The Value of Irrigation Water in New Zealand

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Alexey Kravchenko

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We never know the worth of water 'til the well is dry.

- Thomas Fuller, 1732

ABSTRACT

The aim of this thesis is to examine issues pertaining to freshwater quantity in New Zealand agriculture. Currently, freshwater is managed under the Resource Management Act (1991) and the allocation system is essentially on a "first-come first-served" basis – whoever gains access to water rights first blocks out subsequent users, if catchment allocation limits have been reached. One of the recommendations from a government taskforce engaged to look at the issues of freshwater management suggests that market mechanisms or charges could be viable options of demand management. For any such market or price mechanism to work, it is imperative to know the value of irrigation water in New Zealand as well as to understand wider economic ramifications of establishing such mechanisms. Currently, there is relatively little research concerning these issues and this thesis aims to fill this research gap. The methodologies used include an econometric analysis of dairy farm panel data, a stated choice experiment of irrigation consent holders and a computable general equilibrium [CGE] analysis. In addition to filling the research gap, this thesis also aims to provide improvements in each of the methodologies used. Panel data analysis imputes the water demand function without actual data on water through examining the relationship between milksolid production and output-weighted expected payout – a unique dairy price index developed that more accurately reflects farmers' incentives than the final payout. The choice modelling section pays particular attention to the issue of attribute non-attendance [ANA], examining its effects on model outputs and compares methods of data collection on ANA. The main findings of the survey suggest that the majority of farmers would be willing to pay for water instead of facing an abstraction ban. In terms of ANA, the results indicate that not accounting for ANA, particularly if it is due to heuristics or respondent fatigue, may significantly bias the welfare estimates and decrease statistical significance. A novel calibration method is presented to negate the ANA bias. Finally, the CGE modelling work modifies the well-known GTAP model to include water as factor of production, as well as to disaggregate the results to a regional level within the New Zealand economy. The findings indicate strong interconnectedness between sectors and regions, with policies in one region having the potential to affect economic activity and resource demand in other regions.

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1. INTRODUCTION

New Zealand's current freshwater management system is fast becoming inadequate to deal with the growing demand from competing users. The perception of seeming inexhaustibility of this vital resource is but an illusion fostered by a history of virtually unrestricted access to it. Without a functioning market, in order to better manage this resource, one needs to first know its value to different users. There is currently relatively little understanding with regards to the value of freshwater in New Zealand. Hence, it is the aim of this thesis to quantify the value of irrigation water as well as to model the economy-wide implications of potential changes in the water allocation mechanism.

As part of this research, first, dairy farm panel data analysis is performed to estimate demand for irrigation water for dairy farms – New Zealand's largest freshwater consumers (Chapter II). Next, discrete choice experiment methodology is used to elicit willingness to pay for water among a sample of existing irrigation water consent holders (Chapters III and IV). Finally, Computable General Equilibrium modelling (Chapter V) is used to study the impacts of policy changes on the economy as a whole.

The remainder of this chapter is as follows. First, the issues facing the current freshwater allocation system will be outlined, together with the motivation behind this study. Second, relevant literature outlining studies pertaining to New Zealand, as well as those relating to various methodological techniques will be presented. Finally, the methodologies used as part of this research will be introduced along with their underlying theoretical underpinnings.

1.1. New Zealand Water Issues: Background

New Zealand's freshwater issues are certainly a far cry from those in places such as Murray-Darling Basin, Australia, where the "Big Dry" and generations of intensive irrigation farming depleted the river to such extent that at one time it literally stopped flowing. The situation is certainly not as severe as in Spain, where climate change threatened the agricultural sector so much that the government now provides desalinated water at subsidised prices to agricultural producers (Fuentes, 2011). However, New Zealand's current method of managing of what is arguably one of the most undervalued resources is fast approaching the point of inadequacy, as explained below.

New Zealand is seemingly relatively abundant with freshwater. It has the fourth highest per capita total renewable freshwater resources among OECD countries with over 80 thousand cubic metres per capita (Fuentes, 2011). By comparison, Australia and the US have approximately 15 and 10 thousand, respectively. Even when coupled with our second highest freshwater abstraction per capita level in OECD, New Zealand is still third lowest in terms of abstraction vis-à-vis its relative freshwater endowment (Ministry for the Environment, 2010). However, "much of it needs to be retained in the rivers, lakes and aquifers to maintain the ecological, recreational, or cultural values", with only a relatively small portion allocated for consumptive use (Ministry for the Environment, 2010). Limits are set by regional authorities to manage freshwater abstractions. For example, in the Waikato Region the default allocation for freshwater are only 5% for upland and 10% for lowland catchments of Q5 – the low flow statistic derived from analysing the frequency of 7 consecutive day annual low flow in a catchment that has a 20% of occurring in a particular year (Waikato Regional Council, n.d.).[1] However, Snelder et al (2014) argue that such limits alone

[1] The council determines each catchment's environmental flow – the level deemed necessary for a particular catchment to maintain its environmental and ecological health – through setting it proportional to Q5. For example, the Waikato River at Hamilton is deemed to need an environmental flow of 140 cubic metres per second [cms]. Its Q5 is 156 cms,

are insufficient and further scientific tools are required to improve transparency and efficacy of allocation.

The current system of water take allocation in New Zealand has been described as “first-come first-served”: whoever applies first for a resource consent obtains it first. There is a nominal fee for an application, and a limit is set on the maximum allowable intake, but otherwise the water from freshwater sources is virtually free. This system has been established since the introduction of the Resource Management Act [RMA] in 1991 (Scrimgeour, 1997). According to this legislation, regional authorities are entrusted with managing their territories’ natural resources, including water. The Act stipulates a number of provisions specifically addressing the issues pertaining to freshwater management, including the settlement of limits of fresh water intakes, allocation of rights of freshwater intakes and other functions to maintain quality of water (NZ Parliament, 2011). Regional authorities generally use Regional Water Management Plans to manage water. However, such plans are widely seen as inadequate as they overall lack measurable limits and are generally ambiguous (Snelder, et al., 2014).

When this system was established, there was little need for an alternative solution as freshwater was deemed to be an inexhaustible resource in New Zealand. However, with the proliferation of irrigated farming, as well as a general growth from other competing needs of water such as hydropower generation, ecosystem management, and recreation, among others, this system is fast becoming unable to keep up with its objective.

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which means that 16 cms is available for allocation. The likelihood of flow falling below the environmental level is 20%, during which time water intake restrictions will apply.

Table 1 shows the areas under an irrigation system in 2002, 2007, and 2012. Approximately 3% of all agricultural land in New Zealand is reported to be under an irrigation system.[2] The South Island, Canterbury and Otago in particular, account for most of irrigated land in New Zealand. Still, most regions experienced double digit percentage growth of irrigated land area within the last five year period – an overall increase of 17% since 2007.

Table 1. Irrigable Land[3] by Region (000's ha)

Region	Total agricultural land (2002)	Land under an irrigation system		
		2002	2007	2012
Northland	810	7	9	8
Auckland	302	6	6	6
Waikato	1,730	13	17	21
Bay of Plenty	600	9	10	12
Gisborne	643	1	2	5
Hawkes Bay	962	18	25	26
Taranaki	497	3	3	7
Manawatu-Wanganui	1,545	8	12	22
Wellington	504	10	13	17
TOTAL North Island	*7,593*	*75*	*97*	*121*
Tasman & Nelson	298	10	11	12
Marlborough	696	20	27	30
West Coast	225	2	1	2
Canterbury[4]	3,200	287	385	445
Otago	2,379	69	91	94
Southland	1,198	4	8	17
TOTAL South Island	*7,997*	*393*	*522*	*600*
TOTAL New Zealand	**15,590**	**468**	**619**	**721**

Source: Statistics New Zealand 2002, 2007, 2012

[2] According to Aqualinc, 2010, the area of land consented to be irrigated differs slightly to this figure as not all area has been actually equipped to be irrigated, as defined by Statistics NZ.
[3] Defined, by Statistics New Zealand as *land area that could have been irrigated using existing resource consents and equipment that is on the farm.*
[4] Includes Chatham Islands

Aqualinc Research reported in 2004 that in Waikato surface water is close to full allocation and the current surface water allocation processes do not account for variations in seasonal demand (Aqualinc Research, 2004, p. 15). So much so, that in 2006 Environment Waikato [EW] declined two applications to take "significant volumes of water from the Waikato River for the purposes of dairy farm irrigation" (EW, 2008, p. 26). The applications were particularly opposed by hydro electricity generators and municipal water suppliers (EW, 2008).

In 2010, there were 20,500 consented fresh water takes in New Zealand, 75% of which was for the purposes of irrigation (Aqualinc Research, 2010). In terms of annual consumptive allocation,[5] irrigation was also the dominant user, constituting 53% of annual consumption allocation, in addition to industrial (23%), municipal (17%) and stock (7%) (Aqualinc Research, 2010).

When considering top weekly consumption[6] – irrigation constitutes 78% of allocation. This higher relative and absolute demand is due to the seasonal nature of farming – planting and dairying seasons are predominantly in warmer months from October to March. Of all volumetric annual irrigation allocation, 81% of it is for pasture irrigation (or 76% of consented irrigated area in 2010). On top of the extra demand from farming, hydro power stations, due to the increased demand for air-conditioning in the summers, require more water to generate electricity. Unfortunately, this coincides with the periods of lowest rainfall levels in most regions in New Zealand (NIWA, 2010). In 2012, of the 721,200 ha of irrigable land, 245,000 ha (34%) were under irrigation schemes

[5] For drinking, stock water and industrial users, annual rate is calculated as weekly times 52. For irrigation, annual rate depends on the number of irrigating weeks typically 12 to 22 weeks.

[6] Consumptive use means the usage of water after which no other users can use the same water, like irrigation or municipal water take. Hydro power is generally not considered to be consumptive since water is later made available to users downstream, except in the case of Manapouri Hydro Power Plant, which outlets the water to the Doubtful Sound. For the purposes of this analysis, the consumptive use of water by this power plant is omitted.

(National Infrastructure Unit, 2015). The vast majority of such irrigation schemes lack storage capacity and hence are prone to water restrictions during dry summers.

Jenkins (2013) notes that reliability is increasingly valued among the irrigators, and some farms are choosing to invest in storage capacity to safeguard against droughts and water restrictions. He notes, that, for example instance, during the drought of 2011/2012 it is estimated that $30 million worth of output was lost due to irrigation restrictions at the irrigation Waimakariri Irrigation Scheme. Investment in storage capacity would allow such schemes to have reliable access to water even when restrictions are in place.

1.2. Climate Change and "Virtual Water"

In addition to medium to short-term potential water scarcity in some New Zealand regions, longer term issues arising from climate change will also make managing water more efficiently an important issue. Ministry for the Environment [MfE] (2007) reports that eastern parts of both islands are expected to experience less annual rainfall over the next century. In addition, other parts of New Zealand will experience more variable weather, including more severe floods and droughts (ME, 2001). Droughts, in particular, will require an efficient system of distributing water among the competing users.

Moreover, global demand for food products, arising from rapid population growth, growing scarcity of suitable farmland as well as climate change is increasingly putting stress on global food and water supplies (Chartres & Varma, 2010). Willenbockel (2011) uses a Dynamic Computable General Equilibrium [CGE][7] model to predict that by 2030, global prices of rice and wheat will increase by 75% relative to 2010 prices under a "business-as-usual" scenario which includes only

[7] Discussed in Chapter IV.

population and factor productivity growth. The results are even more pronounced when climate change is factored in: price of wheat more than doubles, as do prices of most other food products.

Allan (1998) introduces the concept of "virtual water" – water embedded in the production of each good – to suggest that water deficit in one region is compensated for by imports of "virtual water", or products that use water intensively in their production process, from another region. In his example, arid regions of North Africa and the Middle East experienced water deficit since as early as 1950's. The region's acquisition of "virtual water" through imports of grain amounts to more than 40 billion tonnes of water annually (embedded in 40 million tonnes of grain). Hence, water endowed countries are likely to be increasingly relied on to be the breadbasket of the world.

New Zealand is in a unique position to profit from these trends because of its comparative advantage in agriculture. However, this would likely to result in intensification of farming, which would put more demand on the already stressed freshwater resources.

1.3. Fresh Start for Fresh Water

Recognizing the growing need to better manage all the more scarce water, the New Zealand government commissioned a task force, the Land and Water Forum [LAWF], to study the current fresh water situation in New Zealand and advise as to how it should be managed better (Land and Water Forum, 2010). LAWF also concludes that many water catchments are fully allocated, or close to full allocation (Land and Water Forum, 2011). They recognize freshwater's growing scarcity and recommend establishing more effective allocative processes than the "first-come first-served" basis system currently in place.

Since there are competing users of water (such as municipal suppliers, farms and hydro electricity generators), who have a rivalrous water demand, it is advisable to establish a system that distributes water to users who hold it in the highest value. This requires actually knowing what that value is to various users. As intakes of water are only just starting to being measured (in relationship to how much a user was consented to take or otherwise) and at source water[8] being virtually free, for most users the value of water has not yet been adequately measured.

Since the time LAWF stakeholder consultations and analysis were carried out, a number of initiatives pertaining to freshwater management have been implemented (MfE, 2016). The initial National Policy Statement for Freshwater Management directed all regional council to set objectives for water quality and quantity (MfE, 2011). The government also created a $14.5 million fund to restore waterways from pollution and a $35 million fund to develop further irrigation infrastructure. CGE modelling by NZIER estimated the benefit of new irrigation schemes to be $8 billion over 35 years in terms of present value consumption (Kaye-Blake, Schilling, & Zuccollo, 2010). Most recently, in 2014, the National Policy Statement for Freshwater Management included a specific framework to help the regional councils evaluate water-related plans. The most recent policy statement also required councils to "account for how much water is taken from a water body and any contaminants that are discharged into it" (MfE, 2016). Measuring water intakes alone, while may induce efficiency, is not enough to address the long-term problem of allocation, and before that issue is addressed, it is imperative to know the value of water.

[8] Meaning at the source of abstraction, as opposed to point of consumption, which incurs further measurable costs, such as equipment and pumping costs.

1.4. Motivation & Objectives

In most cases, an economist's answer to the question of scarcity is a market: let buyers and sellers decide their respective value of a good, and distribute this good accordingly. In the case of water, however, as Ward & Michelsen (2002) note, it is not that easy to achieve:

> "Due to the high cost of capturing and holding water and because its supply is subject to a steady stream of unexpected changes, it is typically expensive or impossible to define, establish, and enforce property rights required by a water market system. Therefore, well-defined market institutions that could generate prices that could serve to allocate water resources are typically lacking" (p.424).

Hence, freshwater allocation among users, time periods and locations is generally, at least partially, regulated by government bodies. Such allocation requires accurate estimates of the economic value of water (Ward & Michelsen, 2002). As Young (2005) puts it, estimating the value of water would "provide signals of relative scarcity that are not available due to the absence of markets" (p.11).

The main objectives of this thesis are therefore:

- to quantify the economic value of water to one of New Zealand's biggest freshwater users – dairy pasture irrigators;
- to study factors that influence the value of water to the pasture irrigators;
- to determine the responsiveness of the pasture irrigators to potential scarcity and price changes of water;
- to model and study the impact of potential availability and price changes of water on the New Zealand economy as a whole.

In addition to answering the above research questions, methodological improvements are developed to the fields of non-market valuation, stated choice modelling as well as applied computable general equilibrium analysis. In Chapter II a novel method to estimate the value of water to dairy farmers through panel data analysis is introduced; in Chapters III and IV a discrete choice experiment is carried out targeting farmers who irrigate, and particular attention is paid to the issue of Attribute non-Attendance. Finally, in Chapter V a well-known CGE model [GTAP] is used as a basis to examine the effect of water charges and disaggregate the results by New Zealand regions.

1.5. New Zealand Water Valuation Studies

There are relatively few studies in New Zealand attempting to measure volumetric value of water to various end users. Part of the reason is that water scarcity was largely a 'non-issue' in New Zealand until relatively recently (whereas other regions, such as Australia and some parts of the United States, have a much longer history of scarcity and/or had episodes of severe droughts). Another reason is perhaps due to such perception of abundance, compulsory measuring of water intakes has not been introduced until just recently as part of the National Policy Statement for Freshwater Management.[9] One of the few valuation studies available actually stated that: "the value of water per cubic metre cannot be calculated as water use data is not yet available" (Doak, 2005, p. 2).

Grimes & Aitken (2008) use a hedonic pricing approach to value irrigation water in a drought-prone area in McKenzie District, Canterbury. This method values irrigation through estimating the

[9] Permit holder must now keep records of water taken (Satyanand, Anand, 2010). These regulations apply only to a takes of 5 liters/second or more.

difference between irrigated and non-irrigated farms' sales price and valuation, while controlling for spatial differences, such as distance from towns, rainfall, soil and slope characteristics. They find that flatter areas with poorly draining soils get the most benefit from irrigation, suggesting that it may be due to water being able to stay longer periods in these lands. Drier areas benefit more than wetter areas. The authors join the criticism of the RMA allocation mechanism by suggesting that some farms that may benefit from irrigation cannot get access to water rights because of existing regulation and lack of mechanisms of transferring water rights. The study finds that net returns of irrigation are negative to farms due to high investment costs.

The Ministry of Primary Industries [MPI] conducted an extensive study attempting to quantify the value of irrigation to New Zealand as a whole (Doak, Parminter, Horgan, Monk, & Elliot, 2004). They put the economic value of irrigation at $920 million[10] (in 2002/2003 dollars) by estimating a counter-factual scenario where currently irrigated land was used as dry land instead. Their method is as follows: they classify all agricultural land into 14 agricultural sectors in each region, subdividing each sector into irrigated and non-irrigated. Next, the authors acquire the difference in yields between irrigated and dryland production for each sector in each region based on specialist opinions. Finally, they decrease the yield on the irrigated farms to match dryland yields and thereby estimate the effect of irrigation. In their subsequent analysis they use yields to estimate the impacts of new irrigation systems, and consider the effect of varying output on sector output prices.

This study was updated in 2014 using NZIER's proprietary New Zealand Regional Computable General Equilibrium model (NZIER, 2014). Using the same methodology as MPI in 2004, the

[10] This figure includes their analysis of price changes resulting from sectoral output changes.

current value of irrigation was estimated to be $2.19 billion (in 2011/2012 dollars). With CGE methodology (which takes into account flow-on effects of irrigation to the rest of the economy) they find that without irrigation GDP would be 2.4% (or $4.8 billion) less.

Most recently, using a variety of imputation methods, Jenkins (2015) estimated the value of water to municipal, irrigation and hydropower generators. The cost of (treated) water supplied to residential and commercial consumers – as estimated by relevant local authorities – ranged between \$0.47/m^3 in Christchurch to \$1.91/m^3 in Tasman; the cost of irrigation water from irrigation schemes – as measured by cost of buy-in access amount allocated – was between \$0.0475/m^3 to \$0.32/m^3; and the value of each cubic metre of water to hydro-electricity generators was between $0.0057 (for one station at Opuha) to $0.036 (for 8 stations at Waitaki).

1.6. Methods of Valuing Water & Water Policy Analysis

Young (2005), in his treatise on determining the economic value of water broadly classifies methods of valuing water into two categories: inductive and deductive. Inductive techniques involve using formal econometric techniques to infer generalizations from individual observations, whereas deductive techniques involve "logical processes to reason from general premises to particular conclusions" (Young, 2005, p. 44). Inductive techniques include methods such as observation of water market transactions, hedonic pricing, choice modelling and estimation of production and cost function. Deductive approaches include mathematical programming; value added estimation, and computable general equilibrium modelling. The following will outline a selection of these methodologies.

1.6.1. *Observation of Water Market Transactions*

Perhaps the only true way to measure an item's economic value to users is by selling it in a well-functioning, full information market, devoid of externalities and market power. In Australia water market comes close to such, where the government established a water transfer system so that farmers are able to sell either temporary or permanent water rights. Temporary rights are the rights to fresh water takes in a particular year, whereas permanent water rights are the allocated water takes rights attached to a property. During the 2006 drought in Northern Victoria, temporary water rights have reached AU$1,200 per mega litre of water, and permanent water reached AU$2,400.[11] This arguably reflects rather accurately how users value freshwater since in this type of spot markets prices are determined through what sellers are actually willing to sell for and, perhaps more importantly if the government is the main seller, what buyers are willing to pay for.

For this method one would need to have a well-defined water market with clear definition and allocation of water rights. While technically allowed for in the provisions of the RMA, it is governed by the same rules as new allocations, hence any trades in water-stressed areas – such as in the case of Canterbury (close to or above full allocation) are governed as new applications and have to go through the same application evaluation procedures – which may or may not be granted and/or require certain conditions (HydroTrader, 2016) . There is some trading activing as part of HydroTrader website operational in the Canterbury Region. Jenkins (2014) noted that traded price was between $1.59/ m^3$ to $0.25/ m^3$ with an average of average of $0.88/m^3$ from 24 instances of trade available between May 2008 and September 2013.

[11] Rob O'Connor, personal communication, 12 May 2011.

1.6.2. *Hedonic Pricing Method*

This method is used extensively in resource economics and involves comparing the values of properties that are at various distances away from a particular environmental factor, while controlling for other variables (Harris, 2006). The price difference is then attributed to the non-market value of that particular factor. For instance, properties that overlook a river command a higher market price than properties of the same size right behind them. The price differential is then an estimate of the "shadow price" that buyers are willing to pay for access to the view – a non-market resource.

As described in Section 1.5, Grimes & Aitken (2008) use a hedonic pricing method to elicit the value of access to irrigation in Canterbury. Young (2005), however, notes that when actual water quantities are not used, it is not, strictly speaking a hedonic approach, but rather what he calls a "quasi-hedonic" approach. He also notes that hedonic pricing approach provides an estimate to "at source" water rather than "at site", as is normally measured by other methods, thereby resulting in higher estimates.

In addition, Young (2005) notes that to obtain meaningful results one needs to have access to a type of natural experiment – a selection of comparable agents scattered randomly with and without irrigation around the same area *and* corresponding property sales prices, while controlling for all other variables that may influence the sales price. To demonstrate the difficulty of obtaining the relevant data, even Grimes & Aitken (2008) had to rely on QV valuations to substitute for relatively low number of actual farm sales figures, hence casting doubt on the reliability of their results, since the derived irrigation value was estimated using figures based on regressions used by the QV valuation agency, rather than relying entirely on scant market price data.

1.6.3. *Survey Methods: Choice Modelling and Contingent Valuation*

Contingent Valuation [CV] basically involves surveying agents and asking them directly how much they would be willing to pay (or accept) for a particular good or service. The fundamental assumption being that the respondents' underlying preferences are revealed in their responses. Hanley, Mourato, & Wright (2001) note this method's original variant included open ended questions with regards to how much one would be willing to pay for a specific item described. This method, they note, suffered from cognitive burden and potential for strategic bidding.

Partly out of such concerns, during the 1980's methodology shifted to incorporate dichotomous choices. However, this method was also shown to suffer from strategic bidding: Posavac (1998) demonstrated that depending on the expectation of whether the actual cost was going to be *actually* incurred by the respondents altered their willingness to pay to a statistically significant level. Moreover, dichotomous choice CVs seemed to elicit substantially higher values than those elicited through open-ended questions, perhaps attributing to the "yea-saying" of the respondents (Hanley, Mourato, & Wright, 2001). Cummings & Taylor (1999) also note that a substantial number of CV studies are prone to "hypothetical bias", although various techniques to address issues have been developed. Finally, CV methods are also noted to be ill-suited with complex multidimensional changes and evaluation of a multiple number of policy options (Hanley, Mourato, & Wright, 2001; Blamey, Gordon, & Chapman, 2002).

Partly due to the shortcomings of CV methods, Choice Modelling [CM] (also known as conjoint analysis) approach became a more popular survey method. This method involves presenting respondents with choices in which attribute levels are varied across choice sets, and then asking the respondents to state their preferred alternative. This method is particularly suited for situations where choices are complex and involve a large number of varying parameters, providing researches with relatively more details on respondents' utility function than the CV approach (Young, 2005; Hanley, Mourato, & Wright, 2001). Since CM approach avoids direct questions with regards to the willingness to pay, through instead eliciting these values indirectly through analysing the choice preferences, it is argued CM minimizes some of the disadvantages of CV, namely strategic behaviour and "yea-saying" (Hanley, Mourato, & Wright, 2001).

There are, however, numerous pitfalls and considerations when designing a CM study, such as cognitive burden, serial status-quo answers and sensitivity to design (Caussade, Ortúzar, Rizzi, & Hensher, 2005; Rolfe & Bennett, 2009; Swait & Adamowicz, 2001). These issues will be discussed in more detail in the *Section 3* of this chapter and Chapters III and IV.

1.6.4. *Budget Residual Method*

A popular deductive method to derive value of water is through the Budget Residual Method. It involves subtracting the value of all non-water inputs away from total revenue of a firm, with the residual being attributed to the shadow price of water (P_W^*):

$$P_W^* = \frac{(Y \cdot P_Y) - \sum_{i=1}^{n} X_i \cdot P_i}{X_W} \tag{1}$$

Where

Y	Quantity of Output
P_Y	Price of Output
X_i	Quantity of input i
P_i	Price of input i
X_W	Quantity of water used

Adapted from Young, 2005, p. 61

However, this method requires detailed knowledge of quantities of water used – data that is currently mostly lacking in New Zealand context. Moreover, this method is very sensitive to specification of what constitutes inputs since they include owners' opportunity costs as well as depreciation of capital equipment, etc.

1.6.5. *Mathematic Programming*

Garrido (2000) suggest that the most popular method of analysing water markets in hypothetical situation is through mathematical programming. This method involves constrained profit maximization, where water quantity is varied to determine its impact on the firm's profit, thereby eliciting what water is worth to the agent. This entails accurate knowledge of a representative farm's production processes. Mathematic Programming through non-linear optimization has been extensively used in the dairy sector in New Zealand for evaluating greenhouse gas emission and nitrogen management policies (Doole, 2012; Adler, Doole, Romera, & Beukes, 2013). The same model can be used to compute shadow prices of unpriced inputs, such as 'feed energy' and 'marginal value of metabolized energy' (Doole, Romera, & Adler, 2013); and can also be used to estimate the shadow price of water.

1.6.6. *Computable General Equilibrium*

The effects of a drought, an introduction of volumetric water pricing or extensive irrigation schemes would be felt not just by industries directly relying on water, such as dairy and electricity production, but also by industries relying on these industries. They may include both their suppliers (such as fertilizer firms or farm labour for dairy), as well as their customers (electricity dependent producers for electricity generators). This inherent degree of interconnectedness between various sectors of an economy requires a modelling technique that is commonly not present in conventional cost-benefit analysis which typically only looks at the effects of the industry directly affected by an event.

One method to account for this interconnectedness is to use Regional General Equilibrium analysis, which essentially is using a simplified model of the whole economy where inputs (land, labour and capital) are converted into outputs by interconnected sectors of the economy. This approach is going to be discussed more thoroughly in the *Section 4*.

1.7. Selected Methodologies

The selected methodologies to address objectives set by this thesis are panel data analysis (Chapter II), choice modelling (Chapters III and IV) and CGE analysis (Chapter V). The reasons for choosing these methodologies include the authors' previous experience with such, the availability of suitable data, supervisors' respective expertise, and, perhaps more importantly, the deemed appropriateness to address the issues at hand. The next sections will outline each methodology in greater detail and review relevant literature pertaining to each method.

2. Estimating the Value of Water: Farm Panel Data Analysis

One problem with trying to elicit water value through methods that rely on hypothetical scenarios, such as survey methods, mathematical programming or residual budget analysis, is that agents' actions are largely theoretical: it is assumed that a farmer would actually pay however much s/he said s/he would, or that the said farmer would spend all of their residual on water – these actions are not observed. Methods such as hedonic pricing, observing market transactions and experiments, on the other hand, observe actual behaviour and arguably, if modelled correctly, provide more generally accepted and realistic values. As mentioned earlier, New Zealand largely lacks a functioning water market; hedonic pricing requires hard-to-obtain information; and ethical considerations and logistical difficulties would prohibit execution of meaningful randomized controlled trials. However, as outlined in the following section, it is argued that market-linked water value can be elicited through analysis of farms' marginal cost curves using readily available data of dairy farms. As mentioned earlier, dairy irrigation is the largest consumptive user of freshwater in New Zealand.

2.1. Theoretical Foundation

For any given profit-maximizing firm, a profit is simply the difference between its costs and revenues. For a dairy farm, the bulk of the revenue comes from sale of Milk Solids [MS]; hence the profit function, $\pi(Q)$, is as follows:

$$\pi(Q) = P \cdot Q - C(Q) \tag{1}$$

where

P	price of MS
Q	quantity of MS
$C(Q)$	the total cost of producing a set quantity of MS

Assuming that individual farmers are price takers in both output and input markets and that the profit function is concave at its maxima, a reduction in the payout for MS (i.e. a P decrease) would mean that the profit maximizing quantity of MS they produce decreases, and vice versa. Figure 1 illustrates this: when output price is P_0, a firm's profit maximizing output is Q_0 - where the difference between the Total Revenue $[TR]$ and Total Cost $[C(Q)]$ is the greatest. Stated differently, profit maximization (or loss minimizing) is at Q at which marginal costs equals marginal revenue ($C'(Q) = TR'(P,Q)$), subject to the second order condition (increasing marginal costs, or $C''(Q) > 0$). The firm's profit is the difference between the Total Revenue and Total Cost (Figure 2). When price falls to P_1, profit maximizing quantity decreases to Q_1.

Figure 1. Firms Total Revenue and Total Cost Curves

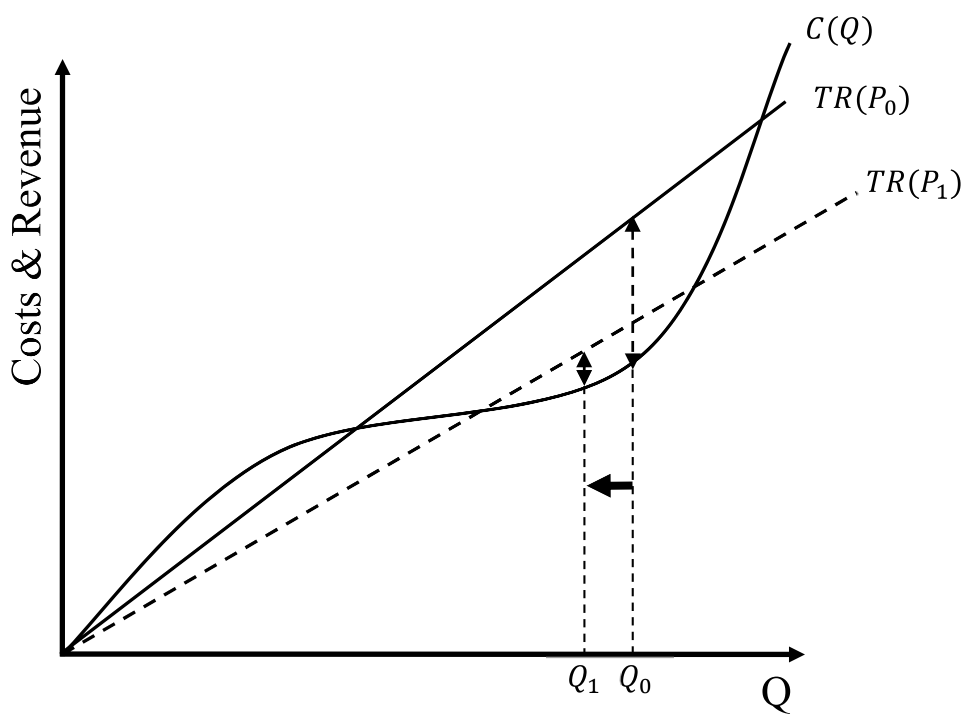
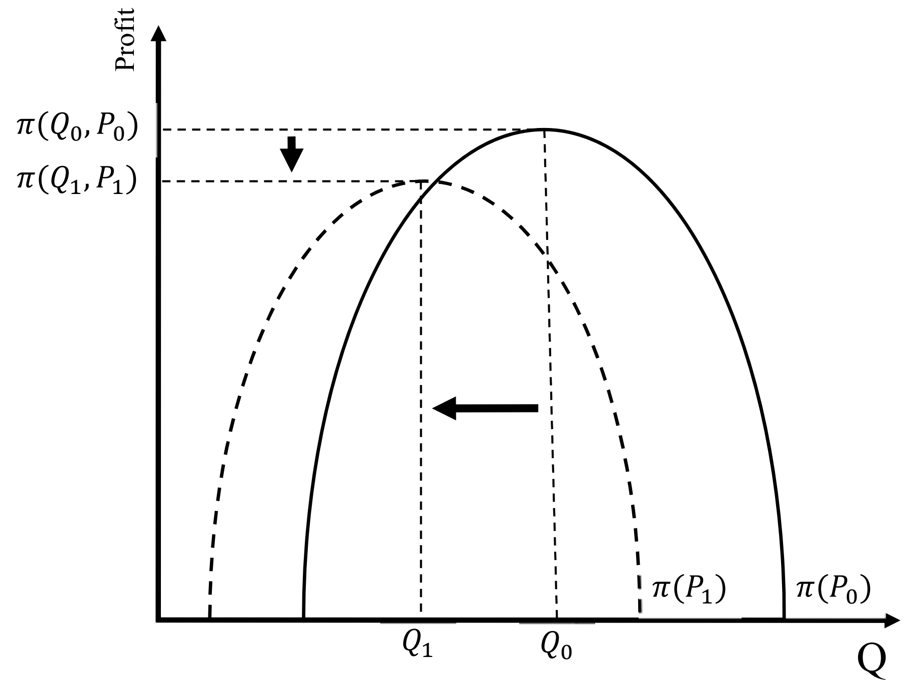


Figure 2. Firm's Profit Function



The total cost function, $C(Q)$, can be disaggregated into fixed (quantity invariant) and variable costs:

$$\pi(Q) = P \cdot Q - (C_F + C_V(Q)) \tag{2}$$

Where

C_F	Fixed costs (i.e. land, interest, etc)
$C_V(Q)$	All the costs that depend on the amount of MS produced (i.e. labour, supplementary feed, fertilizer, etc)

It is true that some variable costs can be considered to be as fixed costs in the short run, and hence would be incurred even if no MS production takes place. For instance, one would still purchase supplementary feed and pay for labour to distribute this feed to the stock, even if due to adverse climatic conditions the stock had to be dried off and hence no MS production took place. In such an instance, these costs would be considered fixed, and one would still be willing to incur them so as to preserve the cows in good health for the next year (a case of loss minimizing). However, these same costs (feed and labour) can be considered as variable if the MS payout is relatively high, and in order to produce more, one would be willing to incur these higher marginal costs since they would be offset by higher marginal revenue. Whilst the distinction can be somewhat blurry, the premise of the existence of output variant costs is paramount to this analysis, since in the absence of such a farmer would always produce a set quantity of MS, irrespective of both the price of the variable inputs and its output.

Qualitative study by Watters, Rowan, & Williams (2004) partially confirms the existence of this relationship as they conclude that there seems to be a "wide-spread inclination for farmers to respond to increasing prices through increasing input and production outputs" (p. 22). As one of their respondents confirms "if payout allows" s/he maintains or increases the use of fertilizer and brought in feed to increase the MS production.

Irrigation water is currently an unpriced good, or $P_W = 0$. If one were able to establish the relationship between the quantity of water used to produce a set quantity of MS, then the cost of that water would fall into the category of variable costs. This follows the logic that lowering the quantity of water would inevitably lower the amount of grass available for feed, and hence lower the amount of the MS production.

Including the water price per milksolid (P_W) in the equation – currently set at zero – would render the following equation:

$$\pi(Q) = P \cdot Q - C_F - C_V(Q) - P_W \cdot Q \quad (3)$$

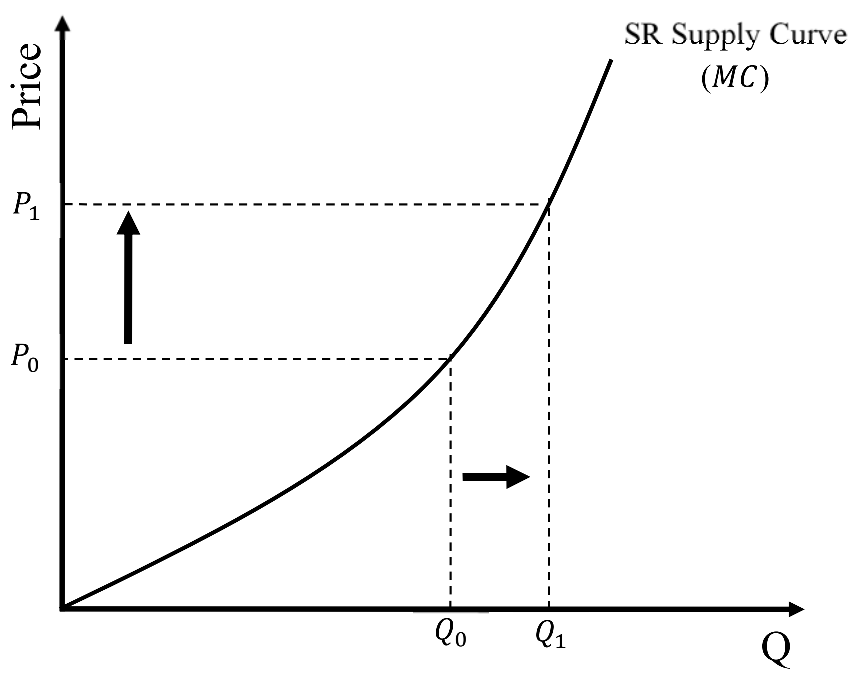
Again, term P_W is set to zero, hence (3) equals to (2), except that all the water used to produce Q has been explicitly accounted for in (3). Rearranging terms on the RHS of (3) results in:

$$\pi(Q) = (P - P_W) \cdot Q - C_F - C_V(Q) \tag{4}$$

Stated differently, profit is a function of quantity produced, equal to the revenue less cost of water minus fixed and all other variable costs. Increasing the price of water per Q would result in lower revenue less cost of water, and hence lower profits, resulting in lower profit maximizing quantity of production. The consequence of (4) is that increasing the price of water per quantity of MS (P_W) is equivalent to a decrease of the Marginal Revenue (P) of the same magnitude.

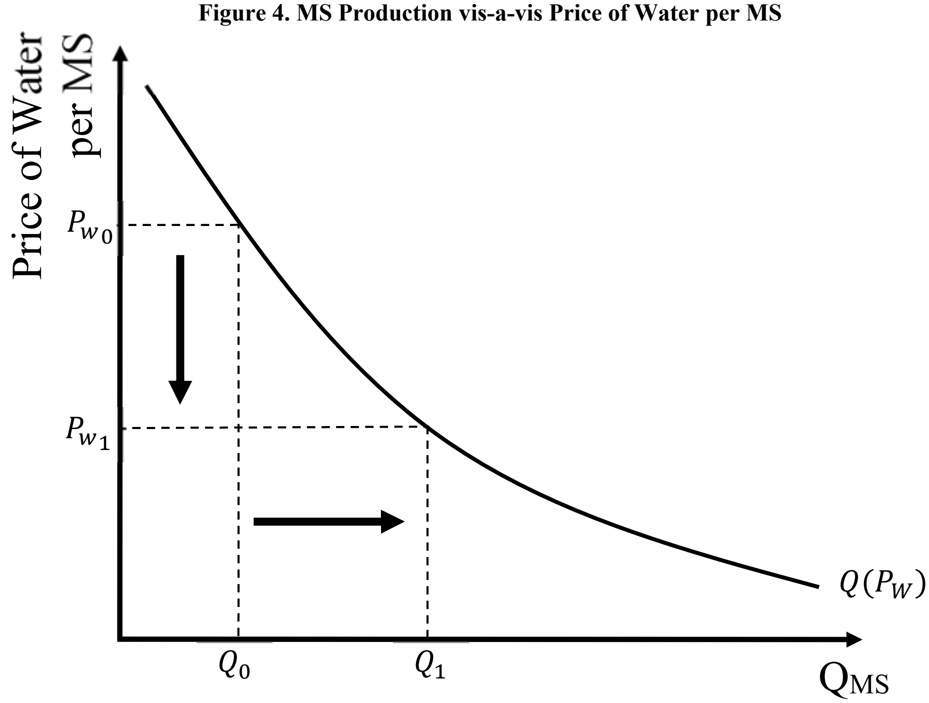
The relationship between price and quantity produced, controlling for all other factors, is relatively straightforward to determine – it is a firm's marginal cost or a short-run supply curve (Figure 3). A higher output price would encourage a producer to produce more (incur higher variable costs), and vice versa.

