Simulating institutional dynamics in the context of water in outback Australia

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Water availability in outback Australia is event driven and flips often from a situation of scarcity to a temporary abundance. Informal institutions are often able to translate such dynamics in sustainable user rules. Policy interventions are mainly focused on changing access rules to avoid over use or inefficiencies. Ripple effects of such formal institutional changes can lead to unexpected unsustainable outcomes; outcomes that are often captured in the 'story' behind informal arrangements.

This paper analyses one case study on water access in outback Australia and translates field work results into an agent based model. In order to project ripple effects of institutional changes interventions in water access is assumed in an applied context. Core focus of the modelling exercise is the treatment of newcomers on a newly created trading scheme for water access rights. Simulations compare different options and how perceived risk of existing irrigators might change.

JEL:

Keywords:

- What are institutions?
- What are institutional ripple effects?
- Why simulation modelling?
- How can simulation models capture institutional change those ripple effects are based on?

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- How does a model look like for an applied context (generally in 2 words)?
- What is the context?
- Explain the model
- Show results and point out how interventions lead to institutional ripple effects

1 Introduction

The fundamental characteristic of a social system is a development of shared concepts. Those shared concepts constrain behaviour of individuals through formal and informal rules and set of norms. The rules and norms developed within the social system are defined in the theoretical discussion as *institutional arrangements* (Dietz et al. 2003). In other words, institutions are "the shared concepts used by humans in repetitive situations organized by rules, norms, and strategies" (Ostrom 1999).

Fundamental frame of institutional arrangements are property rights, especially in the context of constraining access to natural resources like water. Property “is a claim to a benefit or income stream, and a property right is a claim to a benefit stream that some higher body – usually the state – will agree to protect through the assignment of duty to others who may covet, or somehow interfere with the benefit stream” (Bromley 1992: 4). Property rights can therefore be defined as the individual components of relationships comprising institutions (Brunckhorst and Marshall 2006).

Agrawal (2002) argues that institutions have to be analysed within their context, as the same rule can have different impacts in different contexts. This paper argues that changing an institution changes the context. By changing the context even long-existing institutions can change their impact and lead to a different outcome. Therefore, institutional change modifies context and change in context has the potential to trigger unintended ripple effects. Institutional ripple effects describe changes in the effectiveness of institutions that existed before a new institution was introduced (Smajgl and Larson 2006). This leads to two important research questions: First, how the understanding of institutional dynamics can be improved (Smajgl and Larson 2006) and, secondly, how such dynamics and their impacts can be simulated. This paper is focused on the capacity to simulate institutional dynamics.

2 Simulation needs

Simulation models allow testing perturbations of real world systems without risking negative effects of real-world experiments. In the institutional context simulation models could provide the capacity to test net impacts of institutional changes. This would require realistic assumptions on how a new institution impacts other system components, including other existing institutions.

Additionally, even simplified models have the capacity to identify pattern of interaction between two or more variables. If this interaction is located in the institutional domain behavioural response functions with respect to new institutional constraints become most relevant.

This leads to the question about what links institutions. This could allow enhancing the ability of simulating institutional dynamics and institutional ripple effects. It also points out that in the context of applied

research behavioural characteristics of individuals that form a group have to be identified. This paper applied a sequence of field experiments in order to identify behavioural changes under different institutional arrangements. The context is water access rights in the Katherine region of Northern Territories, Australia. Before the model is developed and the approach to employ field experiments for model calibration purposes is explained the case study region is described.

3 Water access in the Katherine region

The Katherine region … (Straton et al. 2006)

4 Model description

Core element of the agent-based model is the bidding behaviour of horticultural agents. The sequence consists of four major steps. Firstly, agents calculate the difference between actual water requirements on a weekly base and get therefore distinguished between those agents that potentially place a bid to sell or to buy water access rights.

Secondly, potential sellers calculate their bid regarding quantity and price based on their marginal value of water and an expectation-based mark-up. This mark-up is calibrated from experimental data as described in the following section. As this model simulates a double call market structure potential buyers pick randomly one offer and compare the requested price with their marginal value. If the marginal value is higher they buy the water. The randomness of access approximates the system as planned, where water rights holders can place bids in an online and others can immediately buy. This means a first-come first-serve situation

has to be mimicked. The random loop is closed when all potential buyers perceived all bids on offer.

In a third step, water rights get updated and water can be applied to crops, which feeds into the dynamic productivity function of crops. The production is measured in number of trays and depends on labour and water as main input factors. The timing of watering is crucial because if early flowering of Mango trees coincides with less –than-average or late rain amounts of water pumped increases significantly. Explain prod fnct.

