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Abstract

Water markets are xpected to lead to efficient use of scarce water by re-allocating water from low value uses to high value uses. However a water allocation system must not only allocate specific volumes of water among users but also allocate the risk of supply shortages. The existence of both a market of water rights and a spot market of water allotments is necessary to allow users to manage better the risk of increased supply uncertainty. Whether the water rights market should be further sophisticated by offering different levels of security for rights is unclear. Indeed, increasing the complexity of water markets can eventually reduce efficiency gains and cost-effectiveness of water trade. We propose an experimental design that captures the main characteristics of water markets. Farmers first participate in the market for water rights while facing uncertainty on water allotments. . Once the water supply is known, they can trade their water allocation on the spot market. We examine two water right scenarios, one with a unique security level and another iwith two levels of security and we compare them in terms of allocation efficiency, risk allocation and cost effectiveness. We vary transactions costs as a treatment variable and elicit risk preferences of subjects. By comparing the performance of the markets in each treatment, we can measure the benefits of having two levels of security for water rights and test whether they are contingent on the characteristics of transaction costs and risk aversion.

JEL Codes: Q25, C91

[*]Professor, Department of Business and Economics, Monash University, Melbourne, Australia, Lata.Gangadharan@Buseco.monash.edu.au

[†]PhD Student, UMR Lameta, Montpellier University, France, marianne.lefebvre@supagro.inra.fr

[‡]Professor, UMR Lameta, Montpellier SupAgro, France, thoyer@supagro.inra.fr

1 Introduction

Water markets are acknowledged to allocate scarce water available efficiently , by moving water from low to high value uses. Although there is now widespread adoption of trading mechanisms to re-allocate water, there is an ongoing debate on how to improve the trading processes. Most of the existing literature has focussed on the issue of transaction costs which reduce efficiency gains [9] and third party impact when trade might affect other users who are not parties in the transaction [10, 11]. However, another important issue deserves attention: what is the role of water markets in the strategy of water users to manage risks of water shortage? The uncertainty of irrigation water supply, due to climatic variations, reduces farmers's benefits because part of their production decisions are made before knowing the water availability for the coming season.This problem is particularly crucial for unregulated river systems where there is no water storage through reservoir dams. But it exists also for regulated systems because the probability of reserve replenisment from one year to another fluctuates increasingly with climatic change. Water markets transform the risk on the availability of the water input into a risk on input prices. Calatrava and Garrido [8] demonstrate theoretically and empirically that allowing farmers to trade water can help to reduce their exposure to risk. However, an efficient risk management system should also enable the reallocation of risk from more risk-averse users to less-risk averse farmers ([6, 22, 14]). Howitt [18] shows that pure spot markets, as well as right markets, have no risk-sharing properties. They cause all the risk to be born by one party.

The co-existence of both a market for water rights and a spot market for water is established in most countries where water can be traded. Farmers can thus obtain water from two sources. They can hold water rights which entitle them to a share of available water each year: for each right held, they get a volume of water, called an allocation[1], which depends on the total water availability in the system for a given season. They can also buy water from the water "spot" market: when water right holders are told what their water allocation is for the year, they can either decide to use it entirely for production, or to sell (buy) excess (missing) quantities on the spot market [3]. Some countries have sophisticated the market by introducing water rights with different levels of security, low security water rights offering less guarantee that water be delivered than high security rights. The expectation is that such differentiated water right system could contribute to improve further the efficiency of water and risk allocation across farmers. However, increasing the complexity of water trading markets could also reduce

[1] In the australian terminology, a water right is an entitlement. It gives the right to an allocation, ie a fraction of the total available water to be issued in the future. An allocation is a volume of water available in a given season.

efficiency. This question is at the heart of a number of water market reforms. Under the riparian right law, as in Chile, Mexico and Australia, water rights are defined as a proportion of stream (or canal) flow or storage ([20]). The level of security is unique and identical for all water rights. If a differentiated system is set-up, the available water is allocated to the high security rights first. The water authority operates its storage so as to guarantee that the high security water rights can be supplied. Once provisions for high security water rights have been made, the remaining volume of water determines the low security allocations. As a result, low security water right owners bear the risk of low water supply. This is the basis of the prior appropriation doctrine, much in use in the Western states of United States: when shortage occurs, priority is given to the most senior rights, those which were historically appropriated first. When a water right is sold, it retains its original appropriation date. The security of a water-right can thus be purchased by buying a senior right on the right market. In Australia, despite the riparian law, the recent water reforms introduced in some States have created a differentiated water right system. Since 1994 in New South Wales and Victoria, farmers can thus constitute a portfolio of water rights of two security levels by trading on the right market. Such reforms are administratively complex and can lead to substantial transaction and learning costs for water users. Before encouraging a wider adoption, it is necessary to better understand whether they can lead to true efficiency gains for water users.

The objective of this paper is to compare the performance of a market with two levels of security for water rights relatively to a market with a unique type of water rights, in terms of allocative efficiency, cost-effectiveness, farmers' profits and profits variability. Field data are limited because water right markets are still thin [2]. Moreover, differences between countries or States in terms of hydrology and socio-economic environment are too important to compare the performance of both systems per-se. This paper therefore uses experimental data. It proposes an experimental design capturing the main characteristics of existing water markets. Subjects first participate in a "share market" (corresponding to the water rights market) without knowing the allocation of "coupons" (corresponding to water allotment) they will get from their shares. In a second stage, they can trade their coupons on the coupon market (corresponding to the spot market for water allocation). The design is noteworthy in two respects. First, it is the first experiment introducing different levels of security for shares. Second, it takes into account the role of transactions costs which are recognized as an important feature of water markets [3, 15]. We use a 2x2 design where the treatment variables are the number of levels of security for shares (1 or 2) and the presence of absence of transaction fees in the share and coupon market. By comparing the performance of the market in each treatment, we can measure the benefits of having two levels of security for water rights and test whether they are contingent on the characteristics of transaction costs and risk aversion. This paper is organized as follows. The second section summarizes the existing literature on the expected benefits of a system with differentiated security rights. The experimental design and corresponding theoretical predictions are presented in the third and fourth sections. The fifth section analyses the experimental results and the last section concludes.

2 Expected advantages of water rights with differentiated security levels

The interests of water trading are well understood theoretically and demonstrated empirically. An increasing number of countries is adopting legislative reforms and necessary technical and administrative adjustments to allow water users to buy and sell water on a market. Most of them have also engaged into the creation - or the enhancement - of water right markets, for example through the formal separation of water rights from land rights, mainly to facilitate real structural change within the irrigation industry. Since water rights are a permanent entitlement providing access to a share of water from a uncertain-sized consumptive pool, they are considered as an asset. Freebairn and Quiggin rightly remind in their 2006 article on water rights that if the water market was perfectly competitive and transaction-cost free, and if water users are risk-neutral, then trading on the spot market is sufficient to reach an efficient allocation of water amongst users [15]. Therefore, in theory, trading on the water right market should not occur since all water users have the same expected value for water rights (expected value of the corresponding allocation on the spot market which is the same for all since there is a unique expected price for water) and thus display the same willingness to pay for rights. Under these assumptions, demand and supply of water rights can only be driven by long term speculation (related to the uncertainty on the level of future water supply) or saving motives (ref). This effect has been experimentally confirmed by Godby et al [17] who designed a market experiment mimicking the canadian emissions trading market, including both a share and a coupon markets. A coupon gives permission to discharge a unit quantity of waste. A share represents an entitlement to a specified fraction of the total available coupons to be issued in future periods. The share market corresponds to a market for ex-ante contracts. The coupon market is equivalent to the spot market. In a world of complete and perfect contingent future markets in coupons, share would be redundant. However, in the practical world of environmental regulation, shares may have some advantages in allowing more secure long term planning for firms acquiring or selling coupons and in providing an explicit method for allocating any future variation in aggregate number of coupons [17].

