Augmenting the conventional input-output framework to consider water as a ‘common pool’ resource

Short summary (150 words)

This paper develops and applies an innovative method around regional input-output (IO) tables that facilitates better understanding of connections between scarce domestic water resources, complex industry supply chains, tightening regulatory constraints and regional economic growth. Specifically, we extend on the conventional demand-driven IO model to develop a framework where the full resource costs of water use and the impacts of regulatory constraints may be examined. This step is necessary where market failure causes a deviation between actual expenditures on the outputs of the water supply sector and actual water resource use by each production sector and final consumer. We then use output and price multipliers derived from the adjusted and unadjusted IO accounts to consider how capturing the full resource implications of water use in supply chains impacts through both up- and down-stream regional supply chains. We also conduct scenario simulations regarding the impacts of potential constraints on water supply.

Extended abstract (1192 words not including reference details)

Introduction – Leontief’s (1970) environmental model

Leontief (1970) extends the standard input–output (IO) accounts to incorporate pollution as an additional commodity (‘bad’) that accompanies production and consumption activities. His extended system also separately identifies sectors that clean up or prevent these unwanted outputs. Thus, the environment is regarded as an example of a ‘common pool’ resource: the services it provides are intermediate between those provided by ‘public’ and ‘private’ goods (Stiglitz 2000). Consumption is rival in that utilizing the resource imposes costs on other users. However, because of ineffective or incomplete property rights, the use of the resource is not fully excludable. Typically, then, the user does not have to pay the full cost and use is not optimally determined through the market mechanism. Also, the use of the resource is not tracked through the expenditures that are typically employed to construct IO tables

Governments are aware of the inherent market failure associated with the provision of ‘common pool’ resources and adopt various mechanisms, including using public expenditure to replenish these resources and reinforce market processes. The full Leontief environmental extension incorporates this replenishment activity, which is at least partly demand driven. Moreover, the extended IO accounts – and the associated price dual – can be used to assess more accurately those costs imposed by the use of common pool resources that are not directly reflected in the price mechanism (Allan et al. 2007).

Water as a common resource

We seek to explore how the Leontief model may be applied to consider the case of supplying a physical resource like water where resource costs may not be fully incorporated in the market prices of some industrial outputs.

Method

The full Leontief environmental model is set up using an expression, here for the output of the water sector (w), which takes the form of the standard IO statement for the IO row of a given sector *i* but with all base year data represented in physical units (q, l and α represent physical units for total output/input, final demand and the standard input-output coefficient representing sector j intermediate or final demand purchases from sector *i,* here water indicated by subscript w):

$$q_w = \sum_{j \neq w} \alpha_{wj}\, q_j + \alpha_{ww} q_w + a_{wy} l + \Delta s_w \qquad (1)$$

Where Δs_w is the change in stock of water.

In practice IO accounts are reported in value not physical terms. In order to incorporate (1) in a monetary IO account, we replace the actual expenditure on water used in the reported tables (e.g. here, the Welsh IO accounts for 2007) with a row where we introduce a value for the demand implied by physical water use. To do so we first calculate the unit cost of water, p_w, taken to be total value of water supplied (so the row total for the water sector minus the change in stocks) divided by the total physical amount supplied (so also excluding the change in stocks). We then multiply this against the physical amount of water used in each sector. In this way equation (2) is reformulated (with the standard notation of x, y and a replacing q, l and α), and stated in terms of the change in stocks:

$$x_w - \left(\sum_{j \neq w} a_{wj}\, x_j + a_{ww} x_w + a_{wy} y \right) = \Delta s_w \qquad (2)$$

Equation (2) tells us that, when we subtract all forms of demand for both intermediate and final consumers from the physical amount of water available in the base year this should equate to the change in stock. If we have case of Δs_w been positive, it means that there is surplus amount of water in the base year. If Δs_w is negative, it indicates that physical amount of water available in the system cannot meet the level of demand. If Δs_w is zero the physical amount available in the given is just enough to meet the intermediate and final demand needs in that period.

Preliminary Results

In the paper we will illustrate the type of insights that may be made using this system. As a case study we work with the industry-by-industry Welsh IO tables for 2007. In terms of the SIC classified water supply sector we relate this to physical data for the public water supply only. In 2007 the total amount of water is 252.9 cubic metres (M3), but with 14M3 of this going to a (positive) change in stock. Thus, we calculate the unit cost of water as:

$$P_w = \frac{x_{18} - £\Delta S_{18}}{x_w - \Delta s_{\mathrm{w}}(\mathrm{M3})} = \frac{£659.3}{238.9(\mathrm{M3})} = £2.76$$

The most basic insights can be gained by comparing the difference between the original (unadjusted) IO entries - what the water sector actually receives for supplying its output – with the new (adjusted) entries - reflecting the implicit demand implied by the actual physical amount that each sector uses. We find that most industries are net under-payers, including are agricultural and food and beverage production, while petroleum refining, metal manufacturers and construction are examples of net over-payers. Overall we find that the production side of the economy is subsidised in terms of direct payments for water by the household sector in particular. This may reflect incomplete/ineffective water metering in the Welsh region.

However, the approach outlined above allows us to move beyond considering issues of direct water use and payments. We use the IO framework to derive and examine output and price multiplier effects in the original and adjusted systems (with the water sector row of the A matrix changing between the two systems, which then impacts throughout the multiplier matrices).

The price multiplier tells us the overall price to final demand for sector j output per £1 spent on primary input. We are concerned with how the price multiplier changes between the unadjusted and adjusted system. When we considered the agricultural sector its unadjusted price multiplier was 1.303 increasing to 1.479 in the adjusted system, reflecting the full resource cost through the supply chain.

Output multipliers account of output generated by all sectors in an economy per £1 of final demand for sector *j's* output. However, in the unadjusted IO the analysis output multipliers are understated in terms of the impact on water sector output in sectors that are net under-payers for their water use, and/or have backward linkages to others that are net under-payers. Taking agriculture sector as an example, its adjusted output multiplier 1.480 is higher than its unadjusted output multiplier of 1.435.The difference reflects positive impacts in the water sector as the full resource cost is realised.

We also use output multipliers for attribution analysis to consider what type of final consumer be impacted if the full resource costs of the public water supply were reflected in the payments made by water users Here, for example, we find that 68% of agricultural output is supported by export demand from the rest of the UK. This implies that, through their direct or indirect consumption of agricultural production in Wales (indirect may be via, for example, food and drink purchases) RUK consumers are currently impacting Welsh water resources to a greater extent than what is implied by examination of the unadjusted IO accounts.

We report full results in our full paper. We also consider different scenarios regarding how much water is actually made available to the public water supply system via changes in what is allocated to the stock (that may then be made available to other uses).

References cited in extended abstract

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