Figure 3. Firm's Short-Run Supply Curve (or MC)



Knowing by how much quantity of production (Q) would change following an increase in the marginal revenue (P) would reveal by how much Q would change following a decrease in price of water per Q (P_w) of the same pecuniary magnitude. Thus, a relationship between the price of water per Q and quantity of water per Q can be derived:

Figure 4. MS Production vis-a-vis Price of Water per MS



Once this relationship is established, it would further be possible to use it to derive a volumetric price vs. quantity relationship (i.e. dollars per gigalitre, etc) though determining the amount of water required to produce a given quantity of MS. The relationship between MS and water is indirect, since water is used to grow grass, which is then fed to the stock. Brown & Haigh (2005) while building an irrigation model of the Waikato Region suggest that the amount of dry matter [DM] – staple stock feed in New Zealand –per hectare grown from a set quantity of water depends on slope of the land, soil's response to irrigation, irrigation rates as well as type of feed grown. Additional factors that affect the total pasture growth per unit of water are the climatic conditions, fertilizer regime as well as time of the year. Thomson (1996) also suggests that grazing intensity as well as intervals between grazing periods provide a difference to the amount of DM grown under irrigation schemes.

Since the amount of DM grown using an amount of water varies significantly according to a number of factor, it would be impossible to produce one "universal demand curve" for water directly. What can be done, however, is defining the relationship between the quantity of water, DM production, *conditional* on various parameters, and subsequent MS production. The relationship between DM and MS production is well understood. DairyNZ (2010) provides an extensive list with formulas to establish MS production from DM which depends on a multitude of factors, such as how old the cows are, how far they have to walk, whether they are pregnant, their weight, whether the terrain is mountainous, etc. IntelactNZ (2010) suggests, as a rule of thumb, that 1kg of DM yields approximately 100 grams of MS, when taking into consideration a cow's sedentary requirement.

2.2. *Estimating the MC Curve*

2.2.1. *Data*

For the purposes of this research project, Ministry of Primary Industry [MPI] kindly agreed to grant access to their annual financial dairy monitoring survey data under a strict confidentially agreement. This data includes detailed annual accounts from dairy farms participating in the survey across major dairying regions for the last 11 years. Variables include revenues from all sources (mostly MS, but also cattle trade, among others), as well as all operating expenses, including feed, fertilizer, water charges, labour, electricity, as well as physical statistics such the quantity of MS, the number of cows and the stocking rates. Sample size for Waikato Regions is 45; Taranaki – 25;

Southland – 25; Northland – 20; Lower NI – 20; and Canterbury – 25. In addition, NIWA database is used to control for the effect of rain since more rain translates into more DM grown and hence higher MS production, potentially causing an identification issues if excluded. MS payout forecast data from Fonterra, New Zealand's largest dairy cooperative were used to estimate expected output prices.

2.2.2. *Methodology*

Since this data is longitudinal, which includes observations of farms within the same regions across time, a fixed effects specification was used. Farm systems within regions are likely to be relatively stable over time, hence an region-fixed effect, α_i, is specified in the model:

$$\mathbf{q}_{it} = \mathbf{x}_{it}\boldsymbol{\beta} + \alpha_i + \lambda_t + u_{it} \tag{5}$$

In addition, regulations, such as with regard to surrounding water quality and effluent management are likely impact all farmers at the same time, hence time fixed effect, λ_t, is also included. Independent variables comprised observables that were likely to influence the output of MS, $\mathbf{q}_{it}$ for farmer i in year t.

The coefficient on the MS pay-out variable, $\hat{\beta}_P$, could be interpreted as the marginal effect of price on quantity produced. Its negative, or, $-\hat{\beta}_P$, would be the effect of an increase in Price of Water per MS. This estimate then needs to be conditional on a range of factors coefficient (farm size, etc) which would yield a volumetric value of water.

2.3. Limitations

It should be acknowledged that there are limitations to this approach. Most notably is that varying levels of water utilization are likely influence the usage of other resources and hence the relationship between quantity and the price of water may not be an exact inverse relationship between price of output and quantity. For instance, if price of water were to exceed a certain threshold, farmers may well find it more profitable to buy feed instead of water (as in the case of Australia), hence demand for water would fall more sharply than predicted. However, such threshold is arguably irrelevant to this analysis, at least at this stage, where water is yet unpriced, and any price variations sensitivity analysis are unlikely to breach this threshold.

3. Estimating The Value of Water: Choice Modelling

The second approach as part of this PhD thesis to elicit the value of water is through use of Stated Choice Modelling. It may not actually matter how much water is required by a farm to maximize profit, but how much farmers *think* is required. Individual risk preferences may cause risk-averse farmers to value irrigation higher in the face of uncertainty over weather patterns and/or expected MS payout, exchange rate, etc. When combined with unpredictability of rain, particularly in the short run during the critical milking or calving periods, water demand may prove to be substantially more inelastic than predicted by a model based on annual aggregation. To address these issues, a CM study is carried out. The following will outline theoretical underpinning of CM and review the relevant literature.

3.1. Methodological Overview

3.1.1. *Random Utility Model*

As noted in section *1.6.3 Survey Methods: Choice Modelling and Contingent Valuation*, CM involves presenting survey respondents with a set of options with varying levels of different attributes, and asking them to pick or rank their preferred options. The theoretical framework of CM is based on Random Utility Theory (Alberini, Longo, & Veronesi, 2007). According to this theory, individuals always select an option that maximizes their utility subject to various constraints. This indirect utility of person i with respect to alternative j, V_{ij}, can be represented in the following form:

$$V_{ij} = \bar{V}(\mathbf{x}_{ij}, \boldsymbol{\beta}) + \varepsilon_{ij} \qquad (6)$$

The first component of the model, $\bar{V}(\mathbf{x}_{ij}, \boldsymbol{\beta})$, includes a vector of observed choice attributes (and individual characteristics in some specifications), $\mathbf{x}_{ij}$, and a set of unknown parameters, $\boldsymbol{\beta}$. The second component, ε_{ij}, is an error vector that captures unobserved to researcher choice attributes and individual characterises.

The deterministic component of the model, $\bar{V}$, can be represented as linear function of attributes and individual characteristics, as well as the individual's residual income $(y_i - C_{ij})$, if the price is one of the attributes:

$$\bar{V}_{ij} = \beta_0 + \mathbf{x}_{ij}\boldsymbol{\beta}_1 + (y_i - C_{ij})\beta_2 + \varepsilon_{ij} \tag{7}$$

In a simple case, when there are just two choices, $j = 0; j = 1$, the deterministic component of the each choice's utility takes on the following form (Cameron & DeShazo, 2011):

$$\bar{V}_{i0} = \beta_0 + \mathbf{x}_{i0}\boldsymbol{\beta}_1 + (y_i - C_{i0})\beta_2 + \varepsilon_{i0} \tag{8}$$

$$\bar{V}_{i1} = \beta_0 + \mathbf{x}_{i1}\boldsymbol{\beta}_1 + (y_i - C_{i1})\beta_2 + \varepsilon_{i1} \tag{9}$$

The difference between the utilities of two choices can be written as:

$$\begin{aligned}\bar{V}_{i1} - \bar{V}_{i0} = (\beta_0 + \mathbf{x}_{i1}\boldsymbol{\beta}_1 + (y_i - C_{i1})\beta_2 + \varepsilon_{i1}) - (\beta_0 + \mathbf{x}_{i0}\boldsymbol{\beta}_1 \\ + (y_i - C_{i0})\beta_2 + \varepsilon_{i0})\end{aligned} \tag{10}$$

Both the intercept and income drop out, since they are common across both choices, resulting in:

$$\bar{V}_{i1} - \bar{V}_{i0} = (\mathbf{x}_{i1} - \mathbf{x}_{i0})\boldsymbol{\beta}_1 + (C_{i0} - C_{i1})\beta_2 + (\varepsilon_{i1} - \varepsilon_{i0}) \tag{11}$$

The coefficient on the difference in cost attributes, β_2, is excluded from the matrix of other observables since it is used in determination of the willingness to pay $[WTP]$. By setting the difference between the utilities to zero, (i.e. $\overline{V}_{i1} - \overline{V}_{i0} = 0$), a money metric estimate of the person's i WTP_i can be derived:

$$WTP_i = (C_{i1} - C_{i0}) = \frac{[(\mathbf{x}_{i1} - \mathbf{x}_{i0})\boldsymbol{\beta}_1 + (\varepsilon_{i1} - \varepsilon_{i0})]}{\beta_2} \tag{12}$$

In more general terms, when there are more alternatives, the probability of choosing an option would be the highest if it commands the highest utility in a choice set:

$$\pi_{ik} = \Pr\left(V_{ik} > V_{ij}\right) \ \forall j \neq k \tag{13}$$

Substituting the linear functional form from (7) yields:

$$\pi_{ik} = \Pr\left(\beta_0 + \mathbf{x}_{ik}\boldsymbol{\beta}_1 + (y_i - C_{ik})\beta_2 + \varepsilon_{ik} > \beta_0 + \mathbf{x}_{ij}\boldsymbol{\beta}_1 + (y_i - C_{ij})\beta_2 + \varepsilon_{ij}\right) \ \forall j \neq k \tag{14}$$

This, similarly to the two-choice case, causes income and intercept to drop out, since they are common across choices, simplifying to:

$$\pi_{ik} = \Pr[\left(\varepsilon_{ik} - \varepsilon_{ij}\right) < \left(\mathbf{x}_{ik} - \mathbf{x}_{ij}\right)\boldsymbol{\beta}_1 - (C_{ik} - C_{ij})\beta_2] \ \forall j \neq k \tag{15}$$

The most common model to analyse discrete choices is Conditional Logit Model (Caussade, Ortúzar, Rizzi, & Hensher, 2005). This model was pioneered by McFadden who used it to examine discrete choices of urban travel – a methodological breakthrough for which he was later awarded a Nobel Prize in economics (Stock & Watson, 2007; Caussade, Ortúzar, Rizzi, & Hensher, 2005). Under the assumption that the error terms are identically and independently distributed with a standard Type I extreme value distribution, (15) can be re-written as:

$$\pi_{ik} = \frac{\exp(\mathbf{x}_{ik}\boldsymbol{\beta})}{\sum_{j=1}^{K} \exp\left(\mathbf{x}_{ij}\boldsymbol{\beta}\right)} \tag{16}$$

This, in turn, can be used to determine the log-likelihood function, which then allows for estimation of the vector of parameters, $\boldsymbol{\beta}$, using Maximum Likelihood estimation. Finally, willingness to pay for any attribute change can be calculated through:

$$WTP_i = -\frac{\mathbf{x_i}\widehat{\boldsymbol{\beta}}_{\mathbf{1}}}{\hat{\beta}_2} \tag{17}$$

3.1.2. *Experiment Design*

To carry out a choice experiment, one must decide on attributes and their respective levels, as well as how to arrange them with a specified number of choice tasks. Caussade *et al*. (2005) note that the design of CM study can have a significant impact on the results. Their literature review summarizes the studies that show that dimensions such as the number of alternatives per choice, the number of attributes, the levels of attributes, and the total number of choices have all shown to affect the elicited values. In their own study, however, they found that the most significant dimensions were the number of attributes (optimum at 9-10) and the number of alternatives (optimum at four). Rolfe & Bennett (2009) tested two- versus three-alternative specification and found that the three-alternative CM design provide a more robust model.

Recognizing large cognitive burden associated with considering all attributes of choices, Swait & Adamowicz (2001) examine strategies employed by respondents while making choices and conclude that faced with higher choice complexity (higher number of attributes and alternatives) respondents tend to focus more on brand effects and less on attributes, with higher instances of avoiding choice (i.e. they stick with status quo). Earlier work by Russo & Dosher (1980), who utilize eye tracking and debriefing, find that their respondents resorted to dimension reduction – simplifying choices by concentrating on fewer attributes – and ignoring magnitudes of attributes as cognitive burden reduction strategies.

3.2. Water Valuation Studies Using Choice Modelling

Choice modelling is a popular method of valuing water as an environmental public good (Young, 2005). Such studies usually examine consumers' willingness to pay for some sort of improvements in the quality of water (*for examples see* Blamey, Gordon, & Chapman, 2002; Marsh & Baskaran, 2009; and Peters & Adamowicz, 1995). Young (2005) suggests that the primary use of CM is in non-use valuation of environmental goods. Similarly, Rigby, Alcon, & Burton (2010) suggest that CM, in general, is not a preferred method to value water as an intermediate good. However, a number of recent studies employed CM in valuing consumptive use of water as well.

Rigby, Alcon, & Burton (2010) used CM methodology to reveal the marginal values of irrigation water in Campo de Cartagena, Spain. Their methodology included asking farmers to choose between two options for water contracts, which included such attributes as price, quantity of guaranteed water and quantity of additional water (from rain) bundled with probability of rain, to study the effects of uncertainty. The last attribute (with levels of 0.5 and 0.25) was shown to be a highly significant factor.

The authors also opted to exclude status quo choice in an effort to control serial non-participation, arguing that farmers would not want to opt for any option with a higher price than they already pay. This is an important concern pertaining to this study, since it is highly likely to be an issue as the price of water is currently zero and it is doubtful than any farmer would be willing to accept any mention of a water tariff. However, excluding status quo may inhibit elicitation of true willingness to pay, since the respondents' current status must be present to enable "to interpret the results in standard welfare terms" (Hanley, Mourato, & Wright, 2001), as is noted by the authors. In their defence, they refer to studies that excluded the 'opt-out' alternative in choice modelling studies. However, these studies are hardly compatible as they look at premium "ethical" food attribute (Carlsson, Frykblom, & Lagerkvist, 2007) and GE content on labelling attribute (Kontoleon & Yabe, 2003). The choice in the first study, arguably, commanded less emotional attachment to consumer since it was a non-necessity type of purchasing decision; whereas the second study outright confirmed the biasness of values elicited through exclusion of the 'opt-out' choice.

In another study, Barton & Bergland (2010)[12] conduct a choice experiment among farmers in Karnataka State, India, to evaluate hypothetical irrigation water pricing. The focus of the study was methodological development of status quo interpretation, since given the choice, most surveyed farmers (66 percent) showed preference to the status quo scenario, rather than choosing any one of the alternative scenarios with improved irrigation and a different charge (Barton & Bergland, 2010). The authors purport that by examining the farmer heterogeneity, meaningful and significant preferences can be derived from the status quo choice.

Finally Kunimitsu (2009) conducts a choice experiment among paddy rice farmers in Japan in an attempt to elicit the marginal value of water. The author's conclusion was that the marginal value of water was substantially higher than is currently charged, hence may hinder economic prosperity of rice farmers in Japan. A notable methodological difference is that the study used random parameter multinomial logit model (mixed logit). The researcher argued that preference parameters may vary across respondents, hence an error terms is added, $\boldsymbol{\beta} + v_i$, where v_i is a random error that accounts for unobservable attributes. This permits a relaxation of independence of the irrelevant alternative (IIA) assumption, which accounts for unobserved factors over repeated choices by respondents, and thus allows for different agents to have different tastes (University of

[12] Who similarly state that they are "unaware of previous examples using CE to assess the value of irrigation water" (Barton & Bergland, 2010, p. 322).

Berkley, 2000). With regards to non-participation, Kunimitsu reports that the opt-out rate was 28%. The author decided to exclude those responses from the analysis, noting that such exclusion did not influence the integrity of the results since there were no observable differences between those who decided to opt-out and other respondents. A relatively low opt-out rate is not surprising given the findings as the respondents clearly demonstrated lower willingness to pay than the existing market price.

3.1. Stated Choice Survey – Methodological Improvements

As per the overall objective of this thesis, the aim of the Stated Choice [SC] study is be to elicit the implicit value of water to farmers. The subset of farmers surveyed are farmers who currently have irrigation consents issued. In addition to eliciting the value of water, a special attention is given towards the issue of Attribute-non-Attendance [ANA] in SC surveys following a growing recognition in literature of its ubiquity. The following is an overview of this issue and relevant literature.

3.1.1. *Attribute non-attendance in DC Research*

A critical assumption in SC is that participants consider carefully all the information (attributes and their levels) presented to them when making a choice. One of the concerns within the field of discrete choice experiments [DCE] is the issue of attribute non-attendance, or participants' ignoring one or more attributes when making a choice. Participants are said to resort to heuristics, or a "method that uses the principles of effort reduction and simplification" (Shah & Oppenheimer, 2008, p. 207).

Swait & Adamowicz (2001) find that respondents use a simplifying choice heuristic as complexity rises (as measured by the number of attributes and choices via a measurement of 'entropy' the authors develop), and hence cognitive load increases. They incorporate the complexity measure into their model and conclude that choice complexity has the potential to influence the decision rule and/or utility structure of the respondents.

Araña, León, & Hanemann (2008) also examine the role of heuristics combined with the role of emotions,[13] as measured by Emotional Intensity Scale. They find that participants are more likely to deviate from the assumption of full linear compensatory decision rule (i.e. engage in heuristics) when their emotional intensity levels are high. Still, their analysis of heuristics was based on econometrics alone – they examined the experimental data and determine the heuristics used as opposed to directly observing participants.

In one of the earlier papers on the subject, Russo & Dosher (1980), tracked participants' eye movements when making discrete choices, in an attempt to examine decision strategies. This methodology included, first determining the participant's utility functions, then conducting immediate post-choice debriefing surveys of participants' own interpretation of the decision strategies. This methodology, however, would arguably be unsuitable for vast majority of applied DC surveys as the eye-tracking apparatus is rather invasive (even today, when they are still conducted at labs with specialized equipment) and the participants were arguably more likely to make sure they looked at each attribute and level as they were directly supervised to do that. Although the authors concede that simplifying heuristic practices are likely to happen (ignoring attributes and/or levels) their methodology did not address such issues directly.

Ball (1997) achieved similar results Russo & Dosher (1980) by tracing the information gathering techniques via a computer aided survey. In his study, participants needed to hover over attribute

[13] Defined as "stable individual differences in the strength with which individuals experience their emotions" (Araña, León, & Hanemann, 2008, p. 756).

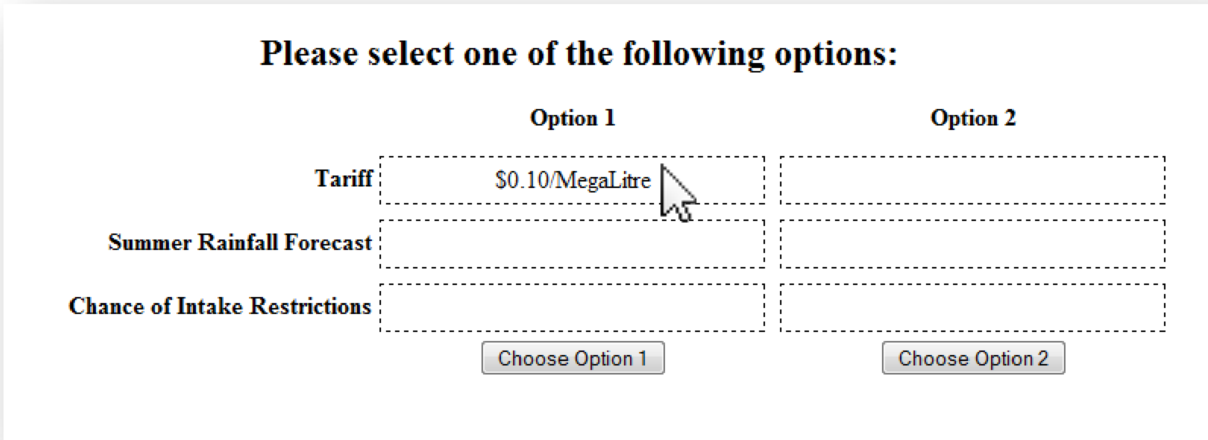
levels to see the actual values. Ball summarized the decision processes and heuristics involved. For instance, when choice complexity increased (the number of choices was high) some participants concentrated on just a few of the attribute to shortlist the alternatives. The study, however, stopped short of extrapolating the influence of the findings on the decision outcomes.

A study by Kaye-Blake, Abell, & Zellman (2009) similarly made use of computer-aided surveying whereby participants had to first click on the location of the concealed level of attribute on the information display board. Tracking this information enabled the authors to determine which attributes where ignored and which were instrumental in decision making. By collecting information on which attributes were ignored, the researchers were able to apply a zero weigh restriction on the individual coefficients when solving the model. Derived parameters were significantly different to those estimated under the assumption of full information gathering.

3.2. Selected methodology

Following Kaye-Blake, Abell, & Zellman (2009) and Ball (1997), an online survey script was created for the purpose of this thesis which would provide information with regards to participants' attributes non-attendance. Relevant attributes and their levels will be presented, with levels visible only when a respondent hovers their mouse cursor over the relevant attribute:

Figure 5. Screen-shot of a Choice Task



As the respondent hovers over each level, information of each event is recorded. This method provides information on any attribute-non-attendance and decision methods (whether attribute-by-attribute or choice-option-by-choice-option comparison), which is be incorporated in parameter estimation. The expected effects of ANA are first explored via a simulation analysis (Chapter III), then a SC survey is carried out, tracking ANA using the above stated method (Chapter IV).

4. Using the Value of Water: CGE Modelling

As part of the last chapter of this thesis, a Computable General Equilibrium [CGE] methodology is used to measure the impact of price or quantity changes of water on the New Zealand economy as a whole, as well as within regions. There is not currently a publicly available regional CGE model for New Zealand, and rather than creating one from scratch, an existing global CGE model (GTAP) is disaggregated to form the starting point for analysis. At the same time, irrigated water is introduced as a factor of production, allowing for analysis required for this research. The following will briefly outline CGE methodology. A detailed literature review of water-related CGE studies is presented as part of Chapter V. While in New Zealand only very few papers discuss water issues at any level using CGE analysis, there are numerous studies conducted in other countries that apply this analysis to water.

4.1. CGE Methodology Overview

Applied General Equilibrium analysis is a growing field of economic analysis since the proliferation of computational power, hence this method is commonly referred to as CGE analysis. At the very core, CGE analysis relies on a balanced input-output table of an economic region. A simple illustration of this system is presented by Table 2.

Suppose that an economy is made of just three sectors, namely Agriculture, Manufacturing and Power Production. In Table 2 rows of data demonstrate how outputs from that sector are consumed throughout the economy, by both final and intermediate users. For instance, the first data row shows that $20 mil worth of produce from the agricultural sector is used in its own sector as an intermediate good (like hay for dairy or seeds for planting), $15 mil worth of agricultural produce is used in the manufacturing sector (eg. fresh produce for value added processing) and none of the agricultural produce is used for power generation. In addition, $60 mil worth of produce is consumed by households and the same amount is exported. The row total, 155, represents the total output of the agricultural sector, both for final and intermediate use.

Table 2. A Hypothetical I/O Table of an Economy

	Intermediate Use			Final Use		
	Agriculture	**Manufacturing**	**Power**	**Household Consumption**	**Exports**	**Total output**
Agriculture	**20**	**15**	**0**	60	60	155
Manufacturing	**15**	**15**	**5**	90	15	140
Power	**10**	**40**	**5**	10	0	65
Imports	**5**	**5**	**0**	0	0	10
Labour	**50**	**5**	**5**	0	0	60
Capital	**55**	**60**	**50**	0	0	165
Total Inputs	155	140	65	160	75	595

Columns, on the other hand, show what it takes to produce the corresponding amount of output. In the first data column, again, it shows that it takes $20 mil worth of agricultural produce to produce $155 mil worth of agricultural output, as well as $15 mil worth of manufacturing inputs (like machinery), $10 worth of power (electricity required to pump water), $50 mil worth of labour and $55mil worth of capital. Row totals must equal to corresponding column totals, to reflect underlying assumption of market clearance. Thus, such representation of an economy incorporates the above mentioned interconnectedness of the sectors.

Predecessors of CGE analysis used such Input/Output [I/O] tables to analyse policy impacts directly by using technical coefficient through Leontief matrix multiplication. This method includes creating a matrix of technical coefficients, in which the elements represent the value of inputs required to produce \$1 worth of each product. Using the data from table above, this matrix is as follows:

$$A = \begin{bmatrix} 20/155 & 15/140 & 0/65 \\ 15/155 & 15/140 & 5/65 \\ 10/15 & 40/140 & 5/65 \\ 5/155 & 5/140 & 0/65 \\ 50/155 & 5/140 & 5/65 \\ 55/155 & 60/140 & 50/60 \end{bmatrix} = \begin{bmatrix} 0.13 & 0.11 & 0 \\ 0.10 & 0.11 & 0.08 \\ 0.06 & 0.29 & 0.08 \\ 0.03 & 0.04 & 0 \\ 0.32 & 0.04 & 0.08 \\ 0.35 & 0.43 & 0.77 \end{bmatrix} \tag{18}$$

The first column elements' interpretation is that it takes 13¢ of agricultural inputs to produce \$1 worth of agricultural outputs, ¢10 of manufacturing inputs, and so on. These proportions are assumed to be constant irrespective of the levels of production. The total demand, X,[14] is the sum of the intermediate demand and the final demand (which in this case is the sum of household consumption and exports). It follows that the total demand can be expressed as a sum of the final demand and the product of the matrix of technical coefficients and the intermediate demand:

$$X = B + AX \tag{19}$$

Rearranging the terms in (19) renders:

$$B = X - AX \tag{20}$$

Taking the common multiplier out on the RHS:

$$B = (I - A)X \tag{21}$$

In (21) the Leontief matrix is given as $(I - A)$, and its inverse can be used to express the total demand as a function of the final demand:

$$X = (I - A)^{-1}B \tag{22}$$

[14] Matrix is comprised of the first five columns and six rows in Table 2.

Using (22) it is possible to determine the impact on any values in X following a shock to the final demand, B (or any of it components, which in this case are the household consumption and exports). In other words, one could, for instance, estimate the impact of an increase in export demand on the whole economy by seeing how it would impact other sectors. Since an increase in export demand would necessarily require other sectors to produce more, which would, in turn require more inputs from other sectors and so forth, thereby an increase in export demand would actually cause a higher overall impact than the initial increase on an economy due to the stated interconnectedness of the sectors.

There are, however, significant drawbacks to the I/O method. First, input supply is unconstrained, meaning there is assumed to be an infinite amount of land, labour and capital available to each sector (Kaye-Blake, Schilling, & Zuccollo, 2010). Next, I/O analysis does not incorporate prices, thus, for example, more intensive use of land does not translate into higher land prices, and hence firms do not experience higher costs. Another consequence of price exclusion is that there is assumed to be no substitution effect between goods. Among other issues, I/O based models are inherently closed economic representations – any export/import shocks are exogenously introduced. As a result, Input/Output models have been shown to consistently overestimate the impact of various shocks (Partridge & Rickman, 2007; Kaye-Blake, Schilling, & Zuccollo, 2010).

CGE methodology addresses all of these issues and more. CGE models typically contain a set of supply and demand side behavioural equations, based on representative agents, that clear according to Walrasian perfect competition and market-clearing assumptions (Dixon, Parmenter, Powell, & Wilcoxen, 1992). The solution is essentially derived through solving a constrained optimization problem. The behavioural parameters representing agents are either econometrically acquired or based on informed opinions of the modellers (Strutt, 2010; Dixon & Rimmer, 2002).

Supply-side is typically structured so that primary inputs (land, labour and capital) can be substituted one for another using, for example, Constant Elasticities of Substitution [CES] - parameters, which may vary across industries. These incorporate how easy (or difficult) is it to substitute one input for another given a relative price change. Intermediate inputs can also be substituted with foreign inputs (as in the case of GTAP model), but with a distinct “home bias”, governed by Armington elasticities. Value added composite (comprised of combination of primary inputs) and foreign-domestic intermediate input composite are *typically* tied in together to produce the final sectoral output at set proportions, implying no substitution – using a Leontief elasticity function (Burfisher, 2011). The model then can be shocked to examine the effects of policy changes on the whole economy using a money metric equivalent welfare measures, as well as disaggregating and examining the effects on each sector, including output, employment and prices. In addition, dynamic variants of the models can also incorporate cumulative effects over time (static models do not have inter-temporal parameters) such as endogenous physical capital accumulation, financial asset and liability accumulation (though usually not included in CGE models) and lagged adjustment processes, as in the case of MONASH model (Dixon & Rimmer, 2002).

CGE models can be categorized according to the scale of analysis involved. Regional CGE models may incorporate just a small economic area within a country (as by Lennox & Diukanova (2010) of the Canterbury Region). Country-level analysis is possible through use of national models where the whole country is treated as a single entity (such as MONASH-New Zealand), or as an agglomeration of regions (such as TERM – discussed later). Finally, global models, most notably GTAP, may involve a multitude of interrelated countries and regions (usually grouped together for practical purposes) and are typically used to analyse trade agreements, and any shocks that are likely to affect a number of economies (Hertel, 1997).

4.2. Selected Methodology Overview

Creating a CGE model from scratch, particularly with a high level of disaggregation is a very large task, even without developing water market specifics, since currently national I/O tables are not readily available and parameter estimation requires expert knowledge of all the behavioural interlinkages among various sectors. The current study aims to avoid "reinventing the wheel" to the extent possible by starting with an already existing model. Hence, the Global Tariff and Analysis Project [GTAP] model is used as the starting point (Hertel, 1997). While normally reserved for analysis in global trade and lacking within country disaggregation, this model has advantages through being open source and being well recognized and understood. In addition, the dairy sector is the largest consumer of irrigation water in New Zealand, and since 95% of New Zealand dairy is exported (DCANZ, n.d.), trade dynamics play an important part of the outcome. To get the required level of disaggregation, New Zealand is disaggregated within GTAP using production data of various agricultural sectors (litres of milk produced for the milk sector, number of cows and lamb for the cattle-sheep sector, etc.). This is a "second-best" approach, since detailed regional decomposition would arguably more likely capture the dynamics of the interconnectedness of regions. However, even the most advanced New Zealand regional CGE model – NZIER's proprietary MONASH-New Zealand – is also built using a top-down approach (though weighting is done through sectoral employment) since New Zealand lacks regional input-output data (NZIER, 2010). Finally, water is introduced into the CGE using the methodology described in Calzadilla, Rehdanz, & Tol (2011). Irrigation data from Statistics New Zealand is used, as well as publicly available productivity comparisons between irrigated and non-irrigated sectors within regions. The resultant adjusted GTAP model and database enables simulation analysis, including regional decomposition, of water events including droughts, withdrawal restrictions and water charges.

5. Conclusion

New Zealand's current freshwater management system is pushing the limits imposed by the RMA. Many catchments are close to full allocation, and some prospective users are denied access because of the first-come-first-served principle. Any policy change requires detailed knowledge of how much is water is valued by each sector, so as to create a more efficient system of allocation, where users who value it the most get access to it first. Yet any decision must also respect any non-market values, including Māori rights, ecological, environmental and recreational.

This chapter outlined the motivation behind the planned area of study – New Zealand irrigation water valuation. This was accompanied by a review of methodologies, as well as an overview of the related literature. Since it was determined that pasture irrigation is one of the biggest (if not the biggest) user of freshwater in New Zealand, particularly during the summer when water is the most scarce, this study starts with a focus on this sector when estimating its value of water through short-run supply curve analysis. Next, a CM study is carried out, where farmers are surveyed in order to elicit their water values indirectly thorough the analysis of their choices. Particular attention is paid towards the issue of Attribute non Attendance within the choice experiment. Finally, the adjusted GTAP model is developed to assess the impact of water management policies (restriction and charges) as well as examining the impact of weather variability, such as during droughts and as a result of climate change.

6. References

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CHAPTER II: ESTIMATING AN AVERAGE DAIRY FARM'S DEMAND FOR WATER IN NEW ZEALAND

Kravchenko, A. (2014). Estimating an Average Dairy Farm's Demand for Water in New Zealand. In T. Bournaris, J. Berbel, B. Manos, & D. Viaggi (Eds.), *Economics of Water Management in Agriculture* (pp. 297-318). Boca Raton, FL: CRC Press.

CHAPTER

13

Estimating an Average Dairy Farm's Demand for Water in New Zealand

Alexey Kravchenko

Introduction

Freshwater is fast approaching over-allocation in many catchments in New Zealand [NZ] and regional councils are struggling to cope with the outdated, first-come first served principle of allotment enacted by the 1991 Resource Management Act (Land and Water Forum 2011). In all likelihood, some sort of demand management is going to be required to encourage efficiency of use among competing users, through instruments such as tariffs or regulated water markets. Either system will effectively raise the cost of water to users. Whichever system wins governmental support, it will require understanding of water users' responses to such increases. While this paper does not attempt to champion any particular method of solving the problem of water allocation, it does attempt to answer the question of response to changes in water cost to NZ's largest consumptive freshwater users—dairy farmers.

Department of Economics, Waikato Management School, The University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand.
Email: oak1@waikato.ac.nz

NZ water issues: background

Water is an essential building block of life. Not only is it a pivotal element in a vast number of economic activities such as agriculture, horticulture, industry, electricity, and tourism, but it is also a spiritual substance and is a taonga[1] for Māori. NZ is seemingly relatively abundant in freshwater. It has the fourth highest per capita total renewable freshwater resources among OECD countries of over 80 thousand cubic metres per capita (Fuentes 2011). By comparison, Australia and the US have approximately 15 thousand and 10 thousand, respectively. Even when coupled with its highest water abstraction per capita level in OECD, NZ is still third lowest in terms of abstraction vis-à-vis its relative freshwater endowment (Ministry for the Environment 2010a). However, "much of it needs to be retained in the rivers, lakes and aquifers to maintain the ecological, recreational, or cultural values", with only a relatively small portion allocated for consumptive use (Ministry for the Environment 2010a). For example, in the Waikato Region the default allocations for freshwater are only 5% for upland and 10% for lowland catchments of Q5—the low flow statistic derived from analyzing the frequency of seven consecutive day annual low flow in a catchment that has a 20% chance of occurring in a particular year (Waikato Regional Council, n.d.).[2]

The current system of water use allocation in New Zealand has been described as "first-come-first-served": whoever applies first for a resource consent obtains it first. There is a nominal fee for the application, and a limit is set on the maximum allowable intake, but otherwise the water from freshwater bodies and aquifers is virtually free. This system has been established by the Resource Management Act [RMA] of 1991 (Scrimgeour 1997). According to this legislation, regional authorities are entrusted with managing their territories' natural resources, including water. The Act stipulates a number of provisions specifically addressing the issues pertaining to freshwater management, including the settlement of limits of freshwater intakes, allocation of rights of freshwater intakes and other functions to maintain quality of water (NZ Parliament 2011).

When this system was established, there was little need for an alternative solution as freshwater was deemed to be an inexhaustible resource in NZ. However, with the proliferation of irrigated farming, as well as a general

[1] A **taonga** in Māori culture is a treasured thing, whether tangible or intangible.

[2] The council determines each catchment's environmental flow—the level deemed necessary for a particular catchment to maintain its environmental and ecological health—through setting it proportional to Q5. For example, the Waikato River at Hamilton is deemed to need an environmental flow of 140 cubic metres per second [cms]. Its Q5 is 156 cms, which means that 16 cms is available for allocation. The likelihood of flow falling below the environmental level is 20%, during which time water intake restrictions will apply.

growth from other competing needs of water such as hydropower generation (which accounts for approximately 60% of all electricity generated in NZ), ecosystem management, and recreation, among others, this system is fast becoming unable to keep up with its objective.

Table 1 shows the areas under the irrigation system in 2002 and 2007. Approximately 4.2% of all agricultural land in New Zealand is reported to be under an irrigation system.[3] South Island, Canterbury and Otago in particular, account for most of the irrigated land in NZ. Still, most regions

Table 1. Irrigable land by region (000's ha).

	2002	2007	2002	2007	2002	2007
	Total Agricultural Land[4]		**Total Area Equipped for Irrigation**		**Share of Total Ag. Land Equipped for Irrigation**	
Northland	810	765	7.0	8.7	0.9%	1.1%
Auckland	302	245	6.2	6.3	2.1%	2.6%
Waikato	1,730	1,600	12.7	16.6	0.7%	1.0%
Bay of Plenty	600	531	8.8	10.0	1.5%	1.9%
Gisborne	643	615	1.3	2.3	0.2%	0.4%
Hawkes Bay	962	952	18.2	25.2	1.9%	2.6%
Taranaki	497	470	2.9	3.4	0.6%	0.7%
Manawatu-Wanganui	1,545	1,417	8.0	11.7	0.5%	0.8%
Wellington	504	491	9.5	12.9	1.9%	2.6%
TOTAL North Island	*7,593*	*7,086*	*74.7*	*97.1*	*1.0%*	*1.4%*
Tasman	277	253	10.0	10.7	3.6%	4.2%
Nelson	21	18	N/A	0.3	N/A	2.0%
Marlborough	696	507	20.1	26.7	2.9%	5.3%
West Coast	225	200	2.5	0.6	1.1%	0.3%
Canterbury	3,151	3,080	287.2	385.3	9.1%	12.5%
Otago	2,379	2,331	68.9	91.1	2.9%	3.9%
Southland	1,198	1,178	4.1	7.5	0.3%	0.6%
Chatham Islands	49	47	N/A	N/A	N/A	N/A
TOTAL South Island	*7,997*	*7,615*	*393.0*	*522.2*	*4.9%*	*6.9%*
TOTAL NEW ZEALAND	**15,590**	**14,701**	**467.6**	**619.3**	**3.0%**	**4.2%**

Source: Stats NZ 2002, 2007a.

[3] According to Aqualinc 2010, the area of land consented to be irrigated differs slightly to this figure as not all area has been actually equipped to be irrigated, as defined by Statistics NZ.

[4] Farms using land for: tussock and danthonia for grazing; grassland; arable crop, fodder crop and fallow; horticulture; planted production forest; mature native bush; native scrub and regenerating native bush; and other (Stats NZ 2007b; Stats NZ 2004).

experienced double digit percentage growth of irrigated land area within the five year period.

Aqualinc Research reported in 2004 that in Waikato, surface water is close to full allocation and the current surface water allocation processes do not account for variations in seasonal demand (Aqualinc Research 2004, p. 15). So much so, that in 2006 Environment Waikato [EW] declined two applications to take "significant volumes of water from the Waikato River for the purposes of dairy farm irrigation" (EW 2008, p. 26). The applications were particularly opposed by hydroelectricity generators and municipal water suppliers (EW 2008). Similarly, other regions experience a growing number of declined resource consents due to increasing scarcity of allocative water.

In 2010, there were 20,500 active freshwater consents in NZ, 75% of which was for the purposes of irrigation (Aqualinc Research 2010). In terms of annual consumptive allocation,[5] irrigation constituted just over half of the amount. When considering top weekly consumption[6]—irrigation constitutes 78% of allocation (Fig. 1):

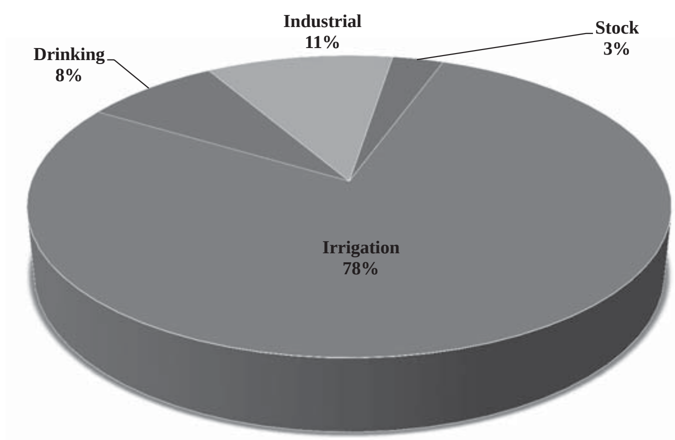

Figure 1. Top weekly consumptive allocation shares by sector.

[5] For drinking, stock water and industrial users, annual rate is calculated as weekly times 52. For irrigation, annual rate depends on the number of irrigating weeks typically 12 to 22 weeks.

[6] Consumptive use means the usage of water after which no other users can use the same water, like irrigation or domestic and industrial water use. Hydropower is generally not considered to be consumptive since water is later made available to users downstream, except in the case of Manapouri Hydropower Plant, which outlets the water to the Doubtful Sound. For the purposes of this analysis, the consumptive use of water by this power plant is omitted.

This higher relative and absolute demand is due to the seasonal nature of farming—planting and dairying seasons are predominantly in warmer months from October to March. Of all volumetric annual irrigation allocation, 81% of it is for pasture irrigation (or 76% of consented irrigated area in 2010). On top of the extra demand from farming, hydropower stations, due to the increased demand for air-conditioning in the summers, require more water to generate electricity. Unfortunately, this also coincides with the periods of lowest rainfall levels (Fig. 2):

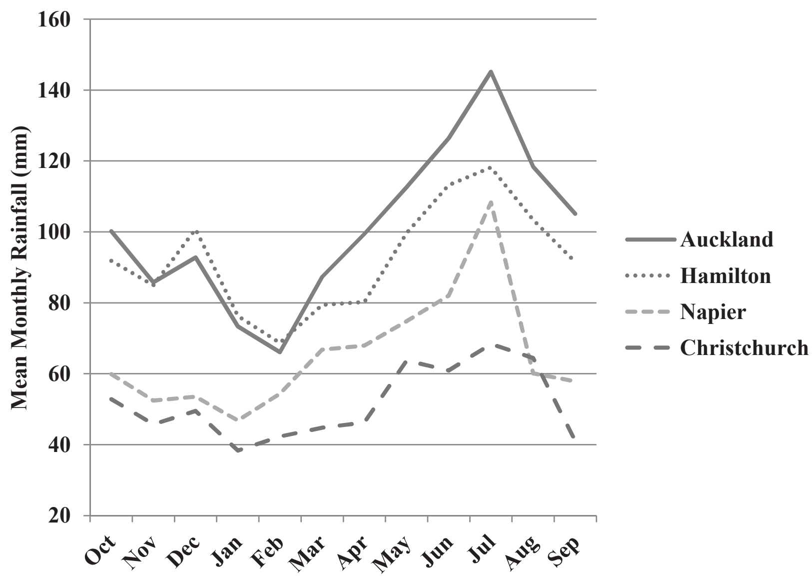

Figure 2. NZ monthly rainfall for selected cities.