It is observed that water right trading is slowly picking up [23]. This growing interest of water users for the water right market reveal that trading water rights becomes strategic. Both transaction costs and risk attitudes can explain the willingness to trade in the rights market.

Firstly, it is well documented that water trading imposes transaction costs which are non negligible both for buyers and sellers: the need to find an eligible trading partner at the rigt time, despite the existence of trade-facilitating solutions such as electronic market places or brokers can be costly ([2]). Freebairn and Quiggin [15] thus argue that the existence of a market for water rights can improve the cost-effectiveness of water allocation by allowing water users to hold water rights which match better their water needs, thus reducing trade on the spot market and corresponding transaction costs. Farmers who are regular buyers on the spot market might find more profitable to increase the quantity of water rights they hold to limit their demand for spot market water and therefore reduce their exposure to transaction costs. Farmers who are regular sellers on the spot market will do the contrary. A system of differentiated security rights allows to sophisticate the portfolio of rights held, therefore improving the matching with water needs under each climatic scenario. Freebairn and Quiggin result is nevertheless controversial because it relies on the assumption that transaction costs on the spot market are greater than transaction costs on the water right market. Australian markets seem to display greater transaction costs on the latter [7]. Differential tax treatment and the administrative complexity and costs associated with markets for water righits are significant factors which drive the preference for spot markets [2]. If water rights' trading is costly, the costs may offset the gains from a portfolio of rights matching water needs (and thus limiting the need to trade in the spot market).

Secondly, farmers are not risk neutral and their willingness to manage risk also explains their interest for water rights. Interviews with farmers indicate that uncertainty on water allocation motivates farmers to hold more rights than necessary [7]. Water markets contribute to reduce the risk born by farmers by converting a quantity risk into a price risk [8], but they fail to share the remaining risk efficiently. As underlined by Quiggin in [12], "the quest to eliminate uncertainty is futile but uncertainty can be managed, allocated and sometimes mitigated". Howitt [18]shows that pure spot markets, as well as right markets, have no risk-sharing properties. They cause all the risk to be born by one party. "On the spot market , the buyer bears all the risk as it has no fall-back source of supply. He bears both the uncertainty of supply in the spot market and the uncertainty on the resulting water price. On the water rights market, the seller bears the burden of correctly valuing the current worth of future water". The principle of risk allocation (or risk sharing) is that risk should be allocated to the party best able to manage or accept it. In principle, this can be achieved through risk-sharing contracts such as options on the spot market or conditional leases of water: risk-averse users could then trade-off lower expected gains for lower variability of gains with more risk-tolerant users, willing to support a greater share of water variability. According to Bjornlund [5], in Australian water market, the risk differential between high value water users (mainly perenial crops) and producers of annual crops should be sufficiently large to enable sophisticated risk-sharing instruments to operate. Water rights with different levels of security can mimic these risk sharing contracts[2]. The agents willing to reduce their risk will pay more to buy secure water rights. The agents willing to bear risk can buy cheaper and less secure rights. Resource security being a zero-sum commodity, the more security is given to a group of users, the less there is for everybody else (Quiggin in [12]).

A differentiated system displays thus two major advantages, compared to a single security system, but it significantly complexifies both the market management task and the trading decisions of buyers and sellers. The water administration will have to define the efficient mix of entitlements (ratio between high and low security rights) in order to adjust best to farmers' preferences, under the constraint that the security levels can be respected [19, 21][3].

Farmers must also be able to understand and to reap the benefits of such system. Overall, the benefits of water rights differentiation will depend on users' participation to the water rights market. Transaction costs on the water rights market (relatively to the spot market) and the heterogeneity in water users' willingness to bear risk are two essential drivers of participation in the water rights market. But higher profits

[2]Australian National Water Initiative (2004) contains a set of risk assignment provisions that were intended to give entitlement holders greater certainty over who would bear the risks of future reductions in the quantity and security of water allocations. The risk of changes in the aggregate availability of water due to new knowledge about the hydrological capacity of the system are born by users, whereas the risk of reductions in water availability arising from changes in public policy will be born by the public, and water users will receive compensation for such reductions. Our approach is different as we study the possibility of sharing actual risk (vs future change) among agricultural users (vs between users and government). In our setting, compensation for higher risk is included in lower market prices for water rights of low security, and "financed" by the higher market prices for high security rights.

[3]The actual mix is a consequence of historical allocation of rights and "sales water", where sales water was the excess water available in storage. It was made available to farmers, in proportion of their entitlements. During unbundling reform in 1994, sales water was converted into low security entitlements. In the recent years, State and Federal governments have buy-back water entitlements to return water systems to environmentally sustainable levels of extractions (implementation of the National Water Initiative of 2004). Governments need to select a suite of entitlements likely to deliver the required volume for the environment at the required time. A secondary objective could also be to take care that the remaining entitlements suit farmers' preferences in term of security. Of course, the more high security entitlements are bought-back, the higher the cost for the government.

and improved risk allocation can be only obtained if agents are capable to constitute the best portfolio of rights (minimizing need for trade). The next section describes the experimental design implemented to measure if such benefits are observed in the laboratory.

3 Experimental design

Our experimental design captures the main characteristics of mature water markets where agricultural users participate both in the rights market and spot market[4]. A subject can decide to modify the quantity and security of water rights he holds by trading in the right market. Water rights give a right to a share of the available water, wich varies stochastically (with a known distribution) and water allocated can be traded on the spot market. The design precludes trading motives associated to long-term strategies such as savings and speculation on the future value of water rights. It enables to observe trading strategies associated with the need to reduce transaction costs and manage risk better, and to compare them for a general security right system and for a differentiated right system.. The objective is to measure the gap between observed market equilibria and theoretical equilibria and, if any, analyse how and why individual trading strategies are different from predictions. The results will help to confirm whether a differentiated right system can contribute to improve resource allocation efficiency.

Terminology

To prevent their prior attitudes about environmental policy from influencing their behavior, subjects are not told they will be trading water. We use a neutral terminology in the experiment where water rights are called "shares" and allocations are called "coupons". A share represents an entitlement to a specified fraction of the total available coupons to be issued. Shares A are shares with high level of security and shares B are low security shares. When only one level of security of shares is available, the shares are simply called "shares". In the paper, we'll use the general term "goods" to mention both shares and coupons. The different goods are linked: shares are converted into coupons after the share trading stage according to the draw of a scenario. Coupons are converted into experimental monetary units (ECU) at the end of a period according to a benefit function. The scenarios are a simplified representation of the climatic

[4] No existing experiment on water markets consider both markets. Cristi and Alevy (2009) and Garrido (2007) only focus on the spot market. Hansen and al (2007) experiment includes the spot market and an option market but no rights market.

variability. A wet season is described by “blue scenario” whereas a dry season is called “yellow scenario”. Both scenario are equally likely. The blue scenario was drawn in periods 1,2,5,7,8 and 12 and the yellow scenario in 3,4,6,9,10,11. The distribution of scenarios is equal for all treatments and sessions (drawn in advance).

Game structure

Figure 1 represents the game structure. All subjects start stage 1 of each period with an equal number of shares they are given for free (table 1) and an equal initial endowment of 50 ECU. They know also the probability of occurrence of both scenarios and the number of coupons obtained from shares in each scenario (table 2). In stage 1, they can choose to modify the number of shares they hold by buying and selling in the share market. In stage 2, a random draw selects the scenario (blue or yellow). Subjects then know the number of coupons they get from their shares. Then can then trade coupons in the coupon market: they can either hold back their coupons, or sell them or buy more, provided they have sufficient ECU to do so. At the end of stage 2, gains of subjects are calculated: it is the sum of ECU they hold after the trading stages plus the value in ECU of their coupons. They start next period with the initial number of shares and initial cash (no banking).

