, catchment, development and site.<br>Can avoid energy-intensive and costly infrastructure. |
| Maximum Impervious Thresholds | Water Sensitive Design for Stormwater - Auckland Design Manual GD04 | Discharge volume and content/concentration<br>Discharge location | Measures to control the ratio of impervious surface on a particular site |
| Annual Exceedance Probability (AEP) | The chance or probability of a natural hazard event occurring annually based on a percentage | Risk<br>Flooding | Measures the risk to determine the level of rule control |
| Discharge Quality Standard | Minimum quality standard for the discharge of water into the receiving environment or centralised systems | Discharge volume and content/concentration<br>Discharge location | Measures the water quality to determine the level of rule control |
| Assessment of site condition | Defining the conditions of a land site to ascertain the most appropriate development potential | Landscape and features | Measures the land type to determine the level of rule control |
| Freshwater Limits | The maximum amount of water available to be used which still allows for freshwater objectives to be met | NPSFM requirement<br>Water quality<br>Water quantity | Water quality and quantity to determine the level of rule control |
| Freshwater allocation in order of priority | Freshwater allocated based firstly on health and wellbeing requirements for humans and animals and then considers economic, technical and dynamic efficiency, and for emergency shortages. | NPSFM requirement<br>Water quantity<br>Economy | Primarily a needs assessment to determine the allocation of water for different users. Provides for comprehensive review of all consents. Often implemented on a first come first served basis |
| Instream Value | Values that are associated with the river's natural environment, traditional Maori uses, recreational and aesthetic values | NPSFM requirement<br>Water quality<br>Water quantity<br>Mana Whenua | Water quality and quantity to determine the level of rule control |
| Network Operation Plan | Consolidated overview of network flow and capacity | Asset management | Measures the existing and designed capacity of infrastructure |
| Overflow Mitigation Plan | Long term, progressive plan to reduce overflow events typically through growth or renewal CAPEX | Overflow mitigation<br>Asset management<br>Asset renewal<br>Risk | Measures the exiting capacity and the committed upgrades of infrastructure |
| Wastewater Overflow Response Procedure | Plan that details the required procedures and actions in an event of overflow | Overflow mitigation<br>Risk | Measures the risk to determine the level of rule control |
| Best Practice Option and Industry Standards | Procedures and actions that are accepted or prescribed as being correct or most effective | Water quality<br>Water quantity | Establishes the standard for operational processes |

| Consents and Permits | | |
|---|---|---|
| **Option** | **Description** | **Articulation** |
| Network Discharge Consent | A resource consent that Auckland Council is required to obtain for stormwater discharges from the region's stormwater networks. | Asset management<br>Discharge volume and content/concentration<br>Discharge location.<br>Use of Consolidate Receiving environments enables management of major water bodies (coastal waters and their contributing sub-catchments) and better prioritisation of stormwater management |
| Land use consent | Activities that will affect the use of land such as buildings and structures, earthworks, retail etc. | Land use |
| Coastal permit | Resource consent for coastal activities such as the use of the coastal marine area,discharges of contaminants and certain works that affect the Coastal Marine Area and the landward component of the coastal environment | Manage the use, development and protection of the natural and physical resources of the coastal marine area |
| Water permit | Resource consent for the take and use of surface water or groundwater | Water quantity<br>Water quality |
| Discharge permit | Discharges of contaminants into water, or onto or into land | Land management<br>Water quality |

