The Value of 'Free':

Estimating the Contribution of Free Water Inputs to Agriculture Industry Productivity

Paper presented at the New Zealand Association of Economists (NZAE) Conference,
at Wellington, New Zealand,
30 June 2011

Jodi York, PhD
Senior Statistical Analyst, Macroeconomic Statistics Development
Statistics New Zealand
P O Box 2922
Wellington, New Zealand
jodi.york@stats.govt.nz
www.stats.govt.nz

Citation
York, J (2011, June). *The value of 'free': estimating the contribution of free water inputs to agriculture industry productivity.* Paper presented at NZAE annual conference 2011, Wellington, New Zealand.

Abstract

The productivity model used by national statistical organisations assumes that the total product of a given input to production is equal to its total cost. This means that any free inputs, such as natural resources, are implicitly assumed to add nothing of measurable value to the production process. This paper uses the case of water, which is currently free to farmers, to examine the potential impact of free natural resources on industry productivity. It also considers methods for estimating their contribution. Analysis uses volumes derived from Ministry for Environment water allocation data for irrigation and stock 1999, 2006, and 2010.

JEL Codes: D24, Q32, O44

Keywords: natural resources, productivity, agriculture

Introduction

The productivity model used by national statistical organisations assumes that the total product of an input to production is equal to its total cost. This means that any unpriced inputs, such as natural resources, are implicitly assumed to add nothing of measurable value to the production process. This is a convenient fiction, but does not pass the pragmatic test of removing theoretically ‘valueless’ natural resource inputs like fresh water, minerals, or fish stocks from the industries that depend on them.

Natural resources consumed in the production process make an important contribution to the output (value added) of various industries. However, they are only counted as inputs into the production function in cases where they are paid for as part of a firm’s intermediate consumption (eg water to Auckland businesses). Free natural resources like fresh water are not counted as inputs into the production function for the purposes of productivity analysis.

Unspecified inputs are known to be a source of distortion in productivity, driving up multifactor productivity. For example, failing to estimate the capital services provided by farm land would lead to a distorted understanding of growth in the agriculture industry. This is of particular concern in industry-level productivity estimates, since the industry-specific impact of any missing inputs is not diluted in aggregation across various industries.

This paper uses the case of fresh water, which is currently free to farmers,[1] to examine the potential impact of free natural resources on industry productivity. It also considers methods for estimating their contribution. The purposes of this paper are (1) to identify and assess data sources available for estimating the volume and value of water used by the agriculture industry, (2) to approximate the impact on agriculture industry input volume and multifactor productivity of incorporating water use as an input, and (3) to challenge the validity of the ‘total cost = total value’ assumption in productivity analysis in the case of free but finite goods.

[1] The water itself is free, although there are costs associated with accessing it, including permits for taking water, pumping infrastructure, and electricity. These costs are currently accounted for in value added, the numerator of productivity calculation.

The current situation

The System of National Accounts (SNA) excludes water supply from gross fixed capital formation because water is not a produced asset.[2] To keep the measures closely aligned with the production measure of GDP, water and other natural resource inputs are excluded from current productivity estimates. However, productivity measures and the National Accounts answer related, but different, questions.

The fundamental question of the value-added measure of GDP is: how much value was added in the transformation of inputs to outputs in production function of a given industry? It is at its core output-focused – the net figure is generated by subtracting goods produced in other output functions. The aggregate of those functions provides a good net picture of everything produced in the economy. As a non-produced asset, fresh water supply is not particularly relevant to the question answered by the industry-based value-added measure of National Accounts. The core question of productivity is: what explains changes in the output of a production process in relation to its inputs? This is the relationship of all inputs of a production function to its output.

A necessary input to any agricultural activity is in situ fresh water supply of a sufficient level for the particular activity. Needs vary by activity; dairying and wet crops such as rice require large volumes, while sheep farming and dry crops such as winter wheat require smaller volumes. This in situ fresh water supply properly constitutes a capital input into agricultural production, much as dairy sheds and tractors do. However, because water and other natural inputs are not separately purchased inputs, they tend to be taken as given environmental variables.

The problem with this is two-fold. First, these environmental variables are variable, and both the volume and value of their input changes over time. New Zealand is blessed with an abundance of fresh water, but it is not limitless. Competition for consumptive and non-consumptive water use has become a prominent issue in recent years, especially in Canterbury where water allocations have increased by 25 million cubic metres (Mm3) per week (11 percent) between 2006 and 2010 (Aqualinc, 2011). In a market setting, when demand for an input increases strongly with no change in the underlying supply, one expects its price to increase. This price increase flows in turn into the relative weight of that asset in the calculation of capital service. With no market price, changes in the asset’s scarcity, economic value, or contribution to the production process over time are not reflected in calculation of inputs or productivity.

Secondly, the contribution of unmeasured natural capital – or any other unspecified input – to an industry’s productivity is reported as multifactor productivity (MFP). MFP is that portion of productivity that is not attributable to growth in labour or capital inputs. Statistics New Zealand calculates MFP by dividing the index of output volume (value added) by an index of total inputs[3]. Because it is calculated as a residual, the quality of a multifactor productivity estimate depends greatly on the quality of measurement.

With perfect measurement, agriculture MFP reflects things like improved technology and management practices, such as herd management, crop rotation, and tillage techniques. These drivers of growth are monitored by policy makers in efforts to optimise the economic performance of this key industry. In practice, agriculture MFP also picks up a variety of other factors:

[2] Statistics New Zealand produces a number of environmental accounts under the integrated System of Environmental and Economic Accounting (SEEA) framework, which dovetails with the System of National Accounts. These measure the physical and monetary stocks and flows of natural resources, including forestry, energy, fisheries, minerals, and fresh water. At this time they do not align with industry production statistics.

[3] This yields MFP change between the two periods in question, not the *level* of MFP.

- ‘resource rents’, or revenue surpluses above the cost of production (allowing for a normal rate of return on capital) generated by free natural resource inputs to agriculture
- capital or intermediate input quality changes that have not been accounted for elsewhere, such as improved seed varieties, fertilisers, or breeds
- environmental changes that have an impact on agricultural production, like drought, flooding, and soil quality
- any mis-specification or measurement error.

The impact of these environmental factors on agriculture MFP is likely to be non-trivial: Kokic, Davidson, and Boero Rodriguez (2006) identified moisture availability as the dominant factor affecting productivity in the Australian grains industry 1988–2004, swamping the impact of improved management practices. Clearly, the analytical value of MFP estimates can be improved by controlling for or minimising the scope of these factors wherever possible. Any attempt to control for such factors must begin with identifying them.

Data needs and availability

Natural resource inputs can be incorporated into productivity analysis in one of two ways. Actual water consumed can be assigned a price and treated as intermediate consumption in the manner of electricity and gas. Volume of these inputs can be measured directly or derived by dividing expenditure by price. In the case of fresh water use in agriculture, none of those measures (volume consumed, price, or expenditure) exist. Additionally, modelling water use as intermediate consumption to be subtracted from industry value added (the productivity numerator) creates an undesirable divergence between official industry value added and productivity. This would reduce the coherence of the suite of economic statistics and reduce the value of productivity as a tool for decomposing economic growth (ie growth in industry value added from the National Accounts).