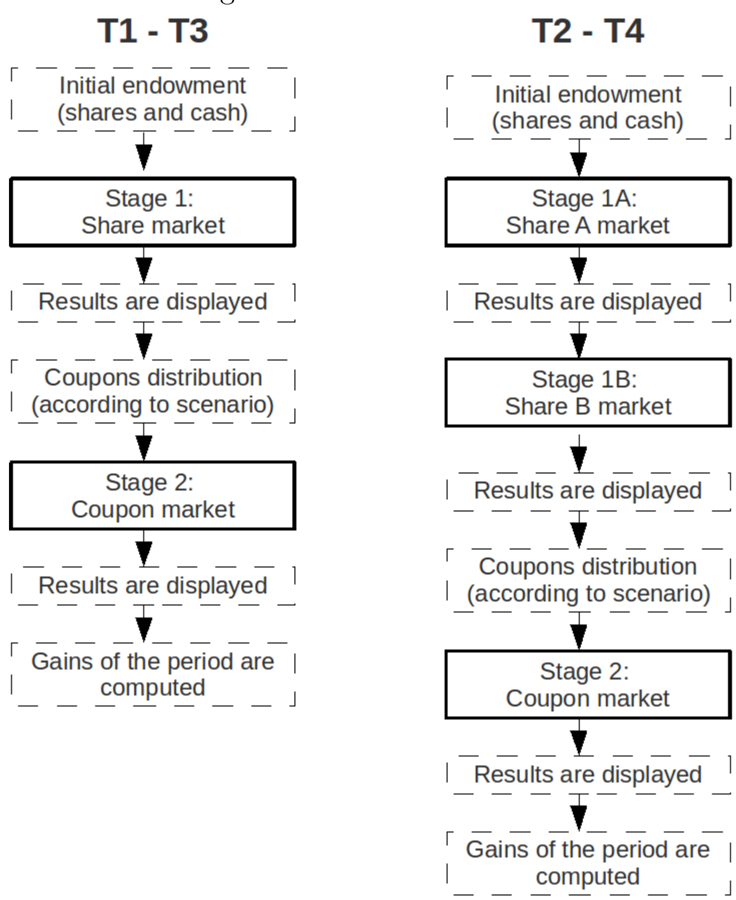
	Number of shares
General security share	9
High security share	3
Low security share	12

Table 1: Initial endowment of shares per subject

	Blue scenario	Yellow scenario
General security share	1	0.33
High security share (A)	1	1
Low security share (B)	0.5	0

Table 2: Number of coupons received per share

Figure 1: Game structure



Trading mechanism

Subjects trade within a group of 6 participants, constant along the all experimental session. The share and coupon markets are organized as a continuous double auction (CDA)[5]. Subjects can place their bids to buy extra goods, and/or offers to sell their goods. All these strategies -namely purchase, sell and keep- can be pursued simultaneously, letting the market equilibrium price allocate the goods to the most efficient use. Each trading stage is open for 2 minutes.

Treatments

We use a 2x2 factorial design with 6 observations per cell to achieve the maximum information from our experimental budget (table 3). The treatment variables are the number of levels of security for shares (1 or 2) and the presence of absence of transaction fees in the share and coupon market. TFc stands for transaction fees in the coupon market and TFs transaction fees in the share market. Each subject participates in one of four treatments (between subject design).

	One level of security	Two levels of security
TFc=2 TFs=0	Treatment 1(T1)	Treatment 2(T2)
TFc=0 TFs=2	Treatment 3(T3)	Treatment 4(T4)

Table 3: Treatments

The first treatment dimension is the number of security levels. In treatment 1 and 3, there is only one type of shares called "general security shares". In the two levels of security treatment (treatment 2 and 4), high security and low security shares are traded sequentially, with the high security shares being traded first[6].

[5]This system is similar to the on-line electronic trading system that are used by farmers to trade water. In Australia, Watermove, Murray irrigation Exchange, Water Exchange, Water find ... offer platforms that act as electronic clearing houses for water rights and spot trades where farmers post buy or sell bids for particular zone, which are then matched in ascending order for sellers and descending order for buyers to clear the market (Brooks and Harris (2008)). Most of these platforms work on the basis of posted sell and buy bids (a part from the largest (Watermove) where a pool price is calculated weekly) (Productivity Commission (2010)). We choose a CDA because multiple trading opportunities are important in experimental markets to generate increases in efficiency (Cason and Friedman (2008)).

[6]In the Australian context, both markets operate simultaneously but the high security market tends to be the most active. Traders try to buy high security water rights to secure a minimum water allocation (the minimum requirement in dry years), and then eventually buy low security shares. Theoretically, the order of the two markets will not impact the equilibrium of both markets. Experimentally, some order effect may be observed. To limit the number of treatments, we stick to empirical reality and we choose to run the experiment with the high security share market first then the low security market.

The second treatment dimension is the transaction fees. There is empirical evidence of significant transaction costs in water markets (Carrey and al (2002), Allen Consulting group (2006)). Freebairn and Quiggin (2006) suggest that spot trading is likely to be associated with larger transaction costs, and thus will be less efficient than water rights trades over the long term. They show under this assumption that differentiated markets for rights improves the efficiency and cost-effectiveness of water allocation. This treatment with transaction costs in the coupon market only is not empirically relevant. Nevertheless, it is necessary as a baseline because the benefits from having two types of shares are theoretically higher in this case (treatment 1 and 2). Alternatively, Brennan (2006) suggests that the financial and administrative costs of spot trade are small. Field interviews we have conducted in Northern Victoria (Australia) largely provide evidence of higher transaction costs on the water rights market. If there is quasi no transaction fees to trade in the spot market and positive transaction fees in the share market (treatment 3 and 4), as observed in the fields, no trade should happen in the share market, differentiated shares yielding therefore less benefits.(see theoretical predictions for more details). The transaction fee $TF_{s,c}$ are set to two ECUs per coupon traded for both the buyer and the seller in T1 and T2 and two ECUs per share traded for both the buyer and the seller in T3 and T4[7]. We could have run complementary treatments with no transaction fees at all ($TF_s = TF_c = 0$) or equal transaction fees in both markets ($TF_s = TF_c = 2$) but these treatments are theoretically equivalent to T3 and T4. Indeed, there is no gains from share trading if trading in the coupon market is not costly, or if it's not more costly than trading shares. The justification of the treatments will appear more clearly in the section with the theoretical predictions.

Subject types

We have two types of subjects. The only difference between types if the the marginal benefits from each coupon (table 4). In the lab, we can induce participants' preferences in order to mimic field water users. Type 1's marginal benefits mimic a mixed crop producer, with relatively low value of water and elastic water demand. Parameters are

[7]Reported to the market price, this fee is high compare to the fees in water trading platforms. We set a high monetary transaction fee to capture all the transaction costs born by farmers in the field that cannot be captured in the lab. Costs of writing contracts, search cost of locating and identifying trading partners ... are time consuming but not necessarily financially costly. In the field, buyer and seller don't pay the same transaction fee to participate in the water market but theoretically, the burden of the fee is shared between the buyer and the seller so we set them equal in the experiment. Moreover, transaction costs on the water rights market are higher than on the spot market for allocation. However, the purchase of water entitlements is amortized over several years. In the experiment we set the transaction fee equal for coupons and shares for simplicity, having in mind that the annualized transaction costs for rights may not be much higher than the annual transaction costs for allocation trading.

chosen so that type 1 does not use water in the dry scenario at equilibrium: because water is too expensive compared to the low value of his crops, type 1 is better off selling water than using it. On the contrary, farmers with high-value crops such as orchards or vineyard are highly sensitive to reductions of water volumes available. They need a minimum quantity of irrigation water to protect the long term productivity of their plantations. For example, horticulturist are prepared to pay very high prices for water during dry periods to limit potential "catastrophic losses" to perennial planting caused by insufficient irrigation[8]. Type 2 represents this type of farmer, with high marginal value of water, rather inelastic water demand, and a minimum water requirement. The first 3 coupons have no value for Type 2 because they are insufficient to ensure production, but the fourth unit yields a high marginal value.

Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	>=16
Type 1	10	9	8	7	6	5	4	3	2	1	0	0	0	0	0	0
Type 2	0	0	0	24	22	20	18	16	14	12	10	8	6	4	2	0

Table 4: Marginal benefit (in ECUs) for coupons held at the end of a period

Experimental procedure

The experiment was conducted at LEMM (University of Montpellier) in september 2010. We conducted two sessions of each of the four treatment, with 18 participants per session, for a total of 144 participants. Each session lasted 3 hours. Each session was conducted in the following manner. We first ask subjects to participate in a lottery game (a slightly modified Holt and Laury lottery game, described in Gangadharan and Nemes [16]) in order to control for risk aversion of individual subject[9]. Subjects were

[8] For Brennan (2006), the risk of losses to perennial plantings has not been so far a driver of water markets. Indeed, the market prices observed are lower than the gross margin of horticulturist. The situation where they are willing to pay water at a very high price has not happened yet because "long-term equilibrium between capital investment decisions and dam reservoir yields ensure than investments in perennial agriculture are secure from catastrophe". In our experiment, the equilibrium of the coupon market in the dry scenario is such that type 2 holds the minimum 4 coupons. This means that type 2 is not at threat of catastrophic losses at equilibrium. A "catastrophic loss" will happen if he had less than 4 coupons.

[9] Participants had to indicate their preferences between two options: a safe option that yielded 3.5 Euros with certainty or a risky option. The risky option has a probability of winning 6 Euros changing from 10% in the first lottery to 100% in the 10th lottery or correspondingly the probability of winning 1 Euro changing from 90% in the first lottery to 0% in the 10th lottery. One of the games was played at the end of each session. Subjects received an additional 1, 3.5 or 6 Euros, depending on their choice and the outcome of the lottery game. In order to control for wealth effects, the lottery was played and subjects' gains were only revealed to the subjects at the end of the session.

then invited to read the instructions of the experiment explaining the different stages of the game, the trading software and the monetary incentives. They also filled up a quizz to verify their understanding of the game. Subjects played two practice periods, which did not count toward subjects' earnings, followed by a series of between 9 and 12 periods which could potentially be selected for payment. The practice periods used the same parameters as the rest of the periods. At the end of each session, qualitative and quantitative information were collected in the form of questionnaires from the participants. Subjects were also asked to describe their strategies.

Participants are compensated according to their gains in one period, randomly chosen. Gains in one period are equal to the net revenues from buying and selling the shares and coupons in the markets and the benefits from holding coupons. They get an additional payment for the lottery game. Subjects made an average of 18.50 euros for a 3 hours sessions.

4 Theoretical predictions

In this section, we measure the effect of uncertainty on the decisions of agents to participate in the right and/or the spot market. The two markets differ in the way uncertainty is present: decisions about the number of rights users want to hold must be taken before knowing what the water allocation is. The uncertainty is resolved (the water allocation is known) before the spot market opens. We compute the market equilibria of the two markets. We apply input demand theory under uncertainty to a situation where water input is available from both the spot and the right market. We solve the model for two agents under risk neutrality and risk aversion, with agent i being a type 1 agent and agent j being a type 2 agent. For a market of 6 participants (3 type-1 agents and 3 type-2 agents), the price predictions are the same and the traded quantities simply multiplied by 3. We solve the model by backward induction: the equilibrium of the coupon market is computed first, then the equilibrium on the share market is deduced. In the experiment, the share trading takes place first, followed by the coupon trading, once the scenario is drawn.

A risk neutral agent will choose the number of shares as well as his number of coupons in order to maximize his net expected benefit from coupons and trading.

$$\underset{S_i, c_{i,t}}{Max} \quad \mathrm{E}\left[B(c_i) + pc.\left(W.S_i - c_i\right) - TF_c.\left|W.S_i - c_i\right|\right] + p_S.\left(Q_i - S_i\right) - TF_S.\left|Q_i - S_i\right| \tag{1}$$

Notations

Share

Q_i is the initial allocation of shares to agent i

S_i is the number of shares held at equilibrium

p_S is the equilibrium price of a share

Allocation of coupons

t indexes the scenario (2 scenarios: yellow,blue)

W_t is a stochastic variable that can take two values according to the scenario.

$W_t.S_i$ is the number of coupons received by agent i in the scenario t if he holds S_i shares. This value is known before the openning of the coupon market[10].

Coupon

$c_{i,t}$ is the coupons held by agent i in the scenario t

$B(c_{i,t})$ is the marginal benefit function from coupon with $B'(c_i) = a_i - 2b_i c_i$, $a_i < a_j$ and $b_i < b_j$.

pc_t is the equilibrium price of a coupon.

Transaction fees

TFc is the transaction fee to buy and to sell in the coupon market. TFs is the transaction fee to buy and to sell in the share market.

dc_i is the net position of agent i in the coupon market (1 for a net seller, -1 for a net buyer). ds_i is the net position of agent i in the share market (1 for a net seller, -1 for a net buyer).

[10] We do not model the gradual allocation during the season. We assume that the season is one point in time where farmers know the quantity of water they receive from their water rights and then trade on the allocation market with no uncertainty on quantity. Uncertainty is only before the season, at the time of buying rights. With such an interpretation, we do not study intra seasonal allocation risk management strategies.

Equilibrium in the coupon market

Trading in the coupon market will occur until marginal benefits from coupon, net of transaction fees are equalized between agents. In the presence of TC in the coupon market (treatment 1 and 2), the number of coupons held is increased (decreased) for a net seller (buyer) because he has to pay TC if he sells (buys) in the coupon market (table 5 and 6). Type 1 is a net seller of coupons and type 2 a net buyer at equilibrium because type 1 marginal benefits from coupons are lower. When the scenario is yellow, type 1 does not hold any coupon as the price is too high compare to his marginal benefits from coupons (see proof in Appendix A).

	Blue scenario	Yellow scenario
Coupons held by Type 1 at equilibrium	0	7
Coupons held by Type 2 at equilibrium	6	11
Equilibrium price	13.33	5.33

Table 5: Coupon market equilibrium Treatment 1 and 2

	Blue scenario	Yellow scenario
Coupons held by Type 1 at equilibrium	0	5
Coupons held by Type 2 at equilibrium	6	13
Equilibrium price	12.67	4.67

Table 6: Coupon market equilibrium Treatment 3 and 4

Equilibrium in the share market

The maximum price an agent is willing to pay for a share (to sell a share) is equal to the expectation of the coupon price (net of transaction costs) multiplied by the number of coupons obtained from one share. The marginal benefits of coupons have no impact on the WTP for share because agents can buy more or sell extra coupons in the coupon market.

An agent is willing to buy a share if

$$p_S < E\left[W\left(pc - TF_c.dc_i\right)\right] + TF_S.ds_i \tag{2}$$

An agent is willing to sell a share if

$$p_S > E\left[W\left(pc - TF_c.dc_i\right)\right] + TF_S.ds_i \tag{3}$$

In the absence of transaction fees in the coupon market (treatment 3 and 4), under rational expectation and risk neutrality hypothesis, the expected value of a share is equal for all agents. As a result, no trade should happen in the share market because of the transaction fees in the share market. When there are transaction fees in the coupon market (treatment 1 and 2), there is heterogeneity in the value of a share across subjects if they anticipate they will have a different position in the coupon market. As a result, shares' trading happens at equilibrium in treatment 1 and 2. Type 2 being net buyers in the coupon market, they will be willing to pay more for shares than type 1 subjects. As a result, type 1 will sell shares to type 2.

