An agent-based model of environmental water holder and irrigators

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AARES National Conference, Melbourne, 8-11 February 2011

Outline

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- Model structure for Murrumbidgee
- A stylized example
- Future research

Introduction

State and Federal Governments now own roughly 1200GL of water entitlements (Cosier et al., 2010), More planned

Irrigator / policy concerns - Will Environmental Water Holder (EWH):

- exacerbate drought shortages?
- Lead to water price spikes?
- exploit market power?
- Could irrigators charge EWH exorbitantly for water?

This paper is the first step to an exploration of strategic behaviour interactions between EWH and irrigators in auction market where both trade and carry over

Research questions

Main focus on irrigators bidding behaviour and learning strategies.

- What are the effects of bidders' learning on auction outcomes?
- How do demand shifts impact on auction outcomes?

Model structure for Murrumbidgee

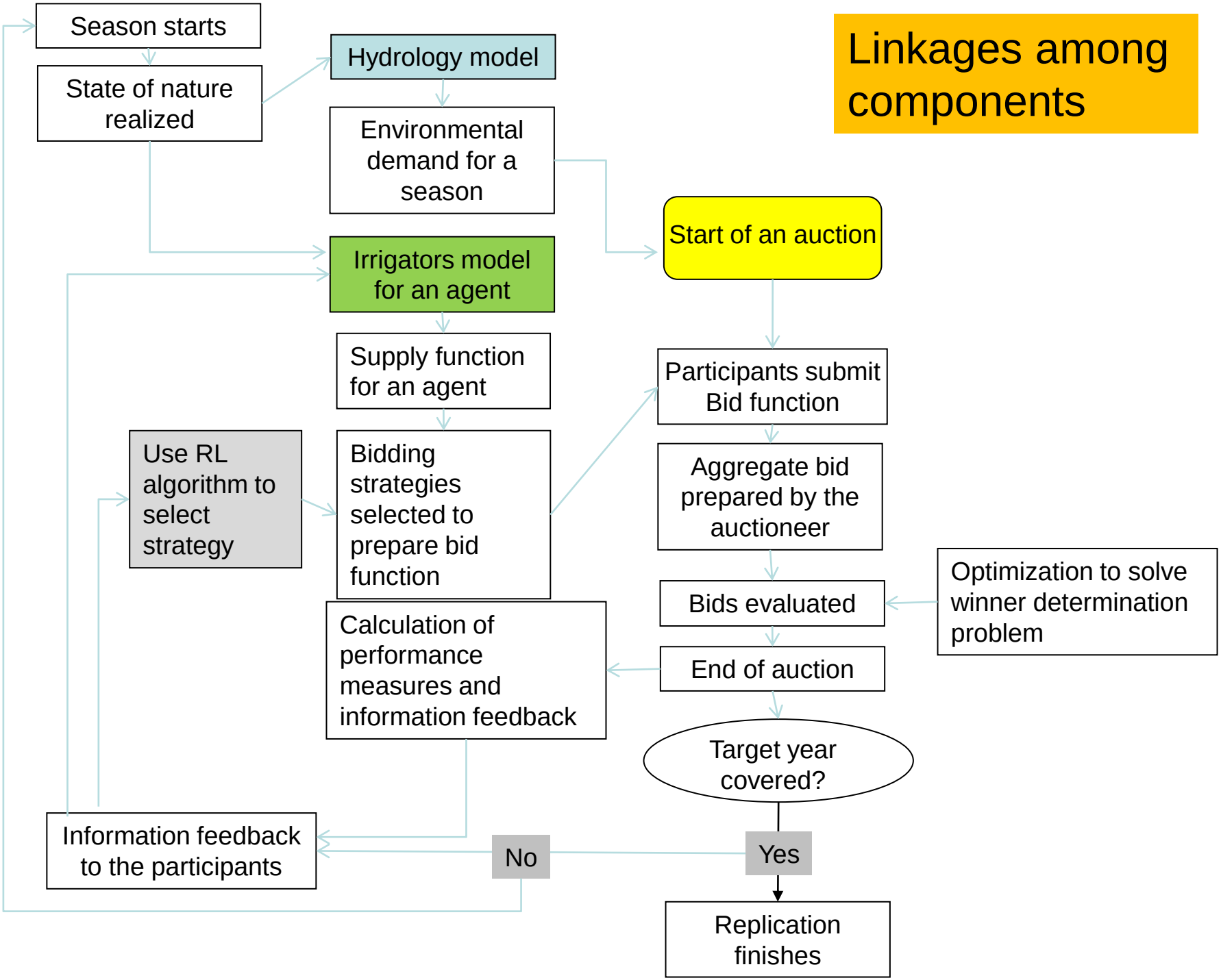
Premise

- Procurement auction to purchase water from irrigators
- Two types of agents
  - Environmental Water Holder with yearly targets (EWH)
  - Irrigators with supply function
- Water allocation problem resembles a multi-unit homogenous good allocation problem
- Considered uniform price auction

