Water, Water Somewhere:
The Value of Water in a Drought-Prone Farming Region

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Abstract

Water is critical for agriculture, yet surprisingly few studies internationally have analysed the value placed on water in specific farming contexts. We do so using a rich longitudinal dataset for the Mackenzie District (Canterbury, New Zealand) over nineteen years, enabling us to extract the value placed by farmers on long-term access to irrigated water. New Zealand has a system of water consents under the Resource Management Act (RMA) that enables farmers with consents to extract specified quantities of water for agricultural purposes. Some water is extracted through large-scale irrigation infrastructure and other flows by more localised means; the RMA and the water consents themselves are a critical legal infrastructure underpinning farming.

Using panel methods, we estimate property sale price and assessed value as a function of the size of the farm's water right (if it has one), farm characteristics, and the water right interacted with farm characteristics to determine how the value of a water consent varies according to local conditions. We find that flatter areas and areas with poorly draining soils benefit most from irrigation, possibly because the water is retained for longer on these properties. Drier areas appear to benefit more from irrigation than do areas with higher rainfall. Farms that are situated close to towns derive especially strong benefits from irrigation since these properties are most likely to have potential water-intensive land uses such as dairying and cropping that require access to processing facilities and/or an urban labour pool.

JEL classification
Q15, Q25, Q12, D23, D24

Keywords
irrigation, hedonics, water supply, New Zealand

Contents

1 Introduction

Water is critical for agriculture, and is becoming increasingly scarce in many places.[1] Water allocation mechanisms are often non-existent or based on first-come first-served principles that do not allocate water to highest end-uses. Irrigation projects may assist in alleviating water scarcities, but they are often riddled with inefficiencies related to the lack of efficient allocation of the irrigated water.

The importance of these issues suggests that a large body of evidence will be available on the value of water for agricultural and other purposes. Yet surprisingly few studies internationally have analysed the value placed on water in specific farming contexts. We do so using a rich longitudinal dataset that enables us to extract the value placed by farmers on long-term access to irrigated water.

New Zealand has a system of 'water consents' under its Resource Management Act (RMA) that enables farmers with consents to extract specified quantities of water for agricultural purposes. Extraction of water without a consent is illegal. Consents are granted separately for ground and for surface water. Some water is extracted through large-scale irrigation infrastructure and other flows by more localised means.[2] The RMA and the water consents themselves are a critical legal infrastructure underpinning farming. The consents grant farmers the right to extract up to a certain quantity of water (defined by maximum flow rates and by maximum volume flows over time) generally for 30 years, with possible renewal. These consents may enable farmers to change the nature of production on their land (e.g. from sheep grazing to arable or to dairying).[3] However the water rights

[1] In January 2008, the United Nations Secretary-General, Ban Ki-moon addressed the Davos World Economic Forum, Switzerland, stating: "The challenge of securing safe and plentiful water for all is one of the most daunting challenges faced by the world today. Until only recently, we generally assumed that water trends do not pose much risk to our businesses … the notion of water sustainability in a broad sense has not been seriously examined."
Source: www.un.org/News/Press/docs/2008/sgsm11388.doc.htm , sourced 13 May 2008.

[2] From the 1930s to 1984 there was considerable public investment in community irrigation schemes; however since 1985 there has been no direct central government investment in building irrigation schemes. See Le Prou (2007) for a history of New Zealand irrigation administration.

[3] Taylor et al (2003) suggest that land use change comes in waves as irrigation availability is followed by changes in farm ownership and demographic changes. Consistent with this view, there has been a change in the role of irrigation from drought-proofing to being a means of diversifying agricultural production. Ford (2002) notes that land use change can take time, so flow benefits of

are not tradeable, nor can the water itself be sold. Mostly, consents reflect first-come, first-served (or “first-applied, first-granted”) rights to water for local land-owners. If a farm does not use all its entitlement in a certain period, that water is “lost” to the consented properties, and no other property can make use of the lost water (e.g. by diverting the relevant water for its own use).

This system means that we do not observe market prices for agricultural water in New Zealand. Nevertheless, in parts of New Zealand, including the Canterbury Region, water is scarce and a positive shadow price must therefore exist for this commodity. The shadow price can be observed implicitly since resource consents for water remain with the farm when the property is sold. Thus the sale price will reflect, inter alia, the water consents (or lack of them) belonging to the property. Furthermore, if property valuations (for property tax purposes) reflect the full value of the farm (as they are required to by law), they will also indicate the value placed on water consents for each property.

We examine the value that farmers place on water consents using a specially constructed annual (and triennial) dataset. The dataset covers every rural property in one drought-prone New Zealand local authority (Mackenzie District in the Canterbury Region[4]) over a period of nineteen years. We hypothesise that farmers will pay a premium for land that has a water consent and that the value of the premium will be determined by the present discounted value of the extra net farm income due to the consent. The premium may therefore vary according to underlying characteristics of the property (e.g. rainfall, slope, drainage, location) which influence the marginal productivity of the consented water.

Our dataset includes, for every rural property in the region: the sale price of the property (if sold), the land value assessed by an independent body (Quotable Value New Zealand - QVNZ) for property tax (‘rating’) purposes, and the value of improvements on the property (also assessed by QVNZ). The sales price (less improvements) and the land value are used, in separate specifications, as our dependent variable. They are also used to cross-check the validity of the

new irrigation may be delayed. Land prices nevertheless should be forward-looking, so the present discounted value of the irrigation should be impounded in the land value.

[4] Canterbury had 287,000 ha (60%) of New Zealand’s irrigated land in the 2002/03 season (MAF, 2004).

two sets of price/value data. Specifically, we examine whether properties that are sold (and hence for which there is an observable sales price) constitute a representative sample of the universe of rural properties for which valuation data is available. We do so both by comparing data means and by testing (using a probit equation) whether the presence of a water consent affects the propensity for properties to be traded. In addition, for properties that are sold, we test whether assessed capital value (land value plus improvement value) provides an unbiased predictor of sales price. In particular, to use the valuation data for our purposes, we need to test that the irrigation variable provides no extra information over and above the valuation variable in predicting a farm's sale price. (If the contrary were the case, the valuation data would be shown to inadequately account for the irrigation benefits that purchasers are prepared to pay for.)

Longitudinal consents data (at the level of the individual farm) include consent type (e.g. ground water obtained from a bore as opposed to diverted surface water), consent dates (beginning and ending), a measure of irrigated area, and two measures of maximum allowable water flow; these data vary over time for certain properties. Other farm-specific explanatory variables include: land area; measures of average rainfall, slope and drainage; distance from local towns, plus a location variable within small defined statistical areas ('meshblocks'). Variables that are not farm-specific include a measure of climatic developments (the southern oscillation index). The variability in the longitudinal consents data both cross-sectionally and over time enables us to identify the impact of the water consents on property prices, reflecting the implicit market valuation of water rights.

We use panel estimation methods to estimate these values. Specifically, we estimate sales prices (and property values) as a function of a range of explanatory variables including the water consent variables. The consent terms are interacted with other explanatory variables to determine how the value of water consents varies according to variations in other conditions. Our methods therefore enable us both to determine a shadow price for water in the region and to isolate key determinants that affect the price. We find that flatter areas and areas with poorly draining soils benefit most from irrigation, possibly because the water is retained for longer on these properties. Drier areas appear to benefit more from irrigation than do areas with higher rainfall. Farms that are situated close to towns derive especially strong benefits from irrigation since these properties are most likely to have potential water-intensive land uses such as dairying and cropping that require access to processing facilities and/or an urban labour pool. Differing returns across properties with different characteristics indicate that the legal restriction that forbids trading of water most probably results in allocative inefficiency for this resource.[5] These results provide valuable information for irrigation and water planning in New Zealand. The paper's methods, especially in bringing together a comprehensive range of farm-specific data covering a whole region over a significant timespan, can also inform studies of the value of water in other settings where water is a scarce commodity.

To provide a background for the analysis, section 2 outlines the (few) other studies internationally that have examined similar issues. Section 3 builds on these contributions to construct a theoretical model that underpins our empirical analysis. In section 4, we describe our data which have been compiled from a number of separate sources, each collated to match at an individual property level. We test whether the valuation data (covering the universe of properties) is a reasonable proxy for the sale price (i.e. market) data, noting that the latter is inherently available only for a selective portion of properties. Included in this section (and accompanying data appendix) is a test of whether properties with irrigation are more or less prone to be purchased.

Our major results are contained in section 5. For each dataset (i.e. sale price dataset and valuation dataset) we have separate samples - 'large' and 'small'. In each case the 'small' dataset excludes lifestyle blocks[6] and some other properties for which land use is uncertain. The large datasets include some data considered reliable but where we could not be completely certain of its veracity (e.g. because of missing land use data used to identify whether the property is

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[5] We say "most probably" here since our results apply to the total (or average) benefit of the water right to the farm rather than to its marginal benefit. However since water is positively valued and cannot be traded, it is highly likely that differing average benefits also translate into differing marginal returns to water.

[6] Lifestyle blocks are small-holdings that may or may not be used for genuine farming activities.

used for agricultural purposes or not), but they have the advantages of fewer selection issues and greater degrees of freedom. We test the robustness of our results across the four datasets, with different equation specifications. In particular, we pay attention to the nature of our controls, and estimate with and without (two types of) area fixed effects. At the close of section 5 we interpret our results, using our estimates to determine the value (in 2006) placed on irrigated water in different farming circumstances. Section 6 concludes, suggesting both research and policy implications of our findings.