Color image of this figure appears in the color plate section at the end of the book.

Fresh start for fresh water

Recognizing the growing need to better manage all the more scarce water, the NZ government commissioned a task force, Land and Water Forum [LAWF], to study the current freshwater situation in NZ and advise as to how it should be managed better (Land and Water Forum 2010). LAWF also concluded that many water catchments are fully allocated, or close to full allocation (Land and Water Forum 2011). They recognized freshwater's growing scarcity and recommended establishing more effective allocative processes than the "first-come-first-served" basis system currently in place.

The most recent report from the Forum specifically mentioned water pricing as a desirable mechanism to allocative efficiency (Land and Water Forum 2012).

Since there are competing users of water (such as domestic and industrial users, farms and hydroelectricity generators), who have a rivalrous water demand, it is imperative to establish a system that distributes water to users who hold it in the highest value. This requires actually knowing what that value is to various users. Since intakes of water so far have not been measured (in relationship to how much a user was consented to take or otherwise) and water being virtually free, for most users the value of water has not yet been adequately measured.

In order to establish a functioning water market, it is first necessary to measure the value of water, and, subsequently, estimate users' sensitivity to its pricing. At this stage, however, little research has been conducted with regards to the actual of value of water in NZ, much less with regards to users' sensitivity to pricing.

White et al. (2004) reported that estimates of the value of water in New Zealand, let alone elasticities, are few. This is partly due to the perception that water quantity is not an issue in New Zealand and partly due to lack of suitable data (as discussed below). They put the figure at $0.2/m^3 for field and stock watering. It is derived from observing the land values without stock watering as well as per animal consumption of water, and contrasting it against property values with stock water (hedonic pricing method).

McDonald and Patterson (1998, as cited in Ford et al. (2001)) presented results of using a value added technique to determine the value each cubic meter of water generated through various industries. These estimates ranged from an average[7] of $2,783 per m^3 in wood and wood product category to $12.3 per m^3 in horticulture. The authors, among others (see Niewoundt et al. 2004; Young 2005; Schiffler 1998), cautioned against reaching any conclusion based on the figures obtained through this method since production in different sectors also requires other inputs.

In one of the few NZ academic studies, Grimes and Aitken (2008) addressed the subject and used a hedonic pricing approach to value irrigation water in a drought-prone area in McKenzie District, Canterbury. This method valued irrigation through estimating the difference between irrigated and non-irrigated farms' sales price and valuation, while controlling for spatial differences, such as distance from towns, rainfall, soil and slope characteristics. They found that flatter areas with poorly draining soils received the most benefit from irrigation, suggesting that it may be due to water being able to stay longer periods in these lands. Drier

[7] Averages based on Northland, Auckland and Waikato Regions (Ford et al. 2001).

areas benefited more than wetter areas. The authors joined the criticism of the RMA allocation mechanism by suggesting that some farms that may benefit from irrigation cannot get access to water rights because of existing regulation and lack of mechanisms of transferring water rights. The study found that net returns of irrigation were negative to farms due to high investment costs.

Ministry of Primary Industries [MPI] conducted an extensive study attempting to quantify the value of irrigation to New Zealand as a whole (Doak et al. 2004). They put the economic value of irrigation at $820 million[8] (in 2002/2003 dollars) by estimating a counter-factual scenario where irrigated land was hypothetically used as dry land instead. Their method was as follows: they classified all agricultural land into 14 agricultural sectors in each region, subdividing each sector into irrigated and non-irrigated portions. Next, the authors acquired the difference in yields between irrigated and dryland production for each sector in each region based on specialist opinions. Finally, they decreased the yield on the irrigated farms to match dryland yields and thereby estimated the effect of irrigation. In their subsequent analysis they used yields to estimate the impacts of new irrigation systems, and considered the effect of varying output on sector output prices.

Since the recent emphasis of freshwater management restructuring, MPI commissioned the New Zealand Institute of Economic Research to conduct a study using their proprietary Dynamic CGE model to measure the impact of increased irrigation in New Zealand (Kaye-Blake et al. 2010). While this study did not consider pricing of water per se, it did consider the changes in productivity of various sectors' post-irrigation schemes installations, as well as the costs of installing the schemes.

As Doak (2005) noted, "the value of water per cubic metre cannot be calculated as water use data is not yet available" (p. 2). Indeed, it was only in November 2010 that regulations requiring recording of volumetric intake of water came into effect for new consents (Ministry for the Environment 2010b). Still, this study targets to provide a starting point estimate of the farms' short-run (annual) responses to at-site (irrigation cost inclusive) changes of water costs based on panel data analysis of dairy monitory survey data.

Analytical Framework

Scheierling et al. (2004), in their meta-analysis study, summarized the price elasticities of the derived demand for irrigation water using various

[8] This figure includes their analysis of price changes resulting from sectoral output changes.

techniques since the 1960s. Their conclusion was that results obtained through different methods vary to a great extent partly because different methods were used: mathematical programming studies over-estimated elasticities, and field experiments produced the least elastic estimates (econometric studies were in between). Schiffler (1998) noted that the most common way of determining the value of water as an intermediary good is through residual imputation method.[9] In this method "the value of all non-water factor inputs is subtracted from the total value of products generated by an agricultural activity" (Schiffler 1998, p. 42). However, due the lack of accurate water usage data such approaches seemed unfeasible, and hence a unique approach has been developed specifically for the case at hand.

The main premise of this study is that farmers are rational economic agents and respond to changes in incentives by altering their production—the higher the expected profit the more they produce. Indeed, a qualitative study by Watters et al. (2004) partially confirmed this as the authors concluded that there seems to be a "wide-spread inclination for [dairy] farmers to respond to increasing prices through increasing input and production outputs" (p. 22). As one of their respondents suggested, "if payout allows" s/he maintains or increases the use of fertilizer and brought-in feed to increase the milk solid [MS] production.

Perhaps a more economically rational observation is that higher profitability (measured as an output-input price ratio) induces higher levels of production, and vice versa. Hence, an increase in the cost of water would essentially be the equivalent of a reduction in profitability, thus lowering the incentives for extra production. One possible way to visualize this relationship is considering what would happen if a hypothetical water tax for each milk-solid sold was introduced on the portion of the farm's supply relying on irrigation (Fig. 3). If the output price remained unchanged, quantity supplied would fall from Q_0 (quantity of MS produced due to irrigation prior to water tax) to Q_1 (post introduction of water tax). An important feature to note is that production due to irrigation would cease altogether if output/input price ratio falls below unity since the cost of paying for one unit of production would exceed the revenue received (i.e., average variable cost would become higher than marginal revenue). Note too, that the quantity of MS produced in the rain-fed production process would remain unchanged.

Finding a relationship between the volumetric cost of water and farmers' responses one needs to know:

1. the relationship between the quantity of water required for production of each milk-solid, and;

[9] Also known as farm budget residual method when estimating value in the agricultural sector (Schiffler 1998).

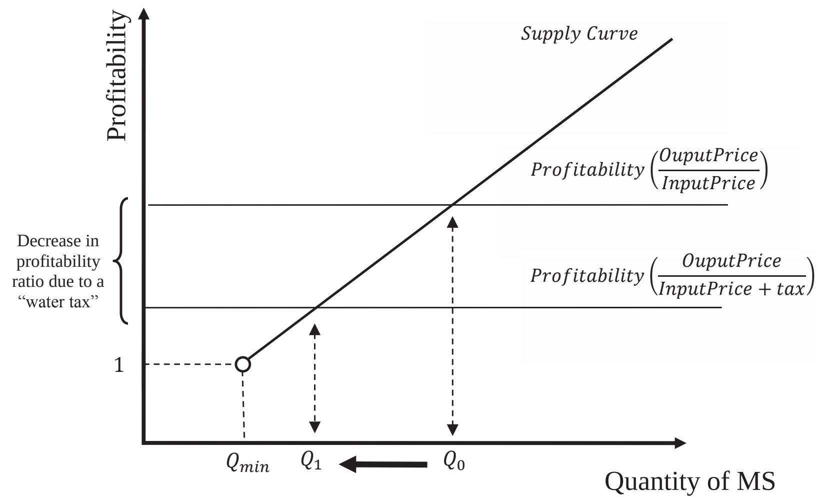

Figure 3. Effect of a hypothetical water tax on production.

2. the relationship between the output variations due to changes in the expected output-input price ratio.

The relationship between a volumetric unit of water and corresponding yields of kgMS production can be derived from the literature on pasture response to irrigation. It is conditional on the slope of the land, soil type, irrigation rates, grass type, fertilizer regime, climatic conditions as well as time of the year (Brown and Haigh 2005; Thomson 1996). Average responses will be used in the following explanation. In the study of predicting future demand for irrigation in Waikato, Brown and Haigh (2005) find that, on average, an extra millimeter of irrigation yields an additional 9.3 kg Dry Matter per hectare (DM/ha). In Canterbury, using an average of 7 irrigations of 100 mm per season yielded an increase from of 6.7 t DM/ha to 11.9 t DM/ha on average, or 5,200 kg/700 mm = 7.4 kg DM/ha per 1 mm (McBride 1994). In Taranaki, the average yield response to 1 mm of irrigation is similarly 7.56 kg DM/ha/year, ranging from 3.9 kg to 10.1 kg DM/ha/year on average across zones (Rout 2003).

In terms of relating DM to milk-solids, numerous factors affect cow productivity, such as cow weight, breed, distance needed to walk, topography of pasture, etc. (as well as the quality of DM itself). DairyNZ (2010) suggests that annual dry matter requirements for 350 kgMS/year producing Jersey weighting 400 kg that walks 4 km/day on flat land and is in milk for 270 days requires 4.6t DM + 6% of wastage = 4.9 t DM. Hence, each kg of DM would yield 350/4,876 = 0.072 kgMS. It follows that, *on average and conditional on a range of factors*, if 1mm of irrigation yields 7.4 kg DM/ha annually (in Canterbury), it is transferred into 7.4 * 0.072 = 0.52 MS/ha/year. Since 1 mm on a hectare is equivalent to 10 m^3, then it follows that it takes approximately 10/0.52≈20 m^3 of irrigated water to produce 1 kgMS.

The relationship between the change in the expected output-input price ratio and corresponding change in output is the subject of subsequent data analysis. It seeks to establish a correspondence between expected profitability (as measured by the output-input price ratio) and its effect on a farm's output in terms of kgMS, while controlling for other factors. Once such relationship is established, it would mean that the coefficient on the output-input price ratio could be interpreted as the expected change of an average farm to a change in profitability, due to an introduced "water tax wedge". Since only a portion of production on farms is due to irrigation, the effect would only apply to that portion (rain-fed production would remain unchanged).

Data

The data has been provided by the Ministry of Primary Industries [MPI] for the purposes of this research. It is an unbalanced panel data of a sample of dairy farms throughout New Zealand's main dairying regions over 11 financial years (from 2000 to 2011), with a total of 1,508 observations. Farm-level data available and used includes the total kgMS produced, effective farming area (in hectares), number of cows and total expenditure (see Table 2 for summary statistics). Additional series, namely precipitation, price indices and payout data were merged as described below.

Table 2. Summary statistics.

	No. of cows	kgMS	area	Total expenses
Mean	384	137,683	153	438,597
Median	330	110,116	127	330,518
SD	236	101,130	95	367,731
Min.	79	15,000	30	56,723
Max.	2,200	800,000	884	3,339,402
Normality Test Statistic	5,225*	6,070*	3,968*	5,991*

*indicates p-value <0.0001.

Output-weighted expected payout and profitability ratio

New Zealand dairy farmers' largest source of income is through the sale of MS to their cooperatives, the biggest being Fonterra (accounting for approximately 90% of all milk production in NZ). The majority of famers do not have the scale to exercise market power, and hence are bound by the payouts. The payout per milk-solid consists of a farmgate milk-solid price as well as a profit share (Distributable Profit—formally known as "value added components") from the profit of value-added activities of the cooperative.

Although farmers receive advance payments to aid their yearly cash flow, the final payout is usually announced well into the next production season (usually around September, whereas the milking season coincides with fiscal calendar and ends at the end of June), hence it has no effect on farm production in the corresponding milking season. What motivates short-run variability in the production is the forecasted payout—or how much the cooperative predicts the final payout to be. After the opening forecast at the start of each season, the cooperative updates its forecast, which is driven by such factors as currency fluctuations, international dairy auction prices as well as the expected profit from the value-added activities.

As per Fig. 4, initial forecasts sometimes substantially differ from the final payout. For instance, in the 2009/2010 season, the opening forecast was only \$4.55 whereas the final payout was actually \$6.55, making the actual payout an inadequate measure of farmer short-run incentive.

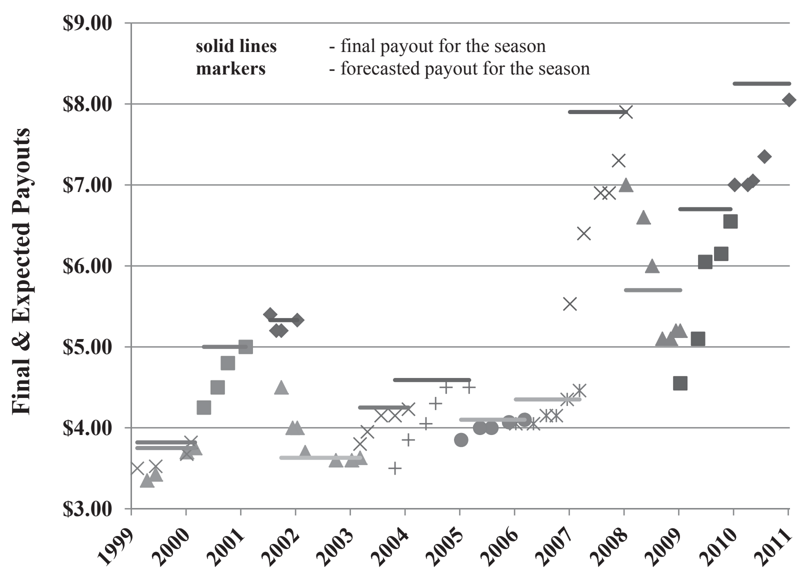

Figure 4. Forecasted vs. Actual Payout.
Source: Fonterra 2000–2012.

Color image of this figure appears in the color plate section at the end of the book.

To obtain a more reliable incentive indicator, an output-weighted forecast (O-W forecast) measure was developed, where the forecasts were weighted by the quantity of MS produced NZ-wide when each forecast was in effect. For example, the opening forecast for the 2009/2010 season of $4.55 was updated on 22nd September, 2009 to $5.1. Between the start of the season and 22nd September, approximately 205,340 thousands of kgMS was produced NZ-wide (DCANZ 2012).[10] This corresponds to 14% of the 1,438,496 thousands kgMS produced in the 2009/2010 season. Hence, for 14% of the total production, the expected payout was $4.55 (see Fig. 5). Similarly, for 23% of the total 2009/2010 production, the forecasted payout was $5.1, for 43% it was $6.05, for 17% it was $6.15, and for 4% it was $6.55. Weighting each forecast by the proportion of milk produced NZ-wide in the period the forecast was effective results in average weighted expected payout for the season (output-weighted forecast) of 0.14*$4.55 + 0.23*$5.1 + 0.43*$6.05 + 0.17*$6.15 + 0.04*$6.55 = $5.65.[11] Detailed data on NZ-wide total MS production was available only for seasons 2008 through 2011, hence for other years, the average of four years of available total production record was used. Table 3 summarizes the disparity between the final payout and the OW forecast.

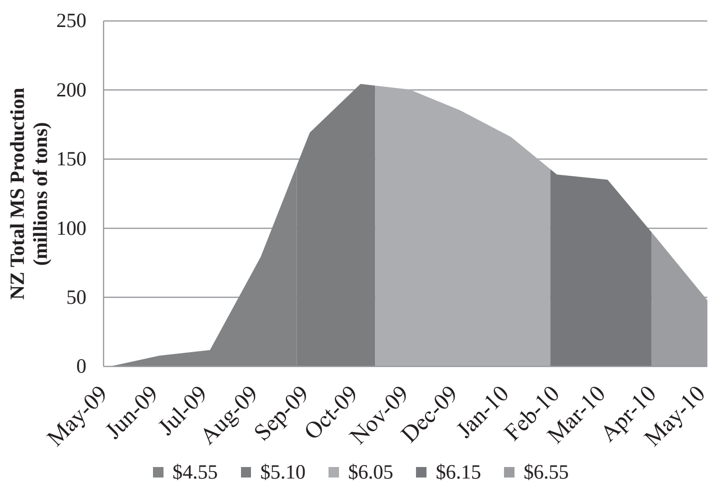

Figure 5. Output-weighted forecast estimation.
Data Sources: DCANZ (2012); Fonterra (2009, 2010).

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[10] DCANZ (2012) only published monthly MS production data, hence the cumulative production up to 22nd September was linearly extrapolated using the end of August and end of September cumulative production figures.

[11] Figures may not add up due to rounding.

Table 3. Output-weighted Forecast vs. Final Payouts.

Season	O-W Forecast	Final	Difference
2010/2011	7.19	8.25	1.06
2009/2010	5.65	6.70	1.05
2008/2009	6.05	5.70	–0.35
2007/2008	6.60	7.90	1.30
2006/2007	4.10	4.35	0.25
2005/2006	3.98	4.10	0.12
2004/2005	4.18	4.59	0.41
2003/2004	4.03	4.25	0.22
2002/2003	3.68	3.63	–0.05
2001/2002	5.30	5.33	0.03
2000/2001	4.43	5.00	0.57
1999/2000[12]	3.40	3.75	0.35

While the nominal payout more than doubled between 1999/2000 and 2010/2011 seasons, the costs of production and costs of living have likewise risen (Fig. 6). The cost of producing (Producer Price Index (PPI))

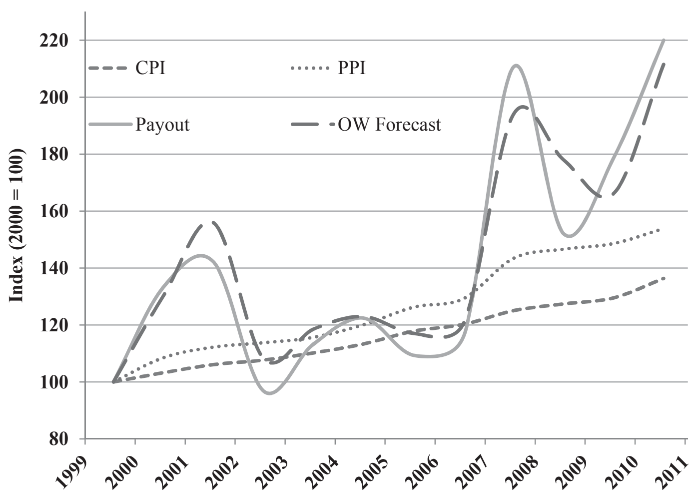

Figure 6. CPI, PPI and Payout Indices (1999 = 100).

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[12] For the 1999/2000 season the NZ Dairy Group forecasts and final payout were used for the purposes of the analysis since this was prior to the establishment of Fonterra.

has risen at a substantially faster pace than cost of living (Consumer Price Index (CPI)).

To adjust for the changing rates of price increases, as well as to mitigate for multicollinearity which would arise since the year and region dummy variables would be perfectly collinear with the same payout experienced by each farm, an output price/input price ratio (O/I ratio) was calculated for each farm. This ratio could be interpreted as profitability ratio, and hence changes in profitability due to either changes in payout or costs per each MS could be interpreted as having the same effect. In lieu of higher payout (output price) or lower expense (input price), the ratio would increase and hence motivate higher levels of production—a supply curve. Moreover, logistic transformation of the ratio could be interpreted as price elasticity of supply (Tauer 1998). As per Fig. 7, the expectation adjusted O/I ratio is centered just above 1.5 and is relatively steady over time except for the low payout year of 2003 and high payout year of 2008.

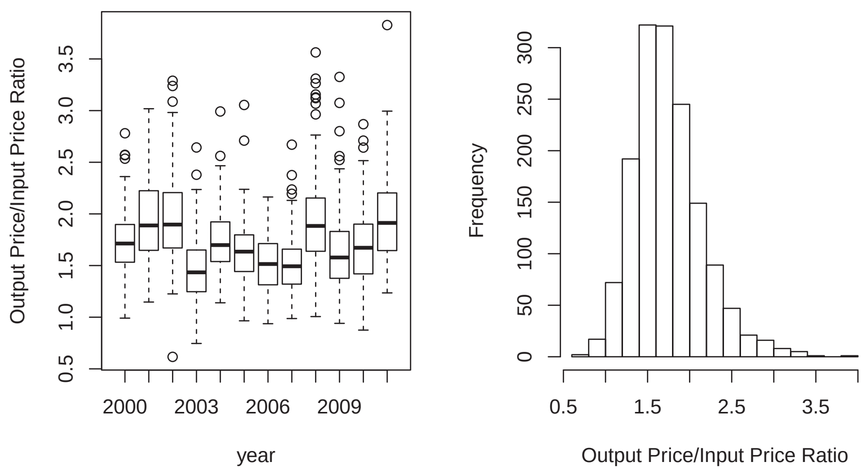

Figure 7. Output price/input price ratio across years and its distribution.
Data Sources: Statistics NZ (2012); Fonterra 2000–2012.

Precipitation

For each dairy region in the sample, a representative weather station was selected from the National Institute of Water and Atmospheric Research [NIWA] weather database and corresponding monthly total rainfall (in mm) was obtained. For each region and each production season, months November through April were selected, deemed to most impact the variation in production. Since both seasons, extremely wet (as in 2003) and extremely dry (in 2008), can potentially negatively affect DM growth, the rainfall variable for each region was first centered on the mean in each corresponding region, then split into negative and positive deviations from it.

Results

To derive the relationship between the O/I ratio and output, total production of kgMS in a year from individual farms was regressed on the available explanatory variables. Table 4 summarizes the results of the model. The following describes each variable and their significance.

The number of cows (*cows*) was included to control for the scale of farms. Having the most explanatory power, the coefficient suggests that an additional cow can add extra 413 kgMS. This is somewhat larger than the average MS production per cow in the sample (344), but in line with the averages from recent years. Interestingly, variables attempting to control for the intensity of dairying—*stocking_rate* and *area* were not found to be statistically significant in most regressions. While farming area is highly

Table 4. Regression output.

Regressor	Dependent Variable: **Total kgMS**
cows	413*** (15.6)
dry_year_rain (mm)^{CR}	52.8*** (10.5)
wet_year_rain (mm)^{CR}	–26.0** (8.0)
OI_ratio	10,865*** (1,704)
OI_ratio × *stocking_ rate*^{C}	–4,183** (1,368)
OI_ratio × *area* (ha)^{C}	–48.7** (18.9)
Standard Error of Regression	23,390
R^2	0.947

Robust standard errors are given in parentheses under coefficients. Individual coefficients are statistically significant at the **1% or ***0.1% significance level. ^{C} denotes that the variable was centered by subtracting the mean of all observations in the sample, while ^{CR} indicates that the variable was centered with the mean of the corresponding region. 1999/2000 season and CANDY region dummy variables were omitted from estimation to avoid perfect multicollinearity with the intercept. Heteroskedasticity adjusted *F*-statistic testing whether all year dummy variables are zero is 5, (*p*-values < 0.0001); and 44.0 testing that all region dummy variables are jointly insignificant.

correlated with the number of cows (r=0.82), suggesting low efficiency due to multicollinearity, lack of explanatory power of the stocking rate is harder to explain.

Next, positive and negative deviations from the region's average rainfall for months November through April were added to control for weather. Note that the coefficient on extra mm of rain in a dry year above the average (*dry_year_rain (*mm*)*) is 52.8, which, when divided by the average farm size (153 ha) yields a marginal effect of 0.35. This is smaller than the effect of 1mm/ha of *irrigation* on MS production derived earlier—0.52 MS/ha/year (page 308)—and is in line with expectations since watering from *rainfall* (unlike from *irrigation*) does not follow an optimal schedule intended for maximum pasture growth.

The effect of rain in a wet year has expected signs (exceedingly wet seasons slow down grass growth and bog down cows) and is less than half the size of the effect in a dry year.

The model also includes dummy variables for time and region specific effects. The rationale behind this fixed effects specifications is that in each year there are explanatory factors omitted that are shared among all farms (such as economic outlook and confidence); whereas some effects are likely to remain constant across time, but shared among neighboring farms (e.g., regional climatic attributes). Inclusion of the dummy variables ensured that these time and region specific effects (although unobserved) are controlled for.

The coefficient on *OI_ratio* has an expected sign, but a comparatively low magnitude, suggesting a low responsiveness of farms to changes in output and input prices. Logistic transformation of both sides of the regression yielded a coefficient of 0.16, which can be interpreted as the price elasticity of supply—a 1% change in price ratio triggers only a 0.16% change in quantity supplied. This inelastic response suggests that farms have low flexibility in the short-run, due to constrained fixed resources (number of cows and land) and diminishing marginal returns to variable inputs (irrigation, fertilizer and feed).

Farm size (*area*) and farming intensity (*stocking_rate*) were included as interaction terms with the *OI_ratio*, and their significance suggests that the effect of expected profit varies with farm sizes and farming intensity. Each interaction was centered by subtracting their respective means, so that interpretation of *OI_ratio* can be taken as that of a farm with an average stocking rate and farm size. Smaller farms and those with lower farming intensity tended to be more flexible when output/input prices changed.

The main advantages of centering of *area* and *stocking_rate* variables at their respective mean values are that the estimates on the variable of interest (*OI_ratio*) remain comparable with estimates from the models that do not include such interactions; and that the coefficient on the variable of interest itself remains meaningful—as opposed to if the interactive terms were unscaled, and the coefficient on the *OI_ratio* would be evaluated for a farm with zero area and zero stocking rate (Woolridge 2003). Although interactions under linear transformation lack scale in variance, Aitken and West (1991) show that post-hoc analysis of interaction is not affected by such scaling. Furthermore, the authors demonstrate that centering has an additional advantage of reducing the chance of multicollinearity of with the original multiplicative terms, thereby increasing the efficiency of the estimates.

The conditional effect of the *OI_ratio* is estimated to be 10,865 kgMS for a unitary change in the *OI_ratio* for an average farm. Since interaction terms were included, it must be qualified by stating that coefficient holds for a farm of 153 hectares and a stocking rate of 2.64. This reduces to approximately 10,865/153 ha = 71 kgMS/ha. The marginal effects of a unitary increase in the *OI_ratio* for larger/smaller farms as well as those with higher/lower stocking rate can be calculating by adding the average *OI_ratio* effect with a product of required values for area and stocking rate and their respective coefficients—see Table 5.[13]

As per Cohen and Cohen (2003), +/– 1 Standard Deviations (StDev) from the mean values were used to estimate the simple slope coefficients in Table 5. Standard errors (in parenthesis below the coefficient) were derived using a technique from Aitken and West (1991, pp. 24–25):

$$\sigma_b^2 = \mathbf{w}' \, \Sigma_{\mathbf{b}} \mathbf{w}$$

Where **w** is the vector matrix of the coefficients included in the interaction and zeros for others ($\mathbf{w}' = [0 \quad 0 \quad 0 \quad 1 \quad stocking\_rate \quad area \quad 0 \cdots 0]$); and $\Sigma_{\mathbf{b}}$ is the heteroskedasticity consistent variance covariance matrix (White's). For each simple slope coefficient corresponding values of *area* and *stocking_rate* were substituted in **w**.

Table 5. Marginal effects of O/I ratio with interaction terms.

		stocking rate		
		1.92 (–1 StDev)	**2.64** (mean)	**3.36** (+1 StDev)
***area* (ha)**	**58** (–1 StDev)	18,504*** (2,525)	15,488*** (1,870)	12,472*** (1,600)
	153 (mean)	13,881*** (1,663)	10,865*** (1,704)	7,849*** (2,233)
	248 (+1 StDev)	9,258*** (2,359)	6,242 (3,717)	3,226 (3,717)

[13] Note that coefficients are for centered variables, hence, the –1 StDev multiplier for stocking rate interaction term, for example, is 1.92–2.64 = –0.72.

Coefficients on the interaction terms suggest that smaller and less intense farms are more responsive to changes in profitability. This makes economic sense as there is inevitably “excess capacity” within farms with lower stocking rates, and they are more likely to be flexible if there is a short-run change in either input or output prices.

Application to Water Demand

To predict the response of a farm to an increase in a volumetric pricing of pasture irrigation water, it is first necessary to include a number of parameters and assumptions, some of which may be changed in accordance to application requirements. As an example, suppose there is a farm with the following attributes:[14]

Number of cows	425
Farm Size	144 ha
- ***Stocking Rate***	*2.95*
Payout	$7.23
Cost / MS	$3.87
- ***O/I Ratio***	*1.87*
MS Production	150,000 kgMS
Pasture Irrigation Response	7.4 kg DM/ha/mm
Proportion of DM grown due to irrigation	10%
DM requirements/cow	5 tons

Each cow requires 5 tons of DM to produce 150,000/425 = 353 kg of MS, so each kg of DM yields 353/5,000 = 0.0706 kgMS. Since 1 mm/ha of irrigation produces 7.4 kg DM/ha/mm, it results in 7.4*0.0706 = 0.522 kgMS/ha. 1 mm/ha of irrigation is equivalent to 10 m^3, then it takes 10/0.522 = 19.14 m^3 to produce 1 kgMS. In absence of water tariffs, the farm would consume 19.14*0.1*150,000 = 287,162 m^3 of water.

Now suppose a 5 cent/m^3 tariff is introduced. Assuming no input substitution (e.g., for brought-in feed), the farm now faces a 287,162*0.05 = $14,358 bill for irrigation water. The overall farm working expense/MS rises from $3.87 to $3.87 + $14,358/150,000 = $3.97. The O/I ratio falls from 1.87 to $7.23/$3.97 = 1.82, hence the O/I ratio changes by 1.87–1.82 = 0.05.

Since the stocking rate and area are not at their mean values, the simple slope coefficient on the O/I ratio needs to be derived by including the multiplicative terms, i.e., 10,865 + (–4,183*(2.95–2.64)) + (–48.7*(144–153)) = 10,015. Using this simple slope coefficient on the O/I ratio, the consequent

[14] Based on averages from the 2010/2011 production season.

predicted fall in the production is 0.05*10,015 = 452 kgMS. As the increase in cost is only for the irrigated production, for the farm to produce 901 fewer kgMS, it would require 452*19.14 = 8,645 fewer m^3 of water (or 8,645/287,162 = 3% less water).

This formula can be extended to include any number of assumptions about the parameters of the farm in question, or the tariff levels. For instance, Figure 8 traces the quantities of water consumed by the farm with average parameters used in this illustrative example under various hypothesized water tariffs. Table 6 presents relative changes in water consumption.

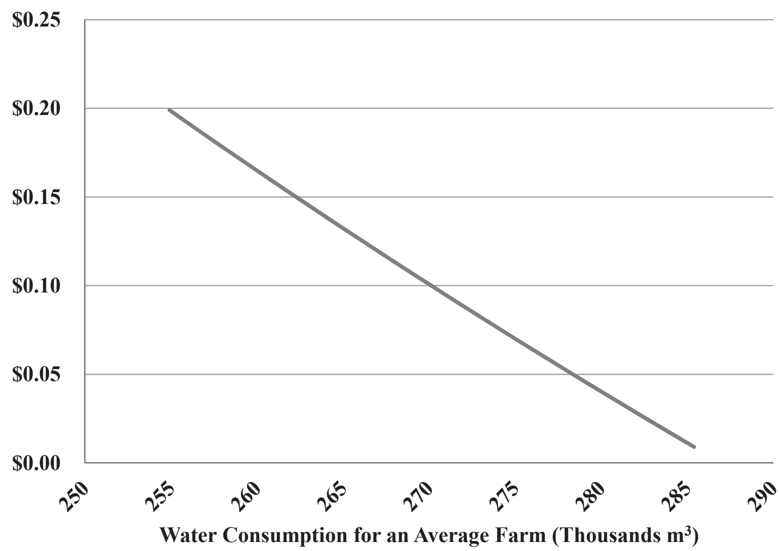

Figure 8. Water consumption for an average farm vs. price (per 1 m^3).

Table 6. Changes in water consumption for an average farm.

Price	Change in Water Consumption
$0.05	–3.0%
$0.10	–5.9%
$0.15	–8.6%
$0.20	–11.2%

Conclusion & Limitations

This study's aim was to produce a "starting point" estimate of the response curve to water price tariffs of dairy farmers and should be treated as such. It requires prior knowledge of a number of sensitive parameters and is based on restrictive assumptions including that all farms employ the same production function, there is linearity in DM yield in response to irrigation, and there is no substitution among factors of production.

In reality, faced with increasing water costs, farmers are likely to substitute to brought-in feed and water usage efficiency technologies. Allowing for substitution would theoretically yield much sharper responses (i.e., more production would be shifted towards using brought-in feed, less irrigated water). Indeed, in Australia farmers have to decide every year before the start of production season whether to invest in "temporary water" and make a loss if the year ends up to be wet, or risk it and face the prospect of having to purchase expensive feed (O'Connor, n.d.). Further study should be carried out to examine the trade-off between brought-in feed and irrigation.

Nevertheless, notwithstanding the limitations of the data and restrictive assumptions, useful conclusions can be drawn: smaller and less intense farms are likely to be more flexible with production should they be faced with a freshwater tax (equivalent of a lower expected payout). Larger farms and those that operate closer to full capacity, on the other hand, are likely to internalize the costs in the short run, and hence their demand for freshwater is likely to be less susceptible to influence in the face of levies.

In conclusion, rather than relying on tools such as water intake restrictions and arbitrary distribution of water resource consents, theoretical rationale suggests that a pricing mechanism can be a viable alternative for water demand management in the face of scarcity. It is expected that this study adds perspective to discussion on the topic.

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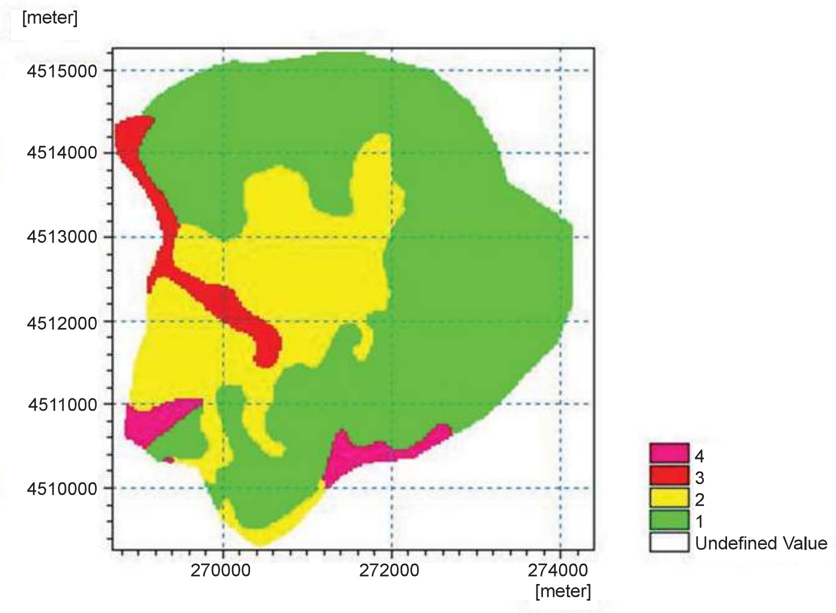

Figure 8. Land Use.

Chapter 13

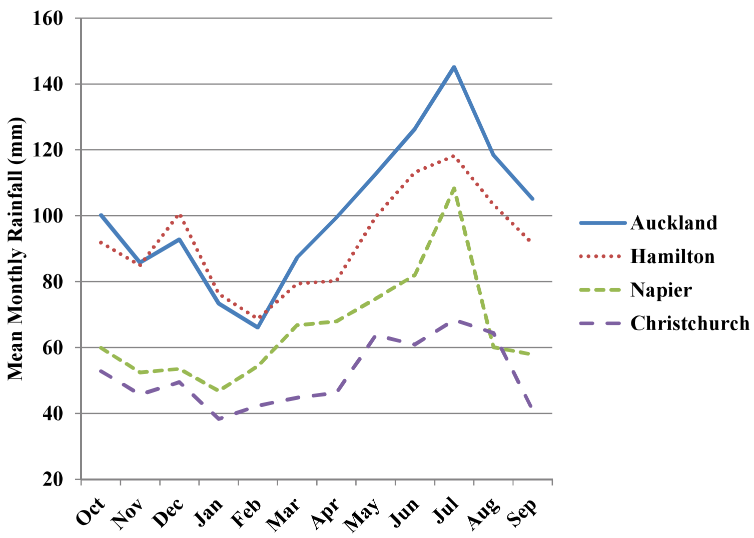

Figure 2. NZ Monthly Rainfall for Selected Cities.

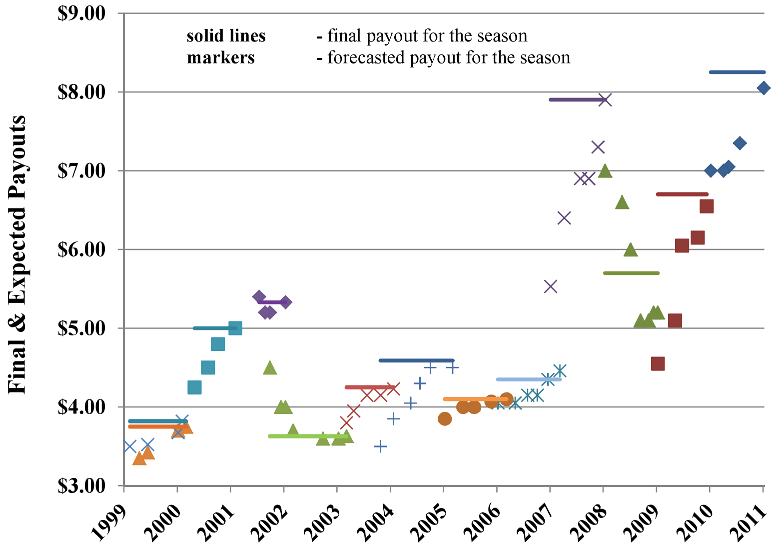

Figure 4. Forecasted vs. Actual Payout.
Source: Fonterra 2000–2012.

Figure 5. Output-Weighted Forecast Estimation.
Data Sources: DCANZ (2012); Fonterra (2009, 2010).

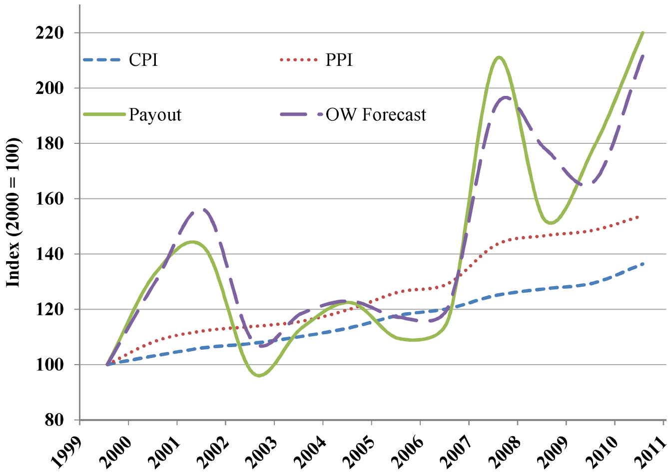

Figure 6. CPI, PPI and Payout Indices (1999=100).