The equilibrium allocation of shares in treatment 1 and 2 is such that the need of costly trade in the coupon market is minimized (table 7). When only general security shares are avaiilable (treatment 1), the equilibrium number of shares is such that trade of coupons is required only in the yellow scenario. Shares are allocated according to the need of coupons in the blue scenario. Simple calculation show that any other allocation of shares is less efficient as it will require more trade in the coupon market. When two levels of security for shares are available (treatment 2), the experiment is parametrized such that, by constituting an efficient portfolio of shares, no trade is required in the coupon market is both scenarios. High security shares A are bought to cover the need for coupons in the yellow scenario when shares B give no coupons. Low security shares B are bought to complement the allocation from high security shares A in the blue scenario.

The equilibrium price will be equal to the average between the seller's minimum price is willing to sell and the buyer's maximum price is willing to buy.

	Treatment 1	Treatment 2	
	General security	High security	Low security
Shares held by Type 1 at equilibrium	7	0	14
Shares held by Type 2 at equilibrium	11	6	10
Equilibrium price	4.89	9.33	1.33
Equilibrium number of Trades (in a group)	6	9	6

Table 7: Share market equilibrium Treatment 1 and 2

We assume subjects can be risk averse and predict the effect of risk aversion on the behavior in the different markets. Risk aversion and uncertainty on the coupon allocation impact both markets because subjects are less willing to participate in the coupon market, thus it modifies their behaviors in the share market. The number of shares held at equilibrium under risk aversion depends on the anticipation of agents on their position in the coupon market. The equilibrium price in the share market will be higher under risk aversion if subjects all anticipate they will have to buy in the coupon market. On the contrary, if all subjects expect they can speculate and buy extra shares in order to sell part of their allocation in the coupon market, the price of shares will decrease under risk aversion (see appendix B for an intuition of the proof).

From these theoretical prediction, one can draw some hypothesis to be studied with experimental data.

5 Hypotheses

Hypothesis 1: The price of shares is equal to the average of the coupon price (net of transaction costs) multiplied by the number of coupons the share yields[11].

Hypothesis 2: Less trade happens in the share market in T3 and T4 (compare to T1 and T2)

The presence of transaction fees in the coupon market creates an opportunity for share trading in T1 and T2. In T3 and T4, the value of a share is theoretically identical among agents, thus there is no scope for shares trading. Moreover, the transaction fees for share trading in treatment 3 and 4 reenforce the disincentive to trade shares.

Hypothesis 3: There is less trade in the coupon market when there are two levels of security for shares.

This is the argument of Freebairn and Quiggin [15]. With the parameter of the experiment, in T1, the equilibrium number of shares is such that trade is required only in the yellow scenario. When two levels of security for shares are available (T2), the experiment is parametrized such that a perfect mapping of subjects preferences is possible by

[11]In the literature on water markets, Bjornlund and Rossini [4]observe a relation between the price of water rights and the prices of water allocation. The price of rights increases with the price of water allocation. The market for water rights seems to lead the market for allocations in the cyclical movements until January 1997. Since then the market for allocations has been leading the market for water rights, as rational economic behaviour would dictate. The magnitude of the cyclical fluctuations in the allocation market is much higher than it is in the right market.

constituting an efficient portfolio of shares, such that no trade is required in the coupon market in both scenarios (table 8).

	Yellow scenario			Blue scenario		
	Coupons allocated		Trade required	Coupons allocated		Trade required
	Type 1	Type 2		Type 1	Type 2	
T1	rd(7/3)=2	rd(11/3)=4	2	7	11	0
T2	0	6	0	7	11	0

Table 8: Number of coupons allocated and traded for each agent (if the share market is at equilibrium) Treatment 1 and 2

Hypothesis 4: The number of coupons traded is equal in T3 and T4.

Hypothesis 3 is verified only if subjects can constitute an efficient portfolio of shares in order to minimize the need to trade in the coupon market. If hypothesis 2 is verified, there is less trade in the share market in T3 and T4. As a result, more trade of coupons is required to reach the equilibrium allocation of coupons in T3 and T4.

Hypothesis 5: The total profits are higher in T2 than T1. Total profits are equal in T3 and T4.

If hypothesis 3 is verified for T1 and T2, higher profits are due to the cost savings in terms of transaction fees. If hypothesis 4 is verified, such effect does not happen in T3 and T4. The total profits have thus no reason to be different between T3 and T4 (table 9).

		T1	T2	T3	T4
	Average Total Profits (group)	664	676	684	684
Blue scenario	Total Profits (group)	855	855	870	870
	Type1	109	124	109	109
	Type2	176	161	181	181
Yellow scenario	Total Profits (group)	474	498	498	498
	Type1	83	75	88	88
	Type2	75	91	78	78

Table 9: Equilibrium profits

Hypothesis 6: Type 2 (type 1) have less (more) variable gains in the treatment with two levels of security for share (see proof in appendix C). The allocation of risk is thus improved in treatment 2 compare to treatment 1 if type 2 is more risk averse[12].

6 Results

We compare the prices, the quantities traded and the efficiency of all markets in the different treatments. We also analyze the determinants of the number of coupons and shares held by a subject and determine some recurrent trading strategies. We can then validate or invalidate our hypotheses drawn from the theoretical predictions. We conduct conservative, nonparametric Wilcoxon's signed-rank tests with exactly one summary statistic value per group (in order to satisfy the statistical independence required for this kind of a test). These tests are valuable as they require a minimum of statistical assumptions. In addition, we report results from multivariate regression models. The regression models evaluate the contribution of different factors on the decisions made by subjects.

Only part of the statistical analysis is presented here. We will intergrate further analyzis in the future versions.

Rk: We compute all statistics as average of the last 4 periods played in each treatment (periods 6 to 9).

6.1 Aggregate maket performance

We assess market performance under four headings: system efficiency, price convergence and stability and trading volumes.

Efficiency

Efficiency is defined as the actual gains from trade expressed as a percentage of the potential maximum gains. The point of reference is the share and coupon allocation that would minimize transaction costs and maximize profits given the institutions available in each treatments. We find high efficiency ratio (table 10). The efficiency ratio are in

[12]Thanks to randomization, there is no reason for type 2 subjects to be more risk averse than type 1 subjects in the lottery game. Nevertheless, because of their marginal benefit function, type 2 subjects may be less willing to bear risk in the experiment. We want to study the interaction between risk aversion elicited in the lottery game and type. Risk averse behaviors observed in the experiment can be explained by the elicited risk aversion or by the type.

average lower in T1 than T2 and higher in T3 than T4. Pairwise mann witney tests (using one observation per group: the efficiency ratio over periods 6 to 9) between T1 and T2 does not confirm that efficiency is lower in T1 than T2. One cannot reject the hypothesis that efficiency is the same in both treatments (two-tailed p-value =0.24). However, the same mann witney test between T3 and T4 show that one can reject the hypothesis that efficiency is the same when two levels of security for share are available (right-tail p-value =0.02)

We also compare the observed profits to the theoretical profits if subjects don't trade at all[13] (no-trade-efficiency). The no-trade-efficiency ratio are higher than 100%, which indicates that subject achieve to increase their profits by trading in the different markets, even if they don't reach maximum potential gains (efficiency). The no-trade-efficiency ratio are in average lower in T1 than T2 and higher in T3 than T4. . We also run mann-witney tests on no-trade-efficiency ratio (using one observation per group: the average no-trade-efficiency ratio over period 6 to 9). One can reject the hypothesis that no-trade-efficiency is the same when two levels of security for share are available. No-trade-efficiency is lower in T1 than T2 (T1-T2: left-tail p-value =0.004) and higher in T3 than T4 (T3-T4: right-tail p-value =0.02). It suggests that having access to more levels of security for rights, can not only increase theoretical profits, but also efficiency ratio. This is the case in T2 but not in T4, because there are gains from trading shares only in the former treatment.