Alternatively, a flow of capital services from the available stock of fresh water can be calculated in a similar way to the services supplied by the availability of inventories, which make possible the sale of goods and services simply by sitting on the shelf[4]. This requires a measure of the available volume, rather than the actual volume used, which may be more suited to the existing water data. Either method requires proxying or modelling prices, as well as accurate volume estimates. Under normal market scenarios, price can be derived using volume and expenditure; with a free good, expenditure is zero, so a ‘price’ must be independently derived. The ‘price’ selected is an essential part of calculating the flow of services, as well as helping determine the relative weight of the natural resource input vis-à-vis other inputs in the system.

New Zealand’s fresh water is managed under the Resource Management Act 1991. To protect the environment, water users generally have to apply for resource consents to take fresh water from its source. There are around 20,000 consented water takes in New Zealand. About three-quarters are for irrigation – most of the other consents are for community water supplies and industry. About one-third of all consented takes (and about one-third of the total volume allocated by consent) is currently measured.[5]

---

[4] Capital assets are those that are not used up (ie 100 percent depreciated within the period) in the production process. Inventories that do not meet this definition are treated as a form of capital in Statistics New Zealand’s productivity estimates.

[5] Measuring and reporting water takes: An introduction to the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010**.**

Unfortunately for those seeking data, most water abstractions in New Zealand are not currently measured. Estimates from 2006 suggest only a third of the total volume of water allocated by resource consent is subject to active measurement. The newly introduced Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 is intended to increase this figure to 92 percent by 10 November 2012, and 98 percent by 10 November 2016.[6]

The data situation is further confounded by the fact that not all agricultural use of water requires resource consent. Section 14(3)(b) of the Resource Management Act (RMA) 1991 allows fresh water to be taken or used for an individual’s reasonable domestic needs, or for the reasonable needs of an individual’s animals for drinking water,[7] provided it does not have an adverse effect on the environment. This provision for stock drinking water does not take into account the other water take activity directly associated with dairy farming, such as dairy shed washdown and milk cooling, which have been estimated at about 40 litre/cow/day (Environment Waikato, 2007). With increased land use intensification, the cumulative amount of water taken for animals may be significant relative to other uses (Environment Waikato, 2007), adding 5 percent or more to total allocated volume (Landcare Research, private communication). With these shortcomings in mind, the next section considers the available data on freshwater use in agriculture.

Ministry for the Environment water allocation data

As part of its National Environmental Reporting Programme, the Ministry for the Environment (MfE) reports on a core set of 22 environmental indicators, plus supporting information, across 10 domains including fresh water. One environmental pressure indicator focuses on fresh water quantity: the volume of water allocated (via resource consent) to consumptive uses. This is a proxy for actual abstraction, which is not measured. This data is collected by individual regional authorities, on bases that are not entirely consistent. To date there have been three reports on the topic published by MfE, detailed in the paragraphs below.

The 1999 report *Information on Water Allocation in New Zealand 1999* showed that 77 percent of the weekly consumptive allocations were for irrigation. The consented irrigation area was 600,000 hectares, of which 400,000 and 84,000 hectares were in Canterbury and Otago, respectively. Irrigated area had increased by approximately 55 percent per decade for the past 30 years (LE, 2000).

The next report on the topic was *Snapshot – water allocation in New Zealand 2006*, prepared by Aqualinc Inc. This report found that consented irrigation takes had increased to 78 percent of all consumptive allocations. The total consented area had grown to 970,000 hectares, with Canterbury and Otago continuing to make up 66 percent and 14 percent respectively.

The most recent iteration of this data collection is a report prepared by Aqualinc Inc entitled, *Update of water allocation data and estimate of actual water use of consented takes 2009–10*. The 2010 data shows 75 percent of allocations used for irrigation, and stock water making up another 6 percent[8]. Total consented irrigated area was over 1 million hectares in 2010. This report breaks down consumptive use allocations into drinking, industrial, stock, and irrigation (by nine crop types).

There are known limitations to the use of allocation data. Consented irrigation includes fields that may be fallow in a given year, water may be authorised for multiple crops, or properties may have consents for both take and groundwater use where one is a

---

[6] ibid

[7] Note that only individual supplies are exempt; multi-user domestic or stockwater reticulated supplies require allocations.

[8] As acknowledged elsewhere, the vast majority of stock water takes have no consent, as they are permitted activity and/or reasonable use.

'backup' option. For this reason, actual irrigated area in any particular season is likely to be significantly lower than the maximum consented volume.

Statistics New Zealand's agricultural production survey

Statistics New Zealand's current programme of agricultural production statistics started in 2002. A census was held in 2002 and 2007, with sample surveys in 2003–06 and 2008–10. The agricultural production survey covers land use, animal farming (livestock), arable crop growing, forestry, and farming practices in New Zealand (including fertiliser and cultivation). As the name suggests, the survey is primarily concerned with accurately measuring agricultural production for National Accounts and the Ministry of Agriculture and Forestry. This takes the form of livestock numbers, areas of arable crops harvested (the principal crops with tonnes harvested also), areas of fruit trees and vines grown, and vegetables harvested.

The 2007 survey included a comprehensive question concerning the use of irrigation equipment by farmers and horticulturists, what area of their farm they could irrigate using their existing resource consents and equipment (by type of equipment), and what the main activity was on the area actually irrigated by them during the year. While this does not address actual water use or provide a time series, it provides a useful crosscheck on the relationship between irrigation consented area and practically irrigable area. The 2010 consented irrigated area (from the consent applications) is 77 percent higher than the 2007 practically irrigable area reported to Statistics New Zealand, reflecting planning for future development in consent applications, as well as actual growth 2007–2010 (Aqualinc 2010).

Lincoln University Farm Technical Manual

The Lincoln University Farm Technical Manual (2003) is considered by many to be the definitive, must-have guide to farming in New Zealand. This publication provides guidelines for crop irrigation and peak water requirements for domestic and livestock purposes. Additionally, Lincoln University maintains a dairy farm to develop and demonstrate best practice in dairy farm systems. This farm is managed by the South Island Dairying Development Centre (SIDDC), which publishes water use and a variety of other dairy farm data on an ongoing basis (see SIDDC 2010).

Environment Waikato surface water use model

The Waikato Regional Council has developed a model for predicting the peak summer permitted and s14(3)(b) surface water use[9] in order to more effectively manage water allocation and establish whether there are, or are likely to be adverse effects on the environment. The model's accuracy was tested against measured water use data from seven rural water supply schemes in the region, and water use for dairy farming was found to have the most influence on model predictions. The resulting report (Environment Waikato 2007) details the water quantity required not just for stock drinking, but for udder wash, milk cooling, plant wash, yard wash, feed pad wash and leakage from reticulated water systems.