# Appendix B Data Sources for NSAM

| Variable | Description | Data Source |
|---|---|---|
| **U** | Intermediate consumption | NSUT |
| **GC** | Government consumption | NSUT |
| **hc** | Household consumption | Household and Non Profit Institutions Serving Households (NPISH's) consumption in NSUT |
| s | Investment | The sum of Change in Inventory and Gross Fixed Capital Formation (GFCF) in NSUT |
| **x** | Export | NSUT |
| **S** | Domestic supply | NSUT |
| **IM** | Import | NSUT |
| $\mathbf{f}_l$ $(CoE)$ | Factor of Production payment for labour | The sum of all Compensation of Employees (COE's) in NSUT |
| $\mathbf{f}_k$ $(GOS)$ | Factor of Production payment for capital | The sum of operating surplus (OS) and the Consumption of Fixed Capital in NSUT |
| $he$ | Trasfer from household to enterprise | Pension Fund Contributions (Table 2.6, S2ND6221S2000) and Miscellaneous current transfer adjustments (Table 2.11, S2ND7530S5000 and S2ND7540S5000) |
| $GOSE$ | Gross operating surplus for enterprise | The total capital income $\mathbf{f}_k$ minus $GOSH$ and $GOSG$ |
| $rowe$ | The transfer from ROW to enterprise | Investment income (Table 2.1 S2ND4600S1000) and reinvested earnings (Table 2.13 S2ND4301S6000) |
| $CoEH$ | CoE payment to household | The difference between $mathbf f_l$ and $CoERoW$ |
| $GOSH$ | GOS allocated to household | GOS received by household and NPISH (Table 2.11, S2NB0200S5000 and Table 2.10, S1NB0200NS4000) |
| $eh$ | Enterprise transfer to household | The sum of (1) enterpreneurial income (Table 2.11, S2NB4100S5000 & S2NB4200S5000); (2) property-related dividends income (Table 2.11, S2ND4210S5000) and (Table 2.10, S2ND4210S4000 for NPISH); and (3) insurance/pension fund (Table 2.11, S2ND4400S5000), (Table 2.10, S2ND4400S4000 for NPISH) and change in net equity adjustment (Table 2.6, S2ND4400S4000) |
| $gh$ | Government transfer to household | The sum of (1) social security benefits (Table 2.8, S2ND6210S3100); (2) social assistance benefits (Table 2.8, S2ND6240S3100); (3) miscellaneous current transfers to household (Table 2.8 S2ND7501S3100); (4) interest concessions (Table 2.11, S2ND7500S4000); and (5) miscellaneous current transfer adjusment for NPISH (Table 2.10, S2ND7500S4000 & S2ND7501S4000 and Table 2.11, S2ND7520S5000) |
| | | *(Table continued on the next page)* |

| Variable | Description | Data Source |
|---|---|---|
| *rowh* | ROW transfer to household | The sum of (1) overseas investment income (Table 2.11, S2ND4600S5000) and (2) miscelleneous current transfers from overseas (Table 2.11, S2ND7550S5000) |
| *GOSG* | GOS allocated to the Government | GOS received by (1) the central government (Table 2.8, S2NB0200S3100) and (2) the local government (Table 2.9, S2NB0200S3200) |
| *eg* | Enterprise transfer to Government | For the central government: (1) dividend income (Table 2.8 S2ND4210S3100); (2) rent on natural assets (Table 2.8, S2ND4500S3100); (3) insurance/pension policy (Table 2.8, S2ND4400S3100) and (4) net miscellaneous current transfer (Table 2.8, S2ND7500S3100 & S2ND7501S3100). For the local government: (1) dividend income (Table 2.9, S2ND4210S3200); (2) insurance/pension policy (Table 2.9, S2ND4400S3200) |
| *hg* | Household transfer to Government | For the central government: (1) social security contribution (Table 2.8, S2ND6114S3100); (2) pension fund contributions (Table 2.8, S2ND6115S3100); and (3) fines and penaties (Table 2.11, S2ND7510S5000). For the local government, only the portion of the fines and penalties applies. |
| **GTI** | Government Tax Income | The cental government: (1) Indirect tax on production and imports (Table 2.8, S2ND2000S3100 & S2ND2010S3100); (2) less the subsidies (Table 2.8, S2ND3000S3100); (3) Direct taxes including income tax (Table 2.8, S2ND5100S3100) and other current taxes (Table 2.8, S2ND5900S3100). For the local government: (1) Indirect tax on production and imports (Table 2.9, S2ND2000S3200 & S2ND2010S3200); (2) less the subsidies (Table 2.9, S2ND3000S3200); (3) Direct other current taxes (Table 2.9, S2ND5900S3200) |
| **TY** | Tax on production | The sum of (1) taxes on products; (2) other taxes on products; and (3) subsidies from NSUT |
| *te* | Direct enterprise taxes | Income tax paid by enterprises (Table 2.1, S2ND5120S1000) and finacial institutions (Table 2.6, S2ND5120S2000) |