Chapter 14

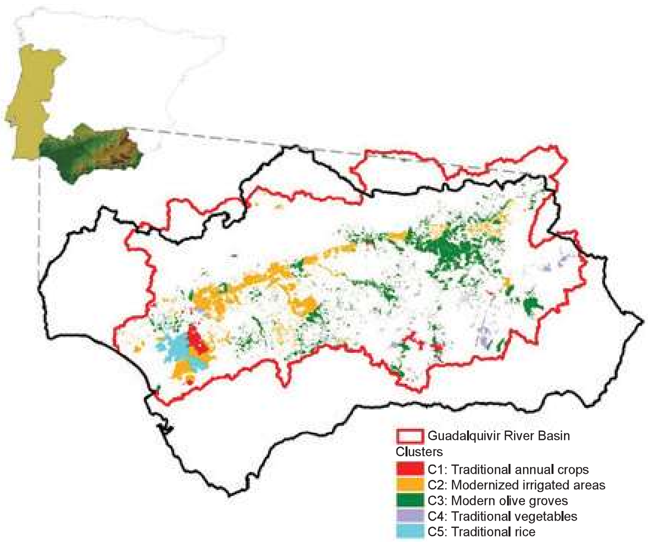

Figure 1. Clusters identified in the GRB.
Source: Gómez-Limón et al. (2012).

CHAPTER III: INFLUENCE OF RUDIMENTARY ATTRIBUTE NON-ATTENDANCE (ANA) ON CHOICE EXPERIMENT PARAMETER ESTIMATES AND DESIGN EFFICIENCY: A MONTE CARLO SIMULATION ANALYSIS[15]

Kravchenko, A. (2014). Influence of rudimentary attribute non-attendance (ANA) on choice experiment parameter estimates and design efficiency: A Monte Carlo simulation analysis. *Journal of Choice Modelling*, *11*, 57-68.

[15] This chapter was initially compounded with the following chapter where simulations were used to examine the effects of ANA during the design phase of the survey. However, upon the recommendations of Prof. Scarpa, it was submitted (and accepted) to the International Choice Modelling Conference (2013) in Sydney, then accepted at JCM as a stand-alone paper.

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Influence of rudimentary attribute non-attendance (ANA) on choice experiment parameter estimates and design efficiency: A Monte Carlo Simulation analysis

Alex Kravchenko

Waikato University, Department of Economics, Hamilton, New Zealand

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ABSTRACT

The issue of attribute non-attendance (ANA) has been gaining increasing attention in the field of choice modeling. While the modeling issues, effects on parameter estimation, and, to a lesser degree, causes of ANA have been the main concern of research in this area, to date few studies have produced generalizable results about the effects of ANA on parameter estimates and little attention has been paid to the efficiency of experimental design in the face of ANA. This paper looks at these issues and also introduces a distinction between random and systematic ANA, which is defined to be ANA that is persistent in the face of choice task and/or attribute order randomization. As part of this study, Monte Carlo simulations are run to examine the effects of ANA on parameter estimation, under the conditions of random and systematic ANA. Simulations with respondent heterogeneity are also carried out to test the efficiency of latent class model estimations. The models perform well, but it is argued that the underlying assumption of serial ANA is indistinguishable from zero preferences with respondent heterogeneity, and such ANA is inconsequential to the choice made (i.e. the same choice is made whether or not the attribute is being attended to). In contrast, when a non-zero preference attribute is ignored, the latent model does not pick up the effects of ANA and additional data is required. Not incorporating ANA data significantly biases estimates of all parameters, especially when the marginal effects of the ignored attribute are relatively large. Finally, it is shown that orthogonal design is significantly disturbed by systematic ANA, and there is scope to improve it by using a D-efficient design.

1. Introduction

The study of the effects of heuristics in choice modeling has been gaining increasing attention in the choice modeling literature. The role of attribute non-attendance (ANA), a heuristic which seeks to decrease cognitive burden by ignoring certain attribute levels in choice tasks or whole experiments, has been particularly prominent. Most literature, however, concentrates on the modeling issues of ANA, examining its effect only on parameter estimation in specific case studies, without resorting to making generalized statements about the role of ANA other than that not accounting for it may (or may not) substantially alter willingness-to-pay (WTP) estimates. This study seeks to examine the effects of ANA with regard to parameter estimation and design through the use of Monte-Carlo simulations. A parsimonious main-effects only binary

E-mail address: alexk@waikato.ac.nz

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1755-5345/

choice model with binary attributes is used, with various ANA specifications included for one of its parameters. The findings effectively conclude that not accounting for ANA, particularly if the true models parameters are relatively large, may substantially bias all parameters in the estimated model. In terms of design efficiency, random ANA, while disturbing choice-task level design efficiency, maintains high design efficiency across pooled responses. However, if ANA is systematic, due to perhaps the effect of other variables or the order of choice tasks, resultant correlations disturb the pooled design efficiency as well. D-efficient design is shown to significantly outperform fractional factorial orthogonal main-effects design. The structure of this paper is as follows. First, the ANA literature will be reviewed, followed by a brief overview of design efficiency concepts. Next, each simulation scenario and its motivation will be explained in detail. Finally, the main results are discussed, followed by concluding remarks. It must be noted, however, that these results are limited in their scope as they were simulated and hence do not allow for any demand-induced design artifacts that would be present should real people be faced with choice tasks. Further study is needed with regard to analysis of the issues described in the real world, particularly with respect to the cognitive processes responsible for ANA, their differences and ultimately how these different types of ANA impact on parameter estimation and design.

2. ANA and heuristics background

The use of what are argued to be less than ideal strategies in decision making has long been recognized in the decision-making literature. Deviation from ideal, or non-fully compensatory processes can, however, "lead to elimination of potentially good alternatives early in the decision process" (Payne et al., 1993, p. 5). The authors argue that there is a trade-off between effort and the accuracy of a decision—more information gathering for more accurate decisions requires more effort. Humans' limited cognitive capacity for storing information in short-term memory has been famously recognized by Miller (1956), who showed that on average only 7 "chunks" of information can be stored in the cognitive brain to help with judgments; whereas typical choice modeling applications involve significantly more than 7 attribute levels per choice task. Shah and Oppenheimer (2008) follow the work of Payne et al. (1993) and introduce an effort reduction framework which summarizes recent research in the field of heuristics—strategies to, broadly speaking, decrease the cognitive burden during decision making "...the weighted additive rule and other optimal strategies place five demands on people: to consider all available cues; to retrieve cue values accurately; to weight cues properly; to integrate information for each alternative, and to examine all alternatives. We therefore believe that people confront limited cognitive resources by addressing these five demands. They can reduce the effort associated with any of these five demands individually or collectively" (p. 219).

Perhaps it is the role of unconscious thought that has been underestimated in models that attempt to only tap into the processing power of the prefrontal cortex. Unconscious thought is distinguished from conscious thought through the role of attention (Dijksterhuis and Nordgren, 2006). Conscious thinkers recall less information overall than unconscious thinkers and the majority of conscious thinkers indicate that they base their decisions on only one or two attributes (hence 7 "chunks" may only be recalled consciously, whereas all or nearly all information can be unconsciously used to make near-optimum decisions). In his earlier work, Dijksterhuis et al. (2004) demonstrated experimentally that people make better decisions when they are induced to do so using subconscious processes.

At the same time, Gigerenzer and Brighton (2009) argue strongly against the common accuracy-effort trade-off paradigm, and suggest that heuristics that incorporate less information, computation and time can actually improve decision accuracy. In fact, they view heuristics as a superior alternative to a fully additive view of decision making, a "less-is-more" view. The crux of the argument is that precisely because of people's limited cognitive resources, forcing respondents to consciously consider more information leads to lower precision in decision making than when using simplifying heuristics.

Seeking to find the underlying reasons behind ANA in stated choice experiments, Alemu et al. (2012) added debriefing questions in their stated choice study. Their conclusion is that although ANA is in most cases a manifestation of zero preferences, combining a simplifying heuristic also plays a part. In addition, the authors find that eliciting the reasons behind ANA may improve parameter estimation.

Yet, as Hensher (2009) states, nearly all practitioners of choice modeling still opt for the conventional full compensatory approach where all attributes are fully considered in the model. Willemsen and Johnson (2010) also note that "decision making research has largely progressed through the use of models that account solely for observed choices without extensive consideration of underlying cognitive structures and processes".

While there are many classifications of heuristics in decision-making research (e.g., Shah and Oppenheimer, 2008), the most common one examined (at least in the context of environmental economics) is that of attribute non-attendance (ANA)—when the respondents ignore one or more attribute levels over the whole experiment (serial ANA) or at a choice task level. Under Shah and Oppenheimer's classification ANA can be a symptom of 'examining fewer clues' and 'integrating less information'.

Choice modeling studies that do consider heuristics (ANA in particular) generally find that it has significant impact on the WTP and parameter estimates. Hensher (2009) concludes that "failure to accommodate process heterogeneity is a significant contributing influence [of a large hypothetical bias]" p. 27. Hensher and Greene (2010) and Hensher and Rose (2009) find the WTP is significantly higher than full relevance and attribute preservation specification. Hensher et al. (2005b) also find that non-accounting for ANA produces significantly different WTP estimates. Scarpa et al. (2010, 2009) note that including ANA data in model estimation improves fit and provides a 'more plausible pattern of signs and greater efficiency'. Campbell et al. (2010) also conclude that by incorporating attribute processing strategies (APS) 'more defensible' estimates were derived. Mariel et al. (2011) follow a simulation approach for non-attendance for 20%, 40% and 60% of individuals and find that only choice task non-attendance (as opposed to serial non-attendance) significantly impacts the estimates of both the non-attended attribute and other, fully attended attributes.

In terms of the prevalence of ANA, Kragt (2012) looked at serial non-attendance, and found that only 50% of respondents attended to all the attributes, and nearly 20% concentrated on just one attribute. In Reisen et al.'s (2008) study, respondents on average examined 22% of the available attributes. In Kaye-Blake et al.'s (2009) study, nearly 50% of cards (on a computer-based information board—discussed below) of attribute levels were left unopened during the experiment.[1]

2.1. Approaches of detecting and dealing with ANA

There are two main methods of integrating ANA into choice modeling—through 'stated' or 'inferred' methods. Inferred methods (such as Scarpa et al., 2009; Hensher and Rose, 2009) use a latent class approach, with the main advantage being that no further data is required. The main assumptions in such models is that there is respondent heterogeneity where some groups do not attend to one or more attributes (or, equivalently, have zero preference to for those attributes). Stated method involves collection of further information on ANA, usually in the form of follow-up questions, such as "is any of the information shown not relevant when you make your choice?" (Hensher et al., 2005b; Hensher, 2006). Coefficients on attributes that are ignored are then restricted to zero in model estimation (at either choice task or whole survey ('serial') level–see Hensher, 2009).

There are contradictory findings with regard to the efficacy of each method. Hensher (2009) notes that stated APS are not significant when included in the latent class model, meaning that the latent class model provides the same result but without the need for further information collection. Yet, Campbell and Lorimer (2009) find a discrepancy between self-reported and modeled attributes that are ignored. Hensher et al. (2012) also cite the concern of reliability of such information. Similarly, Kragt (2012) finds that inferred and stated ANA models provide different results.

Alternative strategies for collecting information on ANA include eye and mouse tracking. However, such tools are mostly used in the context of the actual decision-making process rather than the effect on the outcome and are usually, but not always, confined to controlled lab environments. For instance, Russo and Dosher (1983) use eye tracking to detect decision strategies, but their experiment forces a full compensatory decision strategy, concentrating more on dimensional versus holistic strategies, (i.e. attribute versus alternative based strategies). Similarly, Ball (1997) examines the actual strategies via analysis of the decision information window. Meißner et al. (2013), on the other hand, examine ANA using eye-tracking techniques and conclude that in the later choices, respondents tended to focus only on important attributes. In a case example, the authors describe the movement of attention of a respondent in a task near the end of the experiment, concentrating on the levels of just one of several attributes. Once the desired level of that attribute (considered most important—a lexicographic heuristic) is found, the respondent is then seen looking at the levels of alternative's other attributes—ensuring that nothing is too undesirable before choosing the said alternative. Corresponding levels of other alternatives are entirely ignored.

A study by Kaye-Blake et al. (2009) does consider the effects on the outcome by using an on-screen information display matrix with attribute levels hidden (a type of mouse tracking). The attribute levels that are clicked on show up, thus allowing the researchers to determine what information was potentially used and what was definitely ignored by the respondents when making a decision. The study goes on to conclude that incorporating ANA study significantly influences parameter estimates. However, Franco-Watkins and Johnson (2011) argue that mouse tracking introduces an experimental artefact, influencing the experiment outcomes: mouse tracking takes longer than eye tracking. Mouse tracking increases search costs (effort) compared to eye tracking, hence respondents spent less time double checking attribute levels.

In whatever way ANA is integrated in the modeling, it is important to consider what ANA may represent: perhaps it detects 'irrational' responders who are not motivated strongly enough to take the study seriously; or the levels of ignored attributes are not high enough to motivate full attention and hence lexicographic heuristics are employed. Perhaps it is preference heterogeneity, failure to allow for which may 'confound non-attendance with weak preferences' (e.g., Hole et al., 2012, p. 6). Cameron and DeShazo (2011), find that other attribute dissimilarity and own attribute dissimilarity is what causes respondents to differentially allocate attention across attributes. It is also possible (as argued by Puckett and Hensher, 2008) that the attribute levels may be sufficiently high to deserve attention, but the *differences* in levels are not deemed significant, hence ANA emerges. Kragt (2012) also notes that the way the questions are asked—'species lost' vs 'species present' in her example—also influences attribute attendance.

3. Experiment design in choice modeling

Before respondents are able to ignore attributes during stated choice experiments, the researcher must first design a stated choice study (for good descriptions of this processes, see Johnson et al., 2007; Hensher et al., 2005a; Louviere et al., 2000). Once the researcher decides on the number of choices and attributes, he/she must decide how to arrange those

[1] For a thorough overview of stated ANA studies see Alemu et al. (2012).

choice tasks and set attribute levels in order to extract the maximum information from each survey. Swait and Adamowicz (2001), for instance, examine the role of task complexity, as proxied by the number of attributes and choices. Caussade et al. (2005) summarize the studies that show that dimensions such as the number of alternatives per choice, the number of attributes, the levels of attributes, and the total number of choices all affect the elicited parameter estimates. In their own study, however, they find that the most significant dimensions are the number of attributes (optimum at 9–10) and the number of alternatives (optimum at 4). Rolfe and Bennett (2009) tests two- versus three-alternative specification and finds that the three-alternative CM design provides a more robust model.

Besides the number of choices and dimensions, one of the core concepts in the design process is that of orthogonality, or the correlation structure among attributes. Zero cross-correlation design is said to be orthogonal, which ensures statistical independence of the attributes and the highest level of statistical significance (Rose and Bliemer, 2009). While orthogonality is achieved when a full factorial design is used (every possible combination of attributes and their levels), in most cases full factorial designs are simply too large to be practical, hence a reduction of the number of choice tasks (while maintaining orthogonality) is required. Hensher et al. (2005a) note that failure to use orthogonal design may yield biased estimates, in some cases with wrong signs. Rose and Bliemer (2009) maintain that the estimates will still be asymptotically unbiased even with a moderate level of cross-correlation among attributes, and that having an inefficient design will result in a loss of statistical significance (or the need for a larger sample size to achieve a desired level of statistical significance). Another related consideration is that of level balance. Johnson et al. (2007) note that any imbalance would increase information obtained about one parameter at the expense of another.

The author knows of just one study that considered experimental design in relation to ANA: Rose and Bliemer (2013) derive a more efficient design algorithm when the probability of non-attending to a particular attribute is considered. Other studies ignore the issue altogether or consider it indirectly by estimating coefficients and using a Bayesian dynamic design (e.g., Rose and Bliemer, 2009), which may theoretically include ANA considerations in prior updating. Hensher and Collins (2011) use computer-aided surveys to dynamically adjust levels based on respondents' answers (but not the underlying design)—a pivoted design. Consequently, this study will also examine the performance of an orthogonal design (the equivalent of an efficient design with zero priors) in the face of ANA.

4. Motivation and simulation description

Real-world manifestation of ANA is likely to affect more than one attribute, differ among respondents, and differ depending on the position of the choice task (the first few choice tasks are likely to have less ANA since respondents are learning, while later choice tasks are likely to experience more ANA due to fatigue) and the complexity of the task (if some alternatives are perceived to be very similar, more time/effort/attention is going to be taken; if some tasks have more alternatives/attributes, this is likely to invite further ANA). As the literature overview demonstrated, there are contradicting views on the significance of ANA with regard to parameter estimation. The purpose of this study, however, is not to examine any real-world case study real-data ANA, but rather to isolate the effects of ANA in a controlled fashion and examine them in a very limited scope in order to draw some generalizable conclusions. It is, therefore, necessary to make certain assumptions about the data-generating process. First, in the baseline scenario it is assumed that respondents are homogeneous and that for each simulation they have the same preferences and tendencies to ignore attributes (in contrast to Mariel et al., 2011). This does not correspond to any particular heuristic strategy, but rather demonstrates the effect of not considering a particular attribute level on the subsequent choice.[2] This assumption of homogeneity is later relaxed when examining latent class estimation approach and heterogeneity. The second simplifying assumption is that only one attribute is being ignored (albeit the significance of that attribute is varied). Third, for the purpose of this study, zero priors for unknown parameters are assumed in the baseline scenario, meaning that an efficient design essentially collapses to an orthogonal design (Rose and Bliemer, 2009). This too is later relaxed when examining the role of design on estimate efficiency in the face of ANA.

During analysis, there will be a distinction between when ANA data is used in estimation and when it is not. The source of the ANA data can be thought of as either "revealed ANA" such as through mouse tracking or eye tracking (as in Kaye-Blake et al., 2009; Meißner et al., 2013), or "stated ANA'—when respondents are asked after each choice task whether they paid attention to a particular level or not. Hence, this analysis would assume that there is either very believable choice task stated data, or, preferably, eye tracking or mouse tracking data. The purpose of this study is not to come up with techniques to substitute for this data, but rather to highlight the problems that can arise when such data is not available, even when attempting to use latent-class model estimation techniques. In addition, subsequent analysis demonstrates that even if reliable ANA data is available, ANA disturbs the initial efficiency design when ANA is not purely random (as is most likely to be the case in real-world applications).

4.1. Simulation design

This study used R to simulate utilities and to derive binary logit parameter estimates. A total of five binary attributes (X_1 through X_5) were employed, with X_5 ignored under various conditions. The 'AlgDesign' package was used to generate fractional orthogonal

[2] An equivalent way to think of the data generating process is that respondents are using a full attention strategy, but an attribute level for one of the alternatives is randomly hidden during some choice tasks.

designs (see Wheeler and Wheeler, 2004 for details). Orthogonal main effects design of 16 cards was used (out of a full factorial of $2^5 = 32$).[3] A fold-over method was then used to generate binary choices for a paired comparison design.[4]

The general model for each $i = 1, \ldots, N$ respondents, $t = 1, \ldots, T = 16$ choice sets, and $k = 1$ or 2 choice alternatives in each choice set is

$$U_{ikt} = -5 \times X_{1kt} + 3 \times X_{2kt} - 2 \times X_{3kt} + 2 \times X_{4kt} + \beta_{X_5} \times X_{5kt} \times ANA_{X_5} + \epsilon_{ikt} \quad (1)$$

with $\epsilon_{ikt} \sim$ Type I extreme value; and ANA_{X_5} following a binomial distribution,[5] with the probability, $0 \le p_{ANAX_5} < 1$, following a uniform distribution across all choice tasks and respondents in the random scenario, and identically distributed across each respondent, but randomly across the choice tasks each respondent had to face (this is discussed in more detail below). Furthermore, since one of the prevailing hypotheses was that ANA is largely due to perceived insignificance of the included attribute (i.e. $\beta_{X_5} \to 0$), β_{X_5} took on integer values 1 to 5 to explore the consequence of the importance of this effect. Choice values were set to one when $U_{i1} > U_{i2}$, and to zero otherwise at each choice task. Finally, model parameters were estimated using binary logit specification without alternative specific constants.

4.2. Orthogonality & ANA

Full attribute non-attendance (serial ANA) is essentially the same as excluding an entire parameter from the model, and hence would not disturb the orthogonality as this is akin to removing a column: correlation among the attended attributes would not be affected. Moreover, any ANA of one attribute would only impact its own correlation with other variables, leaving cross-correlations between other variables unchanged. For instance, this study looked at the impact of ANA of just one variable, X_5. Since there is no information on the value of the attribute in the choice tasks in which X_5 is ignored, the correlation analysis must only include rows that were fully attended to. Only the resultant correlations of other attributes with X_5 are of concern (in bold in Table 1a–d), with cross correlations of other attributes (fully attended) assumed to be zero.

While random ANA of X_5 does disturb the initial choice task orthogonality, if such randomness is maintained across choice tasks for every participant (e.g., Table 1a), when choice tasks are pooled for all respondents the cross-correlations with X_5 return to be close to zero due to the randomness of the ANA generating process (e.g., Table 1b). As such, purely random ANA does not impact overall design orthogonality, leaving little scope for design improvement in terms of accounting for ANA.

However, it is conceivable that ANA may not purely random. For instance, the respondents may pay attention to more attributes to get familiar with them in the first few choice tasks, but ignore them in later choice tasks (as found by Kaye-Blake et al., 2009; Meißner et al., 2013). They may also have strong lexicographic preferences for other attributes (or their combination) that would cause systematic non-attendance. In either case, such non-random ANA would maintain a non-zero correlation with and other attributes across pooled choice tasks (Table 1c and d). This study thus sought to differentiate between the two (random and systematic types of ANA). Hence, in the systematic scenario, the ANA pattern was randomly generated for 16 tasks (e.g. with p_{ANAX_5} of 0.5, X_5 would be ignored in 8 random rows out of 16), but this ANA pattern would be repeated for all respondents. In the random scenario, ANA would be random across all choice tasks and respondents. In this analysis any particular pattern of systematic ANA is not itself an approximation of any particular heuristic, but rather of the notion that such ANA can persist across choice tasks even if choice task and/or attribute orders are randomized.

5. Results

A total of 100 simulations of $N = 500$ sample size were run for each of the five β_{X_5}, with randomly generated instances of X_5 ANA, ranging from 0 to less than 1. Next, parameters were estimated using a binary logit specification, with and without integrating ANA data.

Fig. 1a demonstrates the bias pattern of β_{X_1} estimates under various probabilities of random β_{X_5} ANA. The results for β_{X_2}, β_{X_3} and β_{X_4} coefficients follow much the same pattern and henceforth analysis is largely restricted to β_{X_1} with an understanding that it is analogous to other coefficients.

The first thing to note is that values of p_{ANAX_5} close to 1 or 0 have no effect on parameter point estimates, with the bias peaking at 0.5 for every value of β_{X_5}. As expected, the lower the magnitude of the true β_{X_5} parameter, the lower is the effect of its ANA, with a value of 1 resulting in only a very marginal bias, even at maximum impact probability of ANA of 0.5. It is important to note, however, that when the absolute value of the model β_{X_5} parameter is large (4 or 5), even a seemingly negligible ANA of 10% results in as much as a 20% bias of the β_{X_5} estimates. Yet, when the information on ANA is included in the model, this bias disappears (see Fig. 1b).

[3] A large fractional factorial was used for clearer illustration of the difference between the effect of random and systematic ANA.

[4] Street and Burgess (2007) show a mathematical proof that for paired comparison designs with binary attributes, a fold-over method based on regular orthogonal main effects design produces a D-efficiency of 100% for estimating main effects (with zero priors). A D-efficient design with true parameter priors will be compared when exploring the effect of design in a later section.

[5] Restricting the parameters to 0 yields the same outcomes as restricting the corresponding variables to being equal across choices when they are not attended to.

Table 1
An example of attribute correlations with unattended rows skipped (prob ANA = 0.5) using orthogonal coding.

a. In a random ANA choice task

	X_1	X_2	X_3	X_4	X_5
X_1	1.00	−0.25	−0.50	−0.50	−0.71
X_2	−0.25	1.00	0.50	0.50	0.00
X_3	−0.50	0.50	1.00	0.25	0.71
X_4	−0.50	0.50	0.25	1.00	0.00
X_5	**−0.71**	**0.00**	**0.71**	**0.00**	1.00

b. Across pooled random ANA tasks

	X_1	X_2	X_3	X_4	X_5
X_1	1.00	−0.00	0.01	0.00	0.01
X_2	−0.00	1.00	−0.03	−0.00	0.00
X_3	0.01	−0.03	1.00	0.00	−0.00
X_4	0.00	−0.00	0.00	1.00	−0.02
	0.01	**0.00**	**−0.00**	**−0.02**	1.00

c. In a systematic ANA choice task

	X_1	X_2	X_3	X_4	X_5
X_1	1.00	−0.25	−0.50	−0.50	−0.71
X_2	−0.25	1.00	0.50	0.50	0.00
X_3	−0.50	0.50	1.00	0.25	0.71
X_4	−0.50	0.50	0.25	1.00	0.00
X_5	**−0.71**	**0.00**	**0.71**	**0.00**	1.00

d. Across pooled systematic ANA tasks

	X_1	X_2	X_3	X_4	X_5
X_1	1.00	−0.25	−0.50	−0.50	−0.71
X_2	−0.25	1.00	0.50	0.50	0.00
X_3	−0.50	0.50	1.00	0.25	0.71
X_4	−0.50	0.50	0.25	1.00	0.00
X_5	**−0.71**	**0.00**	**0.71**	**0.00**	1.00

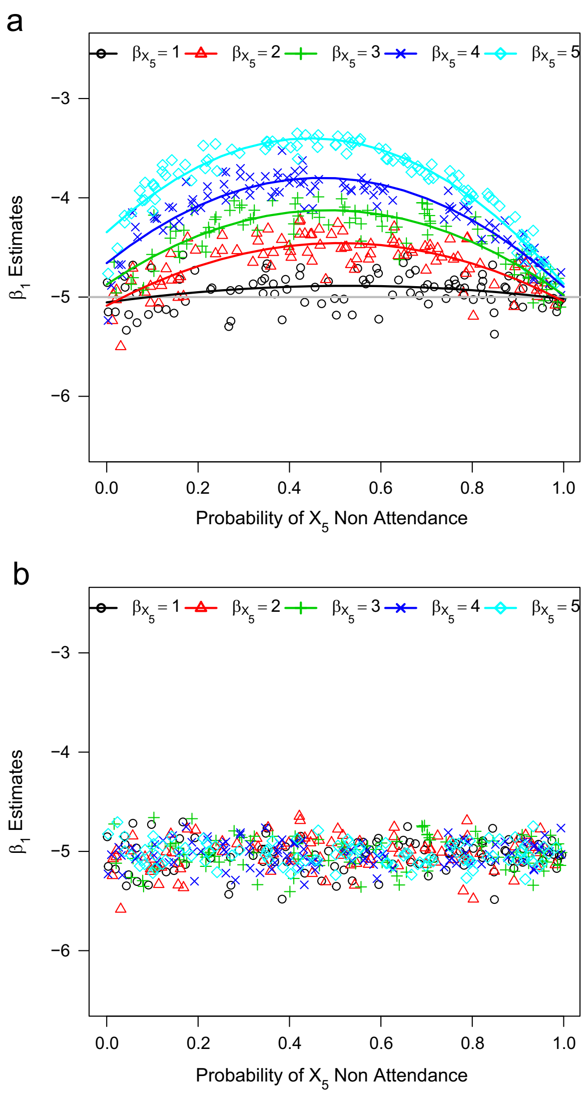

Fig. 1. Effects of random X_5 ANA on MNL estimates of β_{X_1}. (a) Without ANA data and (b) with ANA data.

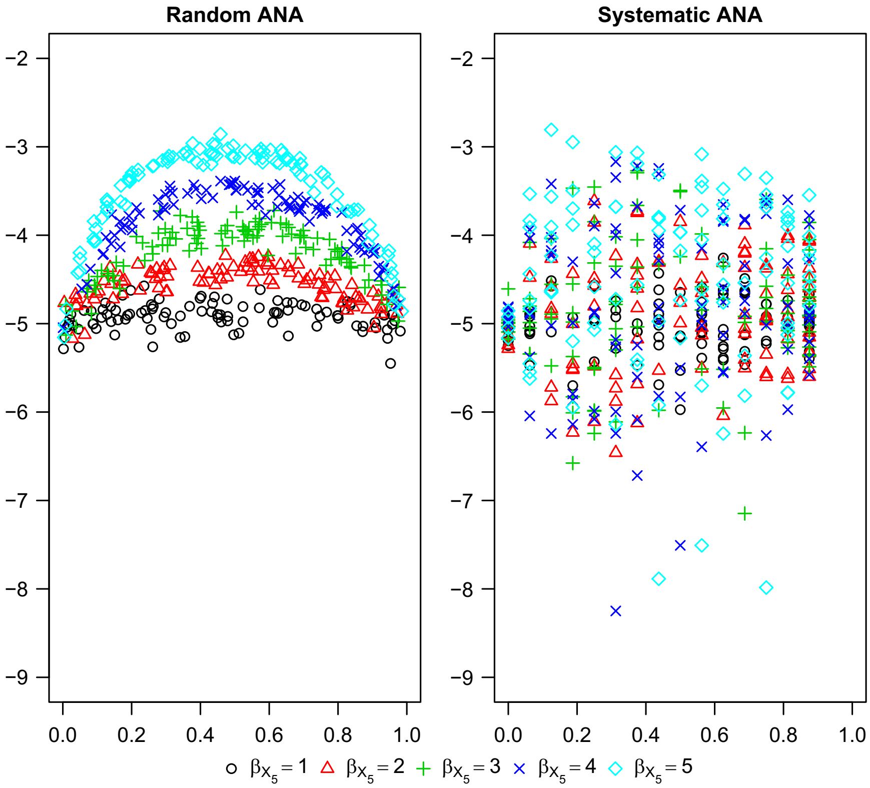

Fig. 2. Estimates of β_{X_1} under the conditions of random vs systematic X_5 ANA.

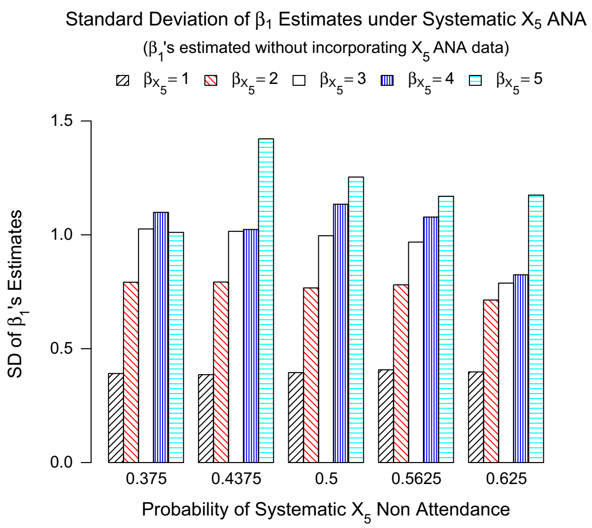

Fig. 3. Dispersion of β_{X_1} estimates for selected probabilities of systematic X_5 ANA.

By comparison, when ANA is systematic (Fig. 2), the distribution of biased estimates does not follow the same quadratic pattern—the estimates are highly dispersed around their true value, with dispersion increasing noticeably with the nonzero instances of systematic X_5 ANA. Moreover, the higher the absolute value of the true model parameter, the higher is the dispersion of the β_{X_1} estimates under systematic X_5 ANA. To demonstrate this, 1000 simulations for each β_{X_5} were run under systematic ANA of X_5; then standard deviations of β_{X_1} estimates were calculated for each possible ANA proportion—see Fig. 3.[6]

[6] For clarity only values for probabilities of ANA from 0.375 to 0.625 are presented, with the rest following the same trend.

Finally, the effect of X_5 ANA has an expected effect on its own (β_{X_5}) estimates for all simulated values—near zero instances of random ANA provide estimates closest to true parameters. The estimates decline steadily with increasing instances of ANA (Fig. 4). The effect is the same for systematic ANA (not shown). It is important to note that when true β_{X_5} values are large (4 or 5), the effects of ANA seem to be non-linear around very small values of ANA—so that even small values of ANA have a disproportionately large impact on parameter estimates without the ANA data.

5.1. Systematic ANA and design efficiency

As noted earlier, when ANA data is included in the model estimation, the point estimates are well-behaved and are closely centered on their true values. This is true for both systematic and random instances of ANA. However, in the face of systematic ANA, standard errors of the coefficients vary significantly across simulations—as shown in Fig. 5. Standard errors of β_{X_1} estimated under the systematic ANA scenario are significantly more dispersed and often higher for each level of ANA

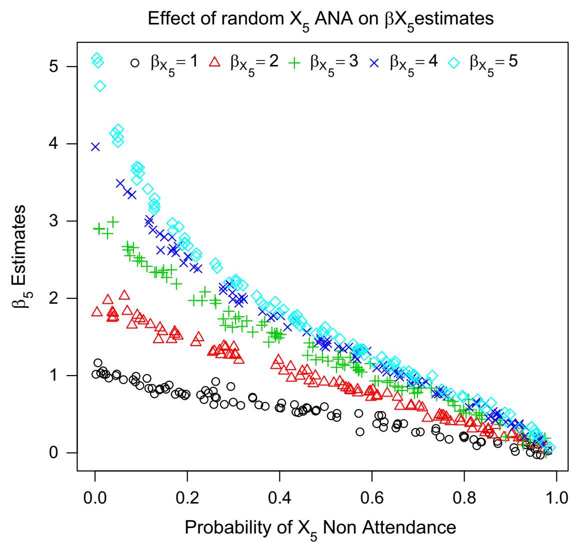

Fig. 4. Effect of random X_5 ANA on β_{X_5} estimates without using ANA data.

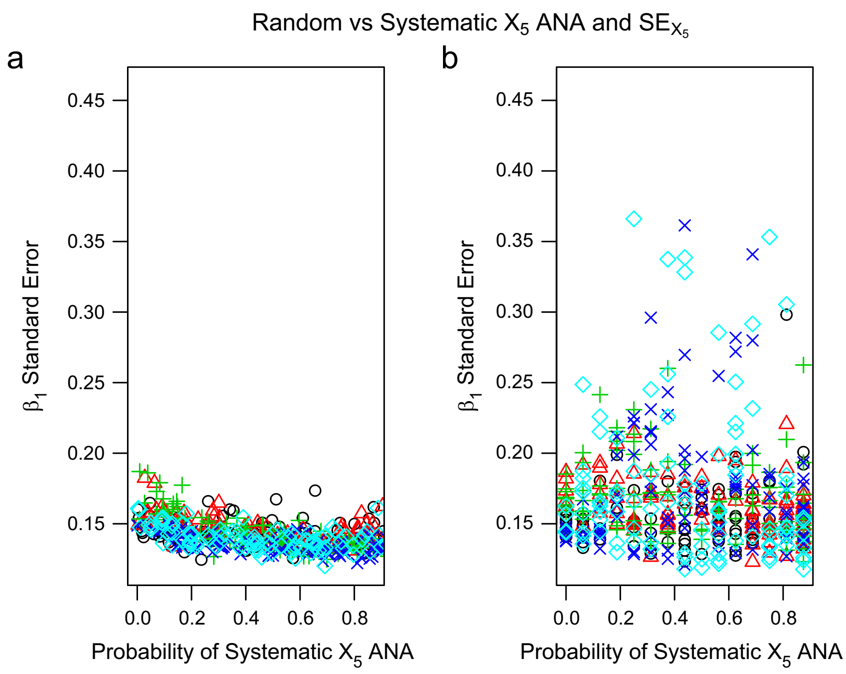

Fig. 5. Effect of systematic vs random X_5 ANA on $SE_{\beta_{X_1}}$. (a) Random ANA and (b) systematic ANA.

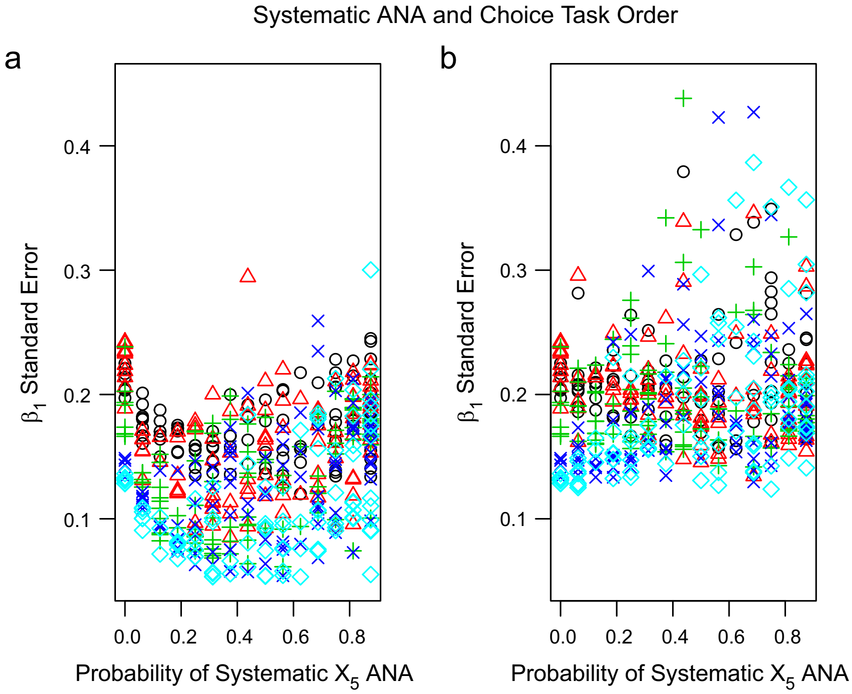

Fig. 6. Effect of randomizing choice tasks in the instance of systematic X_5 ANA due to choice task order on $SE_{\beta_{X_1}}$: if ANA is systematic over the order of choice tasks, a simple and effective remedy is to randomize this order. (a) Random order and (b) constant order.

than they are in the random ANA scenario. This is true for every attribute, including X_5.

To deal with the issue of resultant design inefficiency due to the systematic nature of ANA, it is first necessary to find out the reasons behind it. If this ANA is due to the order of choice tasks (i.e. they are constant across the respondents and respondents follow the same pattern of learning/fatigue, etc.), a simple and marginally effective remedy is to randomize the order of choice tasks—see Fig. 6 for a demonstration.

If, however, systematic ANA is persistent after randomization of choice tasks and attributes, an orthogonal (zero-prior) design may result in significant loss of efficiency. A simple remedy is to use an efficient design with non-zero priors (perhaps obtained after a pilot based on a sufficiently large number of responses). In Fig. 7, panels a and c, $SE_{\beta_{X_1}}$ estimates obtained using a D-efficient design (constructed using true value priors) under systematic and random patterns of ANA are contrasted against panels b and d where orthogonal main-effects designs were used. In all scenarios ANA indicator data were used in estimation. It is clear that under systematic ANA (which arguably is more likely to be evident in “real” data), D-efficient design significantly outperforms orthogonal design, whereas, while still evident, the difference is less pronounced when ANA is random.

5.2. Latent class specification—“Inferred” ANA

The rationale behind ANA latent class specification is addressing respondent heterogeneity with regard to attribute importance. In particular, it is assumed that a subsample of respondents have a zero preference for one or more attributes, and hence these attributes are ignored by the respondents. It is important to note, however, that as Scarpa et al. (2009) states, “in the absence of further information, which in other studies might well be derived by debriefing questions, one cannot distinguish between the case where a zero is the outcome of—for example—a simplifying heuristic, and where it is instead a true manifestation of individual preferences.” In other words, even if all respondents were using a full compensatory principle (not engaging in any heuristics), according to the assumption of such latent class specification the results would be indistinguishable, since those that are not attending to attributes are assumed to have a zero preference, so if they do attend to them, the result should be identical, regardless of whether or not they attend to the attribute or not. Arguably, such models are more suited to explain preference heterogeneity than a true heuristic. ANA due to heuristics, or simplifying strategies, should arguably result in choices that are different to those when a full compensatory additive strategy is used.

As expected, latent class specification estimation attempts were not successful in eliciting better estimates when ANA was homogeneous among the simulated respondents (i.e. each respondent did not attend to X_5 with a probability of p_{ANAX_5}). To simulate heterogeneity, in a separate simulation half of the respondents fully attended to X_5 and half fully ignored it.

