Reforming water use rights in Canterbury: a shared responsibilities perspective

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ABSTRACT

In this paper, we extend the method of Gallego and Lenzen (2005) for quantitative analysis of shared responsibilities in an input-output framework. We also show how the responsibilities of different actors within the three main categories may be differentiated to reflect circumstances and perspectives in real cases. We apply this version of the method to explore alternative perspectives on 'responsibilities' for water use rights of irrigators in the region of Canterbury, New Zealand. These perspectives build on the paradigms of producer, consumer and worker/investory responsibility.

As the combined agricultural and food processing sectors are strongly export-oriented, we find that substantial responsibilities could be associated with these exports. However, if international or even extra-regional purchasers of Canterbury's exports cannot in be held to account in any practical way, this creates a dilemma—who should be responsible? The only other option in the current framework is to make exporting producers responsible. We suggest that a generalised framework based on a social accounting matrix (SAM) could provide a more satisfactory basis for analysing sharing responsibilities in open economies.

Key words: shared responsibility; water use rights; water reform; environmental input-output model

Introduction

In New Zealand, water has historically been relatively abundant and current systems of allocation reflect this (Ministry for the Environment, 2004). However, over the last decades, population and economic growth—particularly of irrigated agriculture and hydroelectricity generation—have led to many water resources becoming scarce and contested in many areas. In the region of Canterbury, extractive, in-stream and passive uses of water play a vital role in the economy and in society. Extractive uses are dominated by irrigated dairy and other agricultural production on the coastal plains, which have a relatively dry climate. In many areas of Canterbury, groundwater resources are at or beyond sustainable limits, as is extraction from many rivers and streams (Environment Canterbury, 2006a, b). The combined pressures of water extraction and nitrate pollution from fertilisers and livestock have led to serious water quality problems in many lowland streams and increasingly in shallow aquifers (Environment Canterbury, 2006b).

This situation demands a system of water allocation that takes account of economic, social as well as natural values and heeds issues of procedural justice. While the need to reform processes of water allocation and for other measures is widely acknowledged (e.g. Ministry for the Environment, 2004; Environment Canterbury, 2006b), doing so is proving extremely difficult and in many cases, contentious (Ministry for the Environment and Ministry of Agriculture and Forestry, 2005). Different actors naturally have conflicting understandings of the current distribution of explicit and implied rights and have conflicting perspectives on the equity and procedural justice implications of any changes to those rights (Harris Consulting and The AgriBusiness Group, 2003).

In this paper we apply input-output techniques to explore alternative views of 'responsibilities' for water rights that have implications of reforming the current system. We focus out attention on water rights in the agricultural sector, which due to its high and growing dependence on irrigation is the largest regional water user. The 'responsibilities' referred to in this paper reflect the facts that different actors may directly or indirectly: influence irrigators' needs for property rights over water, and/or benefit economically from the uses of water permitted by these rights (see also Lenzen et al. 2006). The case study builds on previous work, in which we considered the role of abstractive water uses in the regional economy of Canterbury, New Zealand, by analysing linkages between sectors (Lennox and Andrew, 2005).

Current system of water rights in New Zealand and Canterbury

In New Zealand, regional councils have direct responsibility for allocating water under the Resource Management Act (RMA) 1991, which is intended '*to promote the sustainable management of natural and physical resources*'. Councils are encouraged to develop plans and policies for managing resources under the Act. The RMA also provides for the issuing of water conservation orders, with which councils may give pre-eminence to water bodies with 'outstanding values'. The Local Government Act (LGA) 2002 is also relevant to water allocation because it governs land use planning.

Furthermore, both the RMA and the LGA define responsibilities of local governments to the general community and to Māori. While regional plans for water developed under the RMA have begun to provide policies for balancing of rights and needs of different user groups and the environment, regulatory and economic instruments promoting allocative and technical efficiency of water use are still lacking. These and other issues are to be addressed by a package of actions currently under development by the Government, in consultation with local governments and other stakeholders (Ministry for the Environment and Ministry of Agriculture and Forestry, 2006).

Environment Canterbury is in the process of developing a natural resources regional plan under the RMA. This will cover most areas of environmental responsibility, with drafts of chapters on water quality and quantity currently available (Environment Canterbury, 2005b, a). Specific regional plans for the Opihi (Environment Canterbury, 2000) and Waitaki (Waitaki Catchment Water Allocation Board, 2005) catchments are already operational. These were developed to address major allocation issues that arose between hydroelectric generators, irrigators and other users in these catchments. Finally, Canterbury has three operative water conservation orders (table WQN20, Environment Canterbury, 2005b) that aim to protect environmental values in the areas concerned.