Model components

- Use existing models
  - CSIRO Hydrology model (Kirby, 2008)
  - CSIRO Agriculture sector model for irrigators (Ejaz, 2006)
  - Agent based models (Iftekhar et al., 2010)
- Develop new models
  - Environmental trader model (Connor et al. 2011)
  - Irrigators bidding structure and learning model
  - Auction model

Linkages among components

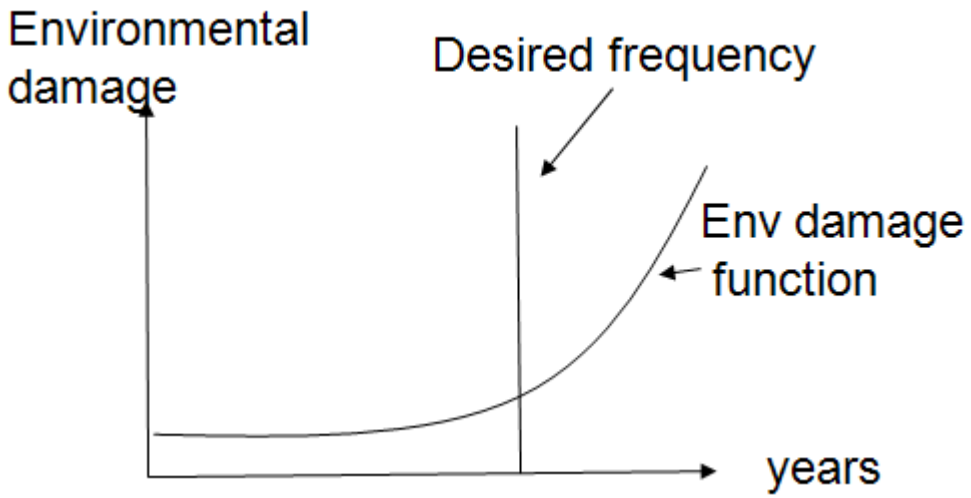


Environmental Water Holder objective

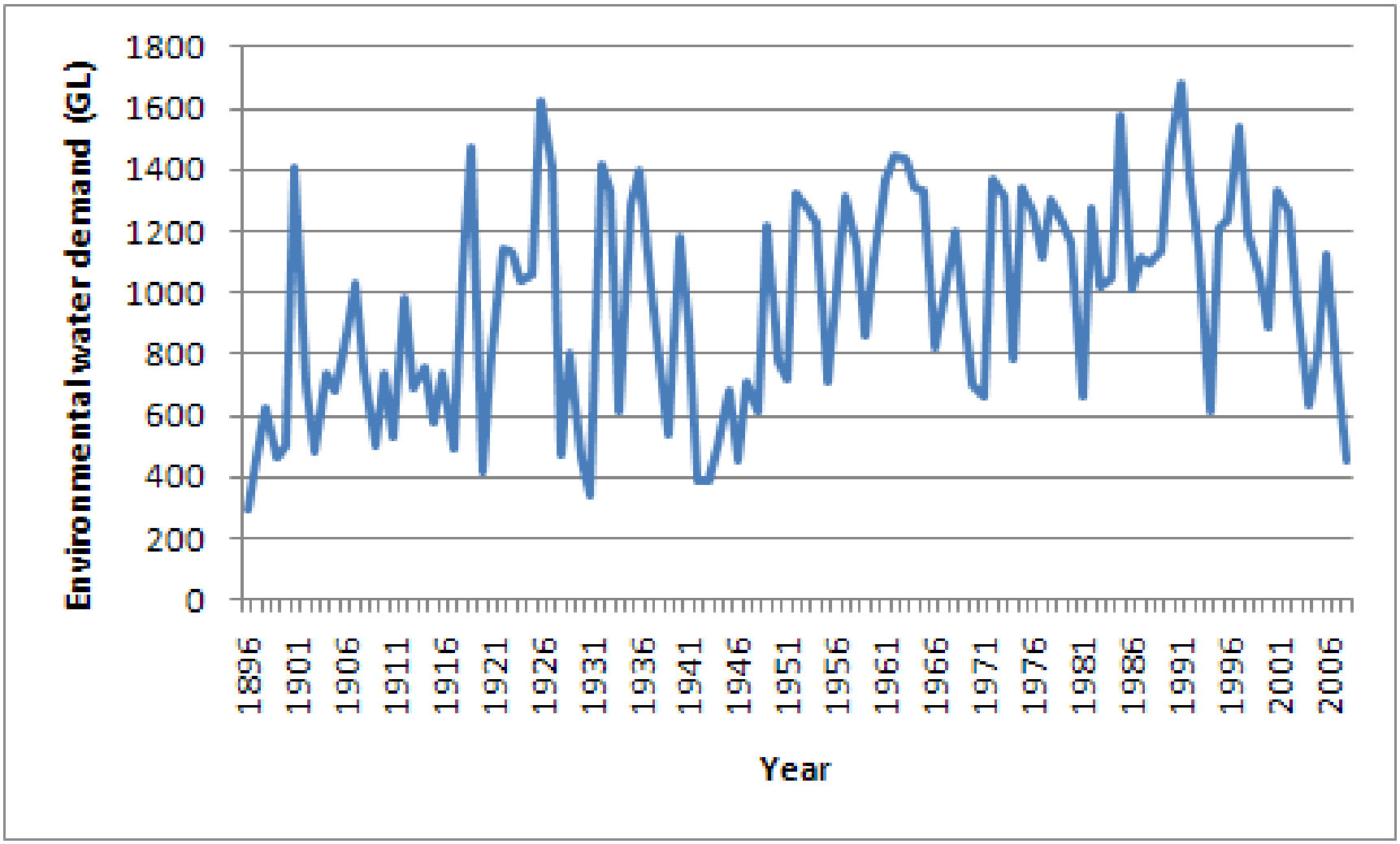
(Connor et al., 2011)