2 Prior studies

Methods for valuing irrigation water traditionally include observing water rights markets, residual methods, and hedonics. Transactions between buyers and sellers of water rights naturally are a useful source of information for valuing water; however lack of data means this method is rare. Residual methods derive shadow prices from models of decisions made by firms and households. The residual method, as applied to irrigation, often takes the form of farm budget or cost and return analysis (Young, 2005). This method involves pricing inputs and outputs and specifying an appropriate farm production function.

An alternative method, and the method used in this work, uses statistical analyses of farm sales prices or valuation data to isolate the net economic contribution of irrigation water. This is an example of the hedonic property value approach to water valuation (Palmquist, 1989). In it, a land sales price represents the market's willingness to pay for a bundle of rights to the land and irrigation water. Appropriate data allow the contribution of irrigation water to be statistically isolated from that of the land and other features such as proximity to urban markets, soil quality, and presence of capital items such as farm buildings. Despite its attractiveness, relatively few studies have applied the hedonic method to irrigation, and those that do frequently use small samples or suffer from some data deficiency, resulting in statistically insignificant results.

Studies using hedonic valuation methods include Crouter (1987), Torell et al (1990), Xu et al. (1993) and Faux and Perry (1999). Crouter (1987) examined 53 observations of farm sales in Colorado from 1970 but was unable to find a statistically significant effect of irrigation water rights on farm sales price. Torell et al (1990) examined a much larger sample of 7,200 farm sales in a six state region in the Ogallala aquifer in the western United States from 1979-1985. Following Palmquist (1989) they estimate two equations, one for dry land and one for irrigated land, and find that the price differential between the two types of land has declined over time. They estimated values of about $3.90 per acre-foot of water in storage over the entire region, with values ranging from $1.09/acre-foot in Oklahoma in 1986 to $9.50 per acre-foot in 1983 in New Mexico (an arid state). These estimates suggested that the water value component of irrigated farm sales ranged from 30 to 60 percent of the farm sale price.

Xu et al (1993) study the effects of site characteristics on the valuation of agricultural land between 1980 and 1987 in Washington State. They find a positive and significant effect of irrigation and also find that the type of water distribution system is important, a central pivot system being more valuable than other sprinkler systems.

Faux and Perry (1999) apply the hedonic method to a sample of 225 farm sales in Malheur County, Oregon between 1991 and 1995.[7] They put considerable effort into evaluating the effect of soil quality on farm land prices. Their research assumes a constant 2.5 acre-feet per acre rate of irrigation across all sales to allow them to derive a value per unit of water volume. Their estimates of this value ranged from $9 to $44 for the lowest to highest quality irrigated soils.

Young (2005) reviews a variety of methodological approaches to valuing irrigation water, and notes that estimates of the value of irrigation water from hedonic estimates tend to be much lower than those derived from residual methods. Torell et al. (1990) compared their hedonic valuations with valuations derived from farm budgeting (residual) methods. They found that their hedonic results were much smaller (in $ per acre-foot) than those derived from residual methods. This could be because many residual estimates are short-run and ignore some fixed costs. Another reason for relatively low hedonic estimates might be the choice to exclude non-irrigated land sales (Young, 2005). If all observations

[7] Young (2005) describes Faux and Perry as a quasi-hedonic approach because they lack data on the quantity of the water right for each property.

represent sales of irrigated land, the range of water supplies across observations is likely to be limited, and relatively little change in output per unit of water input would be expected. Young (2005) also suggests that the hedonic method measures an at-source (or water cost-adjusted) value rather than the at-site measure usually derived by residual methods. To make the two approaches comparable, the estimated costs of obtaining water need to be accounted for in each approach.

Given Young's analysis, successful use of the hedonic approach requires a location where both irrigated and non-irrigated land parcels of relatively similar climate and market conditions are bought and sold on competitive markets. The observations on the extent of the water right must also vary widely enough for a satisfactory statistical estimate. Our comprehensive data sources enable us to meet these requirements.

In New Zealand, little econometric research has been conducted on the value of irrigation, despite an estimated doubling in irrigated area between 1985 and 1995 (Ministry for the Environment, 2000). At a macroeconomic scale, the Ministry of Agriculture and Forestry (MAF) (2004) calculated that the contribution of irrigation water to GDP was $920 million in 2002/03, or approximately 11% of farmgate GDP. An adjusted gross margin method was used to estimate the change in GDP generated by irrigation.[8]

Two community schemes (Waimakariri and Opuha) have been developed during this period. The Opuha dam was the subject of an *ex post* study by Harris et al (2006). They examined the effect of the Opuha dam, commissioned in 1999, on the local Canterbury economy. The study was conducted over a two-year period (2002/03-2003/04) and used detailed revenue and expenditure data from a final sample of 32 irrigated farms and 20 dry-land properties. The authors estimated total revenue (for the two year period) was $2,073/ha for irrigated farms compared to $862/ha for dry-land farms.

Ford (2002) conducted an *ex post* study of the Lower Waitaki irrigation scheme, assessing a wide range of commercial, economic and social parameters. He compared the scheme with economic and social changes in the (otherwise

[8] A gross margin is the total revenue associated with a particular production minus costs, adjusted to take account of differences in overheads between land uses and also for wages and salaries.

similar) Rangitata area which does not have a community irrigation scheme. Farm output models of income, expenditure, and land use were created using data on typical farm budgets and from a comprehensive agricultural database (Agribase) for both irrigated and dry-land farms. Ford compared the two regions over a period of 20 years and found considerable differences in population, income and employment. The net change in annual cash farm surplus from switching from dry-land to having an irrigation scheme is $29 million per annum, representing a 14.1 percent return on capital at the farm gate. The Waitaki regions had a net population gain of 15.4 percent between 1981 and 2001, compared to a 0.6% loss in Rangitata.

3 Theory

We adopt an hedonic approach to valuing farms in relation to their fundamental characteristics [Palmquist (1989); Palmquist & Danielson (1989); Freeman (2003); Taylor (2003)]. Our approach incorporates a semi-log functional form, appropriate for minimising potential heteroskedasticity (Rosen, 1974).

Let Y_{ijt} be real net income[9] (including returns to capital) accruing to the owner of farm i ("the farmer") at time t when the farm is used to produce commodity j (j=1,…,n); for instance, j could represent arable output, sheepmeat, or dairy produce. Nominal net income is given by $P_{jt}*Y_{ijt}$ where P_{jt} is the market price for commodity j at time t. For any j we assume that real net income is determined both by land area, L_{ijt}, (subject to scale parameter, α) and by productivity per hectare, A_{ijt} (after adjusting for scale); thus:

$$P_{jt}*Y_{ijt} = P_{jt}*L_{ijt}^{\alpha}*A_{ijt} \quad (1)$$

Productivity is a function, in part, of land characteristics that cannot easily be changed; these include climate (rainfall), soil structure (drainage), and terrain (slope). It may also be a function of location (e.g. distance from towns) and of human modification, notably irrigation. Furthermore, there is likely to be an interaction between irrigation and the innate characteristics of the land. For

[9] This approach implies that the costs of bringing water to the point of use have already been deducted in forming the net income variable.

instance, we hypothesise that irrigation will be more important to farm productivity where a unit has low rainfall than in a situation where a unit already has plentiful rainwater. Similarly, irrigation may be more or less effective in units with different slope, drainage and location characteristics.

Denoting the vector of farm i's characteristics (which are assumed unchanged across all t) as Z_i and letting W_{it} be a measure for farm i's irrigation at time t, we assume that A_{ijt} is determined as in (2):

$$\ln A_{ijt} = k + f(Z_i) + g(W_{it}) + h(Z_i*W_{it}) + \varepsilon_{ijt} \qquad (2)$$

where f(.), g(.) and h(.) are functions to be specified, k is a constant and ε_{ijt} is a residual term that is uncorrelated with all other explanatory variables. Combining (1) and (2) yields:

$$P_{jt}*Y_{ijt} = P_{jt}*L_{ijt}^{\alpha}*\exp\{ k_i + f(Z_i) + g(W_{it}) + h(Z_i*W_{it}) + \varepsilon_{ijt} \} \qquad (3)$$

For each property i (given its existing characteristics), the farmer chooses an optimal land use, j*, in time t such that $P_{jt}*Y_{ijt}|_{j=j*} = \sup(P_{jt}*Y_{ijt}|_{j=1,\ldots,n})$ to give net income Π_{it}.[10]

The market value (MV_{it}) of farm i in year t is given by the present discounted value of net income from the property. If, in period t, net income is expected to grow at exponential rate φ_t and the discount rate is expected to be constant at rate r_t, MV_{it} will be given by the standard formula for an infinite series:

$$MV_{it} = \Pi_{it}*(1+r_t)/(r_t-\varphi_t) \qquad (4)$$

Combining (4) with (3), and taking logarithms, we obtain:

$$\ln MV_{it} = k + \alpha\ln L_i + f(Z_i) + g(W_{it}) + h(Z_i*W_{it}) + \{\ln P + \ln(1+r)/(r-\varphi)\}_t + \varepsilon_{it} \qquad (5)$$

In (5), the term in braces is not farm-specific so in a panel application it can be proxied by year fixed effects. In our empirical work, we employ linear functions for each of f(.), g(.) and h(.).[11]

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[10] Henceforth we drop the j subscript, assuming that all land is devoted to the optimal land use. Accordingly, we also drop the t subscript for land, since each farm has constant land area through the sample.