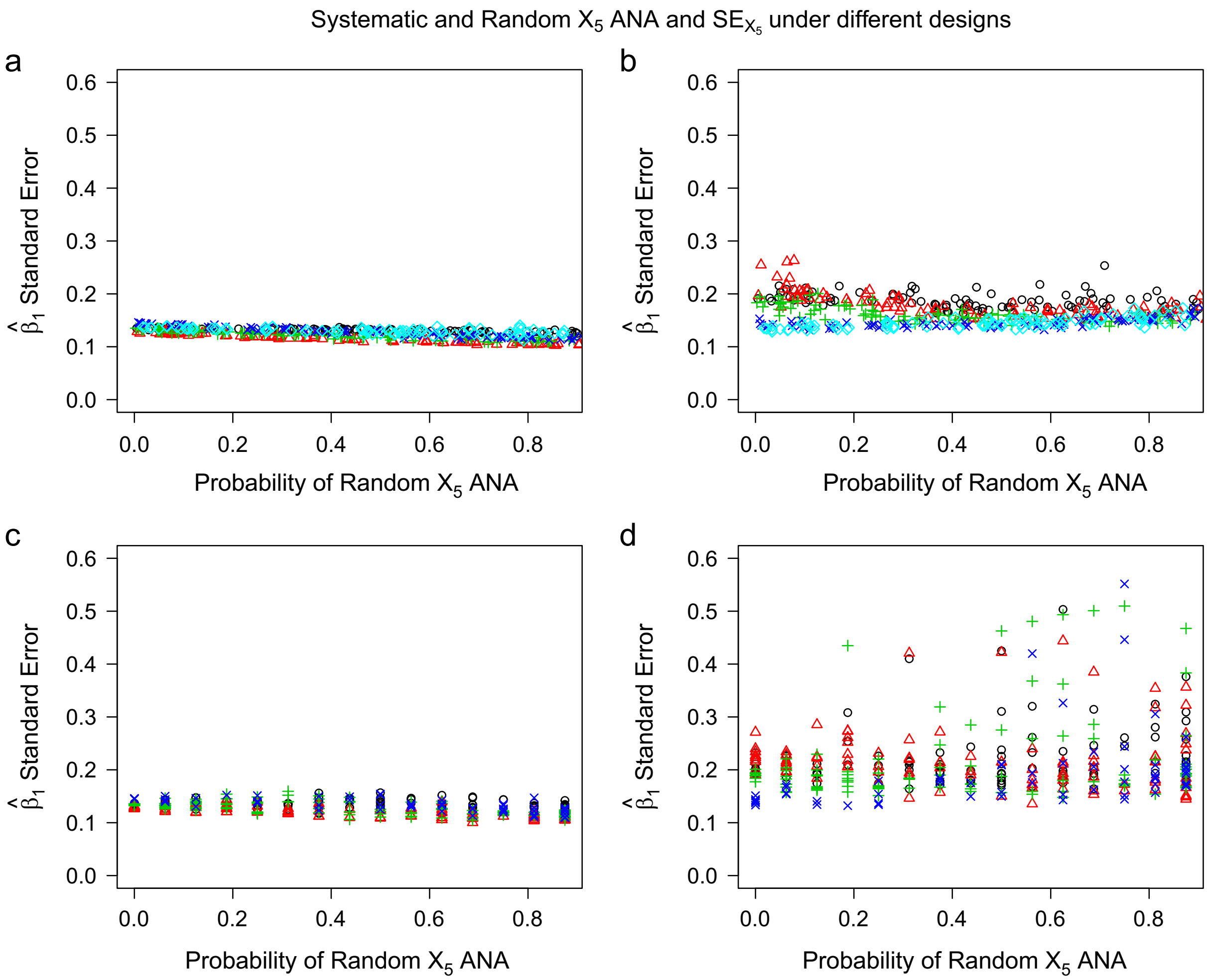

Fig. 7. Orthogonal vs. efficient designs and ANA. (a) D-efficient design random ANA, (b) orthogonal design random ANA, (c) D-efficient design systematic ANA and (d) orthogonal design systematic ANA.

Latent class specification (without an indicator of a class) estimation provided nearly identical results to logit estimation with ANA indicator variables. Hence, under the assumption of serial ANA, such a technique works well.

6. Conclusion and discussion

This paper examined the effect of attribute non-attendance of one attribute on multinomial choice model estimates through Monte-Carlo simulations. A parsimonious binary choice model design with binary attributes and multinomial logit estimation was employed. Notwithstanding the fact that real-world applications are generally much more complex, this study demonstrates a number of generalizable conclusions about ANA and choice design efficiency.

One of the main conclusions is that if ANA is a symptom of a weak preference among a homogeneous population, standard logit modeling implementation should yield sufficiently unbiased results. When weak or zero preference affects only a subsample, latent class modeling is a viable option. However non-attendance of just one attribute can significantly bias its own estimates as well as other parameters when ANA concerns relatively important attributes. Furthermore, if the ignored attributes' true parameters are large enough, relatively small instances of ANA (10%) can cause a relatively high impact (a bias of 20%). While latent class model specification can pick up heterogeneity where classes are assumed to fully ignore one or more attribute, such serial ANA is indistinguishable from zero preference, hence, arguably does not constitute a deviation from a full compensatory strategy which this paper explores. Furthermore, latent class specification fails to pick up non-serial ANA. The primary conclusion, therefore, highlights the importance of obtaining information to account for ANA in estimations by asking a question after each *choice task*, or using mouse or eye tracking, unless a good reason exists suggesting that non-serial ANA is not going to be an issue. Future research should examine whether real-world stated choice studies tracking choice-task ANA of more than one attribute indeed result in biased estimates. For instance, large enough datasets of stated choices can be partitioned according to the levels of stated/observed instances of ANA, then parameters estimated and contrasted for each subsample using and ignoring ANA data. In addition, it is important to further understanding of the behavior sources of ANA, particularly whether it is a symptom of zero or near-zero preference and respondent heterogeneity.

This paper also draws a distinction between systematic and random ANA. Random ANA occurs with the same probability irrespective of the question number in the choice task or the values of other attributes. Such ANA, although it disturbs individual choice-task level design efficiency, allows for close to zero cross-correlations among attributes across the pooled design, and does not significantly affect design efficiency. Systematic ANA, on the other hand, occurs due to either a systematic pattern of attribute/attribute level learning over the course of the choice experiment; or the interaction of other attributes (prompting lexicographic heuristics patterns). Such an ANA pattern is maintained even if the order of choice tasks and/or attribute levels is randomized. Incorporating ANA data mitigates the biases as far as point parameter estimates are concerned; however, systematic ANA can result in significant loss of efficiency if using an orthogonal design. It has been shown, however, that using a non-zero prior D-efficient design can significantly improve efficiency even when faced with systematic ANA. There has not been any mention of studies that distinguish whether actual ANA data patterns are systematic or random, hence it would be interesting to see whether in real-life applications, design efficiency matters due to ANA.

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Chapter IV: Some Findings from 'Revealed' Attribute Non-Attendance in Web-based Choice Experiments: the Case of Valuing Irrigation Water in New Zealand *

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* Please note that in anticipation of journal submission, this paper has been produced in LaTeX format, hence the style does not match the rest of this thesis.

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Thank you too, all the respondents who participated, I hope the results of this survey will be more than of academic interest and your opinions will be considered in future policy planning.

Some findings from 'revealed' Attribute Non-Attendance in web-based choice experiments: the case of valuing irrigation water in New Zealand

Kravchenko, Alexey
oak1@students.waikato.ac.nz

Scarpa, Riccardo
rscarpa@waikato.ac.nz

Abstract

In New Zealand, water taken from rivers, lakes and aquifers is essentially free. However, many catchments area are now approaching full allocation and the current 'first-come-first-served' rights distribution method is inadequate to deal with the growing demand and to secure optimal resource allocation. Currently, however, little research effort has been dedicated to exploring the value of and willingness to pay for water among various users – information that will be vital to designing any new market mechanisms. To circumvent this chronic data paucity we use choice modeling to estimate willingness to pay (WTP) of ground and surface water abstraction destined to irrigation. Particular attention is paid to the issue of attribute non-attendance in the choice experiments, which has been highlighted as a potential source of systematic bias in the literature. Data on attribute non-attendance (ANA) in choice experiments is commonly collected via follow-up questions (stated-ANA) or through latent class modeling (inferred-ANA). Using a custom designed online survey tool, this study suggests a third, relatively unused method of measuring ANA—dubbed 'revealed ANA'—where information on attribute levels is concealed until the choice experiment participants hover their mouse over (or maintain touch on, in the case of touch devices) the location of the screen displaying the attribute values of interest. This methodology is second best when compared to the more expensive eye-tracking approach common in decision making research. Yet, it has the appeal of being able to be applied outside the stringent laboratory conditions necessary for eye-tracking. Our sample has three same size subsamples, each randomly allocated to a treatment for ANA detection. Respondents on treatment 1 were asked a conventional follow-up question regarding ANA asked at the end of the choice sequence (i.e. stated serial ANA); those on treatment 2 were asked ANA questions after each of the eight choice tasks (stated choice task ANA), while the remaining third (treatment 3) were exposed to the hover and reveal condition (revealed ANA). The added burden of choice task and revealed ANA data collection methods results in a significantly lower completion rates for both T2 and 3, so the purpose of this paper is to determine whether additional information gathered is worth the cost. The findings suggest the Stated ANA methods correspond to relative significance of estimates, implying that stated ANA data is a proxy for a measure of preference heterogeneity, whereas Revealed ANA tracks inattention to significant attributes.

1 Introduction

Just over five percent, or 720 thousand hectares, of all New Zealand farmland is defined as 'irrigable'-land that could have been irrigated using existing resource consents and equipment of the farm (Statistics New Zealand, 2013). This represents a significant increase from 2007, when 4.2% (620 thousand ha) and 2002, when 3.0% (470 thousand ha) were recorded as irrigable (Statistics New Zealand, 2008, 2003). The main driving forces behind this increase are most commonly attributed to land use conversion to dairy farming and general intensification of farming within the dairy sector—both of which are expected to continue (Parliamentary Commissioner for the Environment, 2013; Statistics New Zealand, 2013).

The New Zealand water resources suitable for irrigation, however, are not unlimited. In certain locales are reaching the maximum legal abstraction limits—and in some cases have already surpassed them (Kaye-Blake, Schilling, & Destremau, 2014). The Resource Management Act, RMA, enacted in 1992 delegates the operational management of resources from the central government to regional councils, without giving the regional governments sufficient power to decide the ways they are able to manage those resources. The provisions of RMA tasked to govern water allocation have been dubbed 'first-come-first-served' and have not been designed to cope with scarcity. Users of water—be it agricultural, industrial or municipal—are essentially not allocated rights according to the highest utility, and an increasing number of irrigation water applicants are unable to obtain a consent from councils due to the legal limits set. Furthermore, there are no provisions in the Act for the councils to make a preference of applications except for the time of the lodgement. In addition, incumbent users can (and do) challenge new resource applications if they feel that new users may decrease the availability of the resource for them.[1]

Other than a nominal application fee, water taken from water bodies, rivers or aquifers is essentially free, provided the necessary resource consent has been issued. Hence, the cost of the water (zero) does not reflect its true value, since there are often users who would be willing to spend a non zero price to gain access to it. Moreover, water availability in New Zealand is highly seasonal—rainfall (and thus supply in rivers, aquifers and lakes) is generally lowest during the late spring and summer when the demand for water is the highest. To maintain ecological health of water bodies, regional councils limit intakes of water from bodies when supply is below certain thresholds for all users. Again, there are no established mechanisms to identify users who may have a more valuable use to put water to, or whose water related activities might be critically threatened by lack of water, and blanket restrictions are generally set in places during the times of low flows.

There are some limited examples of water trade,[2] and in principle it is not illegal under the Act. However, this practice is very limited and does not include involvement of the government other than the cumbersome process of applying for the transfer, 'which may or may not be granted' (Hydrotrader, 2015a). The largest trading institution locating in the Canterbury/Otago regions had just 65 Sales/Lease agreements between 2007-2015,

[1]For instance, in 2006 a hydro-power electricity generator successfully challenged the application by a dairy farm in the Waikato on the grounds that it would reduce availability of potential energy and hence have a direct negative impact on its (earlier) consent (Ward, 2006).

[2]Most notable is trading with 'http://hydrotrader.co.nz' in South Island

averaging just under 2,000 m^3 per trade (Hydrotrader, 2015b).

A task force was set up by the government in 2010 to deal with the growing concern about water allocation and quality. They identified water quantity issues as a significant concern for the future and suggested that price-based mechanisms could be a pathway to manage water resources more efficiently. There are significant hurdles to establishing such mechanisms, not the least of which is political. First, it is quite unclear how much water is being put to what use—some takes (stock watering) do not require a consent, and even those with existing consents do not necessarily use all the water allocated (Rajanayaka, Donaggio, & McEwan, 2010). Second, there are often competing claims to water, with no clear rights of ownership or single point of governance. In one example, private users were told they had to apply to 14 different iwi[3] to renew the water resource consent for their home (Maas, 2014). Finally, in order to consider any potential price-based mechanisms, it is important to have an idea of how farmers would respondent to changes in water prices—information that is currently critically lacking.

Studies estimating the value of water in New Zealand are few and are generally limited to estimating the overall benefit of irrigation rather than in terms of its volumetric value. Doak, Parminter, Horgan, Monk, and Graeme (2004), in particular, stressed that it is impossible to derive volumetric pricing in New Zealand because data on water usage was not collected. Not until 2010 was legislation put in place to require measuring and recording water takes of $20m^3$/second, and $10m^3$/second from 2012 and 2014, respectively (Ministry for the Environment, 2010). Hence, the purpose of the present study is to fill this literature gap and to estimate farmers' willingness to pay for the volume of water. Below is a short overview of studies looking at estimating the benefit of irrigation in New Zealand.

Doak et al. (2004) estimated the benefit of irrigation to New Zealand to be NZ$920 mil by studying the difference in productivity between irrigated and non irrigated land. Kaye-Blake, Schilling, and L (2011) used a CGE model to estimate the benefit of 14 planned irrigation projects across New Zealand and concluded that there is a substantial benefit

[3] Maori tribes

to the overall economy from irrigation schemes, in the vicinity of of 0.8% of the GDP by 2035. More recently Corong, Hensen, and Journeaux (2014) used their CGE model of the NZ economy to update 2004 values of benefit to the economy due to irrigation from Doak et al. (2004). They estimated the net contribution to the economy to be $2.17 bn in 2011/2012.

Other studies include Grimes and Aitken (2008), who used a hedonic pricing approach and found that irrigated land has up to a 50% premium over unirrigated land of the same characteristics. However, they found that net return to irrigation installation is actually negative for many farms in their study area of MacKenzie District, Canterbury, explaining relative abundance of dryland farms. Jenkins (2015) imputed volumetric costs of providing water for residential, irrigation and hydro-electric generation uses. For the latter, he estimated the value to be between $0.0057 to $0.036 per m^3. By analyzing dairy production data Kravchenko (2014a) estimated the demand elasticity of water for dairy farms. He found that, under certain assumptions, a $0.05 increase in the price of water (per m^3) would reduce the demand by three percent.

Studies looking into the costs of irrigation found that annualized costs of irrigation schemes to be between $0.02-$0.23 per m^3 in Canterbury and $0.01-$0.43 per m^3 nation-wide, with mean values of $0.14 and $0.15/$m^3$, respectively (Reese & Borrie, 2012, 2014). However, these estimates were based on an assumption of usage of full allocation, rather than what is actually used. As Rajanayaka et al. (2010) noted, the amount of water actually used in New Zealand is 35% lower than what was allocated by councils in their resource consents, implying (as later confirmed by some respondents) that some permits are retained for the sole purpose of adding value to properties.

2 Stated Choice Modeling and Attribute Non-Attendance

To estimate the value of irrigation water in our empirical study we use the stated choice approach. Stated choice is a methodology based on a specific type of survey technique where survey respondents—in our case farmers—are asked to consider all the information presented and pick the most desirable option out of a set of mutually exclusive water contracts. Respondents are generally asked to make a number of successive choices in an experimentally controlled setting. Variants of this methodology also include ranking the alternative, picking best and worst options, or assigning likelihood of choosing. Each alternative contract is described in terms of attributes, and each attribute consists of two or more levels to differentiate their contribution to alternatives. Young (2005) observed that stated choice method is generally reserved for non-market valuation, especially common for ecological and environmental values. There are, however, a few recent studies employing choice modeling in estimating the volumetric value of irrigation water (Barton & Bergland, 2010; Alcon, Tapsuwan, Brouwer, & de Miguel, 2014).

Barton and Bergland (2010) aimed to value irrigation water in India using stated choice methodology. The authors, however, ran in to the issue of serial non-participation (choosing status quo over priced alternatives in a majority of choice tasks) since no one wanted to pay for something what at that time provided for free. Rigby, Alcon, and Burton (2010) conducted a choice experiment in Spain with the goal of estimating the economic value of irrigation water. Since during the time of their choice experiment water was an unpriced good (and the government was thinking of charging for water), they also recorded a strong anti-pricing sentiment among the surveyed farmers. Anticipating the potential serial non participation, the authors removed status quo as an available alternative. Such approach, however, does not allow for unconditional WTP estimates.

2.1 Prevalence of ANA

For the purposes of analyzing stated choice data, standard econometric models commonly assume that respondents engage in a fully compensatory decision-making process, meaning that they are expected to carefully consider all the information provided and make their decision accordingly, by trading off the positive with the negative aspects of each alternative. One concern which has recently been highlighted and studied is the issue of attribute non-attendance [ANA] (e.g. Hensher, Rose, & Greene, 2005a; Carlsson, Kataria, & Lampi, 2008; Scarpa, Gilbride, Campbell, & Hensher, 2009; Collins, 2012).

This occurs when respondents do not follow a fully compensatory choice behaviour, but instead engage in heuristics, or simplifying techniques to make the decision process easier. If they do so, compensation for less than a good attribute cannot be obtained by providing more of another good attribute. While it is generally agreed that this phenomenon is common in most stated choice surveys, there is much less consensus on its effect on the outcomes of the studies and on the best way to detect it or correctly measure it.

Some authors (indeed everyone who ignores the effect of ANA in their studies) assume, explicitly or implicitly, that it is not an issue since attributes that are ignored are thought to have been ignored by the respondents because of low importance. Thus systematically ignoring attributes during choice would have no discernible impact on parameter estimates from that of low preference for the ignored attributes. However, it has been shown in a simulation study by Kravchenko (2014b) that not accounting for ANA may significantly bias the estimates of not only ignored parameters, but also of other parameters that are fully considered.

One reason why respondents may potentially ignore useful information is the varying levels of involvement and effort with the choice tasks across the survey. Displayed effort, however, is difficult to measure, although some research used time of completion (response latency) as its proxy (Haajier, Kamakura, & Wedel, 2000). For example, Rose and Black (2006) find that response latency influences both the mean and variance of parameter estimates. Since each respondent is faced with a number of tasks, the first tasks are typically given much more attention and time, while the latter tasks are given less time and 'fatigue' has been a disputed effect: for example, Savage and Waldman (2008) find different effects from those found by Hess, Hensher, and Daly (2012) and Czajkowski, Giergiczny, and Greene (2014). Arguably, when fatigue does occur, it is not that respondents have varying preferences across choice tasks, but rather they are less involved in later than earlier choice tasks and would answer differently if they paid more careful attention to attribute levels of each alternative. Hence, it is possible that ANA is a symptom of fatigue—no necessarily showing zero preference, but rather than an artifact of choice task exercises. If so, including the choices recorded towards the end of the sequence could introduce a systematic bias as these are more likely to be affected by ANA. Similarly, 'learning' has also been highlighted as a possible reason for engaging in heuristics and consequent ANA—respondents get familiar with various attribute levels at earlier choice tasks and engage in simplifying heuristics in later choice tasks Oppewal, Morrison, Wang, and Waller (2010).

3 ANA & Heuristics Background

There has been an increase in recognition that when making decisions respondents deviate from a fully compensatory evaluation process, where every attribute level of every alternative is weighted before a decision is made. Such deviations, however, can "lead to elimination of potentially good alternatives early in the decision process" (Payne, Bettman, & Johnson, 1993, p. 5). Decision makers have a limited cognitive capacity, and resort to simplifying strategies, or 'heuristics', so as to decrease cognitive burden during decision making. As early as 1956, Miller, demonstrated that on average only 7 "chunks" of information can be stored in the cognitive brain for help with decisions, while many choice modeling exercises have significantly more. Payne et al. (1993) proposed that there exists a tradeoff between the effort required to make a decision and accuracy of that decision.

On the other hand, Gigerenzer and Brighton (2009) argued the opposite and suggested that there is no trade-off, and that using heuristics actually improves decision accuracy, hence taking a 'less-is-more' perspective. They suggested that forcing respondents to consciously consider more information leads to lower precision (and hence more error) in decision making than when using simplifying heuristics.

Shah and Oppenheimer (2008) summarized the heuristics recently mentioned in literature and organized them into a framework:

> "...the weighted additive rule and other optimal strategies place five demands on people: to consider all available cues, to retrieve cue values accurately, to weight cues properly, to integrate information for each alternative, and to

> examine all alternatives. We therefore believe that people confront limited cognitive resources by addressing these five demands. They can reduce the effort associated with any of these five demands individually or collectively" (p. 219).

Within the context of environmental economics, the most commonly referred to heuristic is that of attribute non-attendance—either when the respondents ignore one or more attribute levels over the whole experiment (serial ANA) or at the single choice task level (choice task ANA). Under Shah and Oppenheimer (2008)'s classification ANA can be a symptom of 'examining fewer clues' and 'integrating less information'.

There is evidence of ANA being ubiquitous, Kragt (2012) looked at serial ANA and reported that just half of the respondents stated they paid attention to all the attributes, and almost 20% paid attention to just one. Reisen, Hoffrage, and Mast (2008) reported that in their study, respondents examined only 22% of the available attributes. In Kaye-Blake, Abell, and Zellman (2009)'s study, nearly 50% of attribute levels were not attended to. Scarpa, Thiene, and Hensher (2010) monitored ANA via asking a question at the end of each choice task along the sequence. Although their initial suggestion was to monitor the level of attention, this was deemed to be too laborious during the pilot and it was dropped in favor of a dichotomous "attended/non-attended" response. The authors also noted that serial non-attendance is what is most commonly collected. Highlighting the difference, the authors noted that when when ANA monitoring was serial, 5% of or respondents admitted to ANA of the cost parameter, whereas when it was recorded at the choice-task, the proportion increased to 20%, with strong implications for estimates of marginal WTP.[1]

In an effort to understand the causes of ANA in stated choice experiments, Alemu et al. (2013) probed respondents about reasons behind ANA in their survey. They conclude that the most common reason for ANA is lack of interest (zero preference) of particular attributes. They also, however, find that simplifying heuristic—ignoring an important attribute level to make the choice easier also plays a part. The authors also noted that

[1] For a thorough overview of stated ANA studies see Alemu, Mørkbak, Olsen, and Jensen (2013).

explicit questioning about ANA as part of the survey seemed to improve parameter estimation. Puckett and Hensher (2008), also argued that the spread of attribute levels may be significant as when *differences* in levels are not sufficiently large this may induce ANA.

Notwithstanding recognition of ANA prominence in the decision making process, Hensher (2009) suggested that the vast majority of choice modelers still ignore the topic and assume a full compensatory decision making process. As Willemsen and Johnson (2010) put it: "decision making research has largely progressed through the use of models that account solely for observed choices without extensive consideration of underlying cognitive structures and processes". Studies that do account for ANA and heuristics usually find that they have significant impact on WTP and parameter estimates—Hensher (2009) purported that "failure to accommodate process heterogeneity is a significant contributing influence [of a large hypothetical bias]" p.27. Similarly, Hensher and Greene (2010); Hensher and Rose (2009); Hensher, Rose, and Greene (2005b) found the WTP to be significantly higher when ANA was accounted for. Campbell, Lorimer, Aravena, and Hutchinson (2010) found that by including strategies of attribute processing in the model estimation, 'more defensible' estimates were derived.

3.1 Approaches for Detecting and Dealing with ANA

There are two main methods of integrating ANA into choice modelling—through 'stated' or 'inferred' methods. Inferred methods (such as Scarpa et al. (2009); Hensher and Rose (2009)) use an equality constrained latent class approach, with the main advantage being that no further data is required. The main assumptions in such models is that there is respondent heterogeneity where some groups do not attend to one or more attributes (or, equivalently, have zero preference to those attributes). Stated method ANA involves collection of specific respondent's statements on ANA, usually in the form of answers to follow-up questions, such as "is any of the information shown not relevant when you make your choice?" (Hensher et al., 2005b; Hensher, 2006). Coefficients on attributes that are ignored are then restricted to zero in model estimation (at either the choice task level or across the whole sequence of choices (the 'serial' level)—see Hensher (2009)).

There are contradictory findings with regards to the efficacy of each method. Hensher (2009) notes that stated ANA are not significant when included in the latent class model, meaning that the latent class model provides the same result, but without the need for further information collection. Yet, Campbell and Lorimer (2009) find a discrepancy between self-reported and modeled attributes that are ignored. Hensher, Rose, and Greene (2012), too cite the concern of reliability of information. Similarly, Kragt (2012) and Scarpa, Zanoli, Bruschi, and Naspetti (2013) find that inferred and stated ANA models provide different results.

Alternative strategies to collecting information on ANA include eye tracking, mouse tracking and debriefing ('think aloud'). However, such tools are most frequently used in the context of the actual decision making process, rather than in contexts that enable the study of their effect on the outcome. They are usually, but not always, confined to controlled lab environment (with notable exception of recent mouse tracking software, such as recent version of *MouseLab* (Norman & Schulte-Mecklenbeck, 2010) and *Moustracker* (Freeman & Ambady, 2010)). Schulte-Mecklenbeck, Kühberger, and Ranyard (2011) compare such decision process-tracking tools in the context of judgment and decision making research and conclude that each method has its pros and cons, and argues for using a multi-method approach. However, as noted, most research seems to focus on 'how' decisions are made as opposed on what effect these strategies have on the decisions made.

Examples of use of such process-tracking tools include, Russo and Dosher (1983), who use eye-tracking to detect decision strategies. However, their experiment was forcing a full compensatory decision strategy—more concentrating on dimensional vs holistic strategies, (i.e. attribute vs alternative based strategies). Similarly, Ball (1997) examines the actual strategies via analysis of decision information windows. Meibner, Huber, and Musalem (2013), on the other hand, examine ANA using eye-tracking techniques and conclude that in choice tasks later in the sequence respondents tend to focus only on important attributes. In an example, the authors describe the movement of attention of a respondent in a task near the end of the experiment—concentrating on the levels of just one of several attributes. Once the desired level of that attribute (considered most important—i.e. using a lexicographic heuristic) is found, the respondent is then seen looking at the levels of other attributes in the alternatives—ensuring that nothing too undesirable is detected before choosing the said alternative. Corresponding levels of other alternatives are entirely ignored.

A study by Kaye-Blake et al. (2009), does consider the effects on the outcome by using an on-screen information display matrix with concealed attribute levels that might be revealed on demand by respondents (a type of mouse-tracking). The concealed attribute levels that are clicked on become visible, thus allowing the researchers to track what information was sought and when, thereby defining what information was potentially used by respondents in each task, as well as what was definitely ignored. The study goes on to conclude that incorporating ANA study significantly influences parameter estimates. However, Franco-Watkins and Johnson (2011) argue that mouse-tracking introduces an experimental artifact, influencing the experiment outcomes: mouse-tracking takes longer than eye-tracking and also comparatively increases search costs (effort), hence respondents spent less time evaluating attribute levels.

4 Survey Design

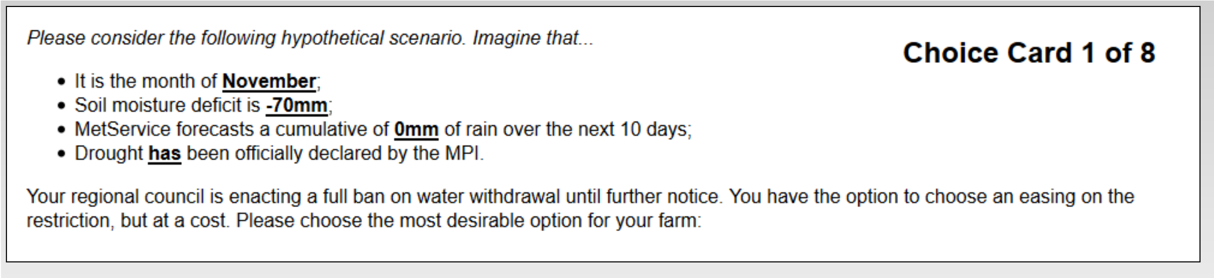
Following Kaye-Blake et al. (2009), we create an online information window with obscured attribute levels to trace attention. The key difference with the Kaye-Blake et al. (2009)'s study is that the levels are revealed to respondents when they hover the mouse's pointer over the attribute space in the matrix cell and are hidden as soon as the mouse pointer leaves the matrix cell. Importantly, this allows us to record timing of fixations, which is correlated with its use in the evaluation of alternative. No clicking is required, thus reducing some of the respondent's effort. The survey is conducted outside a laboratory environment with a control group (thus allowing to estimate the cost of collecting this data in terms of drop out rates).

The stated choice survey was developed to target the population of farmers who irrigate and hence possess water consent. Because the current price of water is practically zero, it was difficult to imagine any farmer with an existing consent willing to voluntarily pay anything more than zero. Previous stated choice studies attempting to value irrigation water under similar conditions grappled with this issue and either ran into serial nonparticipation (Barton & Bergland, 2010) or had to resort to excluding the zero priced status quo to avoid it (Rigby et al., 2010). An alternative, and possibly superior approach, would have been to gain access to a sample of potential irrigators who were refused a water resource consent. But in practice this population would have been very difficult to get in touch with or collect a large enough sample.

Therefore, to obtain meaningful willingness to pay for water estimates from existing irrigators, water scarcity was simulated by designing hypothetical scenarios where respondents were asked to imagine a drought and a local regional council instituting a full water withdrawal ban (not an uncommon scenario during New Zealand's springs/summers—from September to February). The drought scenarios at each choice task also differed in terms of the month, level of soil moisture deficit, cumulative rain forecast over the next 10 days and whether or not drought had been officially declared by the Ministry of Primary Industries [MPI]—see Figure 1.[4][5] Furthermore, if respondents identified themselves as dairy farmers at the start of the survey, an additional dimension in the scenario was added: the milk solid payout forecast.

[4] The scenario attributes had the following probability of occurring of their levels:
Months: September ($^1/_{10}$); October ($^2/_{10}$); November ($^3/_{10}$); December ($^2/_{10}$); February ($^1/_{10}$).
Soil Moisture Deficit: -20mm ($^1/_6$); -70mm ($^2/_6$); -120mm ($^3/_6$).
Rain Forecast: 0mm ($^3/_6$); 20mm ($^2/_6$); 50mm ($^1/_6$).
MS Payout Forecast: \$5 ($^2/_7$); \$6 ($^3/_7$); \$7 ($^2/_7$).
Drought Declared: yes ($^1/_2$); no ($^1/_2$).

[5] In New Zealand, farmers get assistance from government agencies, trusts and cooperatives if a drought is officially recognized.



Please consider the following hypothetical scenario. Imagine that...

Choice Card 1 of 8

- It is the month of **November**;
- Soil moisture deficit is **-70mm**;
- MetService forecasts a cumulative of **0mm** of rain over the next 10 days;
- Drought **has** been officially declared by the MPI.

Your regional council is enacting a full ban on water withdrawal until further notice. You have the option to choose an easing on the restriction, but at a cost. Please choose the most desirable option for your farm:

Figure 1: ***Example of a hypothetical scenario.***

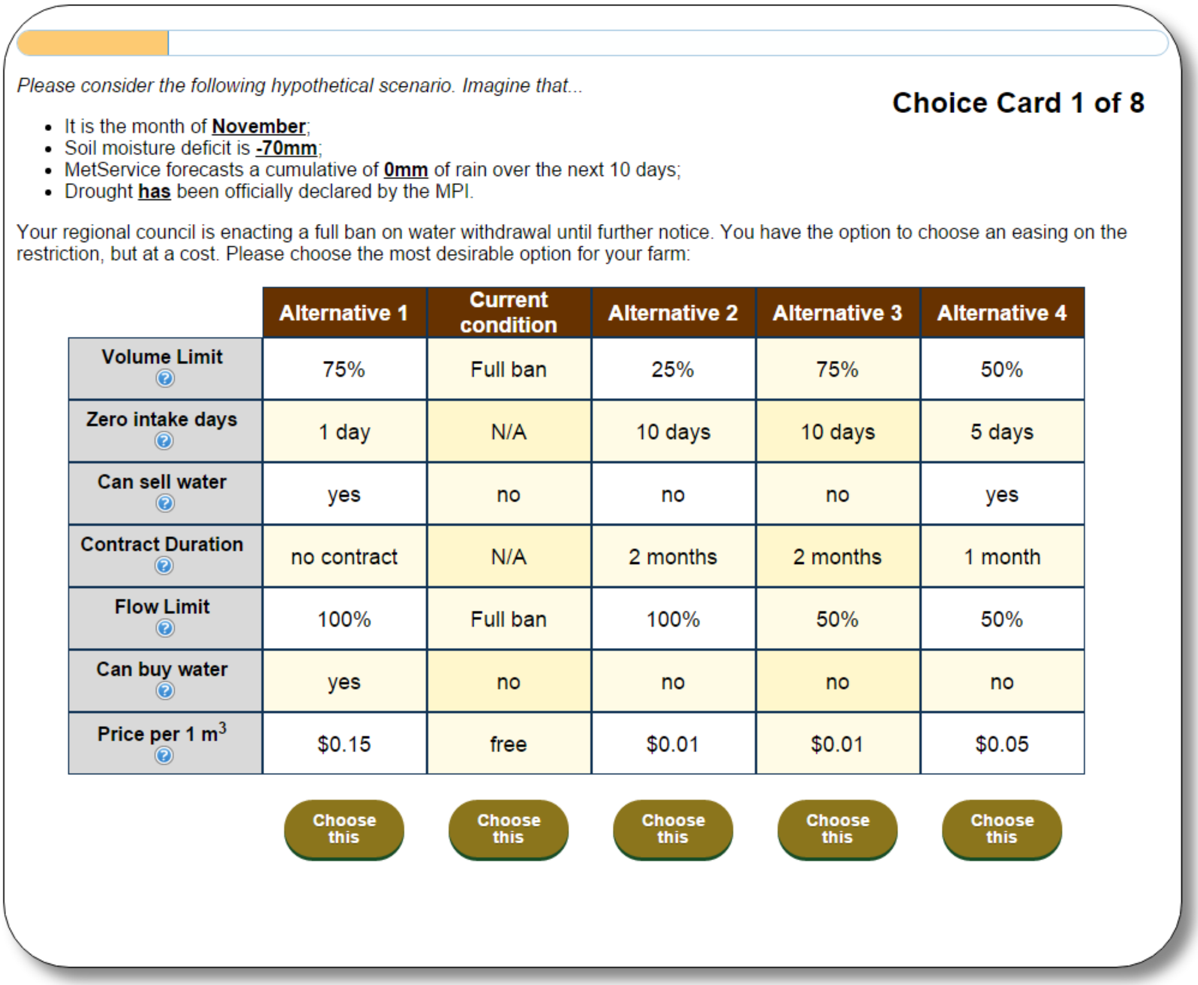
Respondents were then given a choice between status quo and 4 alternatives defined by the following attributes:

Attribute Name	Description	Levels	Status Quo
Can sell water	Ability to sell excess water rights	yes no	no
Can buy water	Ability to buy additional water from other users and/or the council	yes no	no
Zero intake days	Max days of zero intake (per month)	1 day 5 days 10 days	N/A
Flow Limit	Flow Take Restriction (% of consented)	25% 50% 75% 100%	Full ban
Volume Limit	Total Volume Limit Restriction (% of consented)	25% 50% 75% 100%	Full ban
Contract Duration	The compulsory duration of the contract to buy water at the specified price	no contract 1 month 2 months	N/A
Price per 1 m^3	Price per 1 Cubic Metre (10 cubic metres is equivalent to 1mm / ha)	\$0.01 \$0.02 \$0.05 \$0.10 \$0.15	free

Table 1: Attributes and levels

A D-error minimizing design was generated using priors with expected signs and relative magnitude using Ngene (Ferrini & Scarpa, 2007; Rose, Bliemer, Hensher, & Collins, 2008; Scarpa & Rose, 2008).

After 40 completed choice task sets were collected, priors were updated and an improved D-error minimizing design was generated, following the incremental approach suggested by Scarpa, Campbell, and Hutchinson (2007). The final improved design consisted of 8 choice tasks per respondent, with 4 unlabeled alternatives and the status quo per each task. Since Shah and Oppenheimer (2008) point out that the use of heuristics increases with cognitive load, this relatively demanding design was intentionally made this way to induce respondents to resort to heuristics (see Figure 2). To avoid ordering effects, the order of vertical display of attributes were randomized across respondents (but kept consistent in between choice tasks), the left-to-right position of alternatives was also randomized, as well as the choice task order and the assignment to blocks (6 in total).


Please consider the following hypothetical scenario. Imagine that...

Choice Card 1 of 8

- It is the month of **November**;
- Soil moisture deficit is **-70mm**;
- MetService forecasts a cumulative of **0mm** of rain over the next 10 days;
- Drought **has** been officially declared by the MPI.

Your regional council is enacting a full ban on water withdrawal until further notice. You have the option to choose an easing on the restriction, but at a cost. Please choose the most desirable option for your farm:

	Alternative 1	Current condition	Alternative 2	Alternative 3	Alternative 4
Volume Limit	75%	Full ban	25%	75%	50%
Zero intake days	1 day	N/A	10 days	10 days	5 days
Can sell water	yes	no	no	no	yes
Contract Duration	no contract	N/A	2 months	2 months	1 month
Flow Limit	100%	Full ban	100%	50%	50%
Can buy water	yes	no	no	no	no
Price per 1 m^3	\$0.15	free	\$0.01	\$0.01	\$0.05
	Choose this	Choose this	Choose this	Choose this	Choose this

Figure 2: ***Example of a choice task card.***

To distribute the survey, Regional Councils and industry organizations were enlisted to help reaching out the farming community—most were very helpful and provided access to irrigation consent holders/farmers. In addition, online advertisements on Facebook and Google Adwords were also trialled at the early stage, but dropped due to high costs and low response rates. Finally, upon the completion of the survey, respondents were also encouraged to share the survey with other farmers.

Figure 3 depicts geographic distribution and density of the location of farms surveyed according to the respondents' stated closest weather station locations. Overall, the response rates were very low—of approximately 2,000 physical letters sent out to consent holders in Hawke's Bay, Waikato and Otago regions inviting them to partake in the survey, only 58 started the survey.[6] The reasons for such a low response rate are not entirely clear, but include factors such as low incentive value,[7] a possibility that research topic was negatively viewed (existing consent users would not want to pay for something they consider should be free)[8] and the fact that farmers are generally over-surveyed in New Zealand and it is quite common to experience low response rates in surveys targeting them.

[6]Defined as answering the first question regarding the classification of the farm they were operating.

[7]Respondents were offered to be in a draw to win an iPad mini upon the successful completion of the survey.

[8]One respondent who chose not to complete the survey was helpful in emailing their comments and allowed the following quote to be used, *"As far as paying some government agency a resource rental goes, I would rather eat the tip off my left thumb than have any part of that..."*.

In addition, one large industry collective specifically declined to be involved in distributing the survey because it was their stance to be very much against charging for water

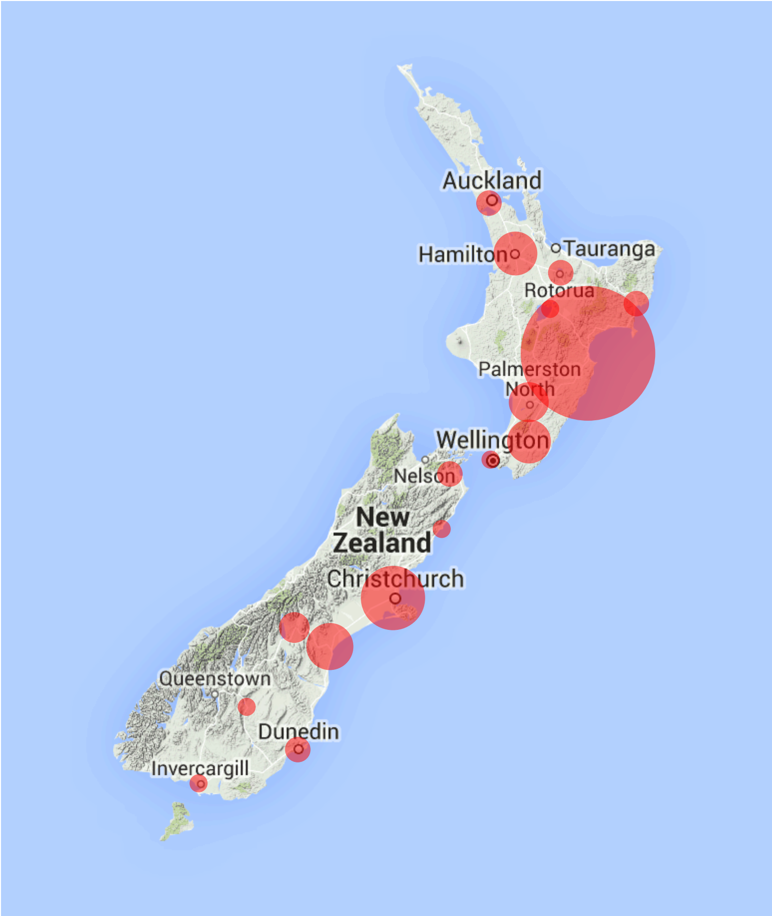


Figure 3: ***Approximate location and concentration of surveyed farms based on the stated closest weather station(n=113)***

The response rates for other sources was less clear since invitations to participate in the survey were placed on various organization websites, newsletters and also emailed through internal distribution systems. Overall, 154 sets of 8 choice tasks were completed by respondents.