- Minimize environmental damage

  = exponent (desired – achieved frequency)



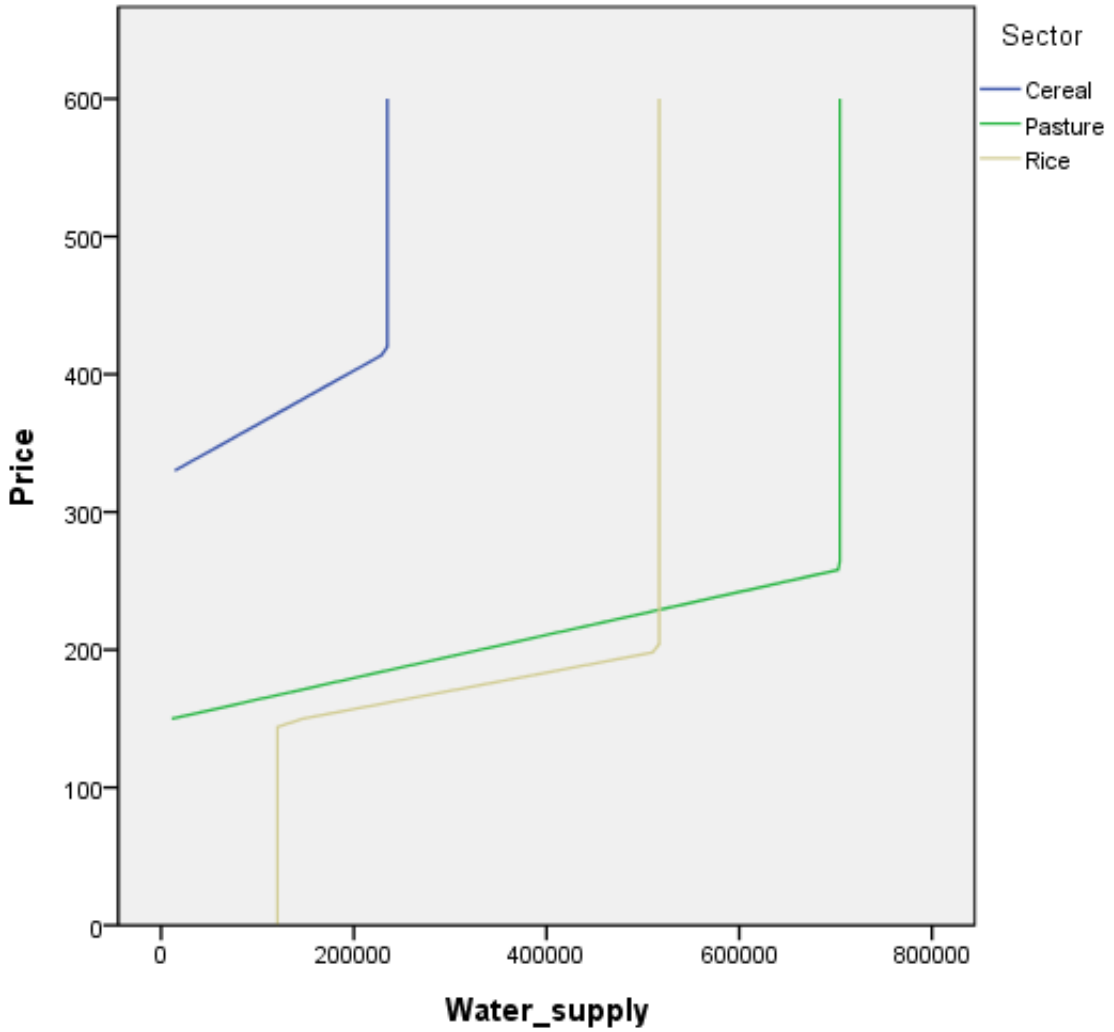
Environmental Water Holder objective



Irrigators' water supply model

•Agriculture sector model used to developed supply functions for three sectors (rice, cereal and pasture)