One issue that we have to deal with is the potential endogeneity of irrigation decisions; for example, irrigation may only be applied to land with certain characteristics. For example, less productive land may require greater irrigation; alternatively, farmers may choose to irrigate inherently more productive land. These possibilities make it particularly important that we control for the underlying characteristics of the farm in our estimation.[12]

We take a number of different approaches in controlling for farm characteristics. First, we account for the characteristics explicitly, controlling for each farm's average rainfall, slope, drainage and location, as well as its land area. Location is proxied in two different ways: (a) by the distance of the farm centroid to both the nearest town and nearest city; and (b) by use of 'meshblock' fixed effects, where a meshblock is a Statistics New Zealand small area definition; in rural areas, this normally comprises a collection of properties with a population of approximately 60 people. We are able to apply these controls consistently across both the sales price and valuation datasets. An even more comprehensive approach to controlling for farm characteristics uses farm fixed effects. We have close to a balanced sample for the valuation dataset and so can apply farm fixed effects in place of all terms in (5) that solely have an i subscript. This is a key reason that we use the valuation data in addition to the sales price data as a dependent variable. We cannot adopt the farm fixed effects approach for the sales price dataset since there are very few repeat sales over the relevant time period. By estimating (5) for both definitions of MV_{it}, we are able to test robustness of results across our two data sources, one explicitly market-based (sales price) and one comprehensive (valuation).

The theoretical specification leading to (5) implies that certain macroeconomic variables may impact on all farm prices and so be reflected in the year fixed effects. The value of irrigation that is impounded into the farm price should not vary over and above these macroeconomic impacts. For instance, temporary developments in general climatic conditions (e.g. recent drought

[11] In earlier work, we tested the impact of quadratic terms but found that the minor extra explanatory power did not compensate for the added complexity.
[12] As described subsequently, we control for farm characteristics using a number of approaches. We do not have additional variables over and above these farm characteristics variables that we can use as instruments; thus we do not adopt an instrumental variables or GMM estimator.

experience) should not impact materially on the present discounted value of irrigation. This is a testable hypothesis. We interact the irrigation variable with an annual climate variable to test whether farmers' valuations of irrigation are affected by short-term developments, possibly reflecting behaviourally-based considerations.[13]

The equations that we estimate are specified explicitly in section 5. Prior to doing so, section 4 discusses the nature of the variables and our data sources.

4 Data

4.1 Sale Price and Valuation data

We use unit record sales price, valuation and resource consent data for the Mackenzie District from 1988 to 2006. The sales price and valuation data are sourced from Quotable Value New Zealand (QVNZ) a state-owned enterprise. QVNZ collates all property sales data across New Zealand and also collates and undertakes valuation of properties for property tax (rating) purposes.

The valuation dataset contains the valuation date, capital value, land value (henceforth denoted VALUATION), improved value, land type,[14] and land area (henceforth denoted LAND) of all rural properties in the Mackenzie District, Canterbury, in the South Island of New Zealand. The dataset also contains a Land Information New Zealand (LINZ) identification number that allows us to map the property boundaries using GIS.[15] Valuations are conducted on a three-yearly cycle; we have seven waves from 1988 to 2006.

[13] Similarly, we have tested a specification in which the irrigation variable is interacted with a mortgage interest rate variable and with relevant commodity price indices to test whether irrigation is valued more highly when interest rates decline and/or when commodity prices rise. We find no evidence to support these alternative hypotheses. Nor do we find evidence that the type of water right (surface versus ground water, for instance) affects the value of the consent. For brevity, we omit the specifications testing these additional issues from the paper.

[14] However the land type data is substantially incomplete.

[15] In 2006 there were 1,252 currently active rural properties in the Mackenzie District. However 56 properties are without a LINZ number and therefore cannot be mapped or spatially merged with the resource consent data.

Significant cleaning of the data was undertaken.[16] One important situation is where a property is subdivided. In this case it is possible to aggregate properties that have been subdivided to form the previous property, thereby allowing us to form a continuous series for each (aggregated) property. Of the 1,169 properties in 2006, 645 are the result of subdivision. After aggregating these subdivisions we are left with 695 properties covering 1988-2006. Most of these properties have data for every valuation wave, but some properties have missing data, resulting in 3,951 usable observations. Thus we have a panel that is mostly, but not completely, balanced.

Due to incomplete land use data, we form two valuation samples for estimation. The first (larger sample with all 3,951 observations) is formed on the basis of land use in 1988 and includes all agricultural categories in addition to properties with a missing land use code in 1988. Table 1 presents a summary of the main variables in this sample. The second sample excludes all properties that had a missing land use code in 1988, reducing the sample to 2,702 observations.[17]

For market sales, we use QVNZ annual sales data for the Mackenzie District from 1988-2006. The dataset includes the sales date, sales price, and land type, of all rural properties sold in the Mackenzie District. Two main samples are formed based on land use.[18] The first sample includes all agricultural properties, plus properties coded as lifestyle properties, and properties with no land use code. The second sample excludes sales of lifestyle properties and those with a missing land use code.

The sales price of a property includes the value of improvements as well as the value of land (i.e. capital value equals improvement value plus land value). For each property, we have the QVNZ valuation of improvements at the most

[16] One reason for doing so is where there are multiple observations for the same property in the same year. This may occur when a change to the property occurs between regular valuations, for example because of major renovation work, and the property is revalued. The exact date of the revaluation is unknown; in these cases the first record (using the date stamp by which the data was exported by QVNZ) is kept. Any valuation changes are picked up in the next regular valuation.

[17] Both the valuation and consent data are aggregated to economic units, as this is the basis on which valuations are conducted. For example a farm may be divided into several parcels with different legal ownership, but may be operated as a single farm, thus 'property' refers to the economic unit not the legal land parcel as defined by LINZ.

[18] Land use data for the sales dataset is substantially complete in comparison to the valuation data; only 75 sales have no land use code out of 1,366 sales.

recent triennial valuation cycle. We interpolate the improvement value between any two valuation cycles by applying a constant growth rate to improvements during that three year period to obtain an estimate of improvement value annually for each property. We subtract the improvement value from the sales price to derive a sales price based land value (since land value is the variable that we require in order to assess the value attributed to the hedonic variables, including irrigation).[19] We denote the resulting variable: SALESPRICE.

Table 2 presents summary statistics for the larger sales price sample. The mean of each variable in the sales price dataset (Table 2) is within one standard deviation of the respective mean for the valuation dataset (using the standard deviations from the valuation dataset, which can be considered the 'universe' in this application). Thus there is no evidence here that the sales dataset suffers from material selection bias.

We also test for selection bias in the sales price dataset by estimating a probit equation explaining the probability of sale for any property (within the valuation dataset) in any year. We include only properties that have not been subdivided (or aggregated) during the period 1988-2006 to ensure a sample with consistent characteristics over time. Within this restricted set of properties, we again have two samples: the first includes lifestyle blocks and properties with missing land use codes, and the second excludes them. Results of the probit equations are reported in the Data Appendix. Consistent with the comparison of data means, the results indicate that the sales samples are representative of the universe of properties in the region. Crucially, there is no evidence that the presence of irrigation alters the propensity of a property to be sold.

Use of sales price as dependent variable has the positive feature that market prices are used in the hedonic valuation of irrigation. However the sales price samples are smaller than the valuation universe; the valuation data have the advantage of comprehensive coverage that also enables use of farm fixed effects.

[19] Of the 1,304 sales, we can only form the interpolated improvement values for 695 properties, since it is not always possible to match every sale with the appropriate improvements data when a sale of a subdivided property has occurred and where we have aggregated that subdivided property back to its pre-subdivision status. In addition we drop some sales (primarily lifestyle blocks) where the ratio of improvement value to sales price is greater than 0.9 (leaving virtually zero, or negative, implied land value). This leaves us with a sample of 678 sales (in the larger sales sample).

The key potential concern with using valuation data is that the usefulness of the data relies on the accuracy of the valuation process. Accuracy in valuing the present discounted value of net benefits derived from irrigation is of particular importance.[20] It is conceivable, for instance, that valuers may not be fully aware of the extent of a property's water consents and hence of its actual or potential irrigation characteristics.

In the Data Appendix, we test whether the valuation data are an unbiased predictor of sales prices for properties sold in the region within the sample period. In addition, we test whether any of the farm characteristics variables helps predict sales prices over and above the influence of the property valuation. We find that land area provides some extra predictive power, contrary to the unbiasedness hypothesis. In the largest sample, the irrigation variable (RATE) has a positive coefficient with a t-value of 1.339 (significant at 10% on a 1-tailed test), but it is not significant at conventional levels for the remaining samples. This evidence indicates that the property valuation data is a reasonable proxy for market value in many cases, but some care must be taken with the valuation-based results since the data are not completely accurate indicators of actual farm market value and may possibly understate the value of irrigation.