	T1	T2	T3	T4
Efficiency	94.14	96.95	95.80	91.96
no-trade-efficiency	104.26	109.31	107.60	103.28

Table 10: Efficiency ratio(average over all groups and over all periods 6 to 9)

Price convergence and stability

One measure of the performance of the market institution is the extent to which the prices converge toward the theoretical equilibrium. The continuous double auction is known to have the property that transaction prices and quantities converge over time to the equilibrium. We do not observe convergence over time in both markets. Median prices of coupons and shares are not closer to the equilibrium level at the end of the session than at the beginning. Prices are relatively stable. Median coupons prices are in

[13]Even if agents don't trade at all during the experiment (they keep their their initial allocation of shares and coupons obtained from it), they can reach an efficiency of more than 85% (T1: 89.16%, T2:87.58%, T3:86.62%, T4:86.62%).

average 41% higher than the equilibrium prices in the blue scenario and 10% lower than equilibrium prices in the yellow scenario (average over period 6 to 9). Shares prices are higher than equilibrium prices. Table 11 gives the deviation in ECU of shares prices from equilibrium price[14]. One should try to explain why subjects are willing to pay high prices for shares. According to our theoretical predictions, risk aversion can increase the equilibrium price of shares if all subjects anticipate they will be net buyers in the coupon market.

	T1	T2	T3	T4
General security shares	3.17		6.75	
High security shares		2.29		14.31
Low security shares		0.17		2.88

Table 11: Deviation of shares median price from equilibrium price in ECU (average by treatment over period 6 to 9)

Trading volumes

The efficiency of the different market institutions can be assessed with the number of trades realized compared to the theoretical predictions of the minimum number of trades required to maximize total surplus. There are more trade than required to maximize social surplus in quasi all the markets and scenarios (table 12 and 13)[15]. As a result, transaction fees paid are higher than minimum transaction fees predicted in all treatments (see table 14). Nevertheless, we observe learning as average transaction fees paid by a subject decrease over time in figure 2.

	T1	T2	Prediction	T3	T4	Prediction
General security	8.33		6	5.42		0
High security		6.29	9		4.62	0
Low security		9.08	6		4.00	0

Table 12: Number of shares traded in a group (average over period 6 to 9) and theoretical predictions

[14] One cannot calculate deviation in % as the equilibrium prices of shares in T3 and T4 is nulle

[15] The high security share market is less active than at equilibrium, as well as the coupon market in treatments 3 and 4. This is due to the more than optimal activity in the share market in these treatments.

	T1	Prediction	T2	Prediction	T3	Prediction	T4	Prediction
Blue scenario	2.83	0	3.17	0	9.42	12	5.75	12
Yellow scenario	4.08	6	2.17	0	5.75	12	3.92	12

Table 13: Number of coupons traded in a group (average over period 6 to 9) and theoretical predictions

	T1	T2	T3	T4
Total TF paid	27.66	21.34	21.67	34.50
Theory : Minimum TF	24.00	0.00	0.00	0.00

Table 14: Total transaction fees paid in a group and theoretical prediction

6.2 Share market

Price of shares

Evidence invalidating hypothesis 1: The price of shares is not equal to the average of the coupon price (net of transaction costs) multiplied by the number of coupons the share yields. Price of shares are between 29% and 102% higher than the expected value of a share (table 15).

	T1	T2	T3	T4
General security shares	53.31		17.38	
High security shares		29.88		47.89
Low security shares		30.55		102.44

Table 15: Deviation in percentage of median price of shares from E[median pCoupon.W](average over period 6 to 9)

Number of shares traded

Evidence supporting hypothesis 2: The number of shares traded is higher in T1 than T3 and higher in T2 than T4 (table 12). Mann-Whitney tests (using one observation per group: the mean number of trades hapenning in a group in the share market over periods 6 to 9) reject the null hypothesis of no impact of treatment on quantities traded (T1 compare to T3 (right-tail p-value=0.09) and T2 compare to T4 (right tail p-value=0.07 for high security shares, right tail p-value=0.02 for low security shares)). One cannot reject the hypothesis that trade of shares is significantly higher in treatments with no transaction fees on shares (T1 and T2). In treatments with no gains from trade (T3 and T4), theory predicts no trading activity in the share market.

Figure 2: Average transaction fees paid by a subject

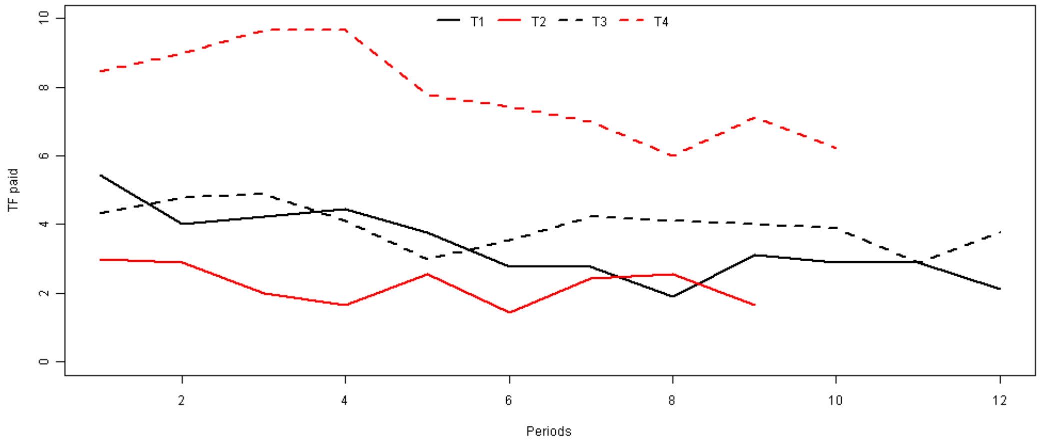
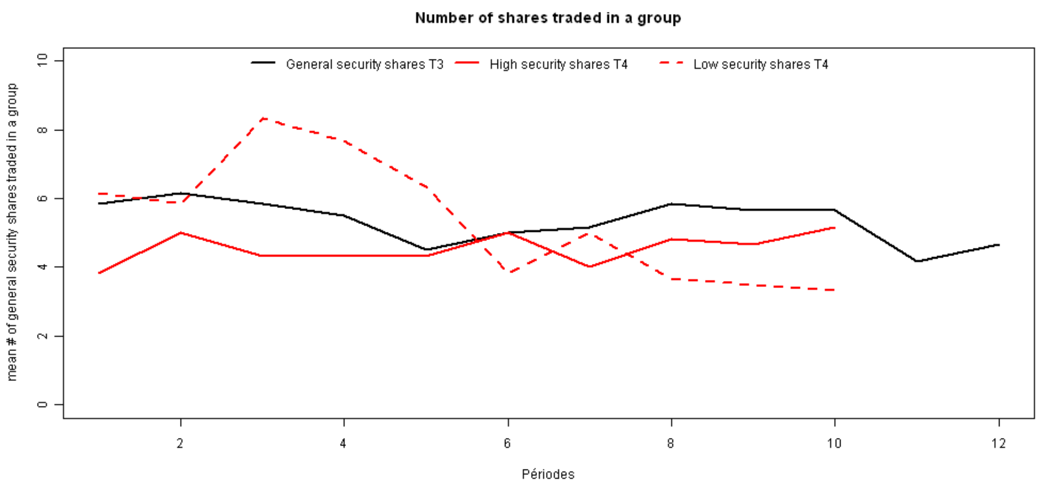


Figure 3: Number of shares traded in a group when there is no gains from trade (T3 and T4)



Our experimental results show that subjects fail to reach the no-trade equilibrium, but they learn to approach it over time[16]. As illustrated in figure 3, number of shares traded in treatment 3 and 4 decreases over time.