Water supply functions



Irrigators bidding strategy

Step 1: Construction of supply function

$$Q_i = a_i^0 + b_{1,i}^0 P + b_{2,i}^0 P^2$$

Step 2: Construction of bid supply function

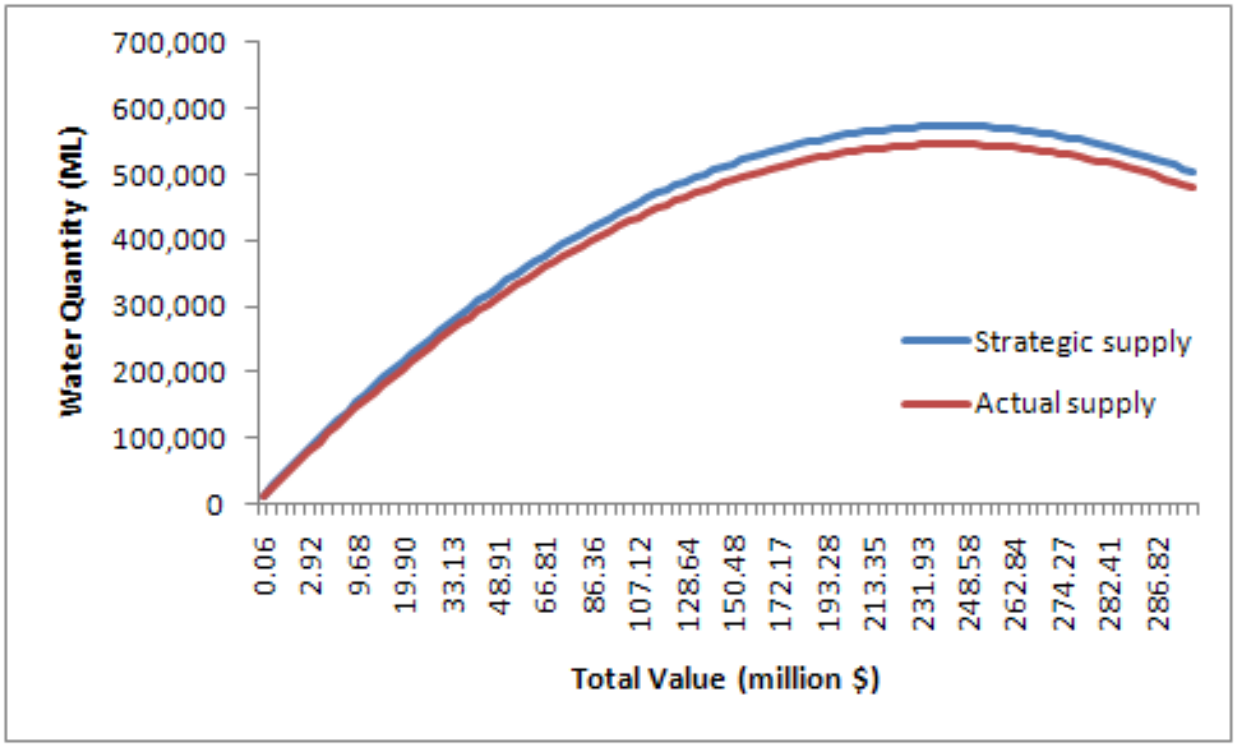
$$B(Q)_i = a_i^0 + (b_{1,i}^0 \pm b_{1,i}^0 \times r1)\, P + (b_{2,i}^0 \pm b_{2,i}^0 \times r2) \quad P^2$$

Irrigators bidding strategy

- Two dimensions of selling strategies: r1 and r2
- Choices are discretized into ten steps
- This produces bid curves with varying levels of rent seeking

Irrigators bidding strategy

Example, a choice of (+5%, +5%) for rice sector



Irrigators learning model

•Bidders should progressively explore different combinations of r1 and r2 and retain the best values

•Reinforcement based learning model is used for bidders learning (frequently used in electricity auction market, multi-unit auctions)