Future sources emerging from virtual water and water footprinting research

Virtual water – the total amount of water required to deliver a product or supply a service – has been identified as a major emerging scientific issue. Virtual water figures are based on a bottom-up lifecycle analysis approach to measuring the water embodied in a product, and is typically measured as litres of water per kilogram of final product or dollar of production (Royal Society of New Zealand, 2009). New Zealand is one of the top three exporters of virtual water per capita in the form of exported agricultural products (ibid).

[9] The fresh water allowance for an individual's reasonable domestic needs or animals' drinking water.

Massey University, Landcare Research, and crown research institute Plant and Food Research are measuring closely related 'water footprints' – the total amount of water used in the production process. It has three components – green water, which is moisture stored in the soil used to grow a plant or animal; blue water, which is water added by irrigation; and grey water, which is the water that would be necessary to dilute to acceptable levels the pollutants produced in the life cycle of the product (Massey University, 2011). To date research has focused on key agricultural export products, such as the analysis recently completed for the NZ kiwifruit industry by Landcare Research (Landcare Research, private communication). While this is a broader understanding of water use than the others under consideration, virtual water research may become an important source of accurate water use data in the future.

Prices

Selecting a proxy price for a free good is bound to be contentious. Within economic statistics, the most available and least methodologically controversial options are the good's production cost (a choice that assumes zero profit, and is used in measuring non-market output), or an existing market price from within the country. These options parallel the treatment of other capital and intermediate inputs.

On a natural (non-produced) asset, there are no production costs to observe. Local authority charges for reticulated water represent the cost of supply (ie reticulation and pumping), rather than the cost of producing or depleting the asset. For example, Auckland users (including residential) are charged $1.30 per cubic metre for water supply (Watercare, 2011), or $1.3 x109 per million cubic metres (Mm3).

There are also limited water markets in fully allocated areas on the Canterbury plains (where water is therefore scarce). These are sold in units of irrigated area, expressed in hectares. On the basis of farm and water supply share sales and recent water trades through Hydrotrader, Irrigation New Zealand suggests an average 2010 price of $4,600/ha emerging from a range of just under $3000 to just over $6000 (private communication).[10]

When combined with 2010 Canterbury irrigation consent area by crop (in hectares) and allocation by crop type (in million cubic metres), this allows for calculation of Canterbury-specific weighted average allocation volume per hectare, yielding a price of $12.7 million per million cubic metres. In addition to pricing different things, the Auckland and Canterbury prices diverge by orders of magnitude, which will have a massive impact on the outcomes.

In the context of fresh water, both the cost of production and any existing market prices address the cost of delivering the water to the tap, rather than offsetting the depletion of a valuable natural resource.[11] This brings to the fore the importance of aligning the price concept with the volume concept. Is the price intended to represent the actual water consumed (or converted from freshwater to greywater) in the process of agricultural production, which is conceptually aligned with intermediate consumption? Or is the price intended to represent the availability of water, which is aligned with treating the water supply as an inventory?

Further ideas on formulating a price representing resource depletion can be gleaned from Australian investigations into natural resource inputs to mining. Topp et al (2008) suggest

[10] This one-off cost pays for the allocation for the duration of the water permit, and reflects in part the increasing difficulty of gaining a water permit directly from the regional council (ie increasing water scarcity). Where water is not yet fully allocated, permits are available from the council at a fraction of this cost. The farmer still pays for reticulation, pumping etc.

[11] Landcare Research (private communication) has suggested that a closer estimate of the capital value of a freshwater supply might be derived from a study of the difference in value of land with and without water permits.

that the ‘resource rent’, or revenue surpluses above the cost of production (allowing for a normal rate of return on capital) generated by free natural resource inputs is the implicit price for the missing elements in the production process. Experimental work underway at the Australian Bureau of Statistics to estimate natural resource input volume is built around the idea of ‘Hotelling rent’. Hotelling (1931) argued that if a natural resource is efficiently exploited, the net price at any given time should equal the discount rate to maximise the net present value of the resource. Put more simply, it should be more profitable to extract it than to leave it in the ground and wait for the price to increase. As more of a resource is exploited, extraction becomes increasingly expensive for product of decreasing quality, often at greater environmental impact (eg oil sands).

The price derived from resource rents reflects the increased scarcity of the non renewable resource. Unfortunately, the applicability of this model to the finite but renewable stock of fresh water is limited. Modelling volume and value of natural resource inputs to mining in this way requires estimates of cumulative extraction and remaining resource stock, which are not applicable to renewable resources.

It is also theoretically possible to model an extended production function whereby one extra cubic metre of irrigation water results in a fixed amount of extra pasture growth, a fixed amount of resulting extra metabolic energy for a cow, and a fixed amount of resulting extra milk solids of known price. Working backwards from that price it is possible to calculate a marginal value of fresh water for dairying, and from there a net present value for water stocks and a value for the loss of natural capital represented by that water consumption.

This would be a valuable exercise, but the data needs are non-trivial and developing a model for reliably apportioning the marginal value of irrigation requires expertise in areas beyond economic statistics. Additionally, this method deviates from the principles of price measurement by defining price in one period by price of a different good in a future period. This implies that the water input has a different price for different agricultural uses (eg dairying and kiwifruit), which should only be true if the product or service is substantively different[12]. Moreover, while market prices are certainly influenced by expectation of future values, information is always imperfect; fresh water contributes value to horticulture even if the entire crop is hit with blight, and to the dairy industry even if the bottom falls out of the market. The realisation of that value is distinct from the one-period production function used for official productivity estimates.

Suitability of data for productivity measurement

In light of the existing data, this paper treats water supply as capital, like land or inventory, whose presence facilitates production whether or not it is consumed in the production process. The data needs for productivity analysis[13] in that scenario are: (1) a time series of water volume attributable to agriculture, (2) a price time series, and (3) a means of weighting the asset relative to other inputs, usually by price.

Information on natural resources is not generally collected with industrial classification in mind, so attribution to industry frequently presents a challenge. The closest fit between natural resource and economic data is often through matching particular uses to particular industries. Fortunately, many agricultural uses of water are distinct and specific to the agriculture industry. In descending order of preference, water volume used by agriculture could be modelled by:

1. water volume used in the agriculture industry

[12] It could reasonably be argued that there is value distinction in water supply based on maximum flow at particular times.

[13] Like the official productivity estimates produced by Statistics New Zealand, this paper focuses on calculating productivity growth rates rather than productivity levels. The requirements for calculating productivity levels would differ somewhat.

2. water actually abstracted from the system by livestock and irrigation (the primary agricultural uses)
3. water allocation for irrigation and livestock
4. rough estimates of water used per head of livestock and per hectare of cultivated land, for the purposes of modelling water used in agriculture.

Among the data sources detailed in the previous section, there are no perfect matches for the preferred options. Aqualinc (2010) and Statistic New Zealand (2008) provide single point estimates of actual use (stock and irrigation) and maximum possible use (irrigation only), respectively. Aqualinc (2010) offers three years of allocated water volume for all uses, three years of consented irrigated area, and a 2010 breakdown of stock and irrigation as a proportion of total allocation. The Agricultural Production Survey offers an extended time series of livestock and cultivation, which can be used alongside the Lincoln University farm manual to model water use.