[16]This is coherent with Angrisani and al [1]. They ran side-by side markets with an without gains from trade. By comparing trading activity under the two conditions, they assessed how effectively and through which channels, the no-trade logic is incorporated to the behavior of experimental subjects.

6.3 Coupon market

Number of coupons traded

Evidence supporting hypothesis 3 and invalidating hypothesis 4: In average, there is more trade of coupons in T1 than T2, thus supporting hypothesis 3. But hypothesis 4 is not supported because this is also the case for T3 compare to T4 (table 12).

	T1	T2	T3	T4
Blue scenario (period 6 and 9)	2.83	3.17	9.42	5.75
Yellow scenario (period 7 and 8)	4.08	2.17	5.75	3.92
All scenarios	3.46	2.67	7.58	4.83

Table 16: Number of coupons traded in a group (average over period 6 to 9)

Using Mann-Witney tests based on one observation per group (average number of coupons traded in a group over period 6 to 9), the data reject the hypothesis that number of coupons traded are the same with one or two levels of security for shares (right-tail p-value = 0.02 for pairwise comparison between T1 and T2 and right-tail p-value = 0.07 for pairwise comparison between T3 and T4).

6.4 Profits

Evidence suporting hypothesis 5: Both type 1 and type 2 profits are higher when two types of shares are available (T2 compare to T1) in both scenarios. When there is no gains from shares trading (T3 and T4), the total profits are lower when there is two levels of security for shares (T4 compare to T3) (table 16).

		T1	T2	T3	T4
	Total Profits (group)	625.54	655.88	655.29	629.00
Blue scenario	Total Profits (group)	796.25	836.33	839.33	814.92
	Profit Type1	109.61	118.28	112.28	117.11
	Profit Type2	155.81	160.50	167.50	154.53
Yellow scenario	Total Profits (group)	454.83	475.42	471.25	443.08
	Profit Type1	84.56	85.31	84.83	82.67
	Profit Type2	67.06	73.17	72.25	65.03

Table 17: Profit in ECUs(average over periods 6 to 9)

Using Mann-Witney tests based on one observation per group (average total profits over period 6 to 9), the data reject the hypothesis that profits are the same with one or two levels of security for shares (left-tail p-value = 0.03 for pairwise comparison between T1 and T2 and right-tail p-value = 0.04 for pairwise comparison between T3 and T4). We also compute a robust-rank order test as the samples dispersions might be different between treatments (FELTOVICH, 2003, Exp economics vol6). We reject the hypothesis of equal medians of total profits in T1 and T2 with a left-tail alpha risk of 0.5% (U = -6.25) and in T3 and T4 with a right-tail alpha risk of 2.5% (U = 2.55).

Evidence invalidating hypothesis 6: Type 1 profits are more variables when two types of shares are available (T2 and T4) whereas type 2 profits are less variable.

	T1	T2	T3	T4
Type 1	18.58	21.05	17.79	21.27
Type 2	52.33	50.81	55.69	52.66

Table 18: Standard deviation of Profit (period 6 to 9)

Nevertheless, using Mann-Witney tests based on one observation per group (average standard deviation of profits over period 6 to 9), the data fail to reject the hypothesis that the profits are equally variables with one or two levels of security for shares (Type1 profits: two-tailed p-value = 0.13 for pairwise comparison between T1 and T2 , two-tailed p-value = 0.24 for pairwise comparison between T3 and T4; Type2 profits: two-tailed p-value = 0.48 for pairwise comparison between T1 and T2 , two-tailed p-value = 0.30 for pairwise comparison between T3 and T4). The robust-rank order tests also fail to reject the hypothesis of equal variability profits. (Type1 profits: U=-1.64 for pairwise comparison between T1 and T2 , U=-1.33 for pairwise comparison between T3 and T4; Type2 profits: U=0.68 for pairwise comparison between T1 and T2 , U=1.06 for pairwise comparison between T3 and T4).

6.5 Summary

More work should be done. We will complete our results by parametric regressions to verify the validity of the hypotheses. Moreover, we'll look at trading strategies of subjects and check if risk aversion explains trading patterns. Table 18 summarizes the hypothesis and the evidence of their validity or invalidity.

Hypotheses	Comparison	Support of the hypothesis
H1	Price of shares = expected value of shares	not supported >
H2	Number of shares traded T1>T3 T2>T4	supported*
H3	Number of coupons traded T1>T2	supported**
H4	Number of coupons traded T3=T4	not supported**
H5	Average Profits T1<T2 T3=T4	supported**
H6	Variability of profits	not supported

Table 19: Summary of hypothesis

7 Conclusion

The economic gains expected from water markets depends on the characteristics of the market design and how participants react to the design in the field. In this paper we focus on two design details relevant for water market performance: the effect of having different level of security for water rights, and transaction costs. This can provide the first steps towards designing more optimal water market regulations to achieve an efficient allocation of water and risks with limited transaction costs.

While most policy discussions of water markets plans envisage the development of future markets in allocation, no previously reported laboratory experiments have implemented any form of trading future entitlements to allocation (rights). Godby and al [17] have shown than the introduction of shares improve the performance of the emission trading markets. This result certainly holds for water markets, as illustrated by the increasing activity on water rights market [23]. We have shown that differentiating shares in terms of security can further increase efficiency. Our results suggest that formal trading of different types of future entitlements to water allocation improve the efficiency of water markets if trading shares is less costly than trading coupons. However, as soon as spot market trading is efficient and costless, there is no gains from shares trading, thus no gains from a complexified water rights market. We do observe in the lab that the costs of trading shares offset the gains from a portfolio of shares matching coupon needs.

In the short term, we could run other treatments and test what is the transaction costs configuration which increases the gains from a differentiated system. Further research could include field experiment with farmers trained in water trading to see if they take better advantage of a differentiated system than non-experimented students.

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References

[1] steffen Hick Nathan Larson Angrisani Marco, Antonio Guarino. No trade in the laboratory. CESIFO WORKING PAPER NO. 2436, october 2008.

[2] Bjornlund. Farmer participation in markets for temporary and permanent water in southeastern australia. *Agricultural Water Management*, 63:57–76, 2003.

[3] Henning Bjornlund. Can water markets assist irrigators managing increased supply risk? some australian experiences. *Water International*, 31(2):221–232, June 2006.

[4] Henning Bjornlund and Peter Rossini. Fundamentals determining prices in the market for water entitlements: An australian case study. *International Journal of Water Resources Development*, 23(3):537 – 553, September 2007.

[5] Henning Bjornlund and Peter Rossini. Are the fundamentals emerging for more sophisticated water market instruments ? In *Proccedings from the 14th Annual Conference of the Pacific Rim Real estate Society, Kuala Lumpur, Malaysia*, January 2008.

[6] Borch. Equilibrium in a reinsurance market. *Econometrica*, 30(3):424–444, 1962.

[7] Brennan. Water policy reform in australia: lessons from the victorian seasonal water market. *Australian Journal of Agricultural Economics*, 50:403–423, 2006.

[8] Javier Calatrava and Alberto Garrido. Spot water markets and risk in water supply. *Agricultural Economics*, 33:131–143, 2005.

[9] T. N. Cason and Lata Gangadharan. Transactions costs in tradable permit markets: An experimental study of pollution market designs. *Journal of Regulatory Economics*, 23(2):145–165, 2003.

[10] Productivity Commision. Rural water use and the environment: The role of market mechanisms. Technical report, Productivity Commision Research Report, Canberra, Australia, 2006.

[11] Productivity Commision. Market mechanisms for recovering water in the murray darling basin. Technical report, Productivity Commission Research Report, Australia, March 2010.