Under the RMA, rights 'to take and use water' are specified in resource consents (henceforth 'consents'). Landholders or lessees also have an automatic right to abstract and use small quantities of water for specified purposes. These include (rural) household supply and provision of stock water. Consents have historically been granted on what is essentially a 'first come, first served' basis—until in some cases, the sustainable limits of the surface or groundwater resource have been reached or even exceeded (Environment Canterbury, 2006a). However, in most cases, data on both actual water use and understanding of the sustainable limits of different resources are lacking. This has only served to exacerbate conflict and mistrust over processes for and outcomes of water allocation in many parts of Canterbury.

Consents are typically granted for periods of 35 years, lapsing after 5 years if the resource is not used. They specify a maximum instantaneous flow rate (m^3/s), which may be abstracted at a specific location, at specified times. This water may be used in specified locations for specified purposes. Many of these conditions can be modified on application. Consents are also transferable along with associated land titles or leaseholds. Additional conditions for the taking of water are specified to protect the environment (e.g. minimum stream flows) and provide for monitoring and compliance. Administrative and compliance costs of this system are met by user charges. However, there are no charges related to consented flow rates or the volume of water actually abstracted.

This system has encouraged application for excessive volumes and discouraged reduction or relinquishment of consents for volumes that are not needed. Environment Canterbury is currently considering new measures for implementing water policies and redesigning the consents system. This could involve measures such as volumetric charging and rebates or other incentives to encourage water-use metering and efficiency of use and water quality management. This will also permit general rates (based on the capital value of land) to be reduced (Jenkins, 2005). Due to their very large water uses, irrigators will necessarily be a key target of any such reforms.

Methodology

Sharing of upstream and downstream environmental responsibilities

The authors (Lennox and Andrew, 2005) and others (e.g. Duarte *et al.*, 2002; Jollands *et al.*, 2004; Lenzen and Foran, 2005; Wang *et al.*, 2005; Okadera *et al.*, 2006; Velazquez, 2006) have developed and applied environmental input-output (EIO) models to study uses of water in the productive sectors of regional or national economies. EIO models most commonly relate commodity or industry final demands **y** to sectoral environmental impacts **r** via the Leontief inverse $L=\left(I-A\right)^{-1}$ and a matrix of environmental intensity coefficients B:

$$\mathbf{x}=\left(I-A\right)^{-1}\mathbf{y} \tag{1}$$

$$\mathbf{r}=B\mathbf{x} \tag{2}$$

Less commonly, sectoral outputs **x** are related instead to factor inputs **v** using the Ghosh model:

$$\mathbf{x}^{T}=\mathbf{v}^{T}\left(I-\overline{A}\right)^{-1} \quad or \quad \mathbf{x}=\left(I-\overline{A}^{T}\right)^{-1}\mathbf{v} \tag{3}$$

Gallego and Lenzen (2005) employ both the Leontief and Ghosh models in an analytical framework for the *ex post*, descriptive analysis of producer and consumer responsibilities for environmental impacts. Households, government and purchasers of exports may be allocated responsibilities on the grounds that their consumption choices are satisfied by production, which generates environmental externalities. This corresponds to a paradigm of *consumer responsibility*. On the other hand, workers, capital owners, investors and government derive income from productive processes, and so may also be considered partially responsible for production externalities. This corresponds to a paradigm of *worker/investor responsibility*. Finally, firms themselves may be considered actors, and in particular, owners and managers have non-financial stakes in production and have the most direct control over the processes and technologies employed. This corresponds to a paradigm of *producer responsibility* (for discussion of these paradigms, see Gallego and Lenzen, 2005; Lenzen *et al.*, 2006).

Gallego and Lenzen (2005) propose a method for allocating responsibilities between producers and consumers at each stage upstream along commodity chains, using the Leontief model. Producers are allocated responsibility for some fractions of their final and intermediate outputs, consumers are allocated responsibility for the remainder of final output, while sectors downstream are allocated 'upstream responsibilities' for the remainder of intermediate output. These upstream responsibilities are allocated in the same way at each stage of the commodity chain. This procedure is expressed in a closed form as:

$$r_j^{(C)} = b_j \sum_i \beta L_{ji}^{(\alpha)} y_i \,, \tag{4}$$

$$r_j^{(P)} = b_j \sum_i \left[\left(1-\beta\right) L_{ji}^{(\alpha)} y_i + \left(1-\alpha\right) L_{ji}^{(\alpha)} \left(x_i - y_i\right) \right], \tag{5}$$

$$L^{(\alpha)} \triangleq \left(I - \alpha A\right)^{-1}, \tag{6}$$

where b_j is the environmental intensity coefficient for the *j*th industry (we consider a single type of environmental impact for simplicity). Equations (4) and (5) calculate the responsibilities allocated to consumers and producers respectively of all sectors *i*, for impacts caused by activities in the *j*th sector. The factor $0 \le \beta \le 1$ determines the responsibility allocated to consumers for each sector's final output. The factor $0 \le \alpha \le 1$ determines the responsibility allocated to downstream (purchasing) sectors for each sector's intermediate output.