Methodology

Water volume data for this paper was constructed in three different ways. The first allocation series is based on total allocation volumes (in Mm3) by region for 1999, 2006 and 2010. The 2010 percentage allocations to irrigation and stock (an average of 46 percent and 2 percent of total allocations, respectively) were applied to the 1999 and 2006 data to derive regional irrigation and stock allocations. These were then summed together to represent total allocation for agriculture. The questionable underlying assumption of this series is that the proportion of water allocated for irrigation and stock use was the same in 1999 and 2006 as it was in 2010. It is likely that this series overestimates past water use.

Table 1

Annual water allocation to agriculture series one (1)
By region

Region	Irrigation 1999	Irrigation 2006	Irrigation 2010	Stock 1999	Stock 2006	Stock 2010	Total 1999	Total 2006	Total 2010
	Cubic metres (million)								
Auckland	57.9	61.5	66.4	1.50	1.59	1.72	59.4	63.1	68.1
Bay of Plenty	140.7	343.9	294.4	0.14	0.34	0.29	140.8	344.2	294.7
Canterbury	6,977.2	10,366.5	11,511.7	424.29	630.40	700.03	7,401.5	10,996.9	12,211.7
Gisborne	34.1	63.9	68.1	0.00	0.00	0.00	34.1	63.9	68.1
Hawke's Bay	429.6	577.0	652.9	4.24	5.70	6.45	433.9	582.7	659.3
Horizons	107.4	218.2	329.0	3.06	6.22	9.39	110.4	224.4	338.4
Marlborough	245.7	579.9	732.2	0.00	0.00	0.00	245.7	579.9	732.2
Nelson	…	0.5	0.5	…	0.01	0.01	…	0.5	0.5
Northland	166.5	111.0	156.1	1.25	0.83	1.17	167.7	111.8	157.2
Otago	2,023.5	2,944.3	3,259.8	2.83	4.12	4.57	2,026.3	2,948.4	3,264.4
Southland	128.9	130.2	130.2	16.11	16.27	16.27	145.0	146.4	146.4
Taranaki	30.7	38.0	55.5	0.55	0.68	0.99	31.2	38.7	56.5
Tasman	186.8	273.3	259.6	0.02	0.03	0.03	186.8	273.3	259.7
Waikato	*78.7*	196.7	*200.5*	*2.26*	*5.64*	*5.75*	*80.9*	*202.3*	*206.2*
Wellington	151.9	332.0	337.2	24.24	52.99	53.81	176.1	385.0	391.0
West Coast	…	48.8	57.3	…	0.00	0.00	…	48.8	57.3
Total	10,759.4	16,285.6	18,111.3	480.49	724.83	800.48	11,239.9	17,010.4	18,911.8
Annualised percentage change		7.34%	2.80%		7.26%	7.33%		2.61%	2.79%

1. Calculated using proportions of total weekly water allocation for consumptive use (Aqualinc 2010, table 3-3) and comparison of weekly allocations by region in 1999, 2006, and 2010 (Aqualinc 2010, table 3-5).

Symbol:
... not available

Source: Aqualinc

For the second allocation series, irrigation allocation volumes are derived from consented irrigated areas (in hectares) by region for 1999, 2006, and 2010. The 2010 irrigation allocation volumes (in Mm3) by region and crop type were used to calculate allocated Mm3/ha by crop type and region. This was applied to the 1999 and 2006 allocated area data at the regional level to derive irrigation allocation volumes slightly lower than the first series, with slightly higher growth rates. Stock allocation was calculated as in the first series, and the two were summed to represent total allocation for agriculture. The questionable underlying assumption of this series is that the distribution of irrigated crops was the same in 1999 and 2006 as it was in 2010.

Table 2

Annual water allocation to agriculture series two

By region

Region	Irrigation (1)			Stock (2)			Total		
	1999	2006	2010	1999	2006	2010	1999	2006	2010
				Cubic metres (million)					
Auckland	71.1	53.6	65.2	1.50	1.59	1.72	72.6	55.2	66.9
Bay of Plenty	158.7	240.6	578.0	0.14	0.34	0.29	158.9	240.9	578.3
Canterbury	6,130.4	9,853.2	10,421.2	424.29	630.40	700.03	6,554.7	10,483.6	11,121.3
Gisborne	97.4	56.7	51.0	0.00	0.00	0.00	97.4	56.7	51.0
Haw ke's Bay	347.5	548.0	705.1	4.24	5.70	6.45	351.8	553.7	711.5
Horizons	104.0	157.3	310.3	3.06	6.22	9.39	107.0	163.6	319.6
Marlborough	120.6	845.9	1,057.6	0.00	0.00	0.00	120.6	845.9	1,057.6
Nelson	…	1.7	0.6	0.00	0.01	0.01	0.0	1.7	0.6
Northland	225.5	107.2	202.9	1.25	0.83	1.17	226.8	108.1	204.1
Otago	1,300.5	1,875.1	2,578.8	2.83	4.12	4.57	1,303.3	1,879.2	2,583.3
Southland	57.2	107.8	140.3	16.11	16.27	16.27	73.3	124.1	156.6
Taranaki	29.4	40.7	44.9	0.55	0.68	0.99	29.9	41.4	45.9
Tasman	220.3	321.4	326.8	0.02	0.03	0.03	220.3	321.4	326.8
Waikato	*87.5*	194.0	*273.9*	*2.26*	*5.64*	*5.75*	*89.8*	*199.6*	*279.7*
Wellington	275.6	516.3	494.3	24.24	52.99	53.81	299.9	569.3	548.1
West Coast	…	178.9	757.0	0.00	0.00	0.00	0.0	178.9	757.0
Total	9,225.6	15,098.4	18,008.0	480.49	724.83	800.48	9,706.1	15,823.3	18,808.4
Annualised percentage change		9.09%	4.82%		7.26%	2.61%		9.00%	4.72%

1. Calculated using consented irrigated areas (ha) by region in 1999, 2006, and 2010 (Aqualinc 2010, table 4-3) and consented irrigation w eekly allocation by crop type 2010 (Aqualinc 2010, table C-13).

2. Calculated using proportions of total w eekly w ater allocation for consumptive use (Aqualinc 2010, table 3-3) and comparison of w eekly allocations by region in 1999, 2006, and 2010 (Aqualinc 2010, table 3-5).

Symbol:
... not available

Source: Aqualinc

A third series was calculated that attempts to model actual water use for comparison purposes. This takes the first irrigation allocation series, and multiplies each data point by the actual use as a percentage of consented volume gathered from a sample of water meters (Aqualinc, 2010), which averages 65 percent of consented volume. This relies on the same assumptions of fixed proportion of allocation to irrigation in series one, as well as an assumption of fixed relationship between allocation and actual use across both time and use type. As such, it should be considered indicative rather than robust.

