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« Do Security-differentiated Water Rights improve the performance of water markets

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Do security-differentiated water rights improve the performance of water markets?

Marianne Lefebvre, Lata Gangadharan and Sophie Thoyer

Abstract

Most existing water markets combine water rights trading and water allocation trading. Offering security-differentiated water rights can make the market more efficient and allow water users to manage the risks of supply uncertainty better. We conduct a laboratory experiment which compares two designs for water rights; one with a single security level and another with two security levels. We find that a two security level system increases overall profits when transactions costs are lower on the water rights market than on the water allocation market. It also improves risk allocation by allowing subjects to trade-off profits variability against expected profits according to their risk type and this result is robust to the existence of transactions costs on either market. *Keywords: experiment, irrigation, risk allocation, risk management, water markets, transactions costs JEL Codes: Q25, C91*

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Water markets are acknowledged to allocate scarce water efficiently, by encouraging water conservation, and by moving water from low to high value uses. Although there is now widespread adoption of such markets, there is an ongoing debate about how to improve the trading process. The existing literature has mainly focused on two aspects of water trading: trading constraints such as transactions costs (Gardner and Fullerton (1968), Colby (1990), Carey et al. (2002), Allen Consulting Group (2006)); and the control of "third party" impacts, when water exchanges affect other users who are not directly involved in the transaction (Productivity Commission (2006, 2010), Bourgeon et al. (2008)). Another important issue deserving attention is the role that water markets can play in mitigating the risk of water shortage for farmers. [1]

The possibility of trading water allocations, i.e. trading water obtained seasonally on the basis of water rights held and contingent on the aggregate availability of water, contributes to a reduction in farmers' exposure to risk as they can transform the risk related to the availability of the water input into a risk on input prices (Calatrava and Garrido (2005)). Moreover, in most countries where water can be traded, water rights have been unbundled from land rights and can also be sold and bought. One of the stated objectives of water rights trading is to allow farmers to manage their water rights as valuable long-term assets and to facilitate structural changes within the water sector. The co-existence of both a market for water rights and a market for water allocation has also been recognized as a useful short-term risk management tool for irrigating farmers since they can shift their participation from the water rights market to the water allocation market (and vice versa) according to their conditions of production and their risk preferences (Bjornlund (2006)). Our research focuses on this second role of water markets.

Due to increasing variability of water supply, water managers are considering the possibility of developing more sophisticated water markets by creating classes of water rights with different levels of water delivery security, in order to offer additional flexibility for the management of water shortage risk. Uncertainty relating to water allocation can often motivate farmers to hold more rights than necessary (Brennan (2006)). With differentiated rights, they could instead buy more secure rights.

Under most statutory water laws, as in Chile, Mexico and some states of Australia, water rights are all identical in terms of security. They are usually defined in terms of water volumes (i.e. megaliters). In times of water scarcity when total available water is not enough to fulfill rights, water must be shared between rightholders. Seasonal water allocations are made on a pro rata basis in proportion to the volume specified in each water right. This is a proportional sharing system. In other countries and states, water rights can have different security levels, with the holders of "high security rights" being served first in case of scarcity. Once provisions for high security water rights have been made, the remaining volume of water determines the allocation to owners of "low security rights". Therefore, the latter bear the bulk of the risk of low water supply. Such a hierarchy of rights is the basis of the prior appropriation doctrine, much in use in western United States: when shortage occurs, priority is given to the so-called 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 rights market.

In 1994 and 2000 respectively, Victoria and New South Wales (two states in Australia) initiated a differentiated water right system in which high security rightholders get a greater proportion of available water than low security rightholders in times of scarcity. The objective of these reforms is to improve the risk allocation across farmers by allowing them to constitute a portfolio of water rights with different security levels. On the other hand, in western United States a switch from the senior-junior right system to a proportional sharing system is being suggested, in order to reduce inefficiencies (Libecap (2011)). However, reforms leading to the creation or removal of differentiated rights are administratively complex and can lead to substantial transaction and learning costs for water users. Therefore, before encouraging a wider adoption of such complex systems, it is necessary to understand and evaluate whether they can lead to genuine gains for water users. This question is at the heart of a number of recent water market reforms.