Using the Ghosh model, responsibilities are allocated between producers and suppliers of factor inputs and upstream sectors, by an analogous procedure, yielding:

$$r_j^{(P)} = b_j \sum_i \left[\left(1-\overline{\beta}\right) \left(\overline{L}_{ji}^{(\alpha)}\right)^T v_i + \left(1-\overline{\alpha}\right) \left(\overline{L}_{ji}^{(\alpha)}\right)^T \left(x_i - v_i\right) \right], \tag{7}$$

$$r_j^{(F)} = b_j \sum_i \overline{\beta} \left(\overline{L}_{ji}^{(\alpha)}\right)^T v_i \,, \tag{8}$$

$$\overline{L}^{(\overline{\alpha})} \triangleq \left(I - \overline{\alpha}\overline{A}\right)^{-1}. \tag{9}$$

Equations (7) and (8) calculate the responsibilities allocated to producers and factor suppliers of all sectors *i*, for impacts caused by activities in the *j*th sector. The factor $0 \le \overline{\beta} \le 1$ determines the responsibility allocated to factor providers for each sector's factor inputs. The factor $0 \le \overline{\alpha} \le 1$ determines the responsibility allocated to upstream (providing) sectors for each sector's intermediate output.

Lenzen and co-workers (2006) have more recently refined their method with a unique determination of transaction-specific responsibility shares[1] as functions of value added shares of net output:

$$1-\alpha_{ij} = 1-\beta_{ij} = \frac{v_i}{x_i - T_{ii}} \tag{10}$$

This also makes the responsibility shares invariant to sectoral disaggregation of the supply chain. Their assumption is that the shares of value added captured by agents at each stage of the supply chain reflect their power over the supply chain, and its environmental impacts. While this may be a reasonable starting premise[2], it provides only a single perspective. In this paper we have taken a 'scenario approach', in which scenarios are defined by different sets of parameter values. We return to this issue in the final section.

Extending the shared responsibility framework

In this section, we propose two extensions to the shared responsibility framework. Firstly, different degrees of moral or practical responsibility will often be borne by different classes of actors, corresponding to different final demands and input factors. For example, it may not be politically or even legally feasible for a country to hold overseas suppliers responsible for certain environmental impacts associated with the use of imported commodities in domestic production by imposing tariffs or other measures. Similarly, it would be economically disadvantageous for a country to unilaterally impose excise duties on exported goods traded in globally competitive markets. Even if the same levels of responsibility are assumed to apply to different classes of actors, it may still be useful to account for their respective responsibilities separately: e.g. governments vs households; employees vs owners/shareholders.

Responsibilities can be decomposed on the basis of different demand vectors $\mathbf{y}_k, k \in K_D$ or factor input vectors $\mathbf{v}_k, k \in K_S$ by exploiting the principle of superposition with the Leontief (11) or Ghosh (12) models respectively:

$$\mathbf{x} = \sum_{k \in K_D} \mathbf{x}_k = \sum_{k \in K_D} \left(I - A\right)^{-1} \mathbf{y}_k \, . \tag{11}$$

$$\mathbf{x} = \sum_{k \in K_S} \mathbf{x}_k = \sum_{k \in K_S} \left(I - \overline{A}^T\right)^{-1} \mathbf{v}_k \, . \tag{12}$$

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[1] This requires a modification of the mathematical form of the framework involving the use of tensors (Lenzen *et al.*, 2006).

[2] Although gross operating surplus could be considered a better proxy for control (p20 Lenzen *et al.*, 2006).

Equations (4) to (6) or (7) to (9) can then be applied for each k. Alphas in the above equations determine the proportion of responsibility for intermediate transactions transferred down/up the supply chain at each round of inter-industry transactions[3], so there is no reason to specify different values for different k. Betas, however, determine the proportion of responsibility transferred to final purchasers of an industry's output at each transaction round. It may therefore be useful to specify different betas for different classes of final purchasers/factor suppliers: $\beta_k, k \in K$ and $\overline{\beta}_{\overline{k}}, \overline{k} \in \overline{K}$.

Our second extension of the Gallego and Lenzen framework is to combine the upstream and downstream perspectives into a single 'mixed' perspective, enabling responsibilities of all classes of actors to be considered simultaneously[4]. This is achieved by introducing a weighting factor $0 \le \phi \le 1$, which acts on the vector of gross outputs, **x**:

$$\mathbf{x} = \phi\mathbf{x} + (1-\phi)\mathbf{x} = \phi(I-A)^{-1}\mathbf{y} + (1-\phi)\left(I-\overline{A}^T\right)^{-1}\mathbf{v}\,. \tag{13}$$