Stock water need for the third volume series was calculated using Statistics New Zealand livestock numbers from the agricultural production survey, multiplied by the required water by animal type. The volume used per dairy cow includes significant uses beyond drinking water associated with dairying, such as dairy shed washdown (Horizons, 2007; Fleming, 2003). This was summed together with the irrigation series above to model total actual use for agriculture.

Table 3.1

Modelled actual water used for irrigation
By region

Region	Percentage of allocation used (2)	Irrigation (1)		
		1999	2006	2010
	Cubic metres (million)			
Auckland	69%	71	54	65
Bay of Plenty	50%	159	241	578
Canterbury	57%	6,130	9,853	10,421
Gisborne	192%	97	57	51
Hawke's Bay	43%	348	548	705
Horizons	30%	104	157	310
Marlborough	42%	121	846	1,058
Nelson	26%	…	2	1
Northland	45%	226	107	203
Otago	43%	1,301	1,875	2,579
Southland	74%	57	108	140
Taranaki	47%	29	41	45
Tasman	45%	220	321	327
Waikato	*49%*	*88*	194	*274*
Wellington	45%	276	516	494
West Coast	48%	…	179	757
Total	65%	9,226	15,098	18,008
Annualised percentage change			9.09%	4.82%

1. Consented volumes for irrigation by region, as calculated in allocation series 1.
2. Estimated Actual annual use as percentage of 2010 consented volume (Aqualinc 2010, table 5-3).

Symbol:
... not available

Source: Aqualinc

Table 3.2

Modelled actual water used for stock needs
By animal type

Animal type (1)	litres per day (2)	Stock w ater (1)		
		1999	2006	2010
		Cubic metres (million)		
Sheep count		45,679,900	40,081,600	32,515,400
Annual Mm3	3	50	44	36
Lamb count		34,853,600	33,809,900	28,151,800
Annual Mm3	2	25	25	21
Dairy cattle count		4,316,400	5,169,600	5,958,200
Annual Mm3 need (	107	169	202	233
Beef cattle		4,643,700	4,439,100	3,949,300
Annual Mm3 need	45	76	73	65
Deer count (3)		1,676,800	1,586,900	1,123,600
Annual Mm3 need	6	4	3	2
Pig count		368,900	355,500	333,800
Annual Mm3 need	11	1	1	1
Total		9,226	348	358
Annualised percentage change			9.09%	4.82%

1. Animal counts from Statistics New Zealand 2007(a).
2. Water needs from Fleming 2003, unless otherw ise noted.
3. Horizons Regional Council 2007.

Source: Statistics New Zealand, Aqualinc

Table 3.3

Modelled actual water used in agriculture
By region

	Irrigation (1)			Stock (2)			Total		
	1999	2006	2010	1999	2006	2010	1999	2006	2010
	Cubic metres (million)								
Total	9,226	15,098	18,008	9,226	348	358	6,044.1	8,973.8	9,918.8
Annualised percentage change		9.09%	4.82%		9.09%	4.82%		6.92%	2.63%

1. From table 3.1
2. From table 3.2

Source: Statistics New Zealand, Fleming 2003, Aqualinc

In the absence of past price observations, the Auckland and Canterbury 2010 water prices were inflated to 1996 dollar value using the 'farm inputs excluding livestock' series of the farm expenses price index (FEPI). The index was re-expressed with 1996 as the base year, so that water is consistent with the other capital data.

The Canterbury price comes from the most contested rural water market in the country, which suggests that it could be inflated. For the sake of comparison, a third price series has been added, which is exactly half the Canterbury price. This might be a more reasonable expectation for other parts of the country where there is less competition for consumptive water use.

Table 4

Water prices per million cubic metres 1999–2010

1999–2010

	1999	2006	2010
Constant 1996 dollars (000)			
Canterbury price series in 1996 dollars (000s)	$ 12,579	$ 15,504	$ 17,344
Auckland price series in 1996 dollars (000s)	$ 1,289,873	$ 1,589,873	$ 1,778,481
Half Canterbury price series in 1996 dollars (000s)	$ 6,289	$ 7,752	$ 8,672
Farm expenses price index (1)	992	1223	1368

1. All farm inputs excluding livestock (rebased to 1996=1000)

Source: Statistics New Zealand, Irrigation New Zealand, Watercare Services

These three prices were combined with the three different volume series to form nine potential estimates of the productive capital stock (PKS) of water available for use in agriculture. Each 11-year series has only three independent data points (1999, 2006, 2010), with the other years populated by means of linear interpolation. The nine resulting water productive capital stock (PKS)[14] series were introduced individually into Statistics New Zealand's productivity calculation system starting in 1997.

The flow of capital services into production is assumed to be proportional to the underlying capital stock of a given asset. Put more plainly, capital items which are expensive, extensive, or both are assumed to provide more capital services than those which are not. In accordance with this principle, year-on-year PKS movements were weighted together with other PKS movements by means of their relative user cost of capital to form a total inputs index for the agriculture index.

Statistics New Zealand calculates user cost of capital using the formula below:

$$u_{ijt} = p_{ijt}\,(i + d_{ijt}) + p_{ijt}\,x_{it}$$

Where p_{ijt} = the price index of new capital asset *j* in industry *i*, period *t*

i = the real rate of return (set at 4 percent)

d_{ijt} = the rate of economic depreciation of asset *j* in industry *i*, period *t* (water, like land, is assumed to have zero depreciation)

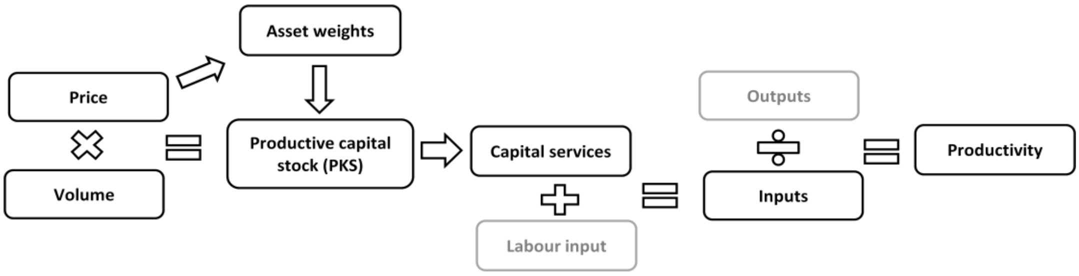
x_{it} = the average non-income tax rate on production for industry *i*, period *t*.

Discussion of results

[14] Volume multiplied by price in current and constant 1997 dollars.

This section examines the impact of water’s introduction into productivity calculation. The schematic below shows the path by which an individual asset influences estimates of industry productivity. The effect is strongest at the lowest levels, on the left hand side, and is increasingly diluted in the calculation process. Initially, a given asset impacts the capital services index by means of one or more of three characteristics: volume, price, and asset weight. Capital services, along with labour input (hours paid) make up an industry’s total inputs. The combined inputs index is the denominator of the productivity equation, with the index of constant price industry value added making up the numerator.