4.1 ANA tracking

Respondents were randomly assigned into one of three ANA tracking conditions: in the first two ANA was based on self-reported statements. In the first case the ANA statements were collected at the end of the sequence of 8 choice task (serial ANA); in the second case after each choice task (choice task ANA). Specifically, statements were collected using the pop up window in Figure 4.

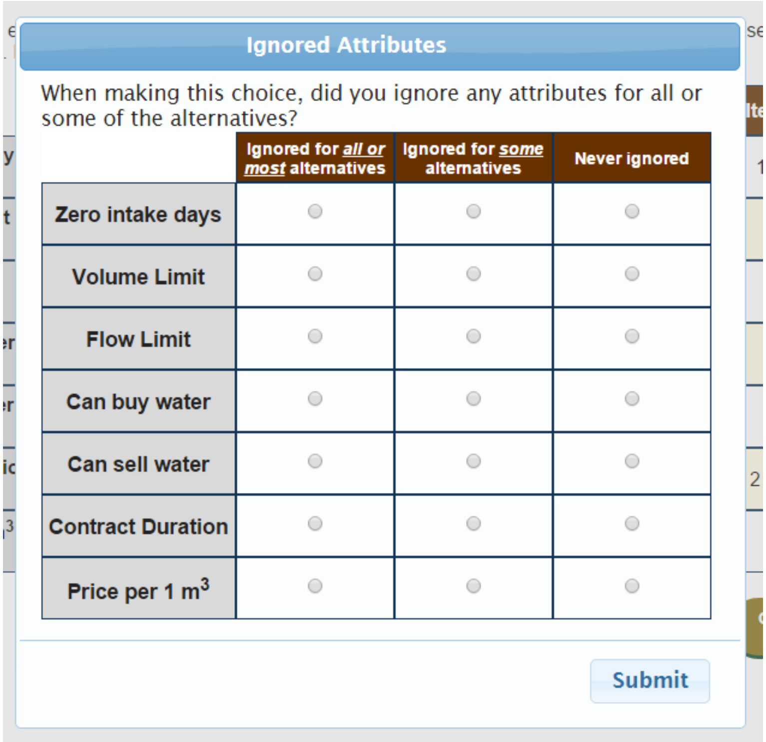


Figure 4: ***Stated ANA tracking–in the serial ANA treatment, nonattendance statements were collected after the completion of 8 choice tasks, whereas in the choice task ANA treatment this question appeared after each choice task.***

In the third case ANA was *revealed* by mouse-tracking. Specifically, attribute levels were hidden until respondents hovered their mouse pointers over the cells of the attributes in the display matrix (see Figure 5). This followed the earlier work by Kaye-Blake et al. (2009); Johnson, Payne, Bettman, and Schkade (1989); Ball (1997). However, unlike previous attempts, this survey instrument was administered outside of the laboratory environment and was targeting a relatively involved decision in terms of both cognitive load and financial implications for the respondents. It was also intended to examine the effects of ANA on parameter estimates rather than to only identify the specifics of the decision making process. In addition, the present study was also intended to compare the three methods of collecting data on ANA, an intent that was never pursued in previous attempts.

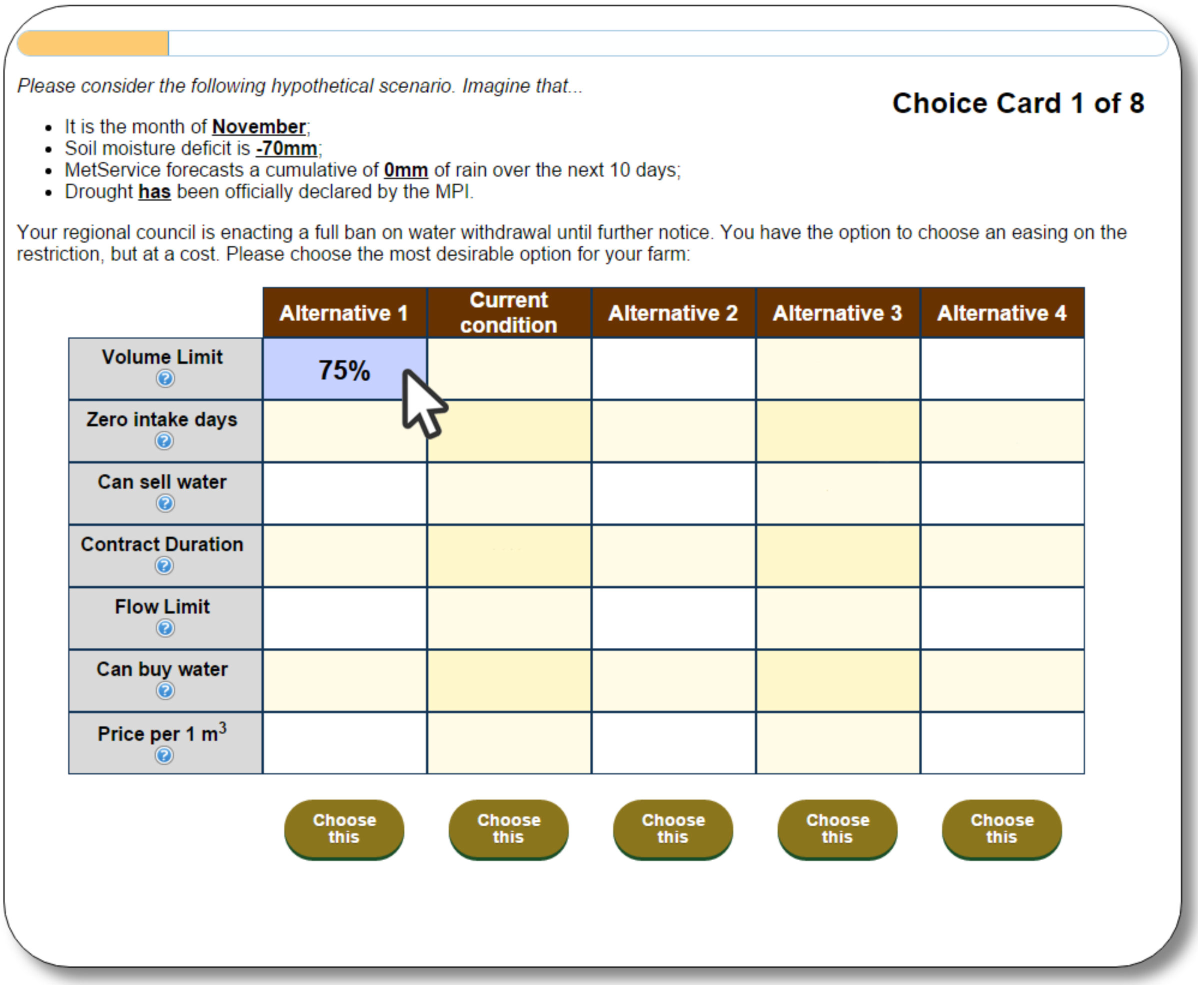


Figure 5: ***Revealed ANA tracking–Attribute levels were hidden until respondents hovered their mouse pointer over the corresponding cell (or touched on the touch devices)***

5 Results

The survey went live between July 2014 till October 2015. While only 102 respondents completely finished the survey—including answering all auxiliary questions about their irrigation system—154 respondents completed all of 8 choice tasks. In addition, the actual choice task completion rates vis-a-vis the assigned ANA tracking method were quite telling (see Table 2):

The completion rate of the full sequence of 8 tasks was lower for task and for the revealed ANA tracking conditions. Assuming a completion rate of the Serial ANA method of 35%, when applied to the other methods, the additional task burden of ANA tracking resulted in the potential loss of $(176 \times 0.35) - 50 = 12$ and $(161 \times 0.35) - 42 = 15$ completed

	Serial	Task	Revealed	Total
Passed screener	176	176	161	513
Answered 8 choice tasks	62	50	42	154
8 Task Completion Rate	0.35	0.28	0.26	0.30
Completed the survey	35	39	28	102

Table 2: Completion rate breakdown by ANA tracking type

sets of responses for task and revealed ANA conditions, respectively. Hence, collection of ANA data at the choice task level, be it via mouse-tracking or via collecting self-reports, significantly impacts on completion rates (for the task condition the potential loss in data collection is: $^{12}/_{(50+12)} = 19.4\%$, and for the revealed condition it is $^{15}/_{(42+15)} = 26.3\%$) and should only be used if data collected adds significant insights, which would otherwise not be available.

5.1 Serial and Task ANA data comparison

The stated ANA for both serial and task conditions are largely the same (see Table 3)[9]—"Volume Limits" and "Flow Limits" attribute levels are paid attention to the most, whereas "Can Sell Water" and "Contact Duration" are attended to the least. It is important to note, however, that even the attribute most attended to was so only 60% of the times, implying that—contrary to the fully compensatory principle assumption—not all attributes were considered all the time (Table 4).

	Serial	Task
Volume Limit	3.7	3.7
Flow Limit	3.6	3.6
Contract Duration	2.5	2.9
Can buy water	2.3	2.8
Can sell water	1.8	2.0
Zero intake days	2.9	3.4
Price per 1 m3	2.9	3.4

Table 3: ANA Reported - Simple Average Scores

An important consideration is whether ANA levels for attributes are stable across choice tasks—i.e. whether choice task ANA data collection adds significant information

[9]To calculate the simple average score "0" was assigned if the respondent stated that the attribute was *ignored for all or most alternatives* "2.5" for *ignored for some alternatives* and "5" for *never ignored.*

	ignored for all or most alternatives		ignored for some alternatives		never ignored	
	Serial	Task	Serial	Task	Serial	Task
Volume Limit	12	13	29	27	59	60
Flow Limit	12	15	33	25	55	60
Contract Duration	29	27	43	31	28	42
Can buy water	40	36	28	18	33	46
Can sell water	55	51	17	19	28	31
Zero intake days	17	18	48	29	34	53
Price per 1 m3	29	19	24	25	47	56

Table 4: ANA Reported Frequencies (%)

over the much less burdensome serial ANA data collection. Table 5 reports the percentage of respondents reporting the same level of ANA for each attribute across the number of choice tasks. For instance, 51% of respondents consistently chose the same level of ANA (whether 'ignored all', 'some' or 'none') for the attribute of "Volume Limit" for each of the 8 choice tasks, whereas a further 14% of respondents chose the same level of ANA for 7 tasks—choosing a different level of ANA for one task. Interestingly, attributes with lowest 8 choice task ANA consistency ("Can sell water" and "Contract Duration"—from Table 5) had the lowest overall reported attendance, as reported by overall serial and task ANA summaries (from Tables 3 and 4). Overall, 66.8% of respondents consistently reported the same level of ANA for different attributes across 7 to 8 choice tasks, implying that Serial ANA collection method is not a perfect substitute for ANA data at the Task level.

	8	7	6	5	4	3
Volume Limit	51	14	14	8	10	2
Flow Limit	49	24	10	10	6	0
Contract Duration	43	27	8	16	4	2
Can buy water	47	18	12	16	6	0
Can sell water	41	24	12	12	10	0
Zero intake days	49	16	12	12	8	2
Price per 1 m3	49	14	22	6	8	0

Table 5: Percentage of respondents reporting the same ANA level for each attribute across choice tasks

5.2 Revealed ANA data

5.2.1 Times spent looking at attribute levels

We mentioned before that as part of the the revealed ANA condition, each time a respondent hovered their mouse pointer over a blank cell in the the display matrix (or tapped with a finger on a touch device) the corresponding attribute level was revealed (see Figure 5). As soon as the pointer left the bounds of the matrix cell, the attribute level was hidden again. The timing of each event was recorded (see Figure 6 for a distribution of timing), along with the corresponding alternative number and attribute. Some events would necessarily be the artifact of the data collection method (such as when making a decision then having to drag the cursor across the matrix to the decision button on the bottom, or when comparing attributes of alternatives on the opposite side of the display matrix) and do not by themselves represent genuine instances of desire to disclose and hence pay attention to attribute levels. It was hence necessary to identify these to remove them. Starr and Rayner (2001) report that a skilled reader on average would focus (i.e. 'fixate') on 7 to 9 letters for 200-250 milliseconds before moving onto the next batch of letters. These batches, or 'fixations', may be a combination words (e.g. 'I went to'), a whole word ('potatoes') or part of a longer word ('interme...'). Hence, events below the 200 millisecond threshold were deemed to be too brief to represent genuine fixations, hence were removed from analysis on ANA. While the hover events are not fixations per se—the survey was not tracking eye movements, since respondents were instructed to uncover attributes, it is reasonable to assume that the eye focus followed closely the position of the cursor in the display matrix, henceforth referred to as 'pseudo fixations' [PF].

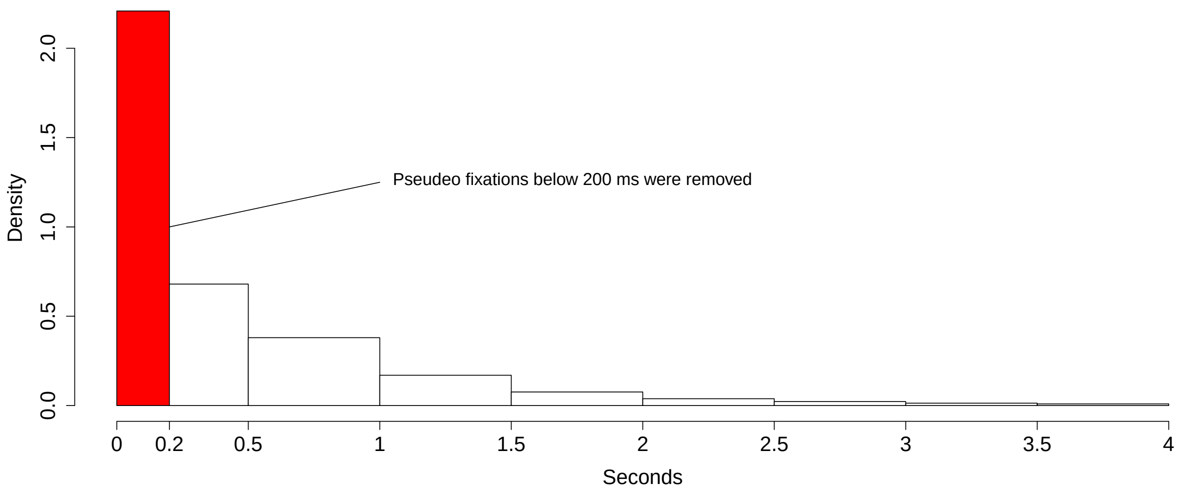


Figure 6: ***Duration of pseudo fixations***

5.2.2 Revealed 'absolute position' attribute non-attention bias

Both the horizontal position of alternative and vertical position of attributes were randomized in this survey (for all types of ANA data collection methods). A fully compensatory choice behaviour would thus imply that, on average, an equal amount of attention would be spent on every cell in the display matrix ($1/7 \times 1/5 \approx 2.9\%$). However, examining the mouse tracking data[10] shows that the number of hovering events is disproportionately skewed towards the top and left of the display matrix. The first alternative on the left, on average, received 83% more events as the alternative on the far right, and attributes placed on the very bottom received approximately 54% less attention that attributes on the top. While mouse-tracking data does not guarantee that an attribute level was paid attention to, it is arguably much more than a mere representation of convenience of uncovering attribute levels—the buttons for making a choice were *below* the display matrix (see Figure 5). Accordingly, on each new choice task, each respondent's cursor would initially be below the choice task matrix (after a page reload) and more hovering events would be expected on the bottom. The opposite result suggests that on average, respondents have an overall top left bias to information gathering, and vertical and horizontal randomization must always be used. This is in line with finding by Campbell and Erdem

[10] 11,652 PF records over 200ms based on the data from respondents who have made at least one choice task decision.

(2015) who investigate a positional bias heuristic in their best-worst scaling survey.

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Attribute 1	5.0	4.7	3.9	3.6	2.6
Attribute 2	4.3	3.9	3.3	2.9	2.1
Attribute 3	3.6	3.2	3.0	2.6	2.0
Attribute 4	3.0	3.0	2.9	2.6	1.9
Attribute 5	3.0	2.8	2.4	2.4	1.5
Attribute 6	2.7	2.6	2.2	2.2	1.5
Attribute 7	2.8	2.9	2.7	2.5	1.7

Figure 7: ***Percentage of mouse hover records across vertical and horizontal positions within the display matrix***

5.2.3 Attended-to Attributes

On average, only 14 alternative levels (cells in the display matrix) out of a total of 35 were uncovered[11] per choice task. The average was higher for the first choice task (21) than for the subsequent choice tasks (16, 14, 13, 11, 12, 12, 12 for choice tasks 2 through to 8). Table 6 summarizes the average number of levels that were opened for each alternative per choice task, and the average total duration per attribute per choice task. On average, only 2 out of 5 attribute levels were uncovered, but there is no significant difference across different attributes. This contradicts the self-reported data of serial and task ANA conditions (see Tables 3 and 4) that suggested lower overall ANA and significant difference in attendance levels across attributes.

	Average number of attribute levels uncovered per choice task (out of 5)	Average Total Duration per Attribute per choice task (seconds)
Volume Limit	2.2	5.1
Flow Limit	2.1	4.4
Contract Duration	1.9	3.4
Can buy water	2.1	4.2
Can sell water	2.0	3.4
Zero intake days	2.1	4.5
Price per 1 m3	2.0	3.6

Table 6: Revealed ANA data summary

[11] Defined as having been viewed at least once for more than 200 ms

5.2.4 Time spent on alternatives

In an eye-tracking study of binary choices Krajbich, Armel, and Rangel (2010) report that subjects spent significantly more time on the alternatives that in the end they have chosen. Confirming this result, we find that respondents had on average nearly twice as many PF as well as time on the attribute levels of an alternative they ended up selecting as most favourite in the set than on other alternatives (see Table 7). In addition, because the Status Quo [SQ] alternative always had the same attribute levels across the choice tasks, as expected it had lower overall PF scores and PF total duration as respondents obviously remembered it from previous choice tasks. This confirms the basis of the empirical regularity of a lower variance of utility associated with SQ alternative captured by error component models (Scarpa, Willis, & Acutt, 2005, 2007; Campbell, 2007).

As a result, in the 77 choice tasks the SQ was selected in the revealed ANA tracking subsample, the time spent on looking at SQ was just 5.1 seconds. What is of concern, if not unexpected, is that when the SQ alternative was chosen, the other alternatives received just 2.8 seconds of attention—less than a quarter of the time spent on non SQ alternatives when they were chosen. This implies that respondents were much more likely to ignore information of the forgone alternatives when choosing the status quo. This is consistent with selection of the SQ being motivated by some heuristics, such as the failure of the non SQ alternatives to satisfy some cut-off threshold in terms of attribute values.

	Combined (n=377)		Status Quo (n=77)		Not Status Quo (n=300)	
	C	NC	C	NC	C	NC
Average Number of PF	9.8	5.0	5.1	2.7	11.0	5.6
Average Total Duration of PF	10.2	4.8	5.6	2.8	11.3	5.4

Table 7: Time Spent on Chosen [C] and Non Chosen [NC] Alternatives per Choice Task

Finally, in 68% of the 377 choices made, the highest number of PF for a given alternative correctly predicted the alternative chosen—regardless of whether the alternative was the SQ or an experimentally designed one. This suggests that number of PF per alternative could have significant explanatory power. Combined duration of all PFs for an alternative had a marginally lower predictive success rate of 60%. It is possible then that either number of PF or duration of PF per alternative can be used to approximate relative preference of alternatives not chosen, providing the sort of information usually collected by favolurite choice, ranking or relative preference methods—though this needs to be confirmed by further research.

5.2.5 Comparing Revealed and Stated Choice Task ANA across the choice sequence

Both the stated and revealed ANA data conditions collected data across choice tasks. The stated choice task ANA, however, was relatively consistent across choice tasks for each attribute (see Figure 8(a)), whereas as stated in section 5.2.3, revealed attribute attendance from mouse-tracking decreased substantially after the first few choice tasks—see Figure 8(b). In addition, there was much less variation among the attribute attendance within each choice task number than in the stated condition. Our initial suspicion was that upon realizing that the SQ levels did not change across choice tasks, respondents ceased to uncover them after the first few tasks, thereby explaining the decrease in overall ANA pattern. Indeed, the average number of PF on the SQ alternative in the first choice task was approximately the same as for non SQ alternatives (10.5 vs 10.4), whereas in the subsequent choice tasks the average number of PF was always lower for the SQ alternative. By the last 2 choice tasks, the number of PF for SQ was 2.9 and 2.5, whereas for non SQ alternatives, the average PF per alternative was 5.4 and 4.3, respectively. A lower response quality in the last part of the sequence was already reported by Savage and Waldman (2008) for on-line surveys, and our results are consistent with this finding.

While explaining some of the decrease in overall choice tasks attribute attendance, it does not explain all of it, since even after removing attribute levels that were part of the SQ alternatives (Figure 8(c)), attribute attendance still decreased across choice tasks. This result suggests that ANA—as measured by the mouse-tracking method—tells a very different story from the one told by the self-report stated choice task ANA tracking method, which arguably only reports respondents' own perception of the importance of attributes (discusses more in the section below), as opposed to an honest recollection of what they paid attention to and accounted for while evaluating alternatives in order to make a decision. Our proposed revealed ANA method on the other hand, tracks what was actually paid attention to, whether or not respondents found to be important, and is arguably a more reliable method to track information access and to make sense of choice heuristics.

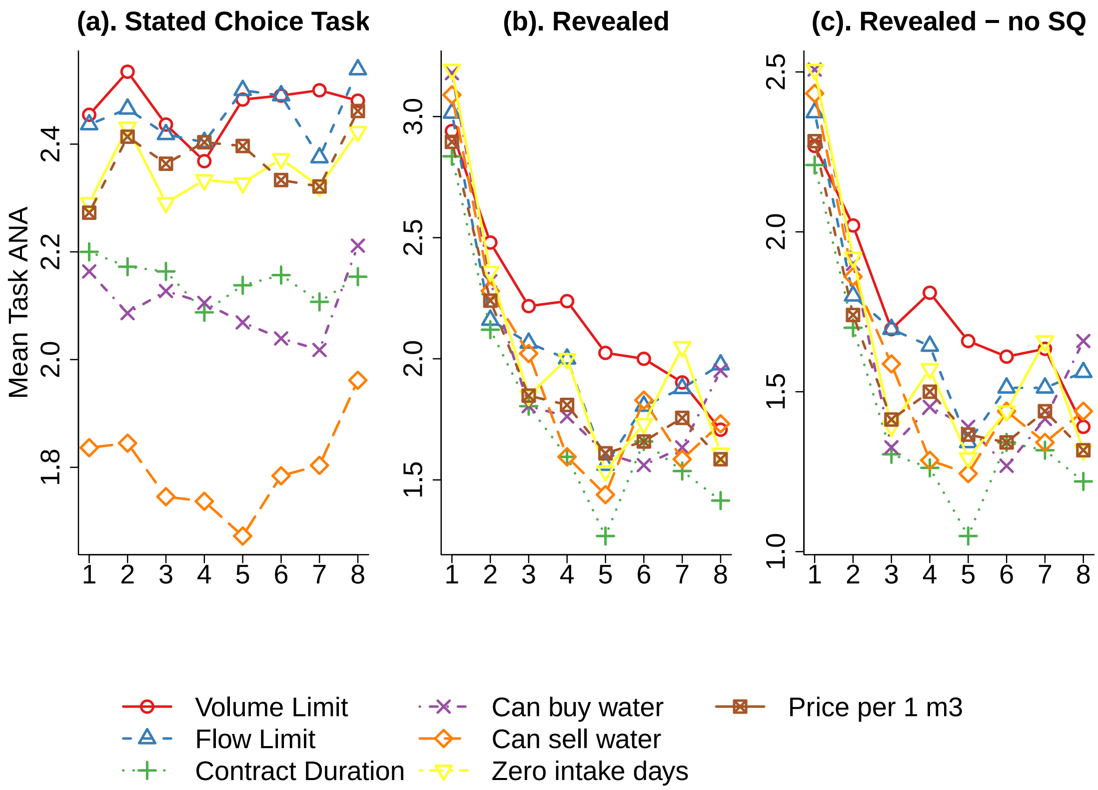


Figure 8: ***Revealed and Stated Choice Task ANA across choice tasks. In the Stated Choice Task condition (a) Mean Task ANA shows the average attendance score across 8 choice tasks stated by respondent (see footnote 9), in Revealed conditions (b) and (c) the Mean Task ANA score shows the average number of PF per task.***

5.3 Modeling Results

5.3.1 Benchmark MNL results

The combined data for all three ANA data collection methods was used to estimate a benchmark Multinomial Logit Model (see Table 8 (1)). The variables "Zero Intake Days" and "Contact Duration" were effect-coded where a variable for *zerointake*5 equaled to 1 if the zero intake days were either 5 or 10, zero otherwise. Variable $zerointake10$ took on the value of 1 if the zero intake days was 10. As such, the coefficient on $zerointake5$ should be interpreted in combination with coefficient on $zerointake10$.[12] All the significant coefficients had the expected signs. Willingness to pay estimates were derived by taking ratios between each coefficient and the coefficient on cost, but in this case should be interpreted in a special manner: because the definition of cost attribute was price per m^3, the corresponding WTP estimates are in terms of dollars per m^3. For instance, the WTP estimate for the benchmark model for volume restriction is ${}^{0.003}/_{-2.342} = -0.001411$, meaning that respondents, on average, were willing to pay 0.14 cents per m^3 to remove a 1% flow restriction (with respect to the consented amount). Hence, a farmer who would demand 50% of the 200,000 m^3 of his consented amount, would be willing to pay $200,000 \times 0.5 \times 0.001411 =$ \$141.10, and twice that for a cessation of a ban altogether.

[12]i.e. subtract $\beta_{zerointake10}$ from $\beta_{zerointake5}$ to see the effect of a 5-day restriction

Table 8: MNL results for the combined data and simulated results

	Pooled Data	WTP (¢)	Simulations with no ANA			Simulations with ANA			Simulations with ANA (DGP only)		
			Serial	Choice Task	Revealed	Serial	Choice Task	Revealed	Serial	Choice Task	Revealed
	(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SQ	$0.426^{\#}$ (0.227)	18.31	0.409 (0.406)	0.438 (0.390)	0.434 (0.429)	0.408 (0.248)	0.420 (0.262)	0.420 (0.152)	0.435 (0.404)	0.423 (0.387)	0.508 (0.432)
volrestrict	0.0033^{*} (0.0016)	0.14	0.0031 (0.0028)	0.0034 (0.0030)	0.0032 (0.0030)	0.0032 (0.0022)	0.0032 (0.0026)	0.0032 (0.0024)	0.0029 (0.0027)	0.0029 (0.0030)	0.0021 (0.0030)
flowrestrict	0.0054^{***} (0.0015)	0.23	0.0054 (0.0026)	0.0056 (0.0025)	0.0054 (0.0030)	0.0053 (0.0022)	0.0055 (0.0022)	0.0054 (0.0024)	0.0049 (0.0026)	0.0049 (0.0025)	0.0030 (0.0030)
buywater	0.152^{*} (0.071)	6.56	0.147 (0.120)	0.152 (0.132)	0.157 (0.139)	0.145 (0.142)	0.152 (0.155)	0.152 (0.198)	0.092 (0.119)	0.087 (0.131)	0.060 (0.139)
sellwater	$-0.124^{\#}$ (0.072)	-5.33	-0.127 (0.119)	-0.125 (0.145)	-0.125 (0.136)	-0.128 (0.160)	-0.129 (0.185)	-0.134 (0.200)	-0.051 (0.119)	-0.074 (0.144)	-0.074 (0.137)
zerointake5	-0.056 (0.093)	-2.41	-0.063 (0.148)	-0.056 (0.172)	-0.052 (0.190)	-0.068 (0.148)	-0.059 (0.173)	-0.065 (0.248)	-0.059 (0.148)	-0.053 (0.172)	-0.002 (0.194)
zerointake10	-0.260^{**} (0.095)	-11.19	-0.265 (0.158)	-0.265 (0.175)	-0.261 (0.196)	-0.262 (0.168)	-0.269 (0.188)	-0.270 (0.298)	-0.215 (0.156)	-0.221 (0.174)	-0.114 (0.194)
dur1Month	-0.147 (0.092)	-6.31	-0.160 (0.160)	0.0003 (0.170)	-0.146 (0.173)	-0.159 (0.169)	-0.152 (0.184)	-0.153 (0.245)	-0.119 (0.159)	-0.119 (0.170)	-0.036 (0.177)
dur2Month	0.0034 (0.091)	0.15	0.013 (0.150)	-0.0049 (0.172)	-0.011 (0.181)	0.010 (0.174)	-0.0015 (0.200)	-0.009 (0.305)	0.018 (0.148)	-0.0043 (0.171)	-0.013 (0.181)
cost	-2.324^{***} (0.661)	–	-2.293 (1.120)	-2.407 (1.268)	-2.354 (1.278)	-2.309 (1.262)	-2.389 (1.309)	-2.424 (1.793)	-1.631 (1.101)	-1.944 (1.259)	-1.070 (1.287)
n	154		58	49	42	58	49	42	58	49	42

Note: *St. err. are in brackets;* $^{\#}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

An interesting finding is that stated ANA roughly corresponds to significance of attributes, as defined by their respective t-statistics. As per Table 3, "Can sell water" attribute has the lowest stated ANA and the lowest t-statistic from Model (1) in Table 8. While volume and flow restrictions were both stated to be equally paid attention to, the model output suggests that flow restriction was more significant than volume restriction. Further investigation uncovered that for a sample of consent holders from Hawke's Bay for whom irrigation consent data was available, all consent holders had flow restrictions, but only 71% had weekly volume limits (the rest had either maximum monthly and/or annual volume limits specified). The respondents, therefore, logically stated that both restrictions were equally paid attention to, but the flow restrictions were of immediate concern (indeed Canterbury Regional Council updates such restrictions daily when they are in place), whereas volume limits had a level of temporal uncertainty attached to it. Hence, the immediate benefit of stated ANA data collection—equivalently serial or task—was the confirmation of parameter significance. As such, stated ANA data may be a proxy of respondents' own perception of the importance of attributes rather than a recollection of what was being paid attention to. Future research should examine the relation between stated ANA, statistical significance and perceived importance of attributes.

5.3.2 The Effect of ANA on Design Efficiency

To study the effects of ANA on design efficiency, three sets of Monte Carlo simulation analyses were carried out. First, parameters were estimated using pooled data from all three conditions assuming no ANA—see Table 8 (1). The estimated parameters were then used as Data Generation Processes (DGP). Next, for the first set of simulations (generated without ANA), full attendance was assumed in both the DGP and in parameter estimation. Indirect utilities were generated by using the designs actually faced by the respondents in each of the subsamples ($n = 58$, 49, and 42), with an extreme value type I quasi-random draw added to each of the alternatives to simulate random utilities. The parameters were then estimated using the same specification as in the DGP, assuming full attendance. The exercise was carried out 1,000 times for each subsample, and the mean values of derived coefficients and standard errors for each of the subsamples are reported in Table 8 (2)-(4).

In the second set of simulations (generated assuming ANA), indirect utilities were simulated by restricting parameters to zero when ANA was reported or observed (i.e. using the actual data). In the Serial subsample, the coefficients were restricted to zero in the DGP where a respondent reported 'always ignored [an attribute]'—this restriction applied to every choice task completed by a respondent, for every alternative with the exception of the Status Quo alternative-specific constant, which was assumed to always benefit from full attendance. In the Choice Task subsample, the coefficients were similarly restricted to zero in the DGP when respondents reported that they 'always ignored [an attribute]', with a key difference that the restriction varied by choice tasks. In the Revealed subsample, coefficients were restricted to zero at a particular choice task *and* alternative when a respondent did not hover above at attribute level at least once for at least 200 ms, again, with the exception of Status Quo, which was always assumed to be attended to. When re-estimating the coefficients from the simulated data sets, coefficients were similarly restricted to zero in the same way specified in the corresponding DGP for each of the ANA data subsamples. Mean value of derived coefficients and standard errors from 1,000 simulations are reported in Table 8 (5)-(7).

The subsets of designs in each of the ANA conditions work reasonably well estimating most parameters, with notable exceptions of the parameters on $dur2month$ that show significant bias. This could be attributed to relatively smaller subsample size in each of the ANA conditions (as compared to the pooled data sample), as well as the actual values of parameters used in the DGP.

An important observation is the difference in the average standard errors—when ANA data was used in DGP and estimation, the resultant average standard errors are generally higher than when full attendance was simulated.[13] This has important implications for estimating the required sample size and design efficiency when conducting choice experiments—assuming full attendance in design may erroneously lower the estimated

[13] An exception is Status Quo—this 'attribute' was assumed to be never ignored in the experiment

required sample size for a given significance and parameter. In addition, it is most likely that given any pattern of ANA, a more efficient design could be achieved. Modeling ANA by restricting coefficients to zero is equivalent to restricting design levels to zero in the design. Hence, such 'latent design' would comprise of (at least in the case of Revealed Condition in this study) 60% zeros, very different to the underlying design optimized for the experiment. Therefore, an improvement over the current practice would be to update the experiment design once better prior are available *and* incorporate ANA data in the design considerations.

5.3.3 The Effect of ANA on Parameter Estimates

As noted in the previous section, apart from the *dur2month* parameters, including ANA data when re-estimating parameters in simulations largely produced the same results as assuming full attendance, albeit with lower average significance for most parameters when compareding with simulations assuming full attendance in both the DGP and estimation.

To examine what happens when full attendance is assumed in estimation erroneously because the DGP involved ANA, we use previously simulated datasets (with ANA), but ignored ANA data when re-estimating the parameters—see table Table 8 (8)-(10) for summary of mean parameters and standard errors (over 1,000 simulations per ANA condition). Excluding the *dur2month* and Status Quo parameters, not accounting for ANA significantly attenuates the parameter estimates by an average of 59% in the Revealed Condition, and 20% and 22% in the Choice Task and Serial ANA data condition, with respect to their true DGP values. The parameter on Status Quo shows a significant upward bias in the Revealed Condition. The average standard errors remain largely similar to those derived in simulations when full attendance was used in estimation and the DGP, implying that in addition to downward bias, all estimates also incur a loss of statistical significance.

5.3.4 Calibrating Parameter Estimates to Account for ANA

The usual approach of dealing with ANA when such data is available is to restrict coefficients on the ignored attributes in the choice tasks (and specific alternatives if data is detailed enough) to zero. However, in our case, due to low farmer response rates, the resultant sample sizes ($n = 58$, $n = 49$, and $n = 42$ in Serial, Choice Task and Revealed subsamples)[14] in each condition rendered such analysis susceptible to small sample bias, hence a different approach was required. The question needing an answer was: assuming that parameter estimates seen in Table 8 (1) were largely attenuated following findings in section 5.3.3, what would the unbiased estimates have to be like to produce the biased estimates seen, given the observed patterns of ANA? To answer this question, calibration procedures were carried out in the following manner:

1. Utilities were simulated with ANA data and corresponding design using the estimated parameters from the pooled data, $\hat{\beta}_{pooled}$, as the initial DGP parameters, β_{DGP}[15];

2. The parameters were estimated from the simulated utilities, *without* incorporating ANA data;

3. The estimated parameters were averaged over a set number of simulations (1,000 for each ANA condition), $\bar{\beta}_{biased}$;

4. β_{DGP} were updated by the difference between the pooled estimates and the observed biased estimates, i.e. $\beta_{DGP_{r+1}} = \beta_{DGP_r} + (\hat{\beta}_{pooled} - \bar{\beta}_{biased_r})$, where r subscript denotes the run of 1,000 simulations;

5. Steps 1. through 4. were repeated until the difference between the parameters estimated through pooled data without ANA and simulated biased data was sufficiently small.

[14] A total of 5 observations had to be removed from serial and choice task condition subsamples since respondents, while completing all 8 choice tasks did not complete the subsequent ANA questions.

[15] Note that dur2Month variable was dropped due to poor replicability in simulations, hence the initial model (serving as the initial β_{DGP} and the $\hat{\beta}_{pooled}$ throughout the simulations) was re-estimated and is presented in Table 9 (1).

The final β_{DGP_r} after $R = 100$ runs (each involving 1000 simulations per ANA data type) are presented in Table 9 (12) - (14). In essence, β_{DGP_r} are unobserved parameters that if estimated by the pooled model without ANA data would yield the same attenuated results as in Table 9 (11), given observed or stated ANA data of the respective condition subsamples. The relative difference between the $\hat{\beta}_{pooled}$ parameters (from Table 9 (1)) and the average of those simulated with ANA data in the DGP and then estimated without ANA data ($\hat{\beta}_{pooled} - \bar{\beta}_{biased_r}$) with respect to β_{pooled} are given in columns (15) - (17) for $r = 1$ and $r = 100$.

Due to the relatively poor performance of the design in small sample sizes used in subsamples, the calibrating algorithm used here does not converge to negligible difference for all parameters. However, the differences do fall significantly for most other parameters as r increased (see columns (15) - (17)), and are within error levels obtained through initial simulations.[16] Further increases in r did not decrease this difference, with parameter differences ($\hat{\beta}_{pooled} - \bar{\beta}_{biased_r}$) oscillating within a few percentage points around an average of 0%. Also note that the difference is loosely tied up to parameter significance—low significance coefficients seem to have higher differences, and vice-versa.

[16]See re-estimated parameters through simulations in Table 8 (5)-(7)—they are -5% to 16% off the parameters used for the DGP in simulations (8 (1))

Table 9: Calibration to Account for ANA Results

	Pooled Data (11)	WTP (¢)	$\beta_{DGP_{r=100}}$ Serial (12)	Choice Task (13)	Revealed (14)	$(\hat{\beta}_{pooled} - \bar{\beta}_{biased_{r=1,100}})/\hat{\beta}_{pooled} \times 100$ Serial (15)	Choice Task (16)	Revealed (17)	Calibrated WTP (¢) Serial (18)	Choice Task (19)	Revealed (20)
SQ	0.426# (0.226)	18.34	0.407	0.441	0.302	$-8.6 \rightarrow 4.4$	$3.3 \rightarrow 2.5$	$-12.6 \rightarrow -4.8$	16.97	15.78	4.78
volrestrict	0.0033* (0.0016)	0.14	0.0032	0.0037	0.0048	$-6.7 \rightarrow 2.8$	$10.0 \rightarrow 4.1$	$40.3 \rightarrow -2.1$	0.13	0.13	0.077
flowrestrict	0.0054*** (0.0015)	0.23	0.0053	0.0062	0.011	$10.2 \rightarrow 2.0$	$11.8 \rightarrow -0.5$	$47.8 \rightarrow -2.4$	0.22	0.22	0.17
buywater	0.152* (0.071)	6.56	0.158	0.253	0.459	$35.8 \rightarrow -3.7$	$43.8 \rightarrow 1.3$	$56.1 \rightarrow 2.5$	6.58	9.03	7.12
sellwater	−0.124# (0.072)	-5.33	-0.126	-0.216	-0.196	$61.2 \rightarrow -2.0$	$32.0 \rightarrow -1.6$	$39.1 \rightarrow -0.7$	-5.26	-7.73	-3.09
zerointake5	-0.057 (0.091)	-2.44	-0.061	-0.054	-0.213	$0.2 \rightarrow -8.0$	$-4.7 \rightarrow -4.0$	$90.2 \rightarrow 9.0$	-2.55	-1.92	-3.37
zerointake10	−0.259** (0.092)	-11.16	-0.257	-0.311	-0.744	$20.3 \rightarrow -0.9$	$14.9 \rightarrow 2.1$	$53.9 \rightarrow -0.6$	-10.70	-11.14	-11.77
dur1Month	−0.145# (0.076)	-6.23	-0.144	-0.185	-0.521	$37.4 \rightarrow 0.8$	$18.8 \rightarrow -5.5$	$71.0 \rightarrow -1.3$	-5.98	-6.61	-8.24
cost	−2.323*** (0.661)	–	-0.2401	-2.796	-6.323	$27.1 \rightarrow -3.3$	$17.1 \rightarrow 3.9$	$54.3 \rightarrow 1.4$	–	–	–
n	154		58	49	42	58	49	42	58	49	42

Note: *St. err. are presented in brackets below coefficient estimates;* #$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$

5.3.5 Influence of ANA on WTP estimates

The effects of excluding ANA in estimation so far pointed towards loss of statistical significance as well as bias (for most part towards zero). Such bias, however, may not necessarily translate in bias of WTP estimates as in MNL models with utility linear in the parameters WTP is calculated as a negative ratio of coefficient estimates. For WTP estimates to remain unchanged, the bias should be of the same magnitude and in the same direction. Alas, this is not so in our case. WTP estimates based on calibrated estimates (β_{DGP_r} from Table 9 (12)-(14)) are presented in Table 9 (18)-(20).