Combining equation (13) with (4) through (9), responsibilities for environmental impacts of the jth sector are attributed as follows:

$$r_j^{(C)} = \phi b_j \sum_i \beta L_{ji}^{(\alpha)} y_i\,, \tag{14}$$

$$\begin{aligned} r_j^{(P)} = \phi b_j \sum_i \left[(1-\beta) L_{ji}^{(\alpha)} y_i + (1-\alpha) L_{ji}^{(\alpha)} (x_i - y_i)\right] + \\ (1-\phi) b_j \sum_i \left[(1-\overline{\beta})\left(\overline{L}_{ji}^{(\alpha)}\right) v_i + (1-\overline{\alpha})\left(\overline{L}_{ji}^{(\alpha)}\right)(x_i - v_i)\right] \end{aligned} \tag{15}$$

$$r_j^{(F)} = (1-\phi) b_j \sum_i \overline{\beta}\left(\overline{L}_{ji}^{(\alpha)}\right) v_i\,. \tag{16}$$

By reversing the order of summation above, the total responsibilities of actors in a single sector i for water use in all sectors j could also be found. It should be noted that producer responsibilities include contributions from both upstream and downstream perspectives. Equations (14) to (16) attribute responsibilities for the total water use of sector j to all three categories of actors in all sectors. The responsibilities are complete and do not involve any 'double-counting'—i.e. they are additive:

$$r_j = r_j^{(C)} + r_j^{(P)} + r_j^{(F)} \tag{17}$$

It must be stressed that 'responsibilities' in this framework do not model cause-effect relations as many types of input-output multiplier do. Responsibilities say nothing about how environmental impacts might change, given an exogenously specified change in either consumption, production or supply of factors inputs.

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[3] Note that the share of responsibility diminishes exponentially with transaction rounds. This makes the results contingent on the level of disaggregation of the input-output model. Lenzen *et al.* (2006) have more recently addressed this problem, as discussed also in the final section of this article.

[4] It is important to reiterate the descriptive rather than causal nature of the model.

Case study

The ongoing process of water reform in Canterbury (and also at the national level) must ultimately address questions of water quantity and quality in physical terms. In some cases this could require capping or even reducing current uses, especially in the water-intensive agricultural sector. Achieving this would most likely require redefinition and/or redistribution of formal water rights as specified by consents to take and use water (see above). Such a process would be costly to some and beneficial for others, and the ultimate distribution of these costs and benefits would depend also on the potentials for price, technical and structural adjustments in the regional economy. Before we can begin to grapple with such complexities, it is useful to understand the economic importance of water rights to different actors in the regional economy. This motivates our application of the shared responsibility framework. To simplify presentation and analysis of the results, we focus exclusively on consents for agricultural irrigation. This is the major extractive use in the region and the corresponding water rights are therefore a crucial element of any substantive reform process.

An EIO model with seven sectors (Table 1 and Appendix) was constructed (Lennox and Andrew, 2005) from a regionalised IO table (McDonald, 2005) for the Canterbury region in 2000/01. Key characteristics of the regional economy are shown by sector in Table 2. The EIO model was then used with the shared responsibility framework to generate six main scenarios illustrating different schemes for the sharing of responsibility for irrigation consents held by the agricultural sector.

Table 1 – Sectors in the aggregate model

Abbrev.	Sector name
AGR	Agriculture
OPR	Other primary industries
FPR	Food processing
OMC	Other manufacturing and construction
U&D	Utilities & distribution
OSV	Other services and distribution
TDCR	Tourism, dining, culture and recreation

Table 2 – Profile of the Canterbury economy by sector

NZ$ billion	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Gross output	**1.8**	**0.4**	**3.2**	**6.9**	**5.8**	**8.5**	**1.2**	**27.9**
Regional final demands & exports	**0.59**	**0.16**	**2.8**	**4.6**	**3.1**	**5.7**	**0.99**	**18.0**
Regional final demands[5]	0.04	0.01	0.55	1.8	2.3	4.8	0.54	10.0
Interregional exports	0.40	0.06	0.61	1.5	0.19	0.69	0.24	3.7
International exports	0.21	0.11	1.6	1.3	0.7	0.18	0.21	4.4
Imports & value added	**1.0**	**0.3**	**1.4**	**4.1**	**4.0**	**6.5**	**0.7**	**18.0**
Gross value added	0.78	0.18	0.69	2.3	3.2	5.6	0.48	13.2
Interregional imports	0.14	0.046	0.43	0.50	0.30	0.41	0.089	1.9
International imports	0.11	0.043	0.23	1.27	0.58	0.52	0.12	2.9

The six scenarios presented have the dual purpose of illustrating the technical implementation of the extended framework for shared responsibility described above, and highlighting real issues around moral and practical responsibilities for water rights in Canterbury. These scenarios provide quantitative realisations of various perspectives on the responsibilities of different classes of economic actors at different scales (regional, national and international). In scenarios A and B, responsibilities are shared between producers and all demand-side actors. Scenario C presents an analogous case of sharing between producers and supply-side actors. In scenarios D to F, responsibilities of regional, national and overseas actors are differentiated. Responsibilities of private and public sector consumers are also differentiated.