A simple model of productivity calculation



Volume and price

The three different volume calculations yield series that are broadly similar in shape, growing 7–9 percent per annum 1999–2006 and 2–5 percent per annum 2007–2010. The series that approximates actual use is about half the level of either allocated series, with comparable growth rates. Although derived stock water needs in this series are radically lower than the consented allocations for stock purposes, this has limited impact on the volume as the vast majority of agricultural water allocation is for irrigation. The shape of the price series, extrapolated as they are from single data points, is that the farm expense price index (FEPI all farms inputs excluding livestock) used to deflate the current price data. As a result, differential price movement will not affect the capital input series except in so far as it sets the magnitude of the PKS (volume multiplied by price), and therefore asset weight.

Productive capital stock (PKS)

The highest PKS estimate is from the highest volume at highest price,[15] the area-based allocation estimates at Canterbury prices. The lowest PKS estimate is from the lowest price/volume combination, the modelled actual volumes at half-Canterbury prices. These form the upper and lower bounds between which the actual PKS is likely to fall, and hence the scenarios of greatest interest for the remainder of the paper. The modelled actual volume at Canterbury prices and primary allocation series at half-Canterbury prices are of equal value, and in the middle of the array.

Asset weights

The asset weight determines how significant the impact of water will be relative to the year-on-year movements of other capital assets used in agriculture. Land has historically been the asset that drives the capital input series for the agriculture industry, with average relative weight 0.35 (out of 1.0) from 1978 to 2009. It has been as low as 0.22, in 1989, but has trended strongly upward with value increases since 1999. In 2009 its weight was 0.59. The next most significant asset from 1978 to 2009 was land improvements (fencing etc), with an average weight of 0.17. Since proportional weights by definition must sum to one, the relative weights of land improvements and all other assets declined from 1999, as land took on more prominence in the inputs profile because of its increasing value.

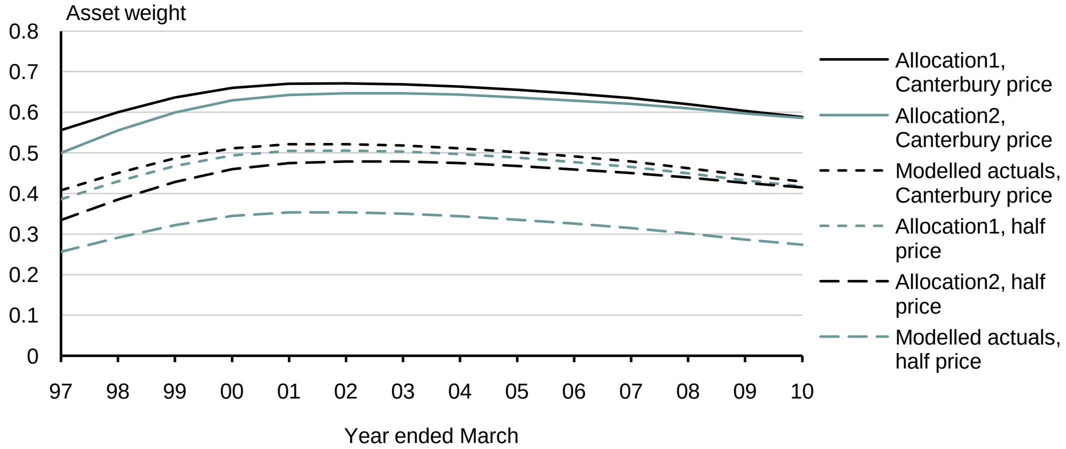
---

[15] Excluding the Auckland price, which is removed for calculation reasons explained below.

Asset weights provide a good litmus test for the plausibility of different scenarios. When the Auckland price of $1.30/m3 is used, the productive capital stock of water outstrips that of land by orders of magnitude. This is true regardless of the volume series with which it is combined, including the modelled 'actual' series which should most closely match the Auckland pricing concept (ie actual water used, rather than water availability). In effect, this is to suggest that no other assets are providing any capital services in the industry. In spite of the fact that this is a real market price, this is not a credible outcome, and does not merit further analysis.

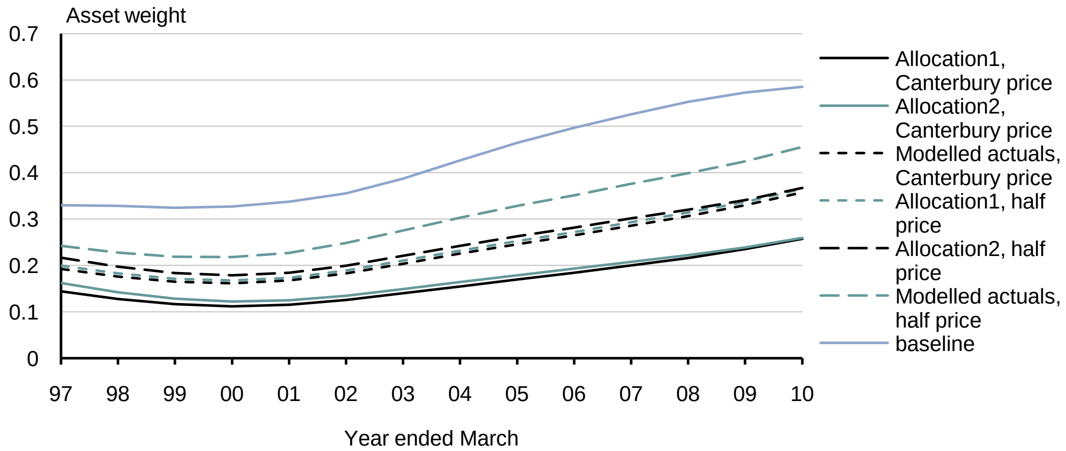
Introducing the new water asset at the Canterbury or the half-Canterbury price yields water asset weights ranging from 0.24 to 0.58, making water the most significant asset for the entire series in most scenarios. Only in the final scenario – modelled actual volumes at half-Canterbury prices – does land take on a greater weight than water, and even then it only does so from 2004. In this scenario the relative asset weights of land and water in 2009 (the latest year for which industry productivity data is available) are 0.46 and 0.26 respectively.