WTP estimates for the SQ for the Revealed Condition (20) are vastly different between those from attenuated (11) and Stated Conditions (18) & (20), with the Revealed Condition calibrated WTP estimates being substantially lower. The coefficients on volume restriction and flow restrictions in the Revealed Condition are also substantially lower than from the Stated Condition calibration or pooled data. The Serial and Choice Task Condition calibrated estimates are generally much closer to each other than for the Revealed Condition.

6 Conclusion

This study conducted a choice experiment amongst NZ farmers who irrigate. The choice situations that farmers faced in the experiment included full restrictions on water withdrawal during dry conditions against having an option to pay for water, which is something that farmers are currently unable to do. The findings suggest that most farmers are happy to pay for water to avoid such restrictions to get access to their consented withdrawal, or at least a part of it. The WTP estimates for a 1% decrease in restrictions, ability to buy and/or sell water, and conditions under which water can be bought were derived, with respect to the consented amounts .

The stated ANA self-reports, within both serial and choice task ANA conditions, indicate that respondents are continuously engaged in ANA heuristics. Revealed ANA data via mouse-tracking shows that the stated choice surveys require randomization of both attribute and choice order as top-left corner of choice cards received approximately three times more pseudo fixations (defined as cumulative duration of mouse hovering of greater than 200 milliseconds) than the bottom right corner. Tracking ANA comes at a cost: it significantly impacts on survey completion rates, and should only be used if it provides significant advantages.

In the choice modeling literature there is a dissent over the effects of ANA. It would seem it derives from a difference in its definition. If ANA is due to respondents' perception of relative unimportance of some attributes (whether overall or at a particular choice task), such ANA represents preference heterogeneity, and is essentially inconsequential since zero preferences of attributes can be accommodated by latent class models with no further information required (if preference heterogeneity is of particular interest, perhaps attached to various demographics indicators), or can be downright ignored since a researcher is typically after only an average preference. Stated ANA seems to point to such behavior in this study, as those parameters that were stated to be least attended to were also estimated to be least statistically significant. On the other hand, if ANA occurs (for whatever reason—respondent fatigue, or relative small difference in levels) to attributes that are considered to be important by the respondents, this has the potential to significantly attenuate estimates and is not generally picked up by most models. Previous simulations analysis by Kravchenko (2014b) demonstrated inability of latent models to pick up ANA when ANA was not a result of preference heterogeneity. Revealed ANA data obtained in the study suggests the existence of such ANA—there seemed to be no persistent differences between the levels of ANA across attributes, and ANA was more pronounced in the choice tasks appearing late in the sequence, implying fatigue or satisficing (as opposed to preference heterogeneity).

While in the context of this study it is possible that the observed difference between ANA data collection methods was due to an experimental artifact. For example, respondents who were forced to study cards more perhaps became more involved and convinced of superiority of alternative, potentially explaining the discrepancy with the coefficient on the status quo. Our findings echo results from other studies, suggesting respondents generally pay less attention to alternatives in choice tasks at the end of the sequence.

In conclusion, ANA, if a symptom of pure preference heterogeneity need not be of major concern since in most cases a researcher needs to find an average preference. ANA as a choice heuristics, however—particularly if it is a case of a survey fatigue (or design) induced cognitive overload, where respondents ignore attributes they themselves consider important in some choice tasks but not in others—may strongly affect estimation results. For example, in this study revealed ANA (as opposed to stated, which may well be a proxy of preference) has been shown to reduce statistical significance, cause attenuated parameters and inconsistent WTP estimates.

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Chapter V: Economic Effects of Irrigation Water Pricing in New Zealand: An Analysis Using the GTAP Model

A working paper version of this paper was presented at the Global Economic Analysis Conference (2015):

Kravchenko, A., & Strutt, A. (2015). *Economic effects of irrigation water pricing in New Zealand: an analysis using the GTAP model*. 18th Annual Conference on Global Economic Analysis, June 17-19, 2015, Melbourne, Australia.

ABSTRACT

The aim of this study is to analyse the effect of irrigation water pricing on the New Zealand economy, using a modified version of the Global Trade Analysis Project (GTAP) model and database. The primary user of irrigation water in NZ is dairy and since 95 percent of New Zealand dairy production is exported, analysis using a global general equilibrium model will contribute important insights.

While use of a global model brings significant benefits, a shortcoming of using GTAP for country-level analysis for analysis of issues such as water is the lack of regional specification within the country. Since regions within a country like New Zealand vary substantially in terms of what they produce and how much irrigated water is used, the impacts on different regions within the country may differ greatly. For example, the Auckland region is the commercial capital, producing over a third of country's economic output, yet it produces only 2% of New Zealand dairy output. To overcome this limitation, New Zealand is split into 15 regions; in the absence of detailed regional input-output data, we use regional product output as weights.

To examine the effects of irrigation water pricing, the GTAP model is further modified by splitting the land endowment into irrigated and non-irrigated for each New Zealand region. This, again, is highly unevenly distributed: the Waikato Region is the largest single dairy producing region in the country (producing 24 percent of all dairy), but it includes less than 3 percent of all irrigated land in New Zealand. By contrast, the Canterbury Region comprises over 60 percent of all irrigated land in New Zealand, but produces only 18 percent of the country's dairy output. This model modification follows the approach of Calzadilla et al. (2011), used in the creation of the GTAP-Water (GTAP-W) model; however, in our work this is only implemented for the newly created sub-regions of New Zealand.

This approach allows in-depth analysis of the impact of freshwater management policies in New Zealand that will affect the price of water with particularly important outcomes for the dairy industry, including on exports to international markets.

1. INTRODUCTION

New Zealand has one of the world's highest renewable freshwater resources per capita (World Bank, 2014). The problem, however, is that most of this water needs to be maintained within freshwater bodies for the purposes of ecological, recreational and cultural values (Land and Water Forum, 2010). The portion that is available for abstraction in many catchments has nearly (or indeed, already) passed the level that is legally allowed to be allocated. The current freshwater abstraction consent allocation mechanism is in effect on a first come first served basis: whoever initially obtained this resource essentially blocks out subsequent users from gaining access to it. Indeed, cases of regional authorities denying new resource consents abound (see, for example, Williams (2009), Littlewood (2011), and Hutching (2014)).

There are limited ways of trading water rights in New Zealand, [16] and apart from the nominal consent application fee, there is no cost applied to water. At the same time, freshwater availability is very seasonal and highly dependent on rain; it is lowest during the months of summer when the demand is at its peak. It is not uncommon for the regional councils which manage New Zealand's water resources to institute partial or even full bans on water withdrawals during the driest periods.

While only 5% of New Zealand's agricultural land was irrigable in 2012 (compared with the world average of approximately 20%), irrigable land area increased by over 50% between 2002 and 2012 (Statistics NZ, 2012). Over 80% of irrigable land is in New Zealand's South Island, with Canterbury alone comprising 62% of New Zealand's irrigable land (see Figure 1).

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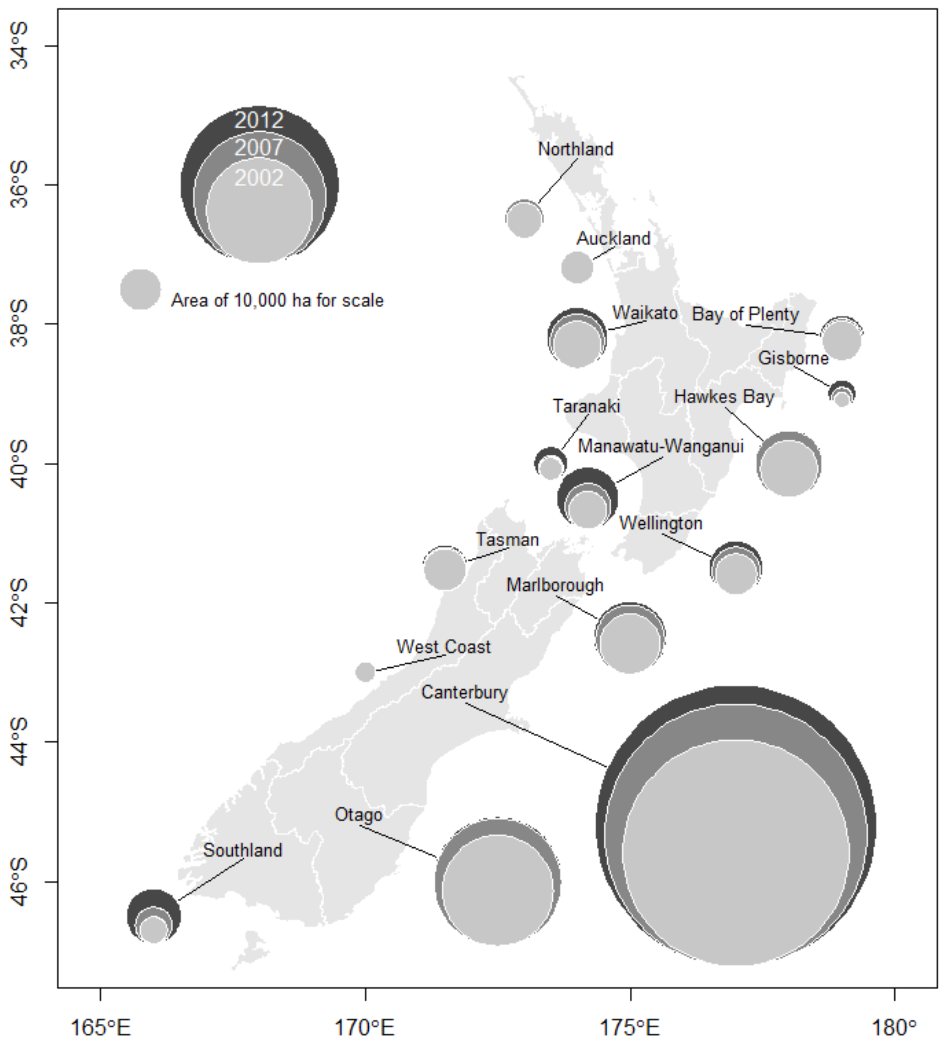
[16] Water rights are inseparable from land ownership, except in private irrigation schemes were trade is possible. Trade that does occur is comparatively scarce.

Figure 6. Irrigable Land by Region, New Zealand 2002 to 2012



Data sources for the figure: Statistics NZ, 2002, 2007, 2012

Agriculture is responsible for vast majority of consumptive freshwater use: of approximately 20,000 freshwater consented takes in 2010, 75% were for irrigation, with a further 6% for stock watering (Aqualinc Research, 2010). In addition, what is classified as "drinking" or "municipal" water intakes (8% of all consents) sometimes ends up being used for commercial irrigation as well (up to 50% in some instances). In terms of volumes of water, in 2010 78% of weekly consumption allocation went to irrigation. Animal husbandry is the dominant sector of New Zealand's land use, utilising 97% of New Zealand farmland and 86% of irrigable land (see Table 3).

Table 3. 2012: Largest Farmland Users - Total and Irrigable

Land Use	Total Land	Irrigable Land
*Sheep Farming (Specialised) **	*34.4%*	*11.4%*
*Sheep-Beef Cattle Farming **	*30.3%*	*3.9%*
*Dairy Cattle Farming **	*17.7%*	*48.8%*
*Beef Cattle Farming (Specialised) **	*9.3%*	*6.6%*
*Deer Farming **	*2.2%*	*1.3%*
*Grain-Sheep or Grain-Beef Cattle Farming **	*0.8%*	*5.1%*
Other Crop Growing n.e.c.	1.1%	2.2%
Forestry	1.0%	0.0%
Other Grain Growing	0.7%	6.6%
Vegetable Growing (Outdoors)	0.3%	4.6%
Grape Growing	0.2%	4.2%
Apple and Pear Growing	0.0%	1.2%
Other	2.0%	4.1%

Data source: Statistics NZ, 2012
** denotes animal husbandry sectors.*

1.1. Motivation

Although not currently in the legislative pipeline, establishing water markets, similar to the model of the Australian Murray Darling Basin, could potentially alleviate inefficiencies arising from demand management through bans in times of droughts and the aforementioned first-come-first-served principle of consent allocation. The first-best method of volumetric pricing and market-based allocation and reallocation have been long recognized as an optimal outcome for the New Zealand water management (Agriculture NZ, 2001; Sinclair Knight Merz, 2006). These outcomes, however, are generally viewed as politically impractical and impossible to implement under the current legislative framework (water rights being inseparable from land rights which, in turn, are owned by the Crown or/and local iwi[17]). Nevertheless, even the latest taskforce charged with looking into the issues, Land and Water Forum [LAWF], explicitly stated that "price based or economic instruments can incentivise desired behaviours or create disincentives through price and market mechanisms" and should be used instead of the current first-come first-served method where there is water scarcity (Land and Water Forum, 2010; Land and Water Forum, 2012).

In this study, we build a model which simulates the economy with water-pricing imposed, to study the impacts including flow-on effects from irrigated farms to the rest the economy. We introduce water as an explicit factor of production for the New Zealand economy within the well-known Global Trade Analysis Project (GTAP) computable general equilibrium (CGE) model. We also split the New Zealand economy into a number of sub-regions.

The structure of this paper is as follows. First, we present a brief overview of water-related literature using CGE methodology. We then outline the procedure used to introduce water as an explicit factor of production and undertake regional splits for New Zealand. Following model modification, we are able to obtain shadow price of irrigation water. We are then able to introduce constraints to water availability, contrast the scenarios with and without water trade and examine the effect of water pricing. We then analyse our results before making some tentative conclusions.

[17] Iwi is roughly translated as "tribe" from Maori. According to the Treaty of Waitangi, 1840, the ownership of water resources is an inherent right of the local iwi.

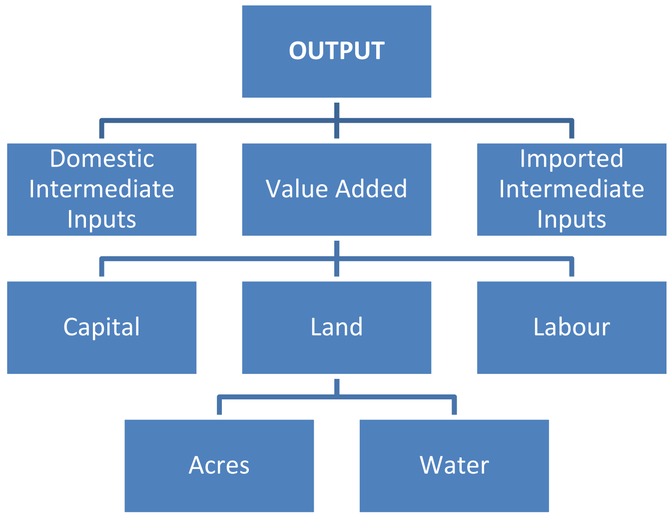
2. CGE AND WATER

2.1. International CGE Studies

The first study to incorporate water in CGE analysis was by Berck, Sherman, & Goldman (1990), who model the effects of decreased water supply in San Joaquin Valley, California. In their model, water was explicitly included as a factor of production, along with land, labour, capital and intermediate inputs. Water was assumed to be in fixed supply, and apportioned among various agricultural sectors, which, in turn, are apportioned among a limited quantity of land. Thus, water mobility was implied if agricultural land use was converted from one crop to another (Figure 7). Given the Leontief functional specification, there was assumed to be no substitution between value added and intermediate inputs. There is assumed to be no substitution between value added and intermediate inputs (as per the Leontief functional specification). The elasticity of substitutability between value added inputs is assumed to be one. This method, in essence, is an aggregate programming model, as the authors use inequality constraints to specify the technology for the agricultural sectors and do not explicitly state their factor demand functions. However, through this method the authors were able to determine the shadow price of water by studying the effects on production through varying the supply of water in the model.

Decaluwé, Patry, & Savard (1999) argue that incorporating water as an exogenous factor of production, coupled with assumptions that it cannot be substituted with intermediate inputs (such as fertilizers) and that only agricultural sectors use water, are very restrictive assumptions and require better incorporation in the modelling. Such assumptions are likely to be of concern when modelling water usage in New Zealand as well, since there is substitution between feed and water during the times of droughts, and conflicts over water intakes involve municipal users as well as power generators (EW, 2008; DairyNZ, 2010).

Figure 7. Nested Production Structure[18]



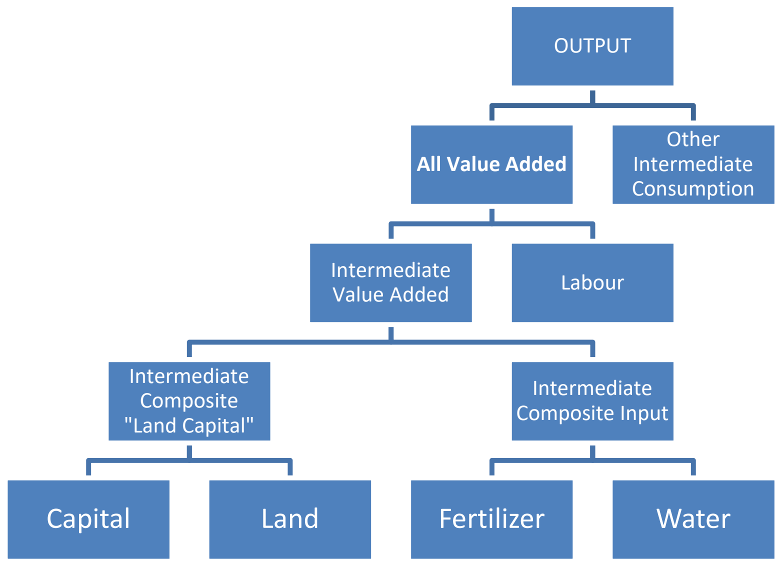
Source: Berck, Sherman, & Goldman, (1990)

Decaluwé, Patry, & Savard (1999) construct an enhanced CGE model of Moroccan economy. They built on an earlier version of their model (as cited in Decaluwé, Patry, & Savard (1999)) in which they segregate the country into two regions: water stressed (South) and water-abundant (North). Both regions have separate production nests, producing similar output that is sold on national and international market as a composite commodity. Figure 8 depicts the agricultural production structure that incorporates water in the process, while allowing it to be substitutable with fertilizer. Model parameters used in this model were acquired through a wide range of literature surveys.

[18] This is the "high-elasticity" variant of the model used. The "low-elasticity" variant assumes than land and capital are used in a fixed proportion and labour is combined to the capital-land aggregated using a Cobb-Douglas production function, i.e. capital is effectively moved down a level under land, like water.

The model also disaggregates water in two segments: that are available through existing dams and water collected through more efficient efforts in retrieving surface water and pumping stations during the times of drought. This enables the authors to establish two types of costs – decreasing marginal costs in the cause of existing dams, and increasing marginal cost in the case of more intensive pumping of groundwater.

Figure 8. Branch of the Agriculture Production Structure



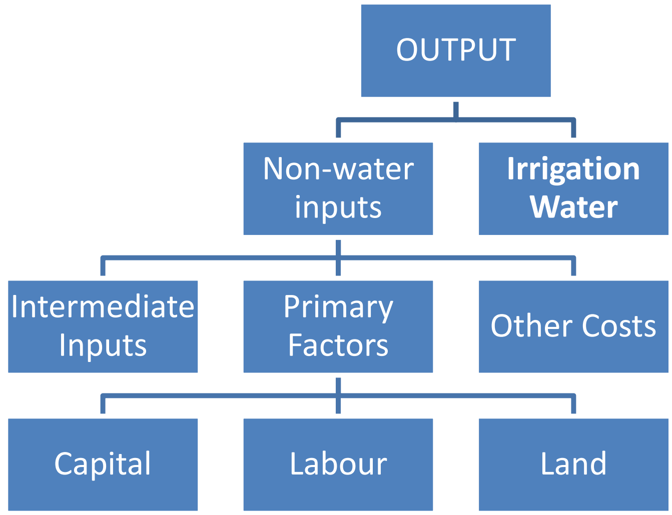
Source: Decaluwé, Patry, & Savard, (1999)

The findings, albeit somewhat expected in terms of direction, do show the significance of such modelling over having water only in agriculture with no substitute. First, when water prices were increased for all agricultural producers, other water consumers experienced a decrease in water prices, as decline in the use of water by the agricultural sector reduced the aggregate marginal cost of water (a part of the marginal cost curve was modelled to be upward sloping). Moreover, fertilizer producers increased their production by 40%, since farmers choose to substitute it for relatively more expensive water. When combined with a reduction of production taxes, the welfare of the economy actually increases (as measured by equivalent variation), hence further demonstrating the importance of modelling the whole economy when analysing water-related policies, rather than just concentrating on agriculture alone.

Appels, Fry, Dwyer, & Paterson (2004) use a modified TERM[19] model – an Australian regional CGE model - dubbed TERM-H2O, to model the effects of water reductions on inter-state trade in water. Their version includes 20 regions that can be modelled as independent regions, and 48 industry sectors, which include detailed representation of the irrigated sectors. In each region, each sector uses a distinct production function, hence, for example, irrigated and non-irrigated grapes are treated as different farms. When water (or its price) is shocked, affected farms shrink or expand accordingly in each region. Water is treated as an endowment, and as such its production is not endogenized by the model (Figure 9). TERM-H2O is built 'bottom-up', meaning that all demands and supplies are built at the regional level, before being aggregated to the nation level (Wittwer, 2012). While this level of disaggregation offers an approach would be very attractive for New Zealand, it would be hard to undertake since Statistics New Zealand does not the publish regional Input/Output tables that would be necessary for such implementation, and estimating them would be beyond the scope of this research.

[19] The Enormous Regional Model

Figure 9. TERM-Water Production Structure for each Sector

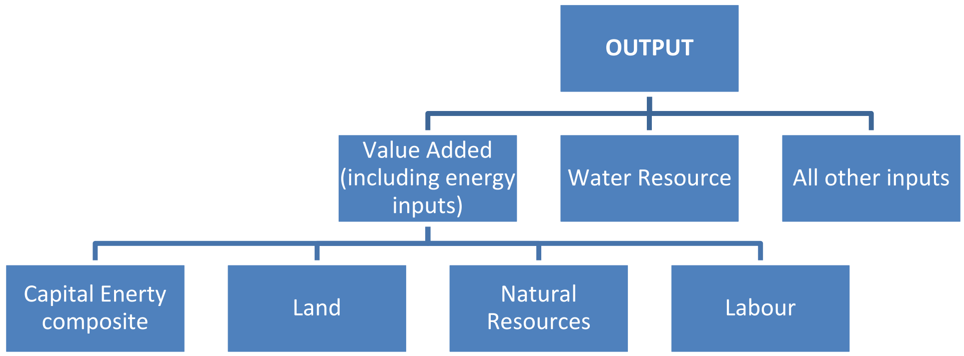


Source: Appels, Fry, Dwyer, & Paterson, (2004)

The degree of substitutability in the TERM-H2O model between water and other inputs is explicitly differentiated across industries. For instance, the rice growing industry has very little available substitute for water, whereas the dairy industry can readily substitute more feed for water.

Berrittella, Rehdanz, Roson, & Tol (2006) develop a GTAP-W model based on a similar extensification by Burniaux and Truong (2002 as cited in Berrittella, Rehdanz, Roson, & Tol, 2006), who develop a GTAP-E model to study energy markets and their effects. The key parameter they introduce in their model is a water intensity coefficient for each sector, which is defined as the amount of water required to produce a unit of output for that particular sector (Berrittella, Hoekstra, Rehdanz, Roson, & Tol, 2007). They let the price of water be determined by markets, with a quantity constraint. This way, water is explicitly introduced as a factor of production, a level above value added inputs (natural resources, land, labour and capital-energy composite) and at the same level as all other inputs (intermediate – both domestic and imported) – see Figure 10 below.

Figure 10. GTAP-W Nested Tree Structure



Source: Calzadilla, Rehdanz, & Tol, (2008)

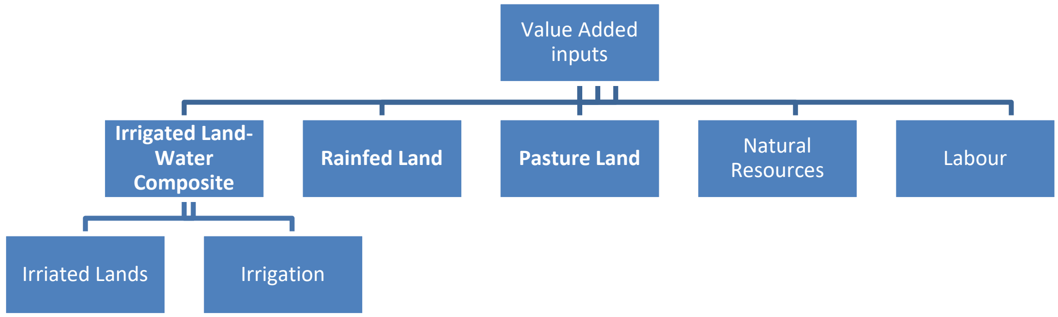
The elasticity of substitution between value added factors of production is constant, but different among 17 sectors in the model. The elasticity of substitution between water and value added and intermediate inputs is set to zero (perfectly inelastic – implying the assumption of fixed proportions). The degree to which water usage is sensitive to changes in prices is captured through water price parameters, specific to each sector. According to the authors, these elasticities, "are little more than informed guesses", hence a parameter sensitivity analysis is used in all studies using this model (Berrittella, Hoekstra, Rehdanz, Roson, & Tol, 2007). In addition, the authors state that they were unable to distinguish between rainfed and irrigated agriculture due to unavailability of data. Hence water-related shocks are applied equally both types of agricultural sectors, even though rainfed sectors are not likely to be directly affected by any fresh-water policies.

This version of GTAP-W model is used by Berrittella *et al* (2006) to determine the impact of increased prices of water (1¢ per cubic meter of water) on "virtual water trade". Their findings are that universal increases in water tariffs tend to lower world welfare as a whole, but countries that are relatively abundant in water (or low water intensity users) are actually better off since they increase exports of virtual water to more water-stressed regions. The authors note that welfare results are primarily driven by the agricultural sector and trade effects are almost entirely driven by the agricultural sector.

In the next use of the GTAP-W, Berrittella *et al* (2007) study the impact of reduced water availability. The main difference in this is that they quantity of water is shocked (simulating, for example, a new law that prohibits intake of groundwater), rather than the price of water as in the previous study. When a restriction on water intakes is introduced, total world welfare falls, but some regions experience an increase in welfare, such as in the case of the US. The authors attribute this to the predominance of overproduction due to agricultural subsidies, which is partially offset when agricultural production falls due to lower availability of water.

GTAP-W's second version is presented in Calzadilla, Rehdanz, & Tol (2008), where the authors use a newer GTAP base data (year 2001) and a new production structure. Rather than creating a non-substitutable factor, as in the previous version, the authors split the land endowment in the value-added nest into "Pasture Land", "Rainfed Land" and "Irrigated Land-Water Composite" (Figure 11):

Figure 11. GTAP-W 2.0 Nest Structure (truncated)

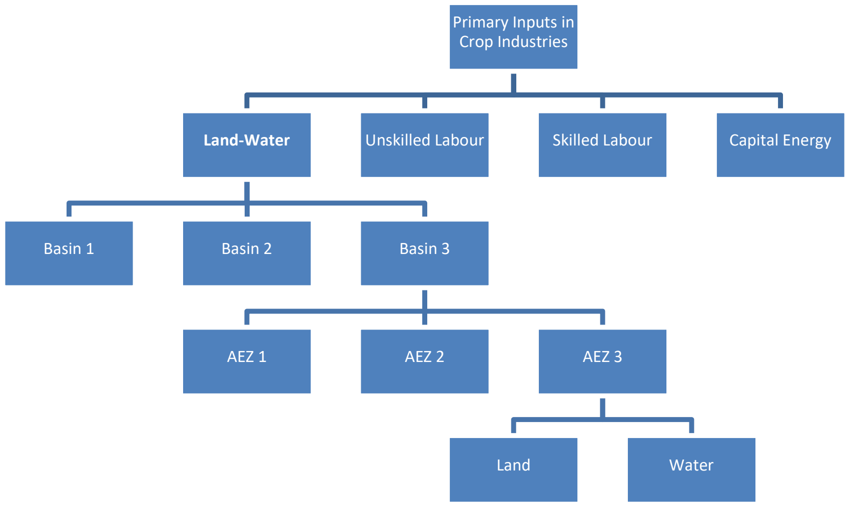


Source: Calzadilla, Rehdanz, & Tol, (2008)

Pasture land (for the production of animals and animal product) and Rainfed land are assumed to require no irrigation, and command lower yields, whereas irrigated land has higher productivity, but is relatively more expensive. To account for the higher land price, this component is split into the value of the land itself as well as the irrigation, which includes the necessary irrigation equipment, as well as the actual water used (Calzadilla, Rehdanz, & Tol, Water Scarcity and the Impact of Improved Irrgation Management: A CGE Analysis, 2008). This reclassification is accomplished through splitting the GTAP social accounting matrix land endowment component based on respective contribution to total production. The split of the irrigated land is undertaken through using the ratios of irrigated yield to rainfed yields.

Taheripour, Hertel, & Liu (2013) adjust the GTAP-W model by combining it with GTAP-BIO model and splitting the Indian region into River Basins [RB] and Agro Ecological Zones [AEZ] to account for different regions' land productivity and water availability with different basins. This model enables, for example, estimation of welfare reduction due to water scarcity in (Taheripour et al., 2015). In this way, the products were homogeneous, yet differentiated by RB and AEZ origin. Their model allows for more accurate modelling of agriculture world-wide as well as enabling disaggregation of results by River Basin levels.

Figure 12. Demand Structure for GTAP-BIO-W



Source: Taheripour, et al. (2013).

2.2. New Zealand Freshwater-Related CGE Studies

There is a relative paucity of New Zealand fresh-water-related CGE studies. This is most likely a result of relative lack of urgency, as compared to more water stressed regions such as the Murray-Darling Basin in Australia. Another reason is that there is no solid data on either prices or volumes used by various sectors, as discussed earlier. Below is a summary of the few fresh-water related studies using CGE methodology in New Zealand.

Cassels & Meister (2001) utilized the GTAP model and database in an attempt to quantify the impact of dairy effluent controls. They shock productivity parameters by a factor estimated through analysis of costs involved in installing new effluent systems.

A more relevant study is by Lennox & Diukanova (2010), who develop a CGE model of the Canterbury Region and integrate fresh water as a factor of production. They then use this model to study the impact of water quantity reductions. According to the authors there were no other studies of water availability using CGE in New Zealand at that time. In their model they link water in fixed proportion to the land factor, used only by the agricultural sectors and sharing the same technology across all agricultural sectors. By having a land-water composite in the Constant Elasticity of Substitution [CES] nest with capital, they allow for substitution effects, should price or quantity of water change. Their preliminary results were that a 10% decrease in availability of water causes a 3% decrease in the dairy output and "other agriculture" sectors.

Since the recent emphasis of fresh water management restructuring, the Ministry of Primary Industries [MPI] commissioned the New Zealand Institute of Economic Research [NZIER] to conduct a study using their proprietary Dynamic CGE model to measure the impact of proposed new irrigation schemes across New Zealand (Kaye-Blake, Schilling, & Zuccollo, 2010). While this study does not consider pricing of water per se, it does consider the changes in productivity of various sectors post-irrigation schemes installation, as well as the costs of installing the schemes.

A more recent effort by NZIER was to update the value of irrigation to the New Zealand economy since the initial study in 2004 carried out by MPI (NZIER & AgFirst Consultants, 2014; Doak, Parminter, Horgan, Monk, & Elliot, 2004). The initial MPI study was an effort to estimate the impact on New Zealand's GDP if there were no irrigation. This was done by applying non-irrigated land productivity rates to irrigated land, with the flow-on effects to the other sectors of the economy largely ignored. NZIER's study re-estimated the aggregate difference in productivity as well as using a general equilibrium framework to examine the flow-on effects. The main findings were that in the absence of irrigation in New Zealand, GDP would be 2.4% lower than present, mostly due to lower output of the dairy sector in Canterbury.

3. METHOD

This section describes the process of building the CGE model incorporating water as a factor of production. We start with the GTAP model and version 9 GTAP database, with a base year of 2011 (Narayanan, Aguiar, & McDougall, 2011).

3.1. Splitting Land and Adding Water as a Factor of Production

Following Calzadilla, Rehdanz, & Tol (2011) we split the land sector into irrigated and non-irrigated land. Unlike in the GTAP-W model, however, we only undertake this for New Zealand and pasture land is not separated as a stand-alone endowment since New Zealand’s agricultural sector is unique in that bulk of irrigation actually goes to the pasture land. The new model specification follows the nested structure described in *Section 2.2* and depicted in *Figure 11*. GTAP-W 2.0 Nest Structure (truncated) with the exception that pasture land endowment is omitted.

Land, as a factor of production, is recorded in the GTAP database as header “VFM” (firms’ purchases of endowments at market prices), with market prices being the units. To split this factor of production, it is necessary to know the how much income the owners of each factor receive from each sector (Burfisher, 2011). Therefore to split the land sector into irrigated and non-irrigated land, it is necessary to know the irrigated and non-irrigated areas in each sector in each region and the difference in productivity of each sector. Statistics New Zealand (2012) agricultural census statistics contain information on the total land area in various agricultural activities in each region, with and without irrigation. When estimating the value of irrigation to New Zealand, NZIER (2014) conducted an extensive study into the productivity differentials; these data are available for each region and for some of agricultural sectors (in regions where at least 5% of farm area is irrigated and which constitute at least 7% of regional gross margin).

Where productivity figures are missing, we use parameters estimated by Calzadilla, Rehdanz, & Tol (2011) for Australia and New Zealand region, see Table 2:

Table 4. Firms' Purchases of Endowments at Market Prices, Modified New Zealand Database

	Wheat	VegFruit	OthCGrains	OtherCrops	CattleSheep	OthAnimal	RawMilk	Total
Land$_{old}$	9	221	13	20	234	39	599	113 5
Land$_{new}$	1	110	3	5	6	2	96	223
Water	0	44	1	2	4	1	22	76
Rainfed Land	8	66	8	13	224	36	481	836
Total	***9***	***221***	***13***	***20***	***234***	***39***	***599***	***113 5***
Share	*13%*	*70%*	*36%*	*36%*	*4%*	*7%*	*20%*	
Yield Ratio	*1.39*	*1.40*	*1.40*	*1.40*	*1.79*	*1.40*	*1.24*	

To get new Land, Water and Rain-fed Sectors, the following formulae were used:

$$\mathrm{Lnd_{new}} = \mathrm{Lnd_{old}} \times share \div YieldRatio \tag{2}$$

$$\mathrm{RfLand} = \mathrm{Lnd_{old}} \times (1 - share) \tag{3}$$

$$\mathrm{Wtr} = \mathrm{Lnd_{old}} \times share \times (YieldRatio - 1) \div YieldRatio \tag{4}$$

Where *share* parameter is the share of value of output within the corresponding attributed to irrigated (as opposed to dryland) agriculture, and *YieldRatio* is the relative productivity of irrigated land versus dryland. Splitting the original land endowment in such way maintains the database balance.

Additional behavioural parameters were added to allow for substitution between land and water in the Land & Water composite for each agricultural sector based on Calzadilla, Rehdanz, & Tol (2011) parameters for Australia and New Zealand (see *Figure 11.* GTAP-W 2.0 Nest Structure (truncated)).

3.2. Splitting New Zealand into 15 regions

New Zealand does not have a publicly available regional CGE model. Building such a bottom-up model from scratch would require detailed input-output tables, however, these are only available at the overall country level from Statistics New Zealand (Statistics NZ, 2005).

One option explored was to divide New Zealand into 15 regions using a top-down approach using tools such as SplitReg or MyGTAP. While SplitReg has been developed with the intent to split regions that are commonly bundled together within the GTAP database, such as members of 'XOC' – Rest of Oceania, which include a multitude of Pacific Island nations (Horridge, 2011), it could also be used to split one country based on simple weights. For instance Lysenko, Ciuriak, & Xiao (2015) use SplitReg to study effects of trade policy on separate provinces within Canada. To perform the split using SplitReg, the program requires only proportional value added information for each sector of every new region. Sectors in other regions remain unchanged, and the sum of headers of new regions remain equal to the original region, thereby maintaining database balance.

Such split would be relatively simple to carry out within relatively autonomous regions with balanced production. However, in NZ there is a highly unbalanced economic and agricultural output among regions, therefore this is would not be appropriate. For example, Auckland produces the greatest economic output, including many products requiring agricultural inputs with little of its own agriculture (i.e. limited land endowment), while Waikato produces extensive primary intermediate input products, though few final products (Statistics NZ, 2014). By default SplitReg does not assume any trade within the newly split regions, and while the splitting of database was possible, any shocks would result in highly skewed results, particularly with respect to sectors relying on land.

One could try to estimate the trade flow within regions. For instance, Standardi, Bosello, & Eboli (2013) develop a sub-regional modal of Italy based on GTAP through estimating inter-regional trade. They note that the most common method to fill-in missing regional trade data is by using gravity models, which involves econometrically estimating trade flows based on distances. However, the authors feel that such method is susceptible to the omitted variable bias and argue for a different approach: they estimate the inter-regional trade flows through using transport data and regional output.

The method used in this research is partially based the methods used in Taheripour et al. (2015) who split GTAP agricultural sectors among Agricultural Economic Zones [AEZ] and River Basins [RB]. As such, they do not create new regions per se, but split commodities into AEZ-and-RB-specific commodities. The advantages of such an approach is that it enables specifying different factor productivity for each split commodities as well as being able to target each locality-specific commodity separately (by policy or climate shock).

Similar to SplitReg, SplitCom enables disaggregating GTAP sectors based on user-specified weights (Horridge, 2008). An additional advantage of only splitting agricultural sectors is that without creating separate regions, NZ-based [newly split] sectors remain local (meaning that they do not face a home bias from other New Zealand regions); and labour remains a mobile factor (whereas making it mobile across different regions would require further model modification). As such, only agricultural sectors that use land are split.

3.2.1. *Data for Split*

Agricultural census statistics were used for weights to perform the sectoral split of the GTAP database (Statistics NZ, 2012). Since only regional proportions of production are required as input in SplitCom, it was possible to derive the split by looking at the agricultural sector census, which provided regional breakdown of selected agricultural production. For instance, GTAP sector 2, 'Wheat' was derived by linking the GTAP national 'Wheat' data with New Zealand Agricultural Census regional output of wheat in tonnage. 'Milk' was derived by linking the proportions of 'Dairy cows and heifers in milk or calf', while other sectors were linked by the total farm area in hectares. The following table summarizes the final weights used to perform the sectoral split:[20]

Table 5. Percentage Split of Agricultural Production Among the New Zealand Regions[21]

	NTL	AUK	WKO	BOP	GIS	HKB	TKI	MWT	WGN	TSN	MBH	WTC	CAN	OTA	STL	TOTAL
Wheat	2.4	2.3	2.6	2.8	1.3	1.8	2.8	1.8	3.0	2.9	2.5	2.1	61.5	4.4	5.9	100
Veg. & Fruit	3.2	7.0	6.9	8.2	3.4	8.9	1.7	4.4	1.7	22.9	7.5	3.0	14.5	4.6	2.2	100
Other Grains	1.6	4.0	9.2	8.0	2.3	7.4	2.1	7.2	6.1	1.8	2.0	1.5	34.0	7.2	5.7	100
Other Crops	1.5	2.2	8.8	3.8	1.0	2.2	2.2	4.4	2.0	25.9	1.1	0.9	19.4	21.2	3.5	100
Cattle & Sheep	3.2	3.6	13.9	4.4	2.4	6.8	4.6	8.4	12.1	3.1	2.8	1.4	19.2	7.6	6.3	100
Other Animal	1.2	6.9	6.3	4.0	0.9	3.9	1.3	4.5	2.8	23.2	1.0	0.9	3.5	25.9	13.7	100
Raw Milk	3.7	4.0	19.4	10.1	1.6	4.4	7.1	5.6	4.8	4.2	3.4	1.6	21.5	4.5	4.1	100

The selection of sectors used was based on data availability in the GTAP database, along with regional output data available from Statistics New Zealand, information on

[20] Note that SplitCom's current settings to not allow commodity splits to be differentiated across the existing regions parsimoniously. While it is possible to specify production and trade splits per regions in greater detail, this would require further model modifications since agricultural products are used as inputs in further production, and splitting an agricultural product within New Zealand only would require careful calibration of any use of split sectors as an intermediary good could be cross regional, which again would complicate the set up and require either regional input/output data or estimation of trade flows.