The scenarios are defined by the choice of parameters for the different input vectors on the supply side and/or output vectors on the demand side. Variation of parameters within the framework determines the extent to which responsibilities are transferred up and down supply chains and between producers and other actors. The choice of $\beta = 0$ or $\bar{\beta} = 0$ allows actors on the demand or supply sides respectively to be attributed zero responsibility for consents. For each scenario, equal values were used for α and $\bar{\alpha}$. Results for values $\alpha = \{0, 0.5, 1\}$ are shown for scenario A to illustrate the effect of this parameter. For the other scenarios, results for a single value are shown (Table 3).

[5] Excludes change in inventories.

Table 3 – Attribution of responsibilities to final purchasers/factor suppliers

Scenario:	A1, A2, A3	B	C	D	E	F
Leontief Model weight (ϕ)	1	1	0	0.5	0.5	0.5
Leontief Model coefficients (β):						
Households	1	1/2	-	0.8	0.8	0.9
Local government[6]	1	1/2	-	0.8	0.8	0.9
Central government	1	1/2	-	0.8	0.8	0
Gross fixed capital formation[7]	0	0	-	0	0	0
Interregional exports	1	1/2	-	0.8	0.8	0
International exports	1	1/2	-	0.8	0	0
Ghosh Model coefficients ($\bar{\beta}$)						
Compensation of employees	-	-	1/2	0.8	0.8	0.9
Net taxes[8]	-	-	1/2	0.8	0	0
Operating surplus	-	-	1/2	0.8	0.8	0
Consumption of fixed capital[9]	-	-	0	0	0	0
Interregional imports	-	-	1/2	0.8	0.8	0
International imports	-	-	1/2	0.8	0	0

Results in the following tables are presented as GL/yr equivalents of the consented maximum flows of agricultural irrigation water[10] for which various actors are attributed responsibility. The total consented volume of water is 9820GL in all scenarios, although this 'grand total' is only shown in some of the tables.

Scenario A illustrates sharing of responsibility between final demands and producers, with different choices of α defining three sub-scenarios: A1, A2 and A3. The choice of $\beta = 1$ in these sub-scenarios means that all responsibilities associated with final transactions are attributed to final purchasers rather than to producers. An exception in this and subsequent scenarios is that responsibilities associated with gross fixed capital formation (GFCF) are always attributed to the producers in the sector supplying these goods (i.e. $\beta = 0$). It would have been preferable to such responsibilities to attribute the producing sectors purchasing the fixed capital. However, the IO table does not provide this information.

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[6] Local government and private non-profit institutions serving households.

[7] Plus increases in inventories. Decreases in inventories are added to depreciation of fixed capital.

[8] Taxes on products and other taxes on production net of subsidies.

[9] See note 7.

[10] It should be noted that *actual* use ower water is substantially lower. See (Lennox and Andrew, 2005) for further details. Furthermore, conditions on consents can restrict permitted volumes during the year.

Scenario A1 (Table 4) shows that with $\alpha = 0$, responsibilities for consents held by agricultural producers are shared between these producers and final purchasers of agricultural commodities, in proportion to intermediate sales and final purchases respectively. This is a rather crude basis for shared responsibility, because there is no clear justification for associating responsibilities with final purchases (e.g. by firms in the rest of New Zealand), but not with intermediate purchases (e.g. by regional food-processing companies). Scenarios A2 and A3 redress this problem with choices of $\alpha = 0.5$ (Table 5) and $\alpha = 1$ (Table 6) respectively. In scenario A2, half of the responsibility associated with intermediate sales is passed downstream at each stage in the supply chain. This results in a greater proportion of responsibility being attributed to final demands. In scenario A3, all responsibility associated with intermediate sales is passed down the supply chain, and ultimately attributed to consumers of final products in different sectors. The only responsibilities remaining with producers are those associated with changes in capital stocks. The dominance of exports over regional final demands means that producer responsibilities in A1 are transferred mainly to export demands in A2 and A3, particularly those on the food processing sector. Even in A3 where households are given greatest responsibility, this amounts to only 16.5%.

Table 4 – Scenario A1 ($\alpha = 0$)

GL/yr consented	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Households	183	0	0	0	0	0	0	**183**
Interregional exports	2 097	0	0	0	0	0	0	**2 097**
International exports	1 112	0	0	0	0	0	0	**1 112**
Demand responsibilities	**3 392**	**0**	**0**	**0**	**0**	**0**	**0**	**3 392**
Producer responsibilities	**6 427**	**0**	**0**	**0**	**0**	**0**	**0**	**6 427**

Table 5 – Scenario A2 ($\alpha = 0.5$)

GL/yr consented	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Households	188	0	432	23	95	20	32	**790**
Local government	0	0	0	0	3	17	2	**23**
Central government	0	0	0	0	0	3	3	**7**
Interregional exports	2 146	6	483	68	9	6	16	**2 734**
International exports	1 138	10	1272	60	33	2	15	**2 530**
Demand responsibilities	**3 471**	**16**	**2186**	**152**	**140**	**47**	**69**	**6 083**
Producer responsibilities	**3 305**	**14**	**209**	**113**	**76**	**13**	**6**	**3 736**