Irrigators learning model

$$q_i^{r1}(t+1) = (1-\varphi)q_i^{r1}(t) + E_c(r1,R)$$

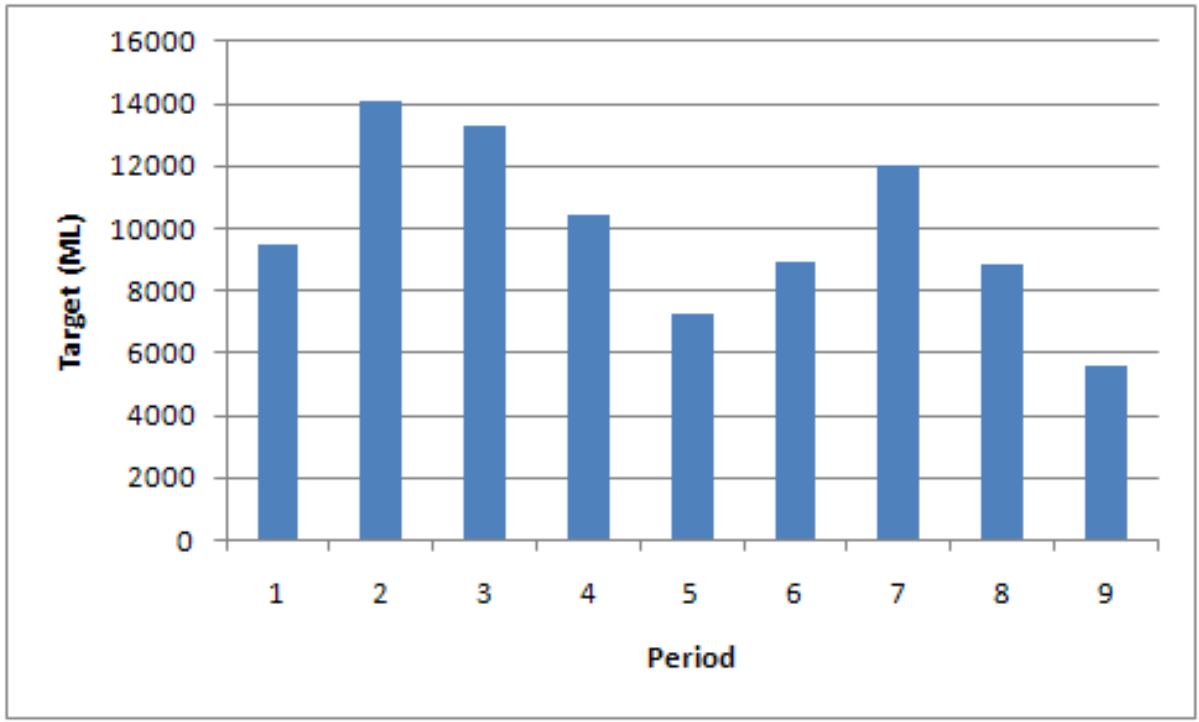
$$E_c(r1,R) = \begin{cases} R(1-\varepsilon) & if\ r1 = c \\ R\left(\frac{\varepsilon}{n}\right) & if\ (r1) is\ neighbouring\ strategy\ of\ (c) \\ 0 & otherwise \end{cases}$$

$$p_i^c(t) = \frac{q_i^c(t)}{\sum_{r1} q_i^{r1}(t)}$$

ϕ is the recency parameter, R is the reward from previous choice, ε is an experimentation parameter and n is the number of neighbours of strategy