4.2 Resource consent data

The second source of data is the Canterbury regional council, Environment Canterbury, which provided details of all irrigation resource consents issued in the Mackenzie District. There are four types of irrigation consents, respectively for surface water, surface divert, ground water and consents for dams.[21] Surface water consents refer to situations where water is drawn directly from a river or lake, surface divert consents refers to situations where a watercourse has been altered. Ground water consents are required for extracting water from underground

[20] Valuations are legally required to reflect the estimated market value of the property; use is made of information from sales of like properties in the area. Thus valuers implicitly conduct an hedonic valuation of the property, but there is no explicit formula for the conduct of such valuations.
[21] All data were provided in the form of point data in ArcGIS shapefiles.

aquifers. Dam consents are for generally small private dams that have been built to store water.[22]

Available data include the start and end date of the consent, the maximum legal rate of water extraction in litres per second and cubic metres per day, the irrigated area and property area. For our empirical work we form three variables from these irrigation data: irrigated area/property area (IRRIG), maximum legal rate of water extraction in litres per second/property area (RATE) and maximum legal rate of water extraction in cubic metres per day/property area (VOL).[23, 24]

The spatial distribution of consents over the period 1988-2006 is shown in Figure 1. There is significant variation in the extent of the water right across different properties. On average, irrigated properties are allowed a maximum extraction rate of 100 litres per second (l/s), ranging from 0.4 l/s to 4,000 l/s (with a standard deviation of 101 l/s). Similarly the average maximum volume is 22,335 cubic metres per day, ranging from 65 m^3/day to 345,600 m^3/day (with a standard deviation of 22,561 m^3/day).

Tables 1 and 2 present information on the prevalence of consents across our large valuation and sales price datasets. In 1988, 2.7% of farms (19/695) in the valuation dataset had a water right; this proportion had increased to 9.1% by 2006. For the sales price sample, 13.6% of sales (97 properties) over the 1988-2006 period involved sale of a farm with a water right. Thus, while most properties do not have legal access to irrigated water, both datasets provide a material number of properties both with and without consents.

[22] We do not directly incorporate the dam consents in our work, but instead indirectly include their impact where water is drawn from the resulting reservoir by way of a surface consent.

[23] These data also required cleaning. Some consents were geocoded outside a property boundary so the consent cannot be linked with the valuation data. Generally these cases relate to consents that are for local council water supply or similar. Some consents lacked any date information rendering these consents unusable. The majority of these are consents for which after initial investigation, no consent was sought or the application was withdrawn. For a few consents without date information it was possible to get this information from the Environment Canterbury online consent search tool. For properties with more than one consent the water right variables are aggregated; irrigated area is summed, and the rate of extraction and volume is averaged (weighted by the irrigated area).

[24] Grimes and Aitken (2008), in an early version of this paper, report equations including IRRIG, RATE and VOL respectively. Each of the variables is consistently positive across all equations; however RATE had greater explanatory power than did either IRRIG or VOL, and we restrict our attention here solely to the RATE results.

4.3 Location, land characteristics and climate variables

GIS was used to compute the distance between the centroids of every property and four towns: Fairlie, Geraldine, Temuka, and Timaru. Two variables were created, one for the distance from each property centroid to the nearest town (DIST1) and another for the distance from each property centroid to Timaru, a port and rail city with a population of 27,000 in 2001 (DIST2). All distances are straight line distances measured in metres.

We use additional data, sourced from Landcare Research (Land Environments of New Zealand) that characterizes natural features of each farm unit, such as average rainfall (RAIN), average slope (SLOPE) and soil drainage (DRAIN).[25] Figure 2 shows the distribution of average rainfall (mm) across the Mackenzie District. Figure 3 shows the average slope (degrees) across the district for each property, and Figure 4 shows the average soil drainage measure across each property.[26]

New Zealand agricultural production is significantly affected by the presence or absence of drought influenced by El Niño and La Niña weather cycles (Buckle et al, 2002). The Southern Oscillation Index (SOI) provides a measure of these weather cycles.[27] We interact our irrigation variable with the current and one-year lagged SOI to test whether cyclical weather patterns affect the net present value that farmers attribute to irrigation.[28]

[25] The data is in raster form in GIS layers and is averaged and merged onto the property boundary layer.

[26] This ranges from very poor, where the soil has pale colours due to water-logging in the horizon immediately below the top layer; to good, where there is a lack of any significant mottling or pale colours. Moderately drained soil has some pale mottled colours due to water-logging at lower depths in the subsoil.

[27] The SOI is calculated from the pressure difference between Tahiti and Darwin. Anomalously low values of this index correspond to El Niño conditions (with tendency to drought in Canterbury), while anomalously high SOI values are called La Niña episodes. El Niño events occur about 3 to 7 years apart (source of text and data: National Institute of Weather and Atmospheric Research, NIWA).

[28] If there is any tendency to extrapolate cyclical weather patterns into perceived long-term trends, one would expect a negative coefficient on this interaction term as farmers raise their valuation of irrigation during drought times (low SOI).

5 Models, Estimation Methods and Results

5.1 Models and Estimation Methods

We estimate two variants of equation (5) for the sales price datasets and three variants for the valuation datasets; the variants differ by their treatment of controls for location and area fixed effects. For each sample, an initial equation is estimated incorporating explicit controls for farm-specific characteristics ($lnLAND_i$, $RAIN_i$, $SLOPE_i$, $DRAIN_i$, $DIST1_i$, $DIST2_i$)[29] but without any form of area fixed effects (time fixed effects, τ_t, are included in each equation). The irrigation variable ($RATE_{it}$) is included by itself and is interacted with each of the farm characteristics variables[30] in order to test whether irrigation is more valuable in some circumstances than others. RATE is also interacted with current and lagged climate (SOI_t) to test for possible short-term re-evaluations of the value of irrigation driven by climatic cycles. The residual term for the initial equation is shown as (7), i.e. with time fixed effects but no area fixed effects.

$$
\begin{aligned}
lnMV_{it} = {} & \beta_0 + \beta_1 RATE_{it} + \beta_2 RATE_{it}{*}SOI_t + \beta_3 RATE_{it}{*}SOI_{t-1} + \\
& \beta_4 RATE_{it}{*}RAIN_i + \beta_5 RATE_{it}{*}SLOPE_i + \beta_6 RATE_{it}{*}DRAIN_i + \\
& \beta_7 RATE_{it}{*}DIST1_i + \beta_8 RATE_{it}{*}DIST2_i + \beta_9 lnLAND_i + \beta_{10} RAIN_i + \\
& \beta_{11} SLOPE_i + \beta_{12} DRAIN_i + \beta_{13} DIST1_i + \beta_{14} DIST2_i + \varepsilon_{it} \qquad (6)
\end{aligned}
$$

$$\varepsilon_{it} = \tau_t + \varepsilon_{it}' \qquad (7)$$

A variant of this specification is estimated for all four samples in which meshblock fixed effects (λ_m) are included in place of the two distance variables. Thus, in this variant, ε_{it} is modelled as in (8), and $\beta_{13} = \beta_{14} = 0$ in (6).

$$\varepsilon_{it} = \tau_t + \lambda_m + \varepsilon_{it}'' \qquad (8)$$

Finally, for the valuation datasets, a variant is estimated in which farm fixed effects (λ_i) are included in place of all farm-specific variables. In this

[29] See Tables 1 and 2 for variable definitions. MV (market value) is proxied variously by VALUATION and by SALESPRICE.
[30] Other than lnLAND; RATE is already expressed as a ratio of land area.

variant, ε_{it} is modelled as in (9), and $\beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$ in (6).

$$\varepsilon_{it} = \tau_t + \lambda_i + \varepsilon_{it}''' \qquad (9)$$

These three variants include increasingly strict controls for farm characteristics, with stricter controls reducing the potential for the results to be driven by reverse causality, i.e. by irrigation being located in inherently more or less productive (valuable) areas.[31] In interpreting the results from (6) - for all of the error specifications - it is important to recognise, as we do in our discussion in section 5.4, that the overall coefficient on RATE varies by farm characteristics (as well as climatic conditions), being given by:

$$\beta_1+\beta_2SOI_t+\beta_3SOI_{t-1}+\beta_4RAIN_i+\beta_5SLOPE_i+\beta_6DRAIN_i+\beta_7DIST1_i+\beta_8DIST2_i \qquad (10)$$

Initial estimation was conducted using OLS. Breusch-Pagan and White tests and plots of residuals indicated the presence of heteroskedasticity, with a negative relationship between residuals and fitted vales of both the sales price and valuation variables. Accordingly we estimate all equations using GLS. In the (unbalanced) sales price samples, the GLS estimator accounts for heteroskedasticity; in the (mostly balanced) valuation samples, the GLS estimator accounts for both heteroskedasticity and AR(1) errors.[32] One feature of GLS (given the weighted estimation) is that there is no standard summary statistic for 'goodness of fit'. As an indication, we provide the R^2 statistic and root mean square error (RMSE) obtained from the corresponding OLS estimate of the same equation.

[31] The use of farm fixed effects (which can be adopted only for the valuation samples) is identical to a difference in differences specification at the farm level.
[32] Estimates of each equation using OLS, variously with robust standard errors and with clustered standard errors (where the clustering is on meshblocks) yields qualitatively similar results to those using GLS and so are not reported separately.

5.2 Sales price results

Table 3 presents the estimates for the first two variants of (6) using the two sales price samples (i.e. the ‘large’ sample that includes lifestyle properties and properties with no land use code, and the ‘small’ sample that excludes these properties). In both cases, sales cover the period 1988 - 2006.

All four sets of estimates provide strong support for a significant effect of irrigation on farm sales prices; they also indicate that the impact of irrigation is moderated by other factors. The raw (uninteracted) coefficient on RATE is positive and significant at the 1% level in each equation; the coefficient on RATE*DRAIN is negative and significantly different from zero at the 1% level in three equations and is significant at 5% in the fourth. Farms that are close to town (i.e. a low value for DIST1) benefit more from irrigation than do those more distant suggesting that proximity to processing facilities situated in town (e.g. dairy factory, packing house, coolstores, etc) or to an urban labour pool is beneficial for water-intensive (horticulture and dairy) land uses. The large sample equation lends support also to the intuitive expectation that flatter farms with low rainfall benefit more from irrigation than do hillier, high rainfall farms.