Asset weight for water under different scenarios
1997–2010



Source: Statistics New Zealand

Asset weight for land under different scenarios
1997–2010



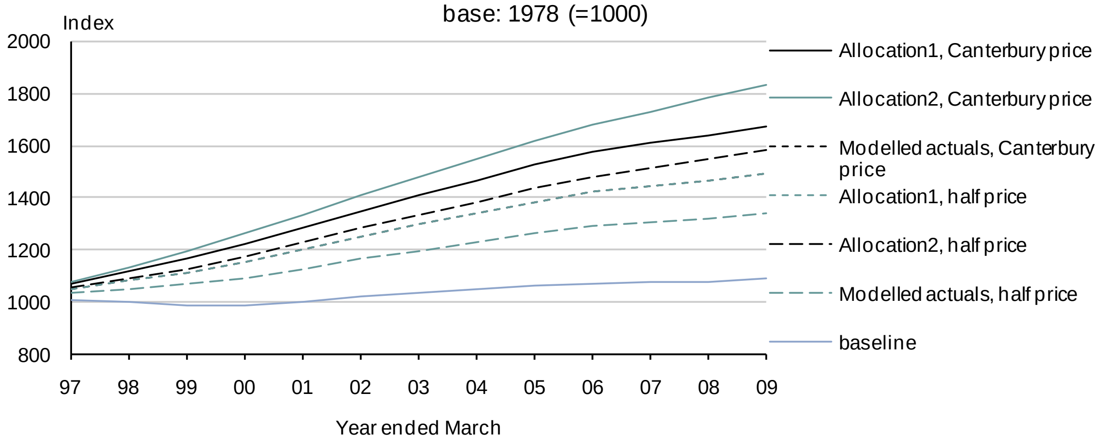
Source: Statistics New Zealand

The asset weights determine how much influence the relatively strong growth in the productive capital stock of water has on the calculation of capital services for the industry. A high growth rate with a very small asset weight has little influence, while a slow growth rate with a large asset weight has a significant impact on the series. Whether that impact is positive or negative depends on the growth rates and weights for other assets in the industry. The unweighted mean productive capital stock annual growth rate for agriculture is 4.6 percent for 1999–2006, and 3.5 percent for 2007–2010, which is slower than water’s 7–9 percent per annum for 1999–2006 and within the range of water’s 2–5 percent per annum for 2007–2010.

Capital services index

The index of capital services in the agriculture industry was relatively flat from 1997 to 2009, rising a mere 72 index points over the period. The inclusion of water drives up that growth by an amount ranging from 330 to 782 index points. The lowest growth estimate is from the modelled actual volumes at half-Canterbury prices, while the highest are from the area-based allocation estimates at Canterbury prices. Water’s impact on indexes of capital services and total inputs (the productivity denominator) under various assumptions is presented below. The solid blue baseline represents the variable prior to water’s inclusion.

Capital services to agriculture
1997–2009
base: 1978 (=1000)

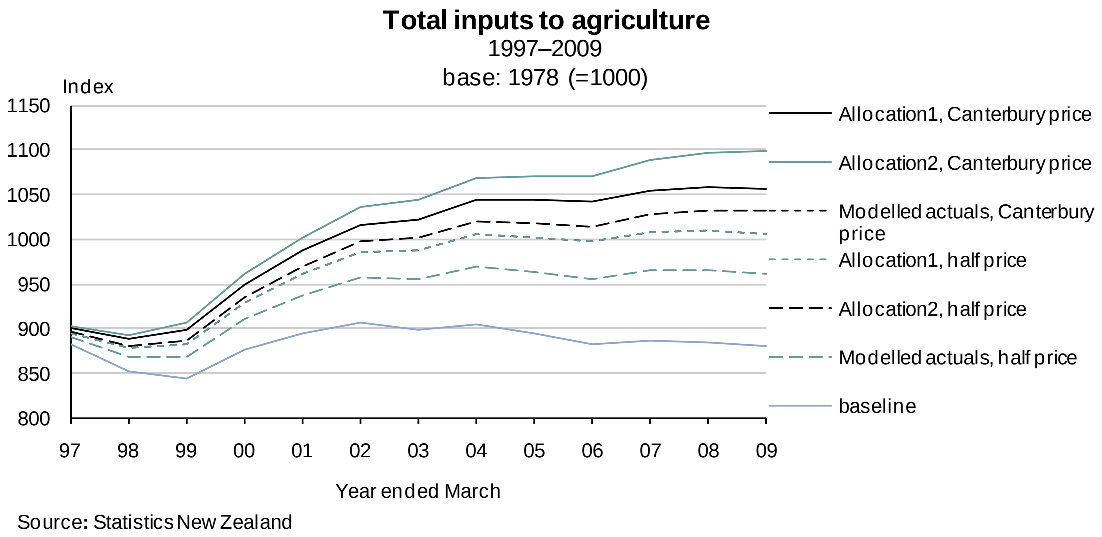


Source: Statistics New Zealand

Total inputs index

Capital services are combined with labour volume to create total input volume for the industry. The two factors of production are weighted together using their modelled share of total industry income (see Statistics New Zealand, 2011). The income shares have favoured labour slightly for much of the period, with capital input providing an average of 44 percent of industry income.

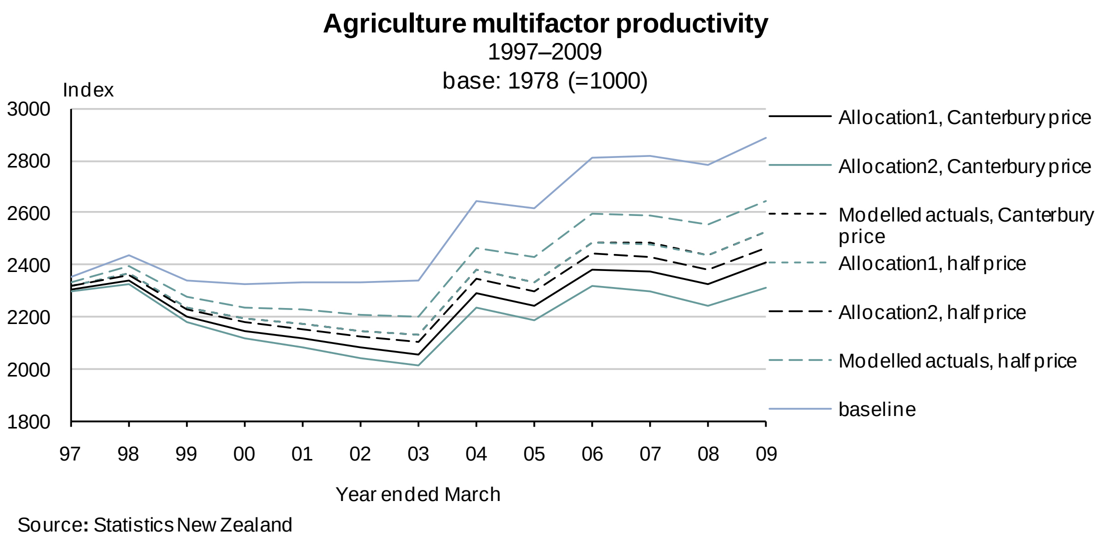
The impact of water’s inclusion on total inputs in the agriculture industry under various assumptions is shown below. The shape of the graph, clearly visible in the baseline series (shown by the solid blue line), reflects the volatility of labour input for the industry. This volatility is moderated by the relative smoothness of the capital services index. The degree to which the series fan out from their origin with differing slopes is a product of the asset weights, which dictate the relative impact that the higher growth water input series have on the industry. The largest underlying PKS yields the steepest slope, while the smallest PKS affects the level of input series significantly while changing the annual growth rate by an average of 0.7 percentage points.