Table 6 – Scenario A3 ($\alpha = 1$)

	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Households	194	1	907	70	264	76	111	**1 622**
Local government	0	0	1	1	9	63	8	**82**
Central government	0	0	0	0	0	13	12	**25**
Interregional exports	2213	13	1013	206	24	23	57	**3 549**
International exports	1173	24	2670	182	93	6	52	**4 200**
Demand responsibilities	**3 580**	**37**	**4 591**	**460**	**389**	**181**	**241**	**9 478**
Producer responsibilities	**33**	**6**	**85**	**184**	**28**	**5**	**0**	**342**

Scenario B involves changing β from 1 to 0.5 with $\alpha = 0.5$ (Table 7). This results in responsibilities attributed to each type of final demand in scenario A2 being exactly halved, so only totals are shown below. However, producer responsibilities do not increase proportionally in each sector, as shown by percentage increases in the table. This is because producer responsibilities in A2 relate primarily to intermediate sales (plus GFCF purchases). The responsibilities reallocated to producers in scenario B are those associated with final and export demands. The two sectors of food processing and tourism, dining, culture and recreation, are most strongly demand-oriented, therefore producers in these sectors are attributed proportionally more responsibilities.

Table 7 – Scenario B ($\alpha = 0.5$)

	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Demand responsibilities	**1 736**	**8**	**1 093**	**76**	**70**	**24**	**35**	**3 042**
Producer responsibilities	**5 041**	**22**	**1 302**	**189**	**146**	**37**	**41**	**6 778**
Increase in producer responsibilities cf. Table 5 (%)	*153*	*160*	*623*	*167*	*192*	*277*	*650*	*181*

Whereas scenarios A and B shared responsibilities between producers and actors on the demand side of the economy, scenario C illustrates sharing of responsibility between supply-side actors and producers. The choice of parameters for this scenario is analogous to that in scenario B, with the relative shares of factor and producer responsibilities determined by the choice of $\overline{\beta} = 0.5$ (except for consumption of fixed capital). However, despite choosing $\overline{\alpha} = 0.5$, a smaller proportion of total responsibilities is transferred to upstream sectors from agriculture than were transferred downstream in scenario B. Percentages of responsibility attributed to actors within the agricultural sector are also shown in Table 8. These limited upstream responsibilities for agricultural consents result from the relatively short and small regional supply chains of this sector. That is, a relatively small proportion of other regional sectors' outputs are delivered to the agricultural sector either directly or via regional supply chains.

Table 8 – Scenario C with $\alpha = 0.5$

Scenario:	AGR	*AGR (%)*	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Producer responsibilities	**5 651**	*83*	**20**	**44**	**258**	**423**	**410**	**35**	**6 841**
Compensation of employees	476	*64*	2	6	49	96	107	6	**741**
Net taxes	198	*87*	0	0	3	8	15	1	**226**
Operating surplus	952	*82*	4	2	25	85	92	5	**1 166**
Interregional imports	377	*85*	2	6	18	20	18	3	**444**
International imports	287	*71*	2	3	46	39	23	3	**403**
Supply responsibilities	**2 290**	*77*	**10**	**17**	**142**	**248**	**255**	**19**	**2 980**

Scenario D combines the perspectives of scenarios B and C, but also attributes a greater share of responsibility to final demands and factors: $\beta = \overline{\beta} = 0.8$. This higher value was chosen to counteract the fact that producers are attributed responsibilities from both the upstream and downstream perspectives. Table 9 shows that most responsibilities are attributed to actors within or imposing final demands on the agricultural sector—75% of the total. A relatively high proportion of this part (56%) is attributed directly to agricultural producers and 25% to factor suppliers. The food processing sector accounts for 13% of the total responsibility and, of this, 71% is attributed to final demands—mostly interregional and international exports. For the same reasons as in scenario C, relatively little responsibility is attributed to supply-side actors in non-agricultural sectors.

Scenario E differs from D in that no responsibilities are attributed to overseas actors[11]. This corresponds to a more pragmatic case, in which actors who may be thought to hold some moral responsibility for use of water resources cannot be held practically responsible (e.g. through imposition of environmental taxes).The nature of the framework dictates that any responsibilities of these actors be reallocated to producers within each sector. This is shown in Table 10, where the responsibilities attributed to international exports and imports in Table 9 are all allocated to producers in the sector that supplies the exports and receives the imports. Other responsibilities are unchanged and are not shown in the table.

[11] Note that from the input-output tables, we cannot distinguish regional, national and foreign ownership of businesses and any associated repatriation of profits..