A stylized example

- Modelled for environmental demand for 9 periods

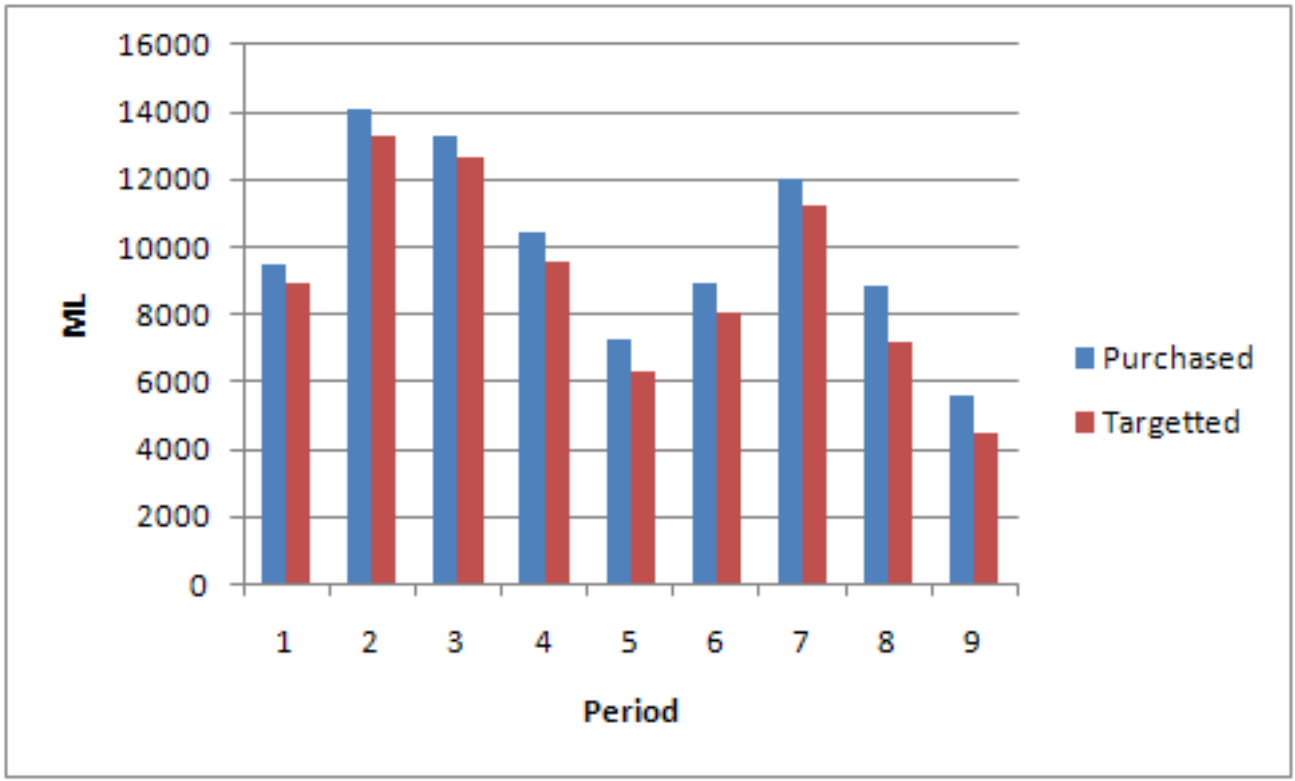


Example (ctd..)

- Only three agents (rice, cereal and pasture)
- Iterative auctions: 50 rounds for each period, 100 replications
- Baseline auctions: 1 round for each period, 5000 replications