There is no support for the idea that irrigation is valued more or less highly depending on recent climatic experiences (i.e. the coefficients on current and lagged RATE*SOI are not significantly different from zero in the large sample, while the sum of the two coefficients is positive in the small sample, contrary to the extrapolation explanation). The raw farm characteristics variables indicate that farm value increases with size but with an elasticity of less than one, possibly reflecting the tendency for larger farms to be devoted to less intensive land uses such as sheep and beef (relative to horticulture and dairying). Hill country land (high slope and high rainfall) tends to be valued at lower rates than flat country land. Location near to the main port and rail-head (Timaru) is important with values declining as distance from Timaru increases.

Incorporation of meshblock fixed effects provides greater explanatory power than does use of the two distance variables. Perhaps surprisingly, root mean squared errors are smaller for the ‘large’ sample than for the ‘small’ sample, even though the former is at greater risk of contamination through possible incorporation of inappropriate properties. Our preferred equation for the sales data is therefore the 'large' sample equation incorporating meshblock fixed effects.

5.3 Valuation results

Table 4 presents the estimates for all three variants of (6) using the two valuation samples. Each panel estimate is conducted at three yearly intervals from 1988 – 2006 (i.e. seven waves), coinciding with the years in which the valuations are conducted. In both samples, the equation with farm fixed effects shows a stronger impact on farm values from the raw RATE variable than occurs in the equations without farm fixed effects. This is consistent with an hypothesis that farms that are more in need of irrigation (and hence with lower values in the absence of irrigation) are those that adopt irrigation. Controlling for local characteristics through farm fixed effects captures such factors more accurately than the other two methods (hence the lower RMSEs), contributing to the greater significance of RATE in this specification.

There is again strong support in the farm fixed effects equations for significant interactions of irrigation with both slope and drainage, and with proximity to town. The large sample farm fixed effects equation lends some support for the hypothesis that farms with high rainfall benefit less from irrigation than do inherently drier farms.

The meshblock fixed effects equation is consistent with the corresponding sales price equation, finding that farm value increases with land area (but again with an elasticity less than one); land with hill country characteristics (especially high slope) is valued less than other land. Consistent with sales price estimates, the equation without any area fixed effects indicates that farm values decline as distance from the main city and transport link increase.

The qualitative consistency in results between the two different data sources for market values is reassuring, given that they have been obtained in quite different manners (directly observed market prices versus officially assessed valuations). Conceptually we prefer the sales price data, but only valuation data permits use of farm fixed effects. Importantly, in both valuation samples, the results using this technique point to an increased value for the coefficient on

RATE than is obtained from the other two techniques. Accordingly, the valuation estimates imply that there is no reason to infer that the sales price results over-state the effect of irrigation due to insufficient farm-level controls.

5.4 Magnitudes of Irrigation Effects

The econometric estimates indicate that the right to extract irrigated water has a significant effect on farm values within the study area. We turn attention to the magnitudes of these effects for different types of farms. These effects reflect the *net* benefit of water rights to the farmer (i.e. to the farm's present discounted returns after subtracting costs associated with accessing the water, capital payments on irrigation infrastructure, etc).[33]

As indicated in Tables 1 and 2, the large majority of farms in the region do not have a legal right to extract either surface or ground water. For many farms, the net returns to investing in an irrigation project will be negative and hence there is no incentive to apply for a water right. Other farms may anticipate irrigation to be of net benefit, but have no water right owing to the first-come first-served allocation mechanism.

Table 5 illustrates how differing farm characteristics impact on the return to a water right, as reflected in the 'irrigation premium' pertaining to the farm's market value (MV). The irrigation premium is defined for a farm with characteristics Z and RATE=R expressed relative to a baseline case where RATE=0 for the same farm; i.e.:

$$\text{Irrigation Premium} = MV(R,Z) / MV(0,Z) - 1 \quad (11)$$

In calculating MV(R,Z), we use two estimates. First, we utilise the large sample valuation equation with farm fixed effects; this equation incorporates the strictest controls. Its drawback is that it uses valuation rather than sales price data, with the former potentially understating the irrigation premium. Second, we utilise the sales price equation with meshblock fixed effects. These estimates are based

[33] Gross returns to irrigation may be higher; however net return is the relevant economic measure since the value of resources used to extract the water must be taken into account. The ability of the hedonic method to capture the impact of irrigation on net (rather than gross) returns is one advantage of this methodology.

on observed market prices paid for farms but have meshblock fixed effects rather than farm fixed effects, so not being able to control as carefully for farm characteristics (and hence for potential reverse causality). For each equation, the overall coefficient on RATE is summarised in (10) for any vector of elements in Z. We examine five separate cases in which we vary these elements and vary RATE to demonstrate how the value attributed to a water right may vary in response to farm characteristics and the maximum allowable flow rate.

Our baseline case (first row of Table 5) sets R equal to the mean water right for properties that have RATE>0 (for each sample) and sets all elements of Z to their respective sample means. The valuation equation indicates virtually a zero irrigation premium in this case, while the sales price equation indicates a negative premium. The lack of a material positive premium when each farm characteristic is held at its mean is consistent with the observed fact that only a minority of farms have invested in irrigation schemes within the region.

The second case sets the value for soil drainage to one standard deviation below the mean for each sample (while holding all other variables at their mean). A positive premium is indicated for both samples. Positive premia are also indicated in cases where: the distance to the nearest town is reduced by one standard deviation, and where each of rainfall, slope and drainage are reduced by half a standard deviation. In the latter case, we illustrate the importance of the magnitude of the water right by initially calculating the premium for the mean water right, and then for a right with RATE at double its mean value.[34]

In each non-baseline case, the premium indicated by the sales price equation is between two and five times that indicated by the valuation equation. As noted above, the valuation equation may understate the premium if valuers are not fully aware of the positive net returns attached to the water right. Conversely, there is potential for the premia based on the sales price equation to be overstated in certain circumstances if farm characteristics are not adequately captured by the meshblock fixed effects. Thus the two columns present a plausible lower and upper bound for the irrigation premium in each case.

[34] The mean value of the water right in each case is approximately one third of its standard deviation, so many properties will have even higher values of the water right.

6 Conclusions

Water is a crucial input into agricultural production. In areas where the demand for (free) water exceeds the available supply, some form of allocation mechanism is required. This may be through a "first-come first-served" approach, but such an approach by itself is likely to be inefficient, with upstream users benefiting relative to those downstream. New Zealand's Resource Management Act (RMA) requires potential users (including farmers) to obtain a resource consent to draw both surface and ground water for agricultural and other purposes. However this system is, to a large extent, a "first-applied first-granted" system. Not only is there no formal price mechanism to allocate the water, the existence of such a mechanism is contrary to current law.

Water rights, under the RMA, are attached to enterprises; thus when a farm is sold, its water right is sold along with it. This feature, together with the scarcity of water in certain regions, means that not only does a positive shadow price for water exist but also it can be observed at the time of farm sale through the sale price. All properties are valued triennially by an independent body (for property tax purposes) and those values are required by law to reflect the current market value of the property. The capital valuations further split the value of each property into value of land and value of improvements. Thus we have two sources of data that we can use to extract the value of water rights after controlling for other features of each farm.

We ascertain the value of irrigation by estimating the price implicitly placed on water (through farm sale prices and valuations) in the Mackenzie District, a drought-prone region of Canterbury, New Zealand. Our hedonic approach contrasts with previous studies in New Zealand which have used other methods (especially the adjusted gross margin method) to determine the value of irrigation for certain areas.

Our approach also contrasts with prior hedonic studies internationally in several respects. First, unlike most previous studies, we have observations on all rural properties in the region – both with and without water rights, and (for the valuation database) those that are sold and not sold. This means we can avoid many of the selection issues and issues of low variation in the irrigation variable that have bedevilled earlier studies. Second, we have more comprehensive data than in most other studies, not only covering a wide range of properties, but also covering a nineteen year timespan. GIS techniques have enabled us to determine comprehensive farm-specific measures of land characteristics such as average slope, drainage and rainfall, as well as farm-specific measures of distance to towns and the nearest city which we use as controls in our equations. Third, we have exact measures of the water rights – and how those water rights change over time – for each farm over the nineteen years. The cross-sectional and time variation in water rights, coupled with controls for other farm characteristics (including meshblock and farm fixed effects) and for macroeconomic variables (through time fixed effects), allows us to identify the impacts of water rights on farm values.

Contrary to some prior hedonic studies that have worked with less adequate data, we find significant impacts of irrigation on farm prices. In addition, irrigation has different impacts on farms with different characteristics. We find that flatter areas and areas with poorly draining soils benefit most from irrigation, possibly because the water is retained for longer on those properties. Drier areas appear to benefit more from irrigation than do areas with higher rainfall.

Farms that are situated close to towns derive especially strong benefits from irrigation since these units are most likely to have potential water-intensive land uses such as dairying and cropping that require access to processing facilities and/or urban labour pools. In accordance with this result, farms with irrigation are, on average, located closer to town than farms with no irrigation (in the sales price dataset, mean distance to town for irrigated farms is 13.9km compared with 29.7km for unirrigated farms).[35]

Based on our estimated sales price equations, reasonable variations in the size of water right and of farm characteristics can give a positive irrigation premium of up to 50% relative to similar unirrigated properties. Estimated valuation-based premia are lower, at up to 15% for the same cases. The former estimates may overstate the irrigation premia owing to potentially incomplete

[35] Other farm characteristics do not differ materially between irrigated and unirrigated farms.

farm-based controls, while the premia may be understated by the latter estimates if valuers do not have sufficient information to account fully for the net benefits derived from irrigation.