Table 9 – Scenario D with $\alpha = 0.5$

Scenario:	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Households	75	0	173	9	38	8	13	**316**
Local government	0	0	0	0	1	7	1	**9**
Central government	0	0	0	0	0	1	1	**3**
Interregional exports	858	2	193	27	3	2	7	**1 093**
International exports	455	4	509	24	13	1	6	**1 012**
Demand responsibilities	**1 389**	**7**	**875**	**61**	**56**	**19**	**28**	**2 433**
Demand of sector	*19*	*22*	*71*	*18*	*13*	*5*	*43*	*25*
Producer responsibilities	**4 138**	**16**	**340**	**158**	**189**	**140**	**22**	**5 003**
Producer % of sector	*56*	*52*	*28*	*48*	*43*	*39*	*34*	*51*
Compensation of employees	381	1	4	39	77	85	5	**593**
Net taxes	158	0	0	2	7	12	1	**181**
Operating surplus	762	3	2	20	68	74	4	**933**
Interregional imports	302	1	5	15	16	14	2	**355**
International imports	230	1	2	37	31	18	3	**322**
Supply responsibilities	**1 832**	**8**	**14**	**113**	**198**	**204**	**15**	**2 384**
Supply % of sector	*25*	*26*	*1*	*34*	*45*	*56*	*23*	*24*
Total sector responsibilities	**7 359**	**30**	**1 228**	**333**	**443**	**363**	**65**	**9 820**
Sector % of total	*75*	*0*	*13*	*3*	*5*	*4*	*1*	*100*

In scenario F, responsibilities for water rights are attributed only to regional actors, excluding the owners of firms[12]. In this case, responsibilities for all extra-regional actors must be attributed to producers in the same sector. As this results in a very high burden of responsibility for producers, the effect is partially offset by allocating all of the intraregional responsibilities (except associated with GFCF) to final demands and supply-side actors. This is achieved by choosing $\alpha = \overline{\alpha} = 1$ and $\beta = \overline{\beta} = 1$ for the corresponding demand and input vectors. This also results in shifting of responsibilities between sectors by comparison with scenarios D and E. Responsibilities attributed to agricultural producers are reduced back to a level similar to that of scenario D, whereas responsibilities attributed to food processors (producers) are significantly increased (see percentage changes in Table 11). These two groups account for 63% of total

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[12] Note that from the input-output tables, we cannot distinguish extra-regional ownership of businesses and any associated repatriation of profits to the rest of New Zealand or overseas. We assume that all profits accrue to owners located outside the region. This is not entirely true, particularly because many farms in Canterbury are either wholly or partially (e.g. share-milking) owned by farmers. We will address this issue in future work.

responsibilities. Total responsibility of households and of employees increase too, but increases are limited by the fact that the framework does not permit shifting of responsibilities between different demands (e.g. from exports to households) or inputs (e.g. from imports to owners and workers).

Table 10 – Scenario E with $\alpha = 0.5$

Scenario:	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Demand responsibilities	**934**	**2**	**366**	**37**	**43**	**18**	**22**	**1 421**
Demand % of sector	*13*	*8*	*30*	*11*	*10*	*5*	*34*	*14*
Producer responsibilities	**4 981**	**21**	**852**	**222**	**240**	**171**	**32**	**6 518**
Producer % of sector	*68*	*71*	*69*	*67*	*54*	*47*	*49*	*66*
Supply responsibilities	**1 444**	**6**	**11**	**74**	**161**	**174**	**11**	**1 881**
Supply % of sector	*20*	*21*	*1*	*22*	*36*	*48*	*17*	*19*

Table 11 – Scenario F with $\alpha = 1$

Scenario:	AGR	OPr	FPr	OMC	U&D	OSV	TDCR	Total
Households	97	0	453	35	132	38	56	811
Local government	0	0	0	1	4	32	4	41
Demand responsibilities	97	0	454	36	136	69	60	852
Demand % of sector	*2*	*1*	*19*	*5*	*16*	*9*	*36*	*9*
Producer responsibilities	4 225	49	1 917	544	508	479	93	7 815
Producer % of sector	*88*	*92*	*80*	*77*	*58*	*59*	*55*	*80*
Supply responsibilities[13]	491	4	15	127	233	269	15	1153
Supply % of sector	*10*	*8*	*1*	*18*	*27*	*33*	*9*	*12*
Total sector responsibilities	**4 813**	**54**	**2 386**	**707**	**877**	**817**	**168**	**9820**
Sector % of total	49	1	24	7	9	8	2	100

Discussion

We have proposed and implemented an extended version of the framework for shared responsibility of Gallego and Lenzen (2005), in which different levels of responsibilities may be attributed to different actors on the supply and demand sides of the economy. Furthermore, we have shown how the upstream and downstream perspectives of Gallego and Lenzen (2005) can be combined using linear weighting to create ‘mixed’ perspectives, in which responsibilities can be simultaneously attributed to all classes of

[13] In this scenario, employees are the only supply actors to whom responsibilities are attributed.

economic actors. Distinguishing different actors adds some complexity to the framework, but this is justified by more direct policy relevance. For example, we considered cases in which, for economic and/or political reasons, responsibilities are geographically bounded. As the mixed perspective is a simple combination of upstream and downstream perspectives, it may not offer any additional insights *per se*, but does simplify presentation and communication of results by 'automating' the task of combining information from each perspective.