Multifactor productivity

Having traced the path of the new asset through its calculation path to total inputs, we can now turn to measures of productivity. Agriculture has had higher than average MFP growth throughout the long-term published series that starts in 1978, averaging 3.5 percent annual growth over those 31 years. For the 1997–2009 period covered in this paper, annual MFP growth has averaged 1.9 percent, in spite of a flat stretch from 1997 to 2003 (shown by the solid blue line below). It was New Zealand's third strongest industry in terms of MFP growth during that period.

With the inclusion of water, the industry's 1997–2009 annualised MFP growth drops from 1.9 percent to somewhere from 0.4 percent to 1.1 percent, depending on the assumptions made.



Conclusions

This paper started with the principle that the value of free inputs exceeds the cost, and their exclusion from productivity calculation may be distorting the productivity estimates for certain industries. The contributions to production made by free inputs are reflected in industry value added (the numerator of the calculation) but excluded from the denominator of total inputs, resulting in artificially inflated multifactor productivity (MFP). In this experiment with freshwater in agriculture, failure to include water has been shown to potentially understate the growth rate of agricultural capital inputs by 1.55 to 3.45 percentage points per year. This in turn leads to an understatement of total input growth by 0.69 to 1.84 percentage points per year and potential overstatement of industry multifactor productivity growth by 0.78 to 1.86 percentage points per year.

What are the implications of this understatement? The reduction in MFP would flatten industry MFP growth over the period 1997–2009 from the currently published average of 1.9 percent annually to somewhere between zero and 1.1 percent annual growth. This changes agriculture from the New Zealand economy’s third-highest performing industry in MFP terms to a lower than average performer. Should water availability or quality decrease in the future, the current system will show that as a decrease in multifactor productivity. In either case, changes in the relative availability of an input outside of the current productivity model[16] are masquerading as changes in multifactor productivity, giving potentially misleading signals about the drivers of economic growth in the industry.

The price and volume series were extrapolated from very few data points, a process that depends on one or more assumptions that merit further exploration:

- unmeasured water abstractions for agriculture display the same volume patterns over time as measured abstractions
- the distribution of irrigated crops was the same in 1999 and 2006 as it was in 2010, and the lines between those data points is straight
- within regions, the relationship between allocation and actual use is fixed across both time and use type
- the value of water outside of Canterbury is not less than half of the price at which it is traded in Canterbury
- the value of water changes at the same rate as other farm expenses.

For these reasons, the estimates of water’s volume and value produced in this paper should not be considered robust, and should not be used as a basis for policy decisions. What has been presented in this paper is a range of estimates designed to approximate the upper bound of the productive capital stock of water available for use in agriculture, and a lower bound of its actual use. The best answer is expected to lie between these bounds.

This raises a question about implications of the ‘total cost = total product’ assumption in the case of free but excludable goods that are used in or facilitate production. If water input is affecting agriculture MFP in such a significant way, what other free inputs should be examined? Currently, other natural resources are only included as intermediate consumption (and therefore subtracted from value added) only when they have gone through an initial transformation process. As an example, underlying mineral deposits are not measured and recorded as an input to mineral exploration. Fish stocks are valued when fishing rights are bought and sold, but not when they are used by the original holder of the right.

[16] This is not unique to Statistics New Zealand, whose official productivity estimates are consistent with international best practice guidelines. To date, no counties are including free natural resource inputs in their productivity estimates.

There may be examples outside of the primary sector, such as the value produced by firms replacing expensive enterprise software with free open source software; removing software input from the calculation of the firm’s productivity because it is no longer costly may lead to underestimating the contribution of capital to its production. Should the practice become widespread in otherwise labour-intensive industries, it could ‘artificially’ give the impression that the industry is undergoing capital shallowing.

There are solid reasons for these choices. Measuring the volume and value of these assets is very challenging, as this paper has demonstrated. The estimates seem unlikely to ever be sufficiently robust to merit inclusion in official estimates of productivity. However, their potential influence on that calculation could be estimated, as this paper has done for water in agriculture. The key question must be asked: if the product is included in value added, is it balanced on the inputs side of the calculation? If not, can estimates be put around the potential impact on MFP?

Acknowledgements

This interdisciplinary paper would not have been possible without the generous and thoughtful assistance of Dr. Jez Weston of the Royal Society of New Zealand, Andrew Fenemor of Landcare Research, and Andrew Curtis of Irrigation New Zealand. Any errors are the sole responsibility of the author.

References

Aqualinc Research Ltd (2006). *Snapshot – water allocation in New Zealand*. Prepared for Ministry for the Environment (Report No H06002/3). Wellington: Ministry for the Environment.

Aqualinc Research Ltd (2010). *Update of water allocation data and estimate of actual water use of consented takes 2009–2010*. Prepared for Ministry for the Environment (Report No H10002/3). Wellington: Ministry for the Environment.

Bloch, H, Parham, D, Soames, L, & Topp, V. (2008). Productivity in the mining industry: measurement and interpretation. Productivity Commission: Melbourne, Australia. Retrieved 13 June 2011 from www.pc.gov.au.

Boero Rodrigez, V, Davidson, A, & Kokic, P. (2006). Australian grains industry: factors influencing productivity growth. *Australian Commodities, 13*(4), 705–12.

Environment Waikato (2007). A model for assessing the magnitude of unconsented surface water use in the Waikato region. (Report TR 2007/47). Retrieved 13 June 2011 from www.waikatoregion.govt.nz.

Fleming, P (2003). *Lincoln University Farm Technical Manual.* The Caxton Press: Christchurch.

Horizons Regional Council (2007). *Reasonable stock water requirements guidelines for resource consent applications.* Retrieved 13 June 2011 from www.horizons.govt.nz.

Hotelling, H. (1931). The Economics of Exhaustible Resources. *The Journal of Political Economy*, *39*, 137–175.Massey University (2011). Responsible water use for better returns. Retrieved 13 June from www.massey.ac.nz.

Ministry for the Environment (2010). Measuring and reporting water takes: an introduction to the resource management (measurement and reporting of water takes) regulations 2010. [Brochure]. Retrieved 13 June 2011 from www.mfe.govt.nz.

Royal Society of New Zealand (2009). *Emerging issues – virtual water*. Retrieved 13 June 2011 from www.royalsociety.org.nz.

SIDDC (2010). Weekly dataset from Lincoln University dairy farm. Retrieved 13 June 2011 from www.siddc.org.nz.

Statistics New Zealand (2007). Agricultural Production Statistics: June 2007. Wellington: Author. Retrieved 13 June 2011 from www.stats.govt.nz.

Statistics New Zealand (2007). Water Physical Stock Account 1995–2005. Wellington: Author. Retrieved 13 June 2011 from www.stats.govt.nz.

Statistics New Zealand (2011). Productivity Statistics: Sources and methods (7th ed). Wellington: Author. Retrieved 13 June 2011 from www.stats.govt.nz.

Watercare Services Inc (2011). *Changes to Auckland's water and wastewater charges.* Retrieved 13 June 2011 from www.watercare.co.nz.