[21] See Appendix A for the abbreviations' definitions.

the proportion of land irrigated as well as difference in productivity between irrigated and non-irrigated land.[22]

The regional split was performed in three steps. First, the single New Zealand region GTAP-W model was created with the separate Land, Rain-fed Land and Water endowment commodities, but without actually assigning any values to the new endowment sectors, to facilitate the splits according to more detailed weights once the new agricultural sectors were created. Next, each of the seven agricultural commodities used (see Table 5) were split into 15 region-specific commodities, using the weights in Table 5. This created 95 new region-specific commodities within the database (i.e. WheatNTL, WheatAUK … RawMilkSTL) in place of the original 7 agricultural sectors. Finally, using the data on agricultural production data from Statistics New Zealand (2012), irrigated areas (Appendix B) and relative productivity yields from NZIER (2014), the Land Factor was split into rainfed land, water and [irrigated] land for each of the new commodities.[23]

3.3. Shadow Value of Water

Freshwater abstraction has only been required to be metered since 2012 – and only for large intakes (Ministry for the Environment, 2010). Consequently, at the time of development of this model, there was no reliable data to show the actual usage of water (as opposed to consented usage) in each region to match the GTAP database output data

[22] See Appendix B for sector concordance and detailed statistics on irrigated land.
[23] The procedure described in section 3.1 was used, the yield and production share parameters for each region are given in Appendix C. A further modification was made to the standard closure used in usual GTAP. Since New Zealand is an open economy with commodity prices being largely driven by international prices, a restriction was placed for commodity agricultural prices to be fixed within New Zealand. For instance, all 15 wheat commodities were grouped into "wheat" set and the price such price restriction was imposed: 'tradslack(Wheat,"NewZealand")=pm(Wheat,"NewZealand");'. Furthermore, when the analysis becomes partial equilibrium, walraslack in the standard GTAP model must be exogenised since equilibria must be forced on the final market as Walras' Law no longer holds.

and the Statistics New Zealand Agricultural Census production data in the relevant year. However, efforts by Aqualinc Research (2010) aimed to provide accurate estimates of actual vs. consented use, with the aim of providing a viable alternative. Based on their report, in the 2009/2010 financial year the total actual water used by the irrigation was 3.33 billion cubic metres.[24]

As per Calzadilla, Rehdanz, & Tol (2011), the shadow price of irrigation water can be calculated by looking at the payments to water factor within the GTAP-W database and dividing it by the corresponding volume of irrigation water used for that sector/region. Dividing the sum of all firms' purchases of water endowment in New Zealand ($67 million)[25] by this figure yields a shadow price of 2.00 cents per cubic metre of water. This is in line with figures derived by Calzadilla, Rehdanz, & Tol (2011), if somewhat lower than in other developed countries (in US and Western Europe the prices are 3.5 and 14 cents respectively). The results can perhaps be attributed to the fact that most irrigation water in New Zealand goes towards lower value added dairy sector – it requires approximately 20 cubic metres of water to grow enough pasture to feed cows to produce 1 kg of milksolid[26] with a current market value of $2.67.[27] It may also signal lower overall scarcity.

The shadow price for irrigation water by region is reported in Table 6. It ranges between 33 cents in the Waikato Region,[28] to 1.1 cents in Canterbury, indicating that the shadow price is weakly related to its abundance and relative benefit (NZIER (2014) reported

[24] Derived from the appendix of the Aqualinc Research (2010) report – figures for 'Sum of actual annual water use (m^3/year) for irrigation total

[25] Please note, as the GTAP database is based in the 2011 US dollars, all dollar figures presented in this paper are in US dollars, unless explicitly stated otherwise.

[26] See Kravchenko (2014) for a detailed breakdown.

[27] The 2015/2016 MS Fonterra payout forecast is NZD3.90 (as of March 2016), approximately USD2.67

[28] This is still not as high as in Japan and South Korea, where the shadow value of irrigation water was calculated to be 113 cents per m^3 (Calzadilla et el, 2011).

that the gross margin difference between irrigated and non-irrigated dairy farming in Waikato was by far the widest). Similarly, Bay of Plenty, Auckland and Tasman use irrigation for relatively high return production (fruit and vegetables, including viticulture).

Table 6. Shadow Value of Water by Region

	VFM[29] USD mil	Sum of actual annual water used (m^3/year)	Shadow Value (cents)
NTL	1.083	32,520,726	3.33
AUK	1.404	4,695,362	29.90
WKO	7.086	21,771,444	32.55
BOP	2.379	20,594,232	11.55
GIS	0.278	3,430,259	8.10
HKB	5.780	81,454,183	7.10
TKI	0.569	8,629,149	6.59
MWT	1.536	27,866,857	5.51
WGN	1.013	28,389,566	3.57
TSN	5.665	44,625,605	12.69
MBH	5.579	80,357,840	6.94
WTC	0.190	11,943,165	1.59
CAN	23.477	2,161,328,322	1.09
OTA	9.757	792,090,607	1.23
STL	0.809	11,652,810	6.95
NZ Total	66.603	3,331,350,127	2.00

3.4. Simulations

3.4.1. *New Zealand-Wide Drought*

A New Zealand-wide drought can be thought of a fall in productivity of dryland farms – not affecting irrigated agriculture. One way to model to a drought through a GTAP simulation is through shocking the primary factor-augmenting technological change that applies to rainfed land only. In an econometric analysis of the effects of droughts

[29] Factor payments to water endowment

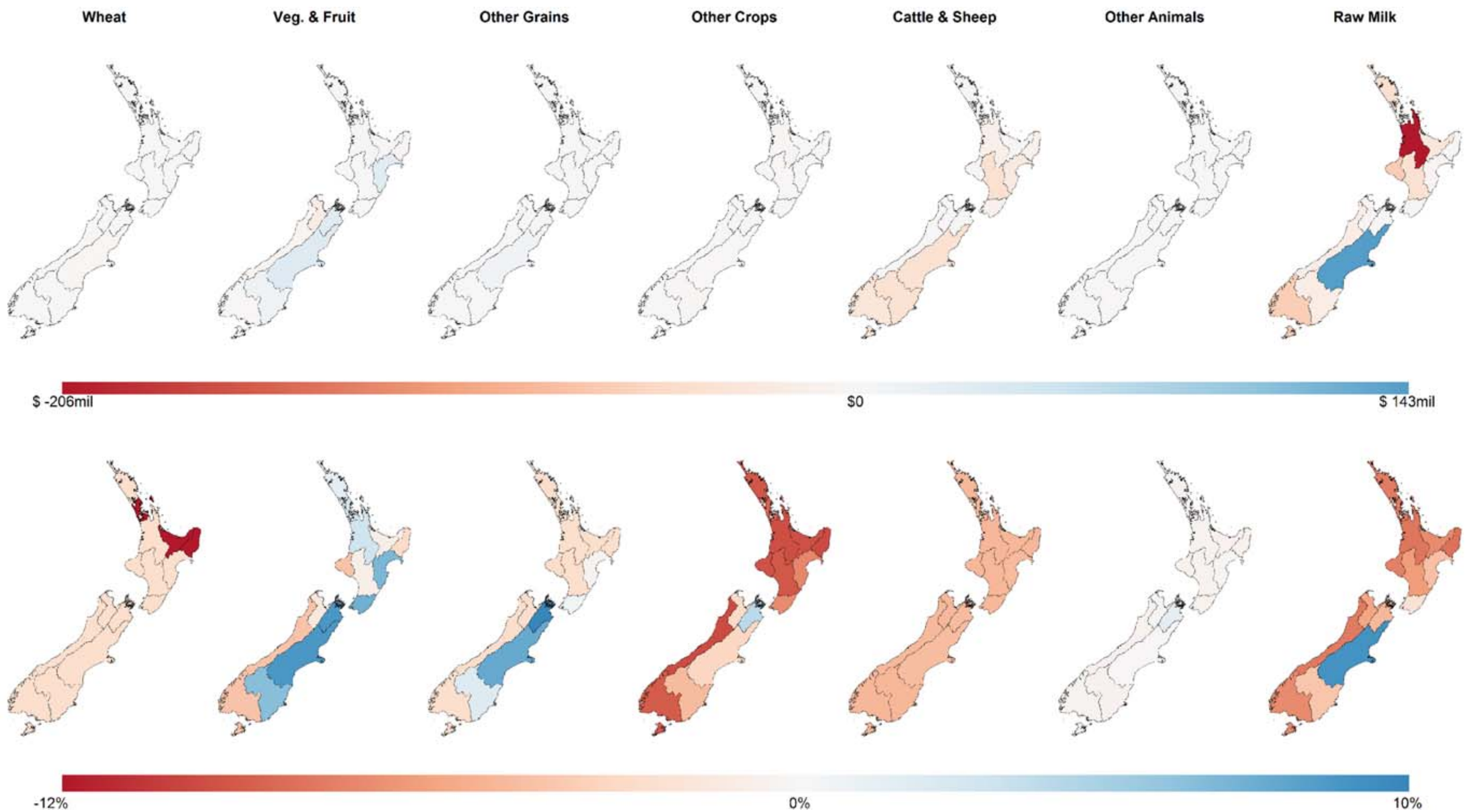
Kamber, McDonald, & Price (2013) note that the effects of droughts are much more pronounced in the North Island where agriculture is more reliant on dryland farming. Our results confirm this conclusion.

Assuming a 10% decline in productivity of dryland production[30] New Zealand's welfare, as measured by Equivalent Variation [EV], falls by $147 mil. Regional decomposition of output changes is presented in Figure 8. In relative terms (with respect to specific sector initial production), Bay of Plenty, Gisborne and Auckland Regions' wheat sectors have the largest declines, but the relative size of this sectors makes the impact comparatively negligible. In absolute terms, the largest change is in Waikato's raw milk sector which decreases by $206 mil. This is somewhat offset by an increase in production of the Canterbury raw milk sector, which experiences a growth of $143 mil. The vegetable & fruit sector seems to benefit the most from the drought-induced re-allocation of resources, particularly in the Canterbury. In general, the drought affects the dairy sector the most in all regions except Canterbury.

Note that due to the assumption of fixed commodity prices, the changes are driven not by relative price changes for the output, but rather through reallocation of factors of mobile factors of production (namely labour and capital).

[30] GTAP shock of 'shock afeall("RfLand",PROD_COMM,"NewZealand") = uniform -10' – this shocks changes irrigation efficiency.

Figure 13. Regional Decomposition of Output Changes in a Drought Simulation in Absolute (Top Row) and Relative (Bottom Row) Terms



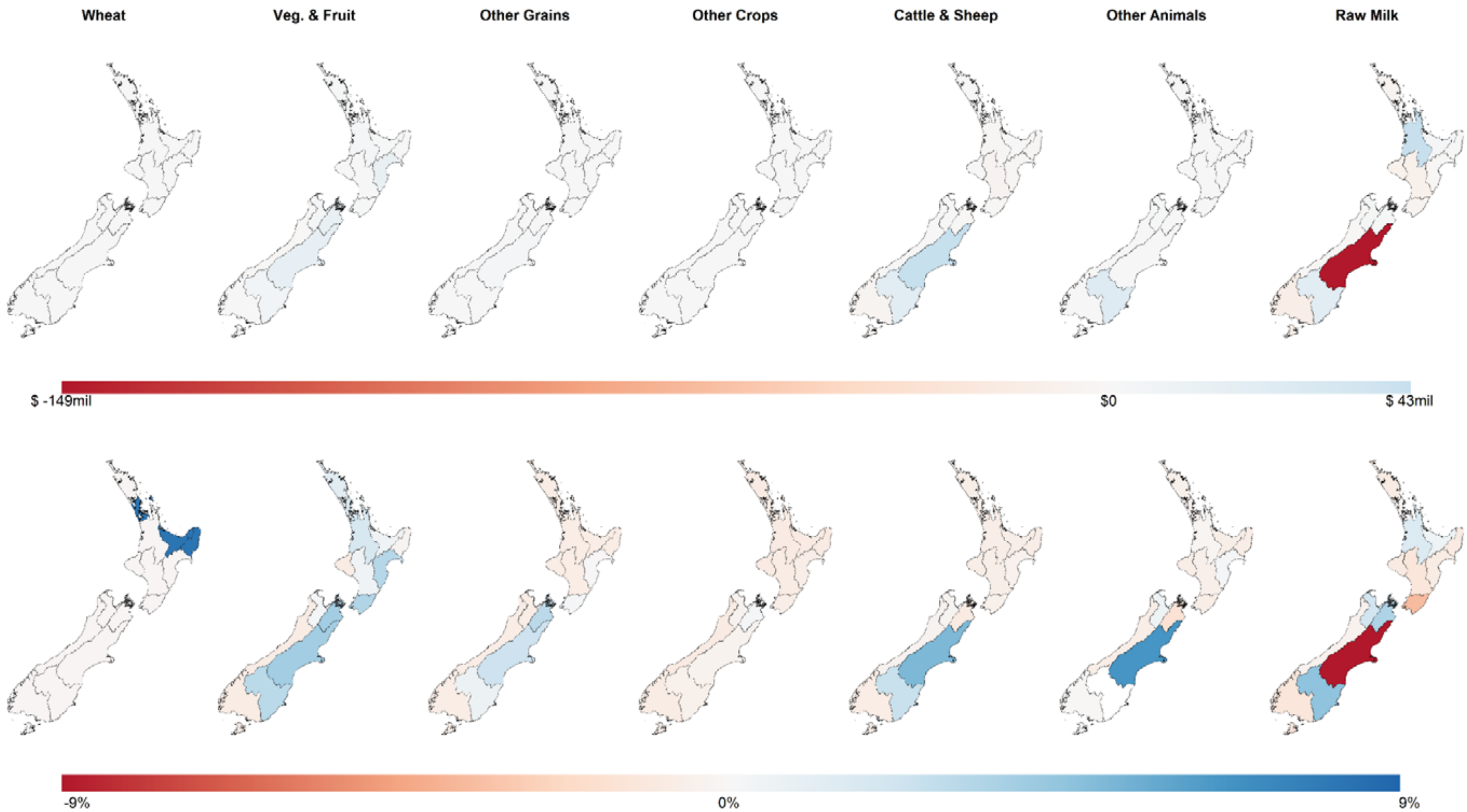
3.4.2. *Removing Irrigation Water as a Factor of Production*

Following the work of MPI (2002) and NZIER & AgFirst (2014) in estimating the value of irrigation through a hypothetical scenario where New Zealand had no irrigation and dryland productivity was applied to the irrigated sector, we modelled a similar experiment.[31] This was achieved through the removal of the water part of the land/water composite endowment. Keeping in mind that in 2012, only 5% of all agricultural land in New Zealand was defined as irrigable (Statistics NZ, 2012), the impact on overall on the New Zealand GDP are still surprisingly small – a decrease in overall welfare by just $16.5 mil. The agricultural output reduction in the most irrigated region – Canterbury – was relatively large – a reduction of 9% or $149 mil. This, however, was largely offset by a shift in resources to other sectors. Cattle & sheep and other animal sectors benefit from no irrigation in Otago and Canterbury, and dairy in Waikato and Otago especially – see Figure 9 for a depiction of results by region and commodity.

The results are significantly smaller than NZIER's estimate, but they come from different assumptions – in our model unirrigated land and capital is reallocated to other sectors, whereas in NZIER's report the authors specify that their analysis "destroys some capital and land", meaning it doesn't get re-allocated to other sectors. Moreover, the results are likely to be cumulative, whereas in our scenario it is modelled as a shock akin to turning off all irrigation for a year.

[31] 'Shock qo("Wtr","NewZealand") = -95'. A larger shock would have been impractical to model in GTAP work and quantity restrictions generally follow this approach (see, for example Anderson & Strutt (2015) who model import bans via a similar approach);

Figure 14. New Zealand without Irrigation



3.4.3. *Simulating a Tax on Water in Canterbury*

To examine the effects of a water tax, a tax rate on water endowment in Canterbury is increased to 100%.[32] This tax decreases New Zealand's welfare by $8 mil. As expected, quantity demanded for water falls for each sector in Canterbury – $0.5 mil (4.3%) in the dairy sector and $0.4 mil (6.9%) in the veg. & fruit sector are the highest. An interesting finding is that demand for water is increased in other regions. While it may be partially an artefact of endogenizing total endowment commodities in the standard closure, and the quantity of water consumed may not increase in other regions to the extend as the model indicates because of abstraction limits, the fact that the model does show an increase in demand means that policies in one region have the potential to put strains on water resources in other regions, even if the catchments are not interconnected.

3.5. Sensitivity Analysis

The results of simulations were tested for sensitivity to elasticity parameter values. Key parameters driving the results of water-related simulations shocks are the 'substitution elasticity of primary factors' (ESBL), and 'substitution elasticity between land and water' (ELLW). Doubling the ESBL parameters increased the impact of shocks: for the drought scenario, the New Zealand's overall welfare decreased by an additional $21.8 mil (on top of the $147 mil decrease), with small, proportional differences in the agricultural production changes. Similarly, for the no irrigation scenario, the overall welfare fell an additional $1.7 mil (on top of $14.8 mil), with minor changes in agricultural production as well.

[32] The original tax rate, close to zero, was the same as the tax rate applied to the New Zealand land factor endowment in the aggregated GTAP database.

Doubling the ELLW parameters made a comparatively smaller difference on the overall welfare in the drought scenario (the welfare was $1.4 mil higher), but the dairy sector in Canterbury increased by 6.1% instead of 8.9% with the substitution parameters used in the baseline simulation. Otago and Canterbury other animal sectors both experience an increase of 1.5% instead of a small decreases experienced in the baseline scenarios.

The ELLW parameters were based on Calzadilla et al. (2011), who in turn based them on price elasticities of demand estimated by Resegrant, Cai & Cline (2002). In their original work, New Zealand's price elasticity of demand and irrigation yield parameters are grouped together with Canada, Iceland, Israel, Malta, Norway, South Africa and Switzerland, whereas Calzadilla et al. (2011) group New Zealand with Australia, for which there is a separate elasticity and yield parameters. Sensitivity to doubling ELLW parameters suggests that there is scope to improve model accuracy with better parameters. Ideally, once more data on water usage becomes available and hopefully some regional authorities decide to price water, a much more accurate CGE model can be built.

4. Conclusion and Limitations

The main aim of this paper was to examine the effects of water pricing on the wider New Zealand economy. This research has culminated in the creation of, to our knowledge, the first publicly available multi-sectoral and multi-regional open economy CGE model of New Zealand. It is based on a well-developed and understood GTAP model, and hence has the appeal of being replicable and available to be used again for other research topics, particularly relating to agriculture.

As theorized at the outset, regional composition of dryland and irrigated agriculture, as well as overall economic activity is highly uneven in New Zealand. Any water related simulation results are primarily driven by the dairy sector, which in turn are driven by Waikato and Canterbury Regions. Shocks benefiting dryland farming (such as water taxes or restrictions) benefit Waikato, whereas droughts benefit Otago and Canterbury. The main finding of the model is that regional policies targeting water has the potential to influence the demand of that resource in other regions, even without hydrological connections. The imputed shadow price of water is 2 cents per m^3 in New Zealand overall, and varies between 30 cents to 1 cent between regions, with Canterbury and Otago commanding the lowest shadow prices, and Waikato and Auckland Regions the highest.

There is currently limited data on irrigation production differences between irrigated and non-irrigated sectors between regions. Hence, there is scope for further disaggregation within this database if regional production data is made available to more sectors. These sectors are all for which irritable land data (and more recently water withdrawals) are available, including grape growing, vegetable varieties and fruit, sheep and beef, etc.

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APPENDIX A – REGION NAMES' ABBREVIATIONS

Region	Abbreviation
Northland	NTL
Auckland	AUK
Waikato	WKO
Bay of Plenty	BOP
Gisborne	GIS
Hawke's Bay	HKB
Taranaki	TKI
Manawatu-Wanganui	MWT
Wellington	WGN
Tasman & Nelson	TSN
Marlborough	MBH
West Coast	WTC
Canterbury	CAN
Otago	OTA
Southland	STL

APPENDIX B – SECTORAL CONCORDANCE BETWEEN GTAP AND IRRIGATED LAND DATABASE

Land use	GTAP Code	Irrigated	Non Irrigated	Total
Nursery Production (Under Cover)	Other Crops	156	589	745
Nursery Production (Outdoors)	Other Crops	3,007	2,128	5,135
Floriculture Production (Under Cover)	Other Crops	129	1,044	1,173
Floriculture Production (Outdoors)	Other Crops	73	672	745
Vegetable Growing (Under Cover)	Veg. & Fruit	285	662	947
Vegetable Growing (Outdoors)	Veg. & Fruit	33,290	34,759	68,049
Grape Growing	Veg. & Fruit	30,173	17,142	47,315
Kiwifruit Growing	Veg. & Fruit	5,690	15,885	21,575
Berry Fruit Growing	Veg. & Fruit	2,977	1,300	4,277
Apple and Pear Growing	Veg. & Fruit	8,918	4,330	13,248
Stone Fruit Growing	Veg. & Fruit	2,097	2,207	4,304
Citrus Fruit Growing	Veg. & Fruit	430	2,335	2,765
Olive Growing	Veg. & Fruit	746	1,735	2,481
Other Fruit and Tree Nut Growing	Veg. & Fruit	2,495	6,575	9,070
Sheep Farming (Specialised)	Cattle & Sheep	82,163	3,601,997	3,684,160
Beef Cattle Farming (Specialised)	Cattle & Sheep	47,365	969,323	1,016,688
Sheep-Beef Cattle Farming	Cattle & Sheep	27,912	3,166,166	3,194,078
Grain-Sheep or Grain-Beef Cattle Farming	Cattle & Sheep	36,783	83,755	120,538
Other Grain Growing	Other Grains	47,431	72,122	119,553
Other Crop Growing n.e.c.	Other Grains	16,110	113,764	129,874
Dairy Cattle Farming	Raw Milk	352,240	1,853,329	2,205,569
Deer Farming	Other Animals	9,327	231,005	240,332
Horse Farming	Other Animals	2,314	27,119	29,433
Pig Farming	Other Animals	1,239	6,551	7,790
Other Livestock Farming n.e.c.	Other Animals	428	6,636	7,064
Forestry		83	106,466	106,549
Revised Other		174	7,781	7,955
Total		721,394	10,465,746	11,187,140

Source for irrigation data: Kaye-Blake, Schilling, & Zuccollo (2010)

APPENDIX C – TABLES FOR REGIONAL SPLITS

Table 7. Share of Irrigated Production by Region and Agricultural Commodity

	Wheat	VegFruit	OthCGr	OtherC	CtlShp	OthAnml	RawMilk
NTL	12.80%	41.01%	0.00%	3.06%	0.42%	0.77%	3.09%
AUK	12.80%	50.42%	0.00%	8.20%	0.23%	1.30%	4.91%
WKO	12.80%	51.91%	0.00%	1.12%	0.33%	2.04%	5.90%
BOP	12.80%	25.30%	0.00%	1.33%	0.65%	0.20%	10.31%
GIS	12.80%	11.09%	0.00%	0.00%	0.32%	0.00%	0.00%
HKB	12.80%	77.87%	15.79%	17.61%	1.79%	4.01%	24.56%
TKI	12.80%	0.00%	0.00%	2.08%	0.39%	0.00%	4.01%
MWT	12.80%	24.87%	0.00%	3.92%	0.47%	0.49%	11.32%
WGN	12.80%	80.86%	21.89%	18.95%	1.10%	0.00%	32.21%
TSN	12.80%	20.18%	0.00%	46.54%	1.17%	4.83%	22.34%
MBH	12.80%	90.00%	83.98%	90.00%	1.42%	9.69%	31.65%
WTC	12.80%	0.00%	0.00%	0.00%	1.80%	0.00%	3.35%
CAN	12.80%	90.00%	69.74%	45.38%	14.35%	17.70%	81.06%
OTA	12.80%	74.71%	32.04%	34.82%	6.77%	19.02%	38.93%
STL	12.80%	0.00%	0.00%	4.92%	0.29%	2.64%	6.12%

Table 8. Ratio of Irrigated and Dryland Yields by Region and Agricultural Commodity

	Wheat	VegFruit	OthCGr	OtherC	CtlShp	OthAnml	RawMilk
NTL	1.39	1.39	1.38	1.33	1.79	1.79	1.33
AUK	1.39	1.39	1.38	1.33	1.79	1.79	1.54
WKO	1.39	1.39	1.38	1.33	1.79	1.79	2.25
BOP	1.39	1.39	1.38	1.33	1.79	1.79	1.54
GIS	1.39	1.39	1.38	1.33	1.79	1.79	1.54
HKB	1.39	1.39	1.38	1.33	1.71	1.71	1.31
TKI	1.39	1.39	1.38	1.33	1.79	1.79	1.31
MWT	1.39	1.39	1.38	1.33	1.79	1.79	1.25
WGN	1.39	1.39	1.38	1.33	1.79	1.79	1.19
TSN	1.39	1.39	1.38	1.33	2.35	1.79	1.54
MBH	1.39	1.39	1.38	1.33	1.18	1.18	1.54
WTC	1.39	1.39	1.38	1.33	1.79	1.79	1.54
CAN	1.39	1.39	1.38	1.33	2.18	2.18	1.16
OTA	1.39	1.39	1.38	1.33	2.51	2.51	1.54
STL	1.39	1.39	1.38	1.33	1.79	1.79	1.22

CHAPTER VI: SUMMARY & CONCLUSION

This thesis was primarily concerned with determining the value of irrigation water and the responses to hypothetical water charges for agriculture in New Zealand, aiming to examine the effects of possible water charges that could address growing freshwater scarcity. Particular attention was paid to the dairy sector – being the largest consumptive user of freshwater. Dairy intensification, in terms of converting from dryland to irrigated pasture, is generally associated with water quality and environmental degradation (see Foote, Joy, & Death (2015) for an estimation of costs of externalities associated with dairy farming). In addition, dairy intensification has also been identified as one of the main driving forces behind the increase in the water demand - a resource that is reaching (or reached and indeed surpassed in many catchments) current allocation limits (Aqualinc Research, 2010; Statistics NZ, 2012). In addition to looking at the non-market value of water, the secondary objective of this thesis was to advance methodological techniques in the fields of non-market valuation, choice modelling and Computable General Equilibrium [CGE] modelling. The first part (Chapter II) examined the dairy sector alone and aimed to estimate the potential demand for water by looking at the dairy farm production data. The second part (Chapters III and IV) involved conducting a choice experiment on farmers who irrigate. The final part (Chapter V) used CGE modelling to examine economy-wide effects of water-related shocks. The following sections will briefly review the main findings of each section, discuss their contribution to the relevant literature, as well as propose potential avenues for future research.

5.1. Panel Data Analysis

Using MPI's dairy monitoring dataset, together with data on dairy payout forecasts that had to be collected from financial and news reports form across ten years, as well as weather data from NIWA, a relationship was established between weighted forecasted payout and the amount of milk produced via a fixed effects regression analysis. With an assumption that a decrease in expected payout for a Milk Solid [MS] is equivalent to an increase of the cost of an input, it was shown that a price/quantity of MS relationship could be converted to a price/quantity of water relationship, conditioned on a parameters of a dairy farm.

Findings by Watters, Rowan, & Williams (2004) confirmed that dairy farmers adhere to the basic economic principle of incentives – farmers increase production (and incurring higher marginal costs) when the expected payout is higher. To develop an accurate relationship between price and quantity, a more accurate measure of incentives was required than the final payout (which is announced months after the milking season is over). In place of the final annual MS payout from Fonterra, New Zealand's largest dairy cooperative, a new weighted price measure was developed that more carefully reflected the incentives that dairy farmers faced throughout the years in the dataset: since the payout forecast changed throughout the milking season and farmers respond to *expected* payouts, a change in the *expected* payout would have triggered a response not accounted for by the final payout. Literature concerning farmer behaviour has not considered the effects of these changes but rather focused on the final payout. Future use of this method would benefit from use of more detailed regional milk production data to be incorporated as weights – only national-level milk production was used in this study.

Once a credible relationship was established between price and quantity of MS produced, together with the knowledge of pasture irrigation yields, and dry-matter to MS conversion, it was possible to impute the relationship between an increase in the price of water (proxied by a decrease in the expected payout) and the corresponding decrease in the quantity of water demanded (proxied by lower production, since however much production declined by, it was possible to estimate the corresponding amount of dry-matter not consumed, which in turn would have required less irrigated water). In other words, a decrease in the expected payout simulated what would happen on an irrigated farm should the price of water suddenly increase by an equivalent amount.

This method is a novel way of non-market valuation, which to the knowledge of the author has not been used previously. It does, however, rest on a strict assumption, namely that there is no substitution with other factors of production. More than likely, an increase in price of water would have resulted in an increase in demand of its substitute – brought-in feed. However, if a reliable source of temporal feed prices could be secured, this too could be accounted for.

In addition, behavioural economists have long noted asymmetry in which people process information (see, for instance, Barberis & Thaler (2003), on behaviour psychology of stock market trading). While equivalent to the bottom line, it is possible that farmers would react differently to a decrease in a payout than to an equivalent increase in costs (aside from the issue of substitution). Data on cost increases (perhaps electricity, interest rates or minimum wage changes) could be used to test this hypothesis.

5.2. Discrete Choice Modelling

Following the initial findings with regard to irrigation water price demand in the case of dairy farmers, a choice experiment targeting farmers who irrigate was carried out. It was expected that most farmers would be against paying for something that they currently get for free (echoing results from previous such studies), hence in choice tasks consent holders were asked to imagine scenarios in which their local regional council instituted a temporary water withdrawal ban. The consent holder would then decide between having to wait out the ban or having to pay a fixed amount per cubic metre of water up to amount the full or partial amount of their initial consented amount. The main aim of the survey was to see whether when faced with such choices respondents would still protest against water charges, or would be willing to pay some money to avoid the ban.

In terms of methodological research questions, particular attention was paid to the issue of Atttribute non-Attendance [ANA]. Reviewed litereature provided mixed indicators about the influence of ANA, but its prevalance was well recognized. Initial simulation analysis (Chapter III) indicated that ANA can, under certain conditions, cause problems. However, if ANA is due to preference hetrogeneity (i.e. some resondents having a zero preferences, while others do not), latent class estimation could be used to pick up this heterogeneity and such heterogeneity does not really bias estimates as the estimates are an average (which includes those who had zero preference as well those who do not). When, on the other hand, ANA was assumed to be random (though not representing preference hetrogeneity) latent class modelling could not help, nor could reliable parameters be estimated without additional data on ANA. Simulations also revealed the importance of randomization – if ANA was order specific, not randomizing could lower the significance of estimates.

Alemu, et al. (2013) sought to understand the reasons behind ANA via follow up questions and found that these included true zero preferences as well as simplifying heuristics. They conclude that not accounting for such heterogeneity biases the results. The research in this thesis did not seek to differentiate between two sources of ANA, and the results are confounded. However, the results suggest that different reporting mechanism yield different ANA evidence. The survey used three methods to collect ANA data for comparison – not previously explicitly done. In the first condition, respondents self-reported level of ANA after all choice tasks were completed; in the second condition they self-reported ANA after each choice task; in the third condition respondents had to uncover attribute levels by hovering their mouse points across the location of attribute levels.

The results of the survey indicate that self-reporting is generally constant and is stable across choice tasks. Together with the corresponding estimated parameter significance, this implies that stated ANA methods – both serial and task choice - pick up the first type of ANA – due to preferences heterogeneity. Revealed ANA, on the other hand – a method whereby respondents uncover attribute levels seems to pick different information – the frequency of hovering events over a 200 ms threshold (Pseudo Fixations [PS]) did not not vary significantly across attributes and declined significantly across choice tasks. Both stated choice task and revealed condition caused additional burden on respondents which caused attrition. Since choice task and serial conditions picked up largely the same information, the recommendation of this study is to use serial ANA data collection method only (if stated method is unavoidable). However, it is strongly argued that revealed method, particularly if it less burdensome, perhaps with an aid of eye tracking, can track ANA due to heuristics or fatigue.

In the case of ANA due to preference heterogeneity, latent class modelling has been shown to improve model fit and also produce substantially different WTP parameters and welfare estimates (Scarpa, et al., 2009). Such modelling does not require (though can still benefit from) additional data collection with respect to ANA, and hence can theoretically be applied to any choice modelling dataset. In the case of ANA due to heuristics (not associated with zero preferences) not tracking such ANA can cause a significant distortion to estimates as well as a loss of statistical significance.

5.3. *General Equilibrium Modelling*

The main advantage of General Equilibrium Modelling is that unlike Partial Equilibrium Modelling, the spill-over effects of economic changes between different sectors are taken into account. As such, while it is obvious, for example, that a water charge in Canterbury would negatively affect farmers who irrigate in Canterbury, CGE modelling allows the estimation of the effect of such of a hypothetical charge on other sectors in Canterbury as well as other regions and the economy overall.

To study the effects of water before introducing water trading in Australia, Appels, et al. (2004) use TERM-H2O to help policymakers examine wider economic implications of water trading policies within regions and catchments. New Zealand does not have a parallel publically available regional CGE model. Hence, for the purposes of this thesis, a well-known global CGE model, GTAP, was adjusted to include water as a factor of production *and* disaggregated by the New Zealand regions.

Data for splits was taken from publicly available sources, including Statistics NZ's agricultural census results; an NZIER & AgFirst (2014) report on valuing irrigation in NZ; as well as Calzadilla et al. (2011) who created GTAP-W model to include water as a factor of production. By integrating irrigable area, relative productivity per hectare between irrigated and non-irrigated sectors, physical output per sector as well as total volume of water withdrawn (estimated by Aqualinc Research (2010)), it was possible to derive the shadow price of water by region. The average shadow value of a cubic metre of irrigated water in New Zealand is 2 cents,[33] which is in line with estimates for other countries.

[33] In 2011 US dollars.

After splitting the database using SplitCom, it was then possible to apply various shocks to see how they affect the New Zealand economy as a whole and by region. For example, assuming a drought that would decrease dryland farm productivity by 10% nation-wide, the largest negative effect was felt in the Waikato Region, whereas Canterbury region actually benefitted from re-allocated resources.

As far as the authors are aware, aside from NZIER's proprietary CGE model of the New Zealand economy, this is the first successful attempt at creating working regional CGE model of New Zealand. While it lacks sufficient detail and assumes some strict assumptions (such as price restrictions of related sectors), it provides a viable starting point for any CGE research of New Zealand, particularly pertaining to agriculture. Further breakdown is possible for various agricultural sectors (i.e. kiwifruit, wine, apples) as there is already publicly available data on irrigated areas and only the corresponding production data would be required for further regional detail. The model would also benefit from better behavioural parameters estimated specifically for New Zealand for more accurate results.

5.4. Policy Implications

Only 19 out 154 survey respondents, approximately 12%, serially chose the Status Quo in each of the eight choice tasks, implying that *vast majority preferred a priced alternative with an easement over a full-out ban* (see Figure 15 for a distribution of total Status Quo selections per respondent). The actual figure may be somewhat higher as some respondents who refused to participate might have not done all eight choice tasks because they were not in favour of paying for water and did not want to participate in the study implying so. In fact, at least one respondent felt strongly enough to make his feelings known via email: "As far as paying some govt agency a resource rental goes I would rather eat the tip off my left thumb than have any part of that". Similarly, a large industry organization refused to promote the survey because "[our organization] is very much opposed to charging for water, especially in times of climatic stress".

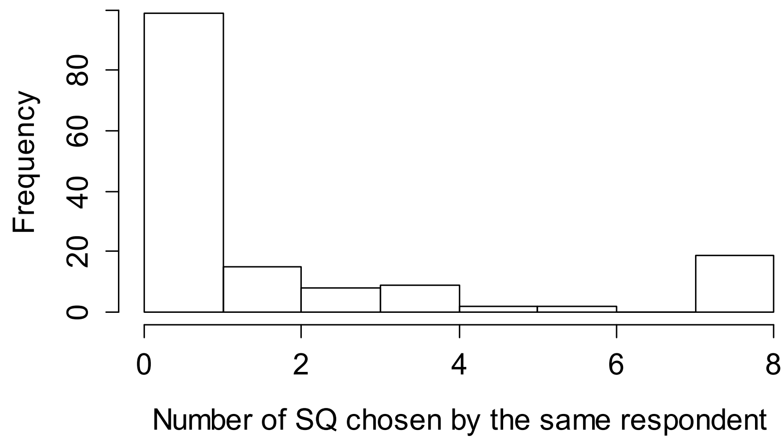

Figure 15. Serial non-Participation by the Respondents: Frequency of Selecting Status Quo

One other respondent called in and in great detailed explained why they thought that irrigation water should always be free, and you should not charge for it under any circumstances, they were opposed to it, etc. However… upon checking the answers they said they submitted, it turned out that facing a ban, even they stated they preferred to pay rather than having their orchard wither.

Overall, this study has important findings that can be of benefit to water future policy considerations:

- From Chapter II, the findings suggest that larger, more intense dairy farms have lower price elasticity of demand. The implication of water management policy is that if water charges are introduced, farming intensity needs to be considered – all else held constant, areas with the same amount of cows but with higher intensity farms would be less sensitive to water charges than less intense farming areas, at least in the short term. However, for more accurate responses substitutes, such as brought-in feed, would need to be considered, for which data is scant. Other findings also point that irrigation, in terms of mm/ha is approximately twice as efficient as the same quantity of rain, hence this could be a gauge of water demand as rainfall data is more readily available.

- From Chapter IV, the choice experiment results suggest that farmers are more concerned with flow restrictions than with volume restrictions, and would be willing to pay more than twice for a decrease in a restriction for flow limit over a restriction for volume limit. This suggests that charges on flows would be effective at managing water demand. In terms of setting up possible water markets, farmers are interested in buying more water, and there seems to be no desire to sell the water at present (no excess available) – hence any selling would have to come from idle consent holders or regional authorities. In addition, a number of respondents confessed to holding onto their irrigation consents without actually using any of it because they know it would raise the value of their property. Such 'hoarding' may make it difficult to rely on consent data alone to determine demand, and suggests that the value of such access as part of property needs to be examined in its own right.

- From Chapter V, CGE modelling results suggest that the impact of irrigation shocks would, as expected, predominantly felt in Canterbury dairy. This is because Canterbury is by far the largest irrigating region in New Zealand, but CGE modelling highlights interconnectedness of sectors and regions. For example, an important modelling result is that when Canterbury dairy declines, Waikato dairy seems to pick up misallocated resources, and vice versa;. Land and other resources released by irrigation tend to go to the cattle & sheep and other animal sectors. Hence, a national coordination policy may be necessary as repercussions from one region's water policy may spill over to other regions.

5.5. Final Words

The largest freshwater user in New Zealand is actually a single hydroelectric power station in Southland – the Manapouri Power Station. It is classified as a consumptive user because it discharges freshwater from Lake Manapouri into the Doubtful Sound (thereby preventing other potential users from using this freshwater, unlike all other hydroelectric power stations in New Zealand). Every year it consumes over 10 billion cubic metres of freshwater – more than all of irrigated agriculture in New Zealand put together. Of course, this does not really imply that this power station prevents irrigated farms from all over New Zealand from benefiting from this water – far from it – literally: the power station is located in Fiordland National Park where there is not one farm in its vicinity. The point here is that each water catchment has its own particularities and it is difficult to fathom a central body applying a one-size-fits-all policy to such a diverse resource. Freshwater management should be very much catchment-based – regional authorities are in the best position to govern them as they know the local conditions best. That is not to say that there is no scope for central government involvement – having a well thought through national legislation to rely on to allow regional authorities to implement efficient resource policies is precisely what the regional governments need. The RMA, implemented when water scarcity was not an issue, has outlived its usefulness, and is now the central cause of inefficient management. From the looks of it, the National Freshwater Policies implemented recently are heading in the right direction – the water takes are now measured, standards on water quality and quantity are going to be set at the national level. The author's biggest concern is that these polices will stop short of laying groundwork for implementing water markets, or, at least, irrigation water charges. If they stop short, the process of re-developing legal framework for resource management will have to happen all over again in the very near future.

When RMA was enacted, freshwater was essentially a public good – there was enough for it to go around for everyone. It has long since became a common-pool resource – now one user's actions have very much an impact on other users' benefit. The tragedy of the commons dictates that such a resource is in danger of being depleted. One need not look far to find similar situations elsewhere – the Murray River in Australia has at one point stopped flowing because of over allocation to irrigation. The government actions were swift – Australia now has arguably the world's best working water market. While the results of the survey conducted as part of this thesis indicate that some respondents are strongly averse to paying for water, the vast majority seem to prefer paying for water than facing the alternative of lack of water access.

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WAIKATO
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Co-Authorship Form

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter IV - Some findings from 'revealed' attribute non-attendance in web-based choice experiments: the case of valuing irrigation water in New Zealand

Nature of contribution by PhD candidate	
Extent of contribution by PhD candidate (%)	

CO-AUTHORS

Name	Nature of Contribution
Alexey Kravchenko	95%
Riccardo Scarpa	5%

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Alexey Kravchenko		19-Mar-2016
Riccardo Scarpa		20-Mar-2016

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter V - Economic Effects of Irrigation Water Pricing in New Zealand: An Analysis using the GTAP Model

Nature of contribution by PhD candidate	Literature review, database and model modification, set-up and analysis of simulations.
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Alexey Kravchenko	Literature review, database and model modification, set-up and analysis of simulations.
Anna Strutt	Contributed expertise on modelling and simulation design.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Alexey Kravchenko	[signature]	20-Mar-2016
Anna Strutt	[signature]	21 March 2016