Our results indicate that the net return to irrigation would be negative for many farms (after investment costs are taken into account). This finding is consistent with the fact that only about one-tenth of Mackenzie District farms have irrigation.

The positive net returns to irrigation found here for certain types of farm indicate that water, and an associated water right through a resource consent, is a valuable commodity in this drought-prone region. Perhaps even more importantly, we find that the shadow price placed on that water varies materially according to other characteristics. Farmers benefit more as their water right increases (i.e. as they have access to a greater water flow) and value the water right more highly in areas with certain characteristics that make them suitable for water-intensive land uses.

For most commodities, agents who value that commodity highly will be purchasers, and those with lower valuations (who have initial ownership of the commodity) will be sellers. However there is no explicit market for irrigated water in New Zealand owing to legal restrictions. Water rights are allocated free of charge to certain applicants but no sale of these rights is permitted. Thus the value of the water is restricted to its on-site benefit, and this benefit is reflected in the market values of farms in the district. Nevertheless, it remains the case that the full value of water is not being realised since returns differ significantly according to farm characteristics. Thus, while irrigation is of net benefit to farms in the region, our findings indicate that full value from irrigation is not being achieved owing to the current restrictions on water trading that are legally in force. Accordingly, reconsideration of the nature of the legal restriction that forbids trading of water appears warranted from an efficiency standpoint.

Data Appendix: Sales Price and Valuation Data Properties

Sales Propensity

We test the representativeness of the sales dataset relative to the (comprehensive) valuation dataset by estimating a probit regression in which the dependent variable is the probability of sale for any property in any year. The explanatory variables are the main variables that we choose for our structural estimates, i.e. log of land area (lnLAND), all three available irrigation variables (IRRIG, RATE, VOL), three land characteristics variables (RAIN, SLOPE, DRAIN), two distance variables, respectively to the nearest town and nearest city (DIST1, DIST2), plus year fixed effects and a constant. Our focus is on whether sales propensity is affected materially by these variables and, particularly, by any of the three irrigation variables.

We estimate the probit regression only on properties that have not undergone any subdivision (or aggregation) over the 19-year period (1988-2006) to ensure that we match sale properties to a suitable universe of titles. In doing so, we form two samples, respectively including and excluding lifestyle blocks. The two samples are used to test robustness of our estimates. If sales are drawn randomly from the universe of properties, the explanatory variables will have no statistical significance and the overall explanatory power of the equation (pseudo-R^2) will be low.

Table A1 presents the probit results based on the two samples. Properties are more likely to be sold if they are larger; although the effect is minor for the more complete sample (implying that the exclusion of lifestyle blocks in the 'small' sample is biasing the size result in that sample). In addition, location, slope and drainage characteristics affect sale propensity. In each case, consistent with the size estimate, the coefficients imply that properties will have a higher probability of sale if they are on high country land (high slope, poor drainage and distant from city and towns).

Importantly for our purposes, however, none of the irrigation variables is linked to sales propensity. This finding is consistent with the maintained hypothesis of the study that irrigation characteristics are fully impounded into the sale price of the property; thus the presence and nature of irrigation should not affect sale propensity over and above any other property characteristic. Another feature of the probit results is that the pseudo-R^2 for both samples is very low, and especially so for the larger sample (0.0274). Thus, the estimated higher probability of sale for "high country" properties has very little overall predictive power for sale propensity. This finding is in keeping with comparison of the data summary statistics in Tables 1 and 2 showing little difference in sample means between the valuation and sales samples. Given these results, we treat the sales samples as constituting random samples from the larger valuation universe.

Valuation Data Accuracy

We test whether the valuation data constitute an unbiased predictor of the market (sales) prices of farms. To do so, we regress the (log of) total sales price including improvements (SALTOT) on the (log of the) most recent capital value (CV) of the farm (where CV equals land value plus improvements value), together with our core explanatory variables (lnLAND, RATE, RAIN, SLOPE, DRAIN, DIST1, DIST2). Year fixed effects are included since valuations are undertaken only three-yearly whereas sales are observed continuously; thus an observed sale price may not equal the most recent valuation even where that valuation was "accurate" at the valuation date.

Our null hypothesis is that the coefficient on lnCV equals unity and coefficients on all remaining variables (other than the constant and time fixed effects) equal zero. It is particularly important for our purposes that the coefficient on the irrigation variable, RATE, is not significantly different from zero. If that were not the case, the implication would be that the valuation data do not adequately capture the market values placed on irrigation.

We estimate the equation (using OLS with robust standard errors) for both sales price samples used in the main body of the paper as well as the two sub-samples used for the probit equation (Sample 1 – Sample 4 respectively). Results are presented in Table A2. For each sample, the coefficient on lnCV is positive and significantly different from zero (as hypothesized) but is also significantly different from unity; in three of the four samples, the coefficient on lnLAND is significantly greater than zero. No other coefficient (except for some of the unreported time fixed effects and constant) is consistently significantly different from zero at the 5% level. These results indicate that sales price is a positive function of capital valuation but that valuations may under-state the value of large farms relative to small farms. Our estimates in the main body of the paper control for lnLAND, thus compensating for this potential source of mis-valuation.

For the purposes of this study, the coefficient on RATE is never significantly different from zero at the 5% level. In the large sample, it is positive and significant at the 10% level on a 1-tailed test, whereas in the other three samples, its t-statistic is in each case less than 0.4. Thus in three of the four samples we cannot reject the null hypothesis that the valuation data fully capture the market value attributable to irrigation. For the largest sample, however, there is some possibility that the valuation data may understate irrigation benefits.

Table A1: Probit regression results

Explanatory Variable:	Sample 1	Sample 2
lnLAND	0.0300	0.1347
	[3.217]***	[10.005]***
IRRIG	0.0285	0.0395
	[0.232]	[0.312]
RATE	-0.1088	-0.0737
	[0.900]	[0.645]
VOL	-1.1248	-1.0813
	[1.219]	[1.114]
RAIN	0.000016	-0.000004
	[0.106]	[0.022]
SLOPE	0.095	0.015
	[3.850]***	[0.510]
DRAIN	-0.014	-0.012
	[2.408]**	[1.806]*
DIST1	0.000002	-0.000006
	[0.798]	[2.689]***
DIST2	-0.000008	-0.000011
	[4.217]***	[5.146]***
Obs.	13205	13205
Pseudo-R^2	0.0274	0.0809

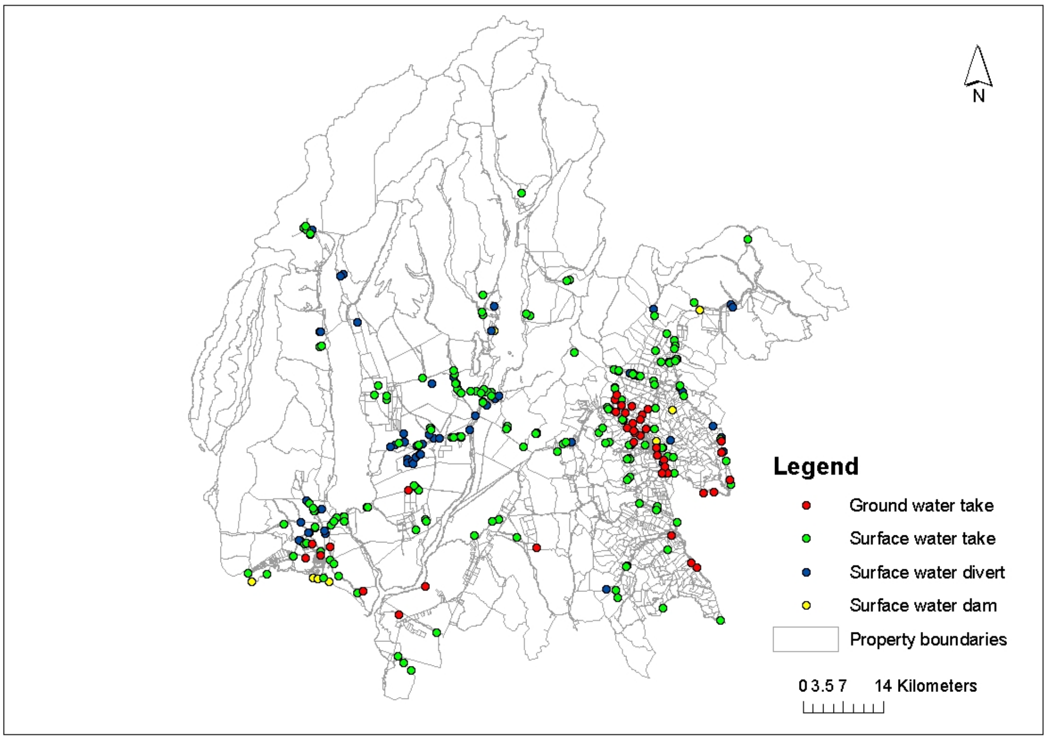
Notes:
Dependent Variable is $DSALE_{it}$ = 1 if property i is sold in year t; = 0 otherwise
Sample 1 includes lifestyle block sales.
Sample 2 excludes lifestyle block sales.
Robust z-statistics in brackets;
*significant at 10%, **significant at 5%, ***significant at 1%.
Time fixed effects and constant included (but not reported).