[12] Lin Crase. *Water Policy in Australia, the impact of Change and Uncertainty.* Resources for the Future, 2008.

[13] Oscar E Cristi. *The influence if heterogeneous risk preferences on water market activity: an application to the Paloma System of the Limari Water Basin, Chile.* PhD thesis, Agriculture and Resource and Economics Department, University of California, Davis., 2007.

[14] Christian Gollier Eeckhoudt, Louis and Harris Schlesinger. *Economic and Financial Decisions under Risk.* 2005.

[15] Freebairn and Quiggin. Water rights for variable supplies. *The Australian Journal of Agricultural and Resource Economics*, 50:295–312, 2006.

[16] Lata Gangadharan and Veronika Nemes. Experimental analysis of risk and uncertainty in provisioning private and public goods. *Economic Inquiry*, 47(1):146–164, 01 2009.

[17] Stuart Mestelman R. Andew Muller Godby, Robert W. and J. Douglad Welland. Emissions trading with shares and coupons when control over discharges is uncertain. *Journal of Environmental Economics and Management*, 32:359–381, 1997.

[18] Howitt. Spot prices, option prices and water markets: An analysis of emerging markets in california. In Dinar Easter, Rosegrant, editor, *Markets for water: Potential and Performance.* Kluwer Academic Publisher, 1998.

[19] Hughes and Goesch. Management of irrigation water storages: carryover rights and capacity sharing. Technical report, ABARE research report 09.10, 2009.

[20] Rosegrant and Gazmuri. Reforming water allocation policy through markets in tradable water rights: lessons from chile, mexico and california. *Cuadernos de Economia*, 97:291–315, 1995.

[21] Tian Shi. Simplifying complexity: Rationalising water entitlements in the southern connected river murray system, australia. *Agricultural Water Management*, 86:229–239, 2006.

[22] Wilson. The theory of syndicates. *Econometrica*, 36:113–132, 1968.

[23] Michael D. Young. Environmental effectiveness and economic efficiency of water use in agriculture: The experience of and lessons from the australian water reform programme. Technical report, OECD Sustainable Management of Water Resources in Agriculture, 2010.

Appendix A: Equilibrium coupon market

Trading in the coupon market will occur until marginal benefits from coupon, net of transaction fees are equalized between agents. The equilibrium number of coupons held by an agent is:

$$c_{i,t} = \frac{a_i - pc_t + TF_c.dc_{i,t}}{2b_i} \tag{4}$$

Because agents have the opportunity to trade in the coupon market, the equilibrium number of coupons held does not depend on the number of rights S_i. In the presence of TC in the coupon market, the number of coupons held is increased (decreased) for a net seller (buyer) because he has to pay TC if he sells (buys) in the coupon market.

The equilibrium price of an allocation clears out the market: $\sum c_{i,t} = \sum W_t.S_i$

$$pc_t = \frac{b_i b_j}{b_i + b_j}\left[\frac{a_i + TF_c.dc_{i,t}}{b_i} + \frac{a_j + TF_c.dc_{j,t}}{b_j} - 2W_t(S_i + S_j)\right] \tag{5}$$

The equilibrium price of coupon decreases with the total quantity of coupons allocated $W_t.(S_i + S_j)$ and increases with the marginal benefit from coupons. Transaction fee in the coupon market increases coupon price because $b_i > b_j$, $dc_j = -1$, $dc_i = 1$.

Appendix B: Effect of risk aversion in the share market

We assume subjects can be risk averse and predict the effect of risk aversion on their behaviors in the different markets. Risk aversion and uncertainty on the coupon allocation impact both markets because subjects are less willing to participate in the coupon market, thus it modifies their behaviors in the share market.

Effect of risk aversion on the number of shares held by agent

An agent anticipating she will be ***net buyer in the coupon market*** ($E[W.S_i - c_i] < 0$) will hold more shares in order to increase her allocation and reduce the need to buy more coupons in the coupon market. A net buyer in the share market ($S_i > Q_i$) will buy more shares and net seller in the share market ($S_i < Q_i$) will sell less shares under risk aversion.

An agent anticipating she will be ***net seller in the coupon market*** ($E[W.S_i - c_i] > 0$) will reduce the number of shares he holds (to reduce her allocation and to reduce the need to sell extra-allocations). A net buyer in the share market ($S_i > Q_i$) will buy less shares and net seller in the share market ($S_i < Q_i$) will sell more shares under risk aversion.

Effect of risk aversion on the shares' price

If all the agents anticipate they will be ***net buyer in the coupon market*** , the price of shares will increase as buyers are willing to pay a markup as a risk premium and sellers are not willing to sell unless the price is increased of the risk premium. Their expected utility is maximized when the price is higher than the value of the share.

$$p_S > E\left[W.pc\right] \tag{6}$$

If all the agents anticipate they will be ***net seller in the coupon market*** , the price of shares will decrease as buyers are not willing to buy unless the price is reduced due to the uncertainty on the value of a share and sellers are willing to sell even if the price is lower than the expected value of the share. Their expected utility is maximized when the price is lower than the value of the share.

$$p_S < E\left[W.pc\right] \tag{7}$$

Effect of risk aversion on the trading activity in both markets

Risk aversion reduces the trading activity in the coupon market. The effect of risk aversion on the number of trades in the share market depends on the heterogenity among agents. If they all have the anticipation on their net position in the coupon market, and all have the same risk aversion, no trade is possible in the share market (when one is willing to sell, the other is not willing to buy and vice versa)[17].

Appendix C: Proof of hypothesis 6

In T1, at equilibrium, the number of shares held is such that trade of coupons is required only in the yellow scenario. One can compute profits and the difference between profits in the blue and in the yellow scenario.

$$\Pi_{blue} = B(c_{blue}) + p_S.\left(Q - S\right) - TF_S.\left|Q - S\right|$$

[17]Cristi and Diaz [13] study what explains water rights trading when farmers can exchange water volumes in the spot market at lower transaction costs. Their main result is that heterogeneous preferences are a sufficient condition for an active market for water rights when farmers can also exchange water in the spot market. Water rights trading occur whenever there are differences among farmers in the reservation value of the water right asset. Differences in reservation values arise from heterogeneity in farmers' risk preferences.

$$\Pi_{yellow} = B(c_{yellow}) + pc_{yellow}.\,(W_{yellow}.S - c_{yellow}) - TF_c.\,|W_{yellow}.S - c_{yellow}| + p_S.\,(Q - S) - TF_S.\,|Q - S|$$

$$[\Pi_{blue} - \Pi_{yellow}]_{T1} = B(c_{blue}) - B(c_{yellow}) + pc_{yellow}.\,(W_{yellow}.S - c_{yellow}) - TF_c.\,|W_{yellow}.S - c_{yellow}|$$

In the treatment with two types of shares (T2), one can reach an efficient portfolio of shares such that no trade of coupons is required in both scenarios. As a results, differences in profits between the blue and the yellow scenario is only due to differences in benefits from coupons held.

$$[\Pi_{blue} - \Pi_{yellow}]_{T2} = B(c_{blue}) - B(c_{yellow})$$

Type 1 subjects are net seller in the coupon market in T1, thus:

$$[\Pi_{1,blue} - \Pi_{1,yellow}]_{T1} < [\Pi_{1,blue} - \Pi_{1,yellow}]_{T2}$$

Type 2 subjects are net buyer in the coupon market in T1, thus:

$$[\Pi_{2,blue} - \Pi_{2,yellow}]_{T1} > [\Pi_{2,blue} - \Pi_{2,yellow}]_{T2}$$

The existence of two levels of security for shares reduces the variability of profits between scenarios for type 2 but it increases it for type 1. To assess the performance of the differentiated system concerning allocation of risks, one should know which type is the more willing and able to bear risk.