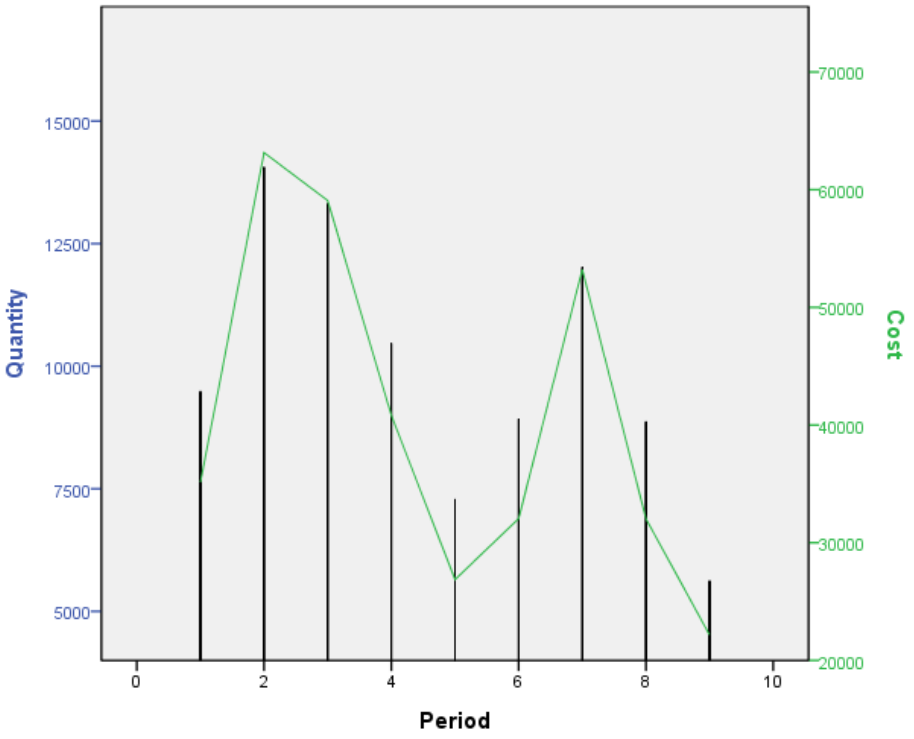
Model results

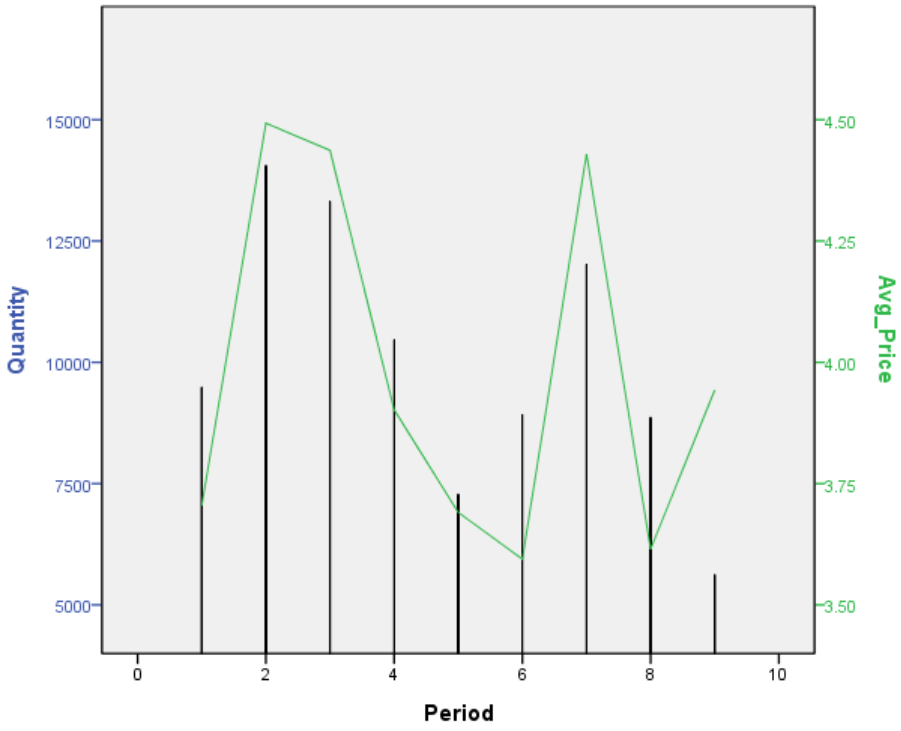
For iterative auction



Model results

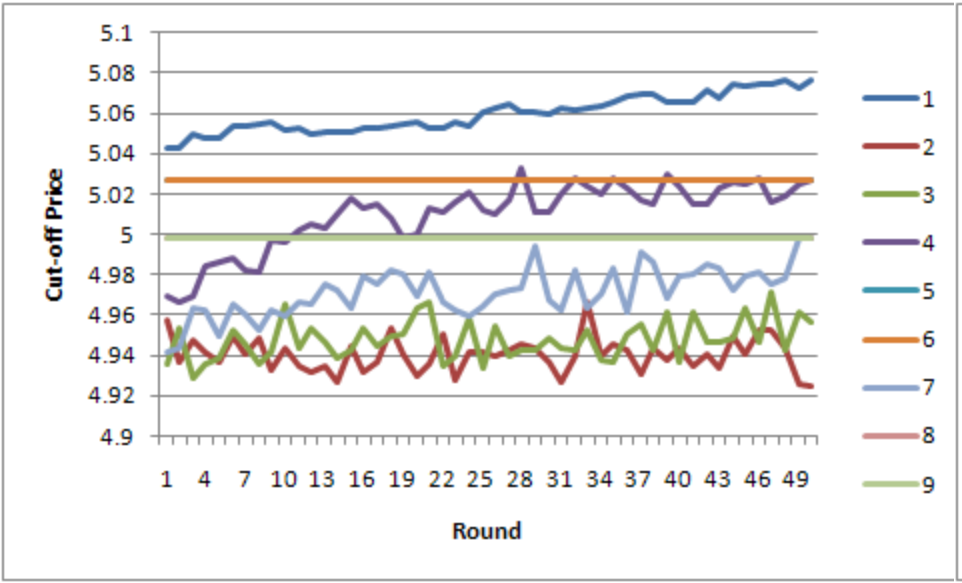
For iterative auction

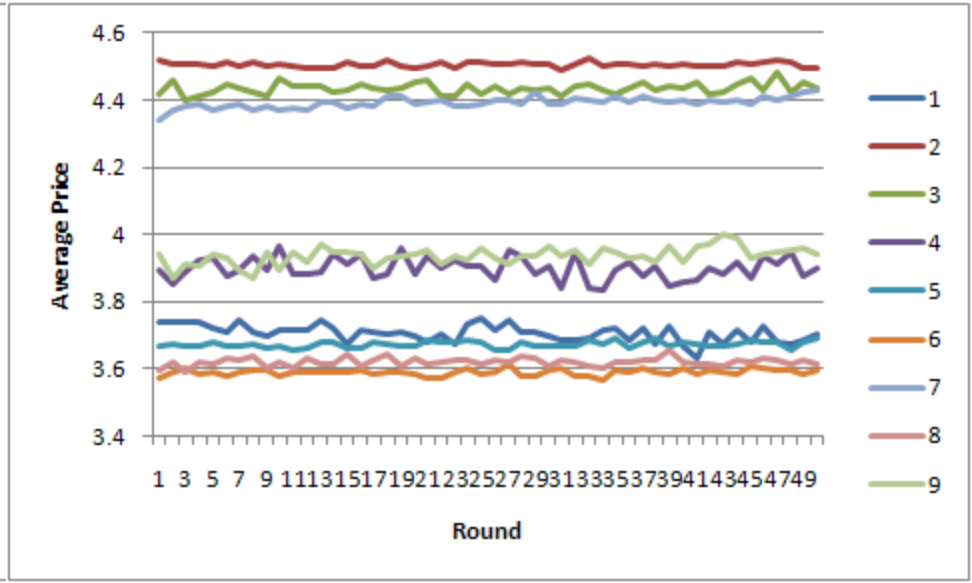




Model results

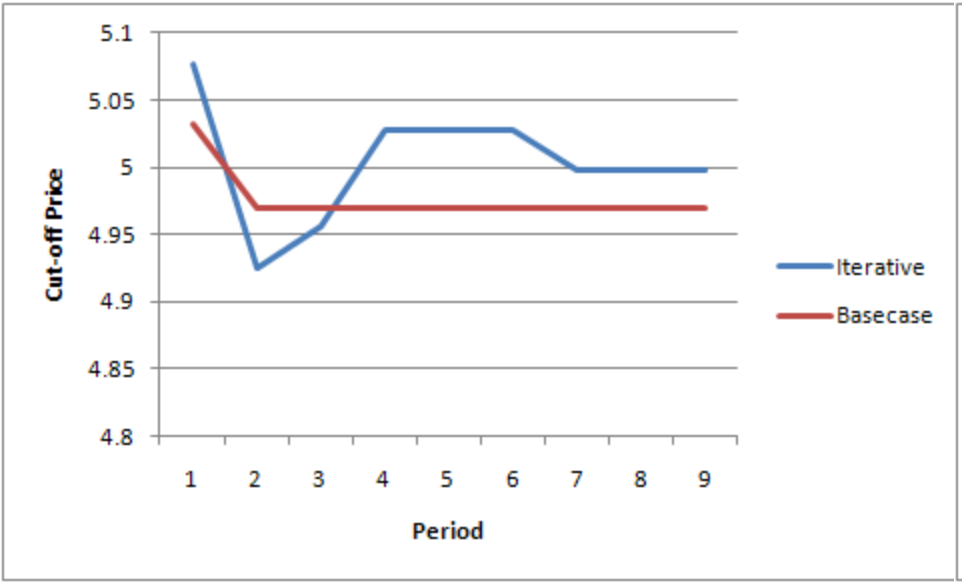
Effect of learning

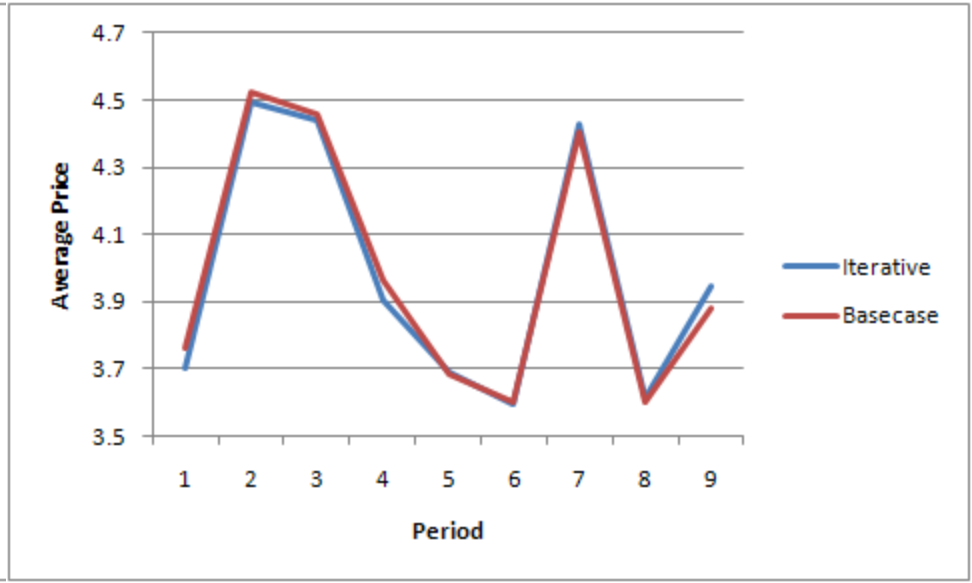




Model results

Comparison with baseline





Future work

- Further development of linkages between sector and agent based models
- Improve representation of irrigators' supply functions and heterogeneity of supply
- Varying the objective functions of environmental trader
- Varying the budget constraints
- Varying risk preference sets, learning and strategic behaviour

Future work

- To determine the relative market power of irrigators and environmental water traders
- To test effectiveness of auction designs to lead to equitable outcome

Thanks