Table A2: Sales Price Regressed on Capital Valuation and Farm Characteristics

Explanatory Variable	Sales Sample			
	Sample 1	Sample 2	Sample 3	Sample 4
lnCV	0.505186	0.535142	0.536448	0.555233
	[7.642]***	[5.802]***	[4.637]***	[3.721]***
lnLAND	0.197477	0.147909	0.185802	0.134195
	[5.364]***	[2.328]**	[2.797]***	[1.136]
RATE	0.025922	0.007545	0.005607	-0.000912
	[1.339]	[0.368]	[0.272]	[0.041]
RAIN	-0.000461	-0.000523	-0.000597	-0.000678
	[1.662]*	[1.625]	[1.676]*	[1.821]*
SLOPE	0.007959	0.008162	-0.007249	-0.001811
	[0.835]	[0.633]	[0.546]	[0.106]
DRAIN	-0.015656	0.007451	-0.001427	0.000308
	[0.503]	[0.131]	[0.023]	[0.004]
DIST1	-0.000003	-0.000003	-0.000003	-0.000003
	[1.325]	[0.785]	[0.565]	[0.546]
DIST2	-0.000006	-0.000004	0.000004	0.000005
	[2.385]**	[1.122]	[1.088]	[1.210]
Obs.	665	413	312	273
R^2	0.7181	0.6897	0.7359	0.6878
RMSE	0.7123	0.7544	0.6833	0.721

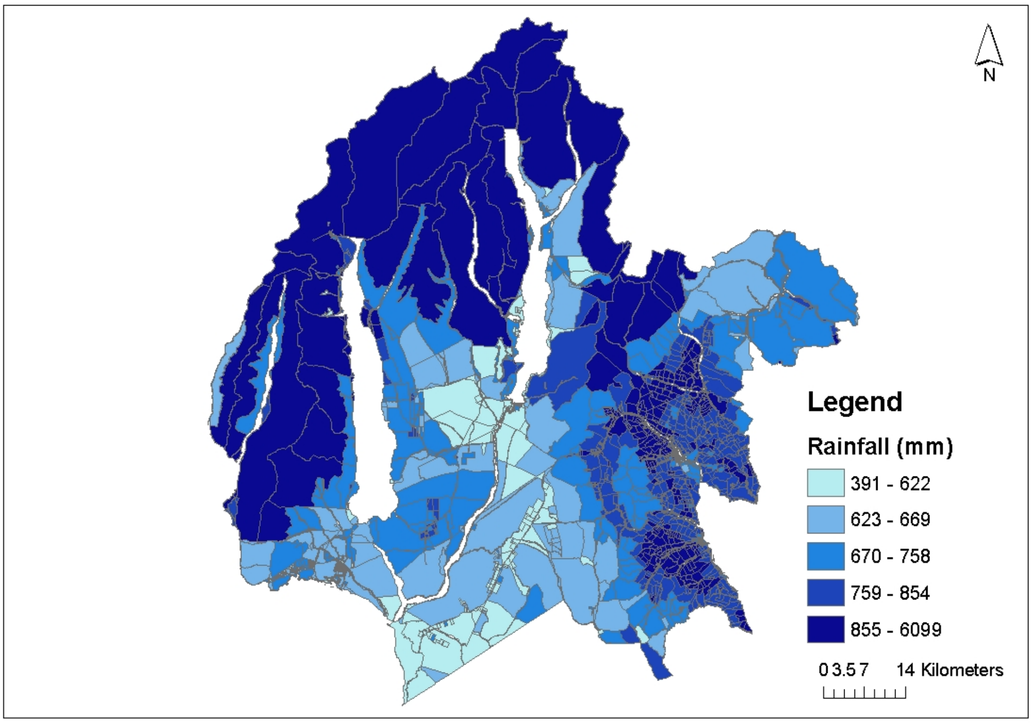
Notes:
Samples 1 and 2 correspond to the ‘large’ and ‘small’ sales price samples used in the main body of the paper. Samples 3 and 4 correspond to the two sub-samples used for the probit regressions reported in Table A1.

Figure 1: Location of irrigation consents in the Mackenzie District



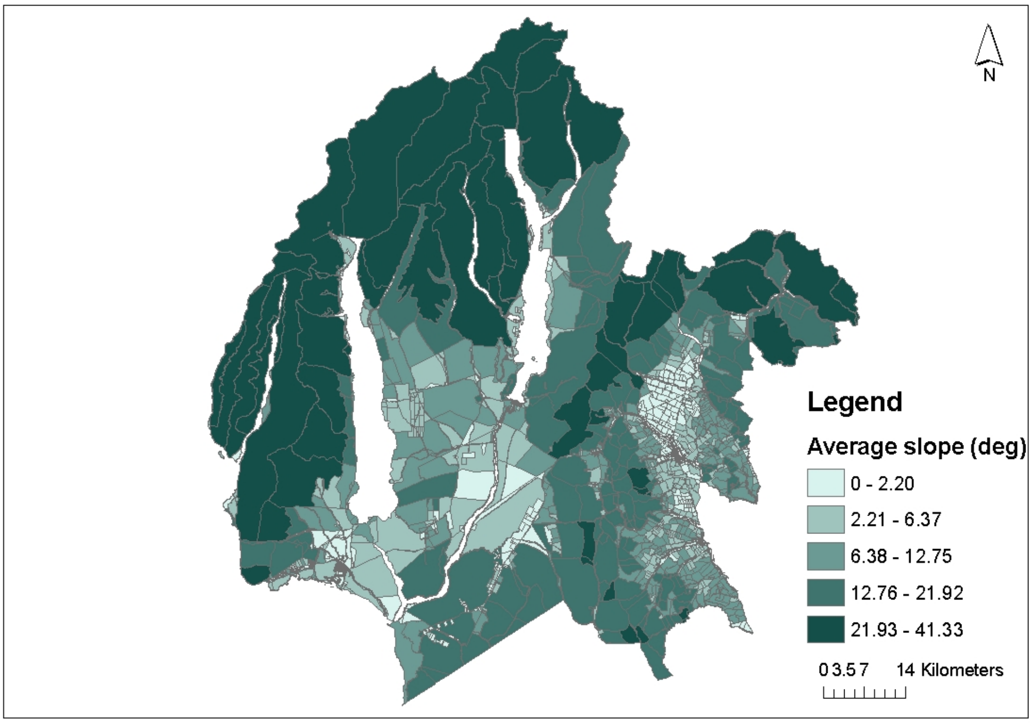
Source: Environment Canterbury

Figure 2: Distribution of average annual rainfall (mm) in Mackenzie District



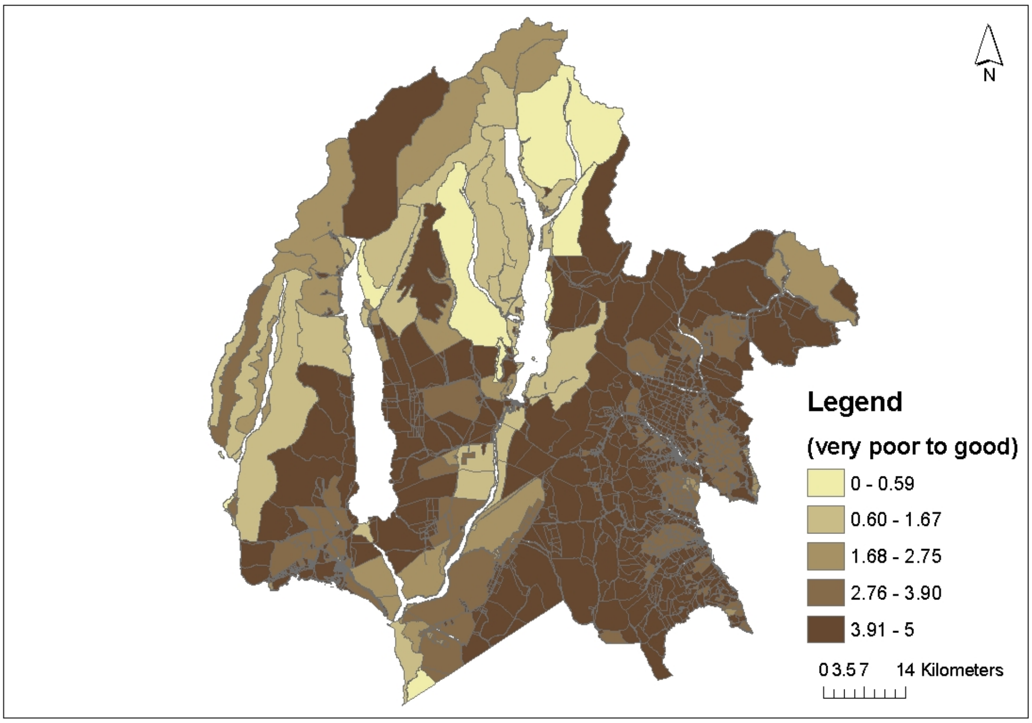
Source: Landcare Research (Land Environments of New Zealand)

Figure 3: Average slope of the land (degrees) in Mackenzie District



Source: Landcare Research (Land Environments of New Zealand)

Figure 4: Soil drainage quality in the Mackenzie District



Source: Landcare Research (Land Environments of New Zealand)