The application to irrigation consents in Canterbury provided a quantitative analysis of some different views on environmental responsibility. Some of these views are evident in current institutions for and the public discourse on water allocation in Canterbury, while others are not. The paradigm of total producer responsibility tends to underlie (implicitly or explicitly) many of the formal institutions for water management in Canterbury; particularly the resource consent process. Nevertheless, most people involved in the debate over water acknowledge some or other grounds for sharing of responsibilities between various actors.

The notion of consumer responsibility (i.e. associated with household consumption either within or outside the region) is not generally recognised in the current debates around water issues in Canterbury. In relation to agriculture more generally, a small but growing number of consumers purchasing organic produce are demanding agricultural practices they perceive to be more environmental friendly; however, this has not direct connection to issues of water use. Corresponding to the worker/investor perspective, it is widely accepted that there are regional and national economic benefits from irrigated agricultural production in terms of employment, regional product and export earnings. Some such benefits have been quantified in national and regional economic assessments of irrigation (Butcher Partners Ltd, 2000; Ministry of Agriculture and Forestry, 2004). However, to the extent that corresponding responsibilities are accepted, they are rather diffuse. Most commonly, they translate into a feeling that the regional and national government must better manage water use to simultaneously protect environmental values *and* foster continued growth of irrigation and related industries.

Conclusions and future directions

A limitation of the extensions we have suggested here is the inability to redistribute responsibilities between different actors on either the demand or supply sides. However, this does at least highlight the fact that *somebody* must have responsibility for water rights and their associated water use and environmental impacts. In the New Zealand context, it is very unlikely that international actors on either the supply or demand sides can be held to account in any practical way (e.g. through direct taxes or levies) for water use in Canterbury. Given the high volume of international exports of both processed and unprocessed farm products form Canterbury, this complicates even a conceptual analysis of responsibilities, not to mention the political economy of actual water reforms.

A Social Accounting Matrix (SAM) extends the input-output structure to describe not only flows of commodities, but also financial transfers between institutions, including households, firms, governments and the 'rest of the world'. The authors are currently investigating the application of the shared responsibility framework in conjunction with a model derived from a SAM. This would permit vectors that are exogenous in the current model (e.g. exports) to be endogenised, following particular assumptions about macroeconomic 'closure'. For example, if a (regional) macroeconomic variable 'regional balance of trade' is introduced, the total value of exports could be determined endogenously as a function of this and the total value of imports. Individual commodity exports could then be endogenously determined with the aid of a vector of coefficients specifying the export commodity composition. This or similar approaches may provide a more satisfactory basis for analysing shared responsibilities in open economies.

In this paper, we suggested that different responsibility shares should be chosen to reflect different perspectives; albeit that the exact numerical values chosen remain arbitrary. By contrast, Lenzen and co-workers (2006) suggest the use of uniquely determined transaction-specific responsibility values,. Besides the technical advantages of invariance to disaggregation and aggregation, uniquely determined parameters make the shared responsibility method suited to standardised corporate reporting, which is one of their main interests. However, we are more interested in the potential of the method to support complex policy decisions, which ultimately involve political considerations. In this context, the possibility of providing different perspectives appears crucial. In future work, we intend to explore these issues in relation to a SAM-based framework fore shared responsibilities.

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Appendix: aggregation of industries into sectors

Abbrev.	Sector name	Industries
AGR	Agriculture	Agriculture Services to agriculture (mostly irrigation supply)
OPR	Other primary industries	Forestry and logging Fishing Mining and quarrying Oil and gas exploration and extraction
FPR	Food processing	Meat and meat products manufacturing Dairy products manufacturing Other food manufacturing Beverage, malt and tobacco manufacturing
OMC	Other manufacturing and construction	Textile and apparel manufacturing Wood product manufacturing Paper and paper product manufacturing Printing, publishing and recorded media Petroleum and industrial chemical manufacturing Rubber, plastic and other chemical product manufacturing Non-metallic mineral product manufacturing Basic metal manufacturing Structural, sheet and fabricated metal product manufacturing Transport equipment manufacturing Machinery and equipment manufacturing Furniture and other manufacturing Construction
U&D	Utilities and distribution ** indicates industries that were classified in 'other services and distribution' in Lennox and Andrew (2005)*	Electricity generation and supply Gas supply (not applicable) Water supply Wholesale trade * Retail trade * Road transport * Water and rail transport * Air transport, services to transport & storage *
TDCR	Tourism, dining, culture and recreation	Accommodation, restaurants and bars Cultural and recreational services
OSV	Other services	Communication services Finance Insurance Services to finance and investment Real estate Ownership of owner-occupied dwellings Business services Central government administration, defence, public order and safety services Local government administration services and civil defence Education Health and community services Personal and other community services