The fourth step in this sequence defines the learning, which is modelled as a fictitious play (Fudenberg and Levine 1998). Reinforcement learning limits simulated cognitive processes to individual strategies and their payoffs and imitation simplifies adaptation processes in an overly rationale way. In order to capture realistic changes in land-use decisions resulting from the introduction of a water rights trading scheme two elements had to be simulated: (1) The ability of agents to observe other agents strategy choice and (2) to add those observations to own considerations and physical, financial and knowledge constraints. Explain fictitious play learning.

This core cycle of four steps of decision making of land managers regarding their water use, bidding behaviour and crop choice, is embedded in a simulation of the broader system. Firstly, the restrictions of the overall use are crucial for the need to trade water access rights. These restrictions are based as in reality on a hydrological model of the Tindall aquifer and the Daly River that is used by the Department of Natural Resources, Energy, Mines, and Arts. In order to keep at least 80% of the flow of the Daly River, the use of the Tindall as its recharge aquifer is restricted accordingly. Rainfall amount and timing are compared with flowering time of Mango trees in the Katherine region and the potential amount of pumping is compared with the 80% mark.

Based on these calculations restrictions are calculated for each month. Important for the model simulations is the aim to compare policy options for applying restrictions differently or equally to potential newcomers and existing farmers. The restriction is modelled as a multiplier for the monthly allocation. Fnct. for hydrology-based allocation.

5 Experiment-based model calibration

The model parameterisation includes five critical values:

(1) Price of first bid,

(2) bid adaptation process (potential convergence) based on perceived price signals,

(3) farmer's aspirations and goals in order to calibrate motivational drivers for decision making,

(4) farmer's attitude regarding crop change, and

(5) farmer's position in social network in order to calibrate expectation dynamics on prices and management strategies.

As the market for trading water rights does not exist, these five values cannot be based on historic data. Instead, they could be parameterised based either on expert opinion or on historic data from other locations. It is also possible to use both of these options at the same time and weigh data from other location by expert opinion.

The case study this paper is based on uses field experiments (Ward and Straton 2006) in order to parameterise values (1) and (2), and semi-structured interviews for values (3) to (5).

The field experiments were conducted in three sessions, in which XXX horticulturalists from the Tindall aquifer region around Katherine took part. These farmers played individual farms and decided in weekly time steps if a given water allocation was used, sold on the market or if additional water rights were purchased. All farmers had equal opportunity to earn money during these 2-day experiments and earning varied from AU$20 to AU$500. Results allowed comparing how bidding behaviour changed between a closed and an open call market and how information on external effects changed individual strategies. The main purpose was to collate data for the two critical parameters of the model, first bid and bidding adaptation.

As the size of the data base was limited in size econometric techniques like cluster analysis were not employed to generate a typology for the first bid value. Instead, it was assumed that the agents were representative for the region. Based on the bids of these representative farmers types of agents were grouped regarding attributes ‘first bid’ and ‘bidding behaviour’. Explain results (A) first bids & (B) bidding behaviour.

Some agents waited while others started in the first round to buy or sell water rights. The crucial element is that marginal values were shown but most the values for marginal value of water varied according to farm size. Those individuals that placed bids in the first round were clustered according to the difference between their marginal value and their bid. These results are fundamental for the agent-based model because model performance is highly sensitive to prices assumed for first bid.

Secondly, simulated price trajectories result from individual bidding behaviour, which themselves is based on expected market prices. Pure assumptions or data from other contexts might lead to critical mistakes in including these expectations. The link between the field experiments and

the agent-based model are based on the assumption that the sample involved in the experiments is representative for the simulated system. In order to develop a typology for bidding behaviour and the underlying adjustment of price expectations, a cluster analysis was employed to identify groups of individuals with similar bidding dynamics. The cluster analysis is based on the difference between bids of different periods.

Show results here

6 Model simulations

What we need as scenarios is the introduction of a water market (Without and with newcomers). Baseline has to be a situation without water trade. Indicators we have to present on are

1. Water price, area of crop type, water use
2. Risk (we will have to get the perceived risk quantified based on Anna's survey)
3. Attitude (Responsibility???) towards community or water (again Anna's survey for quantification)

The principle idea is that people perceive a responsibility for their behaviour and institutional arrangements offer the constraints not only for their strategy choice but also for how they justify their behaviour within the community. I'd like to show impacts of institutional changes due to the water market on the attitude on farmers (indicator for institutional ripple effect). In a first instance farmers could shift responsibility to the market ("I have no choice, they say use it, trade it or loose it!") and with newcomers ("Well, I always said not to give more permits out!"). As we don't have the water market and the survey was not able to look into these attributes, we will have to find reasonable indicators. Risk and responsibility are good candidates.

APPENDIX 1
MAP

MAP OF KATHERINE REGION WITH TINDALL AQUIFER

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