Table 1: Summary Statistics for all variables in main valuation sample

Variable	Mean	Std. Dev.	Variable description
lnVALUATION	11.55827	2.114182	Logged land value (NZ$)
1988	*10.75575*	*2.131853*	
2006	*12.68608*	*1.870366*	
lnLAND	3.59611	2.652807	Logged area of property (m^2)
RATE	.0362	.5570275	Maximum rate of irrigation water (l/s) over property area
VOL	.0059041	.0684627	Maximum volume of irrigation water (m^3/day) over property area
IRRIG	.0209966	.2384297	Irrigation area over property area
RAIN	805.1816	150.0832	Average rainfall of each property (mm p.a.)
SLOPE	4.407813	4.732518	Average slope of each property (degrees)
DRAIN	3.997944	.9158189	Average drainage score of each property
DIST1	22467.81	20443.09	Distance to nearest town (Fairlie, Geraldine, Temuka, or Timaru) (m)
DIST2	57826.53	21350.23	Distance to Timaru (m)
Memo Item: 19 of 695 properties had a water right in 1988 (start of sample), 15 of which retained the water right for the entire sample 63 of 695 properties had a water right in 2006 (end of sample)			

Table 2: Summary statistics for all variables in main sales sample

Variable	Mean	Std. Dev.	Variable description
lnSALEPRICE	11.88952	1.502068	Logged sale price less improved value (NZ$)
1988	*10.87289*	*1.122177*	
2006	*12.45656*	*1.293207*	
lnLAND	3.160063	2.544957	Logged area of property (m^2)
RATE	.0493385	.5484844	Maximum rate of irrigation water (l/s) over property area
VOL	.0141204	.0859315	Maximum volume of irrigation water (m^3/day) over property area
IRRIG	.0745375	.403664	Irrigation area over property area
RAIN	800.4022	137.957	Average rainfall of each property (mm p.a.)
SLOPE	3.830603	4.45555	Average slope of each property (degrees)
DRAIN	4.131274	.9102215	Average drainage score of each property
DIST1	26276.71	23786.24	Distance to nearest town (Fairlie, Geraldine, Temuka, or Timaru) (m)
DIST2	61678.58	23550.11	Distance to Timaru (m)
Memo Item: 97 out of 713 properties sold between 1988 and 2006 had a water right 616 out of 713 properties sold between 1988 and 2006 had no water right			

Table 3: Estimation Results for Sales Price Samples

	'Large' Sample		'Small' Sample	
	No FE	**MB FE**	**No FE**	**MB FE**
RATE	7.7027	7.4681	6.7262	8.0061
	[3.753]***	[2.603]***	[4.478]***	[3.737]***
RATE*SOI$_t$	-0.0048	-0.0219	-0.0689	-0.0027
	[0.121]	[0.358]	[2.130]**	[0.056]
RATE*SOI$_{t-1}$	0.0083	-0.0030	0.1501	0.0960
	[0.360]	[0.072]	[4.648]***	[1.960]**
RATE*RAIN	-0.0025	-0.0029	0.0049	0.0060
	[1.972]**	[1.684]*	[2.460]**	[2.002]**
RATE*SLOPE	-0.1151	-0.0784	-0.0230	0.0157
	[2.650]***	[1.122]	[0.730]	[0.262]
RATE*DRAIN	-1.3118	-1.1703	-1.0614	-1.2701
	[4.079]***	[2.315]**	[6.396]***	[3.160]***
RATE*DIST1	-0.000083	-0.000065	-0.000174	-0.000184
	[3.417]***	[1.822]*	[5.201]***	[3.376]***
RATE*DIST2	0.000031	0.000018	-0.000087	-0.000110
	[1.504]	[0.738]	[2.818]***	[2.859]***
lnLAND	0.4797	0.5117	0.4348	0.4921
	[103.690]***	[82.620]***	[61.113]***	[38.471]***
RAIN	-0.0001	-0.0003	-0.0001	-0.0003
	[1.580]	[2.865]***	[1.151]	[1.963]**
SLOPE	-0.0127	-0.0148	-0.0163	-0.0198
	[5.764]***	[3.600]***	[5.279]***	[4.147]***
DRAIN	0.0252	-0.0887	0.0335	0.0139
	[3.659]***	[7.606]***	[2.212]**	[0.617]
DIST1	0.000006		0.000003	
	[9.170]***		[1.757]*	
DIST2	-0.000007		-0.000005	
	[10.089]***		[3.897]***	
Observations	678	678	416	416
$R^{2\ (\wedge)}$	0.6087	0.7179	0.5087	0.6447
RMSE $^{(\wedge)}$	0.9279	0.8267	1.0302	0.9396

Notes:

Dependent variable is: ln(SALESPRICE).

All equations based on equation (6). Subscripts shown only where necessary for interpretation.

Year fixed effects (FE) included in each equation but not reported.

Column headed 'No FE' has no area fixed effects, corresponding to equation (7).

Column headed 'MB FE' includes meshblock fixed effects (not reported), corresponding to equation (8).

Absolute value of z statistics in brackets; ***significant at 1%; **significant at 5%; *significant at 10%.

$^{(\wedge)}$ R^2 and RMSE are indicative only, being those from corresponding OLS estimates of the specification.

Table 4: Estimation Results for Valuation Samples

	'Large' Sample			'Small' Sample		
	No FE	**MB FE**	**Farm FE**	**No FE**	**MB FE**	**Farm FE**
RATE	0.2874	0.0566	0.6747	0.4427	0.6246	0.8972
	[1.496]	[0.266]	[3.347]***	[1.156]	[1.409]	[2.683]***
RATE*SOI_t	0.0012	0.0032	0.0032	0.0003	-0.0001	-0.0008
	[0.388]	[0.807]	[0.951]	[0.080]	[0.029]	[0.256]
RATE*SOI_{t-1}	-0.0009	-0.0024	-0.0022	0.0002	0.0008	0.0011
	[0.404]	[0.809]	[0.854]	[0.083]	[0.316]	[0.422]
RATE*RAIN	-0.0004	-0.0005	-0.0002	0.0002	-0.0003	0.0001
	[2.241]**	[1.804]*	[1.625]	[0.287]	[0.397]	[0.292]
RATE*SLOPE	-0.0045	0.0102	-0.0283	-0.0231	-0.0282	-0.0439
	[0.848]	[1.831]*	[3.454]***	[1.575]	[1.702]*	[3.210]***
RATE*DRAIN	-0.0252	0.0666	-0.1258	-0.1258	-0.1225	-0.2348
	[4.236]***	[4.936]***	[2.564]**	[1.496]	[1.459]	[3.055]***
RATE*DIST1	-0.000009	-0.000001	-0.00002	-0.00003	-0.00002	-0.00003
	[3.042]***	[0.327]	[3.977]***	[2.434]**	[2.078]**	[3.478]***
RATE*DIST2	0.000006	0.000002	0.000009	0.000007	0.000012	0.000011
	[2.237]**	[0.413]	[2.992]***	[0.992]	[1.201]	[1.856]*
lnLAND	0.6961	0.8207		0.9284	0.9452	
	[93.517]***	[120.035]***		[146.582]***	[172.600]***	
RAIN	-0.0004	-0.0004		0.0002	0.0004	
	[4.761]***	[4.998]***		[2.108]**	[3.526]***	
SLOPE	-0.0663	-0.0710		-0.0672	-0.0672	
	[26.029]***	[31.213]***		[26.090]***	[23.817]***	
DRAIN	-0.0126	-0.1286		-0.0825	-0.1017	
	[0.924]	[9.575]***		[4.685]***	[5.323]***	
DIST1	0.000001			-0.000019		
	[1.045]			[13.272]***		
DIST2	-0.000002			-0.000013		
	[2.023]**			[13.968]***		
Observations	3951	3951	3951	2702	2702	2702
$R^{2\,(\wedge)}$	0.6725	0.7856	0.9738	0.8444	0.8906	0.9845
RMSE $^{(\wedge)}$	1.2128	0.9949	0.3775	0.9489	0.8044	0.3234

Notes:
Dependent variable is: ln(VALUATION).
All equations based on equation (6). Subscripts shown only where necessary for interpretation.
Year fixed effects (FE) included in each equation but not reported.
Column headed 'No FE' has no area fixed effects, corresponding to equation (7).
Column headed 'MB FE' includes meshblock fixed effects (not reported), corresponding to equation (8).
Column headed 'Farm FE' includes farm fixed effects (not reported), corresponding to equation (9).
Absolute value of z statistics in brackets; ***significant at 1%; **significant at 5%; *significant at 10%.
$^{(\wedge)}$ R^2 and RMSE are indicative only, being those from corresponding OLS estimates of the specification.

Table 5: Irrigation Premia for 5 Cases using Estimated Valuation and Sales Price Equations

CASE All variables at means except:	Irrigation Premium	
	Valuation Equation	Sales Price Equation
1) No exceptions (baseline)	0.39%	-21.59%
2) DRAIN less 1 std.dev.	5.66%	23.45%
3) DIST1 less 1 std.dev.	14.41%	53.27%
4) RAIN, SLOPE, DRAIN each less 0.5 std.dev.	7.23%	14.74%
5) As for 4) with RATE = 2 x mean	14.99%	31.66%

Notes:
Valuation equation uses 'large' sample with farm fixed effects (from Table 4).
Sales price equation uses 'large' sample with meshblock fixed effects (from Table 3).
Irrigation premium calculated using expressions (10) and (11).
Baseline calculation sets all variables to sample means.
Other cases vary one or more variables as described.

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