*(Table continued on the next page)*

| Variable | Description | Data Source |
|---|---|---|
| *th* | Tax on households | Direct income tax (Table 2.11, S2ND5120S5000); other direct taxes (Table 2.11, S2ND5900S5000) and Indirect tax on product purchase by household and NPISH (NSUT). |
| **TG** | Tax paid by Government | Tax on products for central government (NSUT) and income tax (Table 2.8, S2ND5100S3100) |
| *ti* | Tax on investment | Indirect tax on products for gross fixed capital formation (NSUT) |
| *tx* | Tax on exports | Direct tax is the net income tax for ROW (Table 2.13, S2ND5120S6000 & S2ND5100S6000) and the indirect tax is on products for international exports (NSUT) |
| *es* | Enterprise saving | The sum of (1) savings from producers (Table 2.1, S3NB8000S1000) and financial intermediaries (Table 2.6, S3NB8000S2000); (2) consumption of fixed capital by producers (Table 2.1, S2NK1000S1000) and financial intermediaries (Table 2.6, S2NK1000S2000); (3) net capital tax received (Table 2.1, S3ND9100S1000); and (4) net capital transfers received (Table 2.1, S3ND9900S1000 and Table 2.6, S3ND9900S2000) |
| *hs* | Household savings | Summing across for both households and NPISH: (1) savings (Table 2.11, S2NB8000S5000, Table 2.10, S3NB8000S4000); (2) consumption of fixed capital (Table 2.11, S2NK1000S5000, Table 2.10, S2NK1000S4000); (3) net capital tax received by households (Table 2.11, S3ND9100S5000); and (4) net capital transfers received (Table 2.11, S3ND9900S5000 and Table 2.10, S3ND9900S4000) |
| *gs* | Government savings | For the central government: (1) savings (Table 2.8, S2NB8000S3100); (2) consumption of fixed capital (Table 2.8, S2NK1000S3100); (3) net capital tax received (Table 2.8, S3ND9100S3100); and (4) net capital transfers received (Table 2.8, S3ND9900S3100). For the local government: (1) savings (Table 2.9, S2NB8000S3200); (2) consumption of fixed capital (Table 2.9, S2NK1000S3200); (3) net capital tax received (Table 2.9, S3ND9100S3200); and (4) net capital transfers received (Table 2.9, S3ND9900S3200) |
| | | *(Table continued on the next page)* |

| Variable | Description | Data Source |
|---|---|---|
| *rows* | ROW savings | The sum of savings (Table 2.13, S3NB8000S6000) and net capital transfers (Table 2.13, S3ND9900S6000) |
| *CoERoW* | CoE payment to ROW | CoE (Table 2.13, S2ND1000S6000) |
| *erow* | Enterprise transfer to ROW | The sum of (1) net property interest paid by producers (Table 2.1, S2ND4100S1000 & S2ND4101S1000) and financial intermediaries (Table 2.6, S2ND4100S2000 & S2ND4101S2000); (2) net dividends (Table 2.13, S2ND4210S6000 & S2ND4211S6000); (3) reinvested earnings on overseas direct income (Table 2.13, S2ND4300S6000) and (4) net non-life insurance premiums for producers (Table 2.1, S2ND7200S1000 & S2ND7100S1000) and financial intermediaries (Table 2.6, S2ND7200S2000 & S2ND7100S2000) |
| *hrow* | Household transfer to ROW | The sum of (1) miscellaneous current transfers (Table 2.11, S2ND7560S5000); (2) net receipt of interest by household (Table 2.11, S2ND4100S5000 & S2ND4110S5000 & S2ND4120S5000) and by NPISH (Table 2.10, S2ND4100S4000 & S2ND4110S4000); (3) net benefits received from non-life insurance for household (Table 2.11, S2ND7200S5000 & S2ND7100S5000) and for NPISH (Table 2.10, S2ND7200S4000 & S2ND7100S4000) |
| *grow* | Government transfer to ROW | The sum of (1) imports and exports of goods and services balance (Table 2.13, S2NB1100S6000); (2) net miscellaneous current transfers (Table 2.12, S2ND7500S6000 & S2ND7501S6000) and (3) net property interest payment of the central government (Table 2.8, S2ND4100S3100 & S2ND4101S3100) |