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Experimental evidence on the relative efficiency of forward contracting and tradable entitlements in water markets

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ABSTRACT

This paper experimentally tests if adding forward trading or tradable entitlements to already commonly used spot trade in water markets improves allocation and production efficiency. We find that forward contracts significantly increase efficiency, while tradable entitlements do not. The advantage of forward contracts increases further after a climate change shock, which reduces the expected total water supply. However, tradable water entitlements are rather more damaging than beneficial. Due to the complexity involved in pricing entitlements they not only fail to increase efficiency, but are often seriously mispriced, which results in concentrated holdings and considerable wealth inequality across market participants.

1. Introduction

Increasing future water scarcity as a consequence of climate change or competition among user groups is recognized as a global risk [1]. Recognition of this risk has led regional governments in countries such as the United States, Spain, Mexico, Chile and Australia to develop and adopt water markets [2] that: facilitate reallocation of scarce resources across competing demands [3], reduce agricultural sector risk and uncertainty in production decisions [4], and minimize productive disruptions during periods of drought [5]. There are some specific properties of the commodity of water and its use in agriculture which have to be taken into account when trading institutions are designed. The three most important are as follows. First the total supply of water varies across time and is not known ex ante. Second, property rights are not naturally assigned. And finally, production decisions (i.e. sowing and decisions on livestock) have to be taken before the total supply for the relevant period is known. These properties imply that an efficient trading system a) assigns property rights conditional on current supply, b) allocates the available water efficiently within a production period, once production decisions have been taken and c) induces efficient production decisions given the uncertainty of water supply. A commonly used market instrument is tradable water allocations. Depending on the total supply of water within a season water is initially allocated according to some entitlement,[1] and can then be traded on a *spot market*. Theoretically, such a setup is sufficient to achieve efficiency if some assumptions hold. If the spot market works efficiently and market power is absent, then annual water supplies will be allocated efficiently conditional on the production decisions taken. Thus, if market participants have enough information and hold rational

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[1] In this case, a water entitlement represents a correlative or mutual relationship right where holders own a share of the total available consumptive pool. This is different to absolute rights, such as those based on seniority, which are based on volume and priority.

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expectations such that they can properly predict water prices for all possible total supply scenarios, they can make efficient production decisions.

If for some reason producers face uncertainty about the ensuing prices for different future rainfall scenarios then additional market institutions have the potential to improve efficiency [6]. The two most appealing mechanisms are: tradeable entitlements akin to permanent property rights, and derivatives such as forward contracts or options. A crop farmer might only want to commit to production (i.e. plant or sow) if she has secured enough future water for irrigation. If entitlements are tradeable (*licenses trade*), then producers who are highly water dependent can mitigate their risk of not being able to secure enough water in the spot market by purchasing additional entitlements ahead of production decisions. Similarly, derivative products (*forward contracts*) enable participants to insure themselves against unfavourable future spot-price movements [7].[2] While it is possible to theoretically evaluate different water market institutions, the results depend on the assumptions made. For an evaluation of the impact of *license trading* and *forward markets*, assumptions regarding rationality and expectation formation by the market participants are particularly important. It is a priori unclear to which extent, and how, deviations from full rationality and rational expectations may influence efficiency under different market institutions. Moreover, given the number of market participants and the complexity of water markets, it is unlikely that all participants always exhibit rational expectations and obey full rationality. This paper therefore uses experimental techniques to evaluate the welfare implications when *tradeable licenses* or *forward contracts* are added to a standard *spot market*.

Our experimental environment captures the most salient elements of agriculture. Farmers live for multiple periods, and survival is stochastic. Production decisions have to be taken before the total supply of water is known. A heterogeneity of production technologies models different crops and different farm sizes and allows for gains from water trade. Finally, we introduce a climate-change shock that reduces the expected amount of water, in order to be able to judge which trading institution best deals with such shocks. Note, however, that our setup is generic. It does not try to closely mimic conditions in any specific region. Instead we are looking for general behavioural regularities. For that reason all results are of a qualitative nature only. The dynamic feature of our environment is crucial for investigating license trade in particular. To our knowledge this paper is the first experimental paper with long-lived farmers who bring forward their tradable water entitlements and bank balances from period to period, and who earn or have to pay interest. This allows us to look at the important long-term implications of license trade. The consequences of water markets and license trading for the long-term efficiency of production and the wealth distribution in the industry can only be assessed in a dynamic experiment.

Besides the obvious policy relevance of our work we also make a methodological contribution. Our setup can be used for other questions where long-term impact of markets, policies or individual decisions is of interest. The underlying model has two main advantages over other models when implementation in the laboratory is a concern. First of all, the equilibrium predictions are time-invariant. For example, dynamic models with finite periods would have declining equilibrium license prices, which make it hard to compare behaviour over periods, and are also known to cause bubbles in asset experiments [8]. The time-invariance in our model not only requires a stochastic stopping rule, but also the modelling trick of including bequests in the farmer's objective function. To our knowledge we are the first to propose such an environment. Secondly, our setup does not require an induced discount rate. Induced discount rates are problematic, as they reduce the money at stake – and therefore the incentives to try hard – for participants in later rounds [9]. We find that adding forward contracts to the spot market significantly increases efficiency, while added license trade does not improve efficiency compared to spot markets alone. If they have an impact at all, then tradable water entitlements are rather more damaging than beneficial. Due to the complexity involved in pricing entitlements, valuations differ largely across market participants which leads to concentration of the entitlements through trade. This both leads to inefficient production decisions and to large wealth inequality. The latter is further exacerbated, since the market is not able to remove mispricing. Further, our finding that forward contracts are a very useful measure to improve efficiency even in an environment where under full rationality spot markets alone could do the job, is highly robust to system shocks. Under forward contracts the adjustment after the climate-change shock works best.

2. Related literature

The most common forms of water market trade involve simple (spot) transfers of temporary water allocations. In some countries more risk-averse farmers are motivated to buy water entitlements from less risk-averse farmers to insure themselves against supply shocks, where in other places complex water right transfer products are evolving to manage water supply-scarcity risk [10]. Complex water trade derivatives may enable farmers to increase earnings and generate additional water transfers at the margin, relative to traditional (spot-market) water transfers [11]. Derivative products include option (futures) and forward contracts that require a buyer to purchase water-rights from a seller at an execution date for a previously agreed price. There is a subtle difference between the two derivative types: once entered into, forward contracts must be fulfilled; whereas with option contracts the buyer (seller) is allowed to forgo the water purchase (sale) before the contract expiration date but the option deposit will forfeit to the seller (buyer) [12]. Ignoring the potential benefits from derivative water trade may place additional and significant future imposts on the public purse [13]. Thus a fuller understanding of water market efficiency outcomes could facilitate improved trading institutions that allow participants to better coordinate their decision making [14].

[2] Following significant legislative evaluation and change forward contracts are being slowly introduced to Australian water markets [36].