The objective of this article is to compare the allocative efficiency, cost-effectiveness and risk management properties of a market with two security levels for water rights relative to a market with a unique type of water right. There is insufficient field data to examine this research question using statistical techniques because water rights markets are still rather thin. For example, little activity is observed in the market for low security rights in Australia (National Water Commission (2009)). In western states of the US, the trading of senior water rights is restricted by regulations concerning third party effects (Howe and Goesmans (2003)). As a result, there are very few field situations where farmers can freely constitute a portfolio of water rights with different levels of security. Moreover, differences between countries or states in terms of hydrology and socio-economic environment can make the comparison difficult. This article, therefore, uses data from laboratory experiments. It presents an experimental design that captures the main characteristics of existing water markets and focuses on the short-term risk management properties of different levels of security for water rights. Using a static framework enables us to capture only the efficiency properties of intra-seasonal water re-allocation through trade and allows us to abstract away from water trading decisions associated with longer-term management issues (such as changes in cropping patterns and structural changes on the farm).

The design is noteworthy in two respects. First, we introduce different levels of security for rights which facilitates a comparison of the one security level system (corresponding to the proportional sharing system observed in South Australia or Chile) with the two-security levels system (corresponding to the senior-junior rights in western US or the differentiated rights in New South Wales and Victoria). While Calatrava and Garrido (2006a) compared these two definitions of water rights using simulation data, they did not consider water rights trading in their analysis. To our knowledge this design feature has not been examined systematically in previous research.[2]

The second novelty of our design is the introduction of two markets: a market for water rights and a market for water allocation. While other experimental studies on water have explored one market in isolation (for example, Garrido (2007) and Tisdell (2011) focus on the allocation market, whereas Hansen et al. (2007) examine the allocation market and an option market but no rights market), this article is the first to consider both markets. In the emissions trading literature, Godby et al. (1997) designed an experiment mimicking the Canadian emissions trading market, including both a shares market and a coupons market. 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 the next stage. Our experiment is inspired by this design. Subjects first participate in a "shares market" (corresponding to the water rights market), knowing only the probability of occurrence of different coupon availability scenarios (identical to different weather situations). Once the scenario is known, they get an allocation of "coupons" corresponding to the shares they own. They can then trade their coupons on the coupons market (which corresponds to the market for water allocation).

The two main treatment variables in our experiment are the number of security levels for shares (1 or 2) and the presence of transactions costs in the share and coupons markets. With these treatments, we examine the role of transactions costs which are recognized as an important feature of water markets and we show how these costs can impact the performance of a two security levels system. While several researchers have studied transactions costs in environmental markets (Kerr and Mare (1995), Gangadharan (2000), Cason and Gangadharan (2003)), the impacts of such costs on participants' decisions to trade in one market relative to the other have been largely ignored. We find that while risk allocation improves with a two security levels system irrespective of which market displays higher transactions costs, the total profits generated are more dependent on the configuration of the transactions costs.

This article is organized as follows. Section 1 summarizes the existing literature on the expected benefits and limitations of having differentiated water rights. The experimental design and corresponding theoretical predictions are presented in Sections 2 and 3. Section 4 analyzes the experimental results and Section 5 concludes with some implications for policy.

Rationale for differentiated water rights

In a simplified theoretical model in which the market is perfectly competitive and transaction-cost free, and in which water users are risk-neutral and have a given water demand, it is predicted that trading on the seasonal allocation market is sufficient to reach an efficient allocation of water amongst users (Freebairn and Quiggin (2006)). No trading on the water rights market should occur since all water users have the same expected value for water rights (corresponding to the expected value of the water allocation, which is the same for all since there is, theoretically, a unique equilibrium price on the allocation market). Thus, they display the same willingness to pay for rights. The market for water rights is mainly justified by the need to provide adjustment mechanisms to accompany long-term changes in water demand by water users such as structural changes in the irrigation industry. In practice however, it is observed that farmers are showing growing interest in water rights trading (Young (2010)). It has been shown that demand and supply of water rights are driven by heterogeneous risk attitudes and anticipations (Cristi (2007)), long term speculation (related to the uncertainty about the level of future water supply) or saving motives. The existence of water rights with different security-levels can reinforce the willingness to hold water rights. Field studies have for example shown that many farmers view high reliability water rights as a hedge against future uncertainties and as high value capital assets which can be used as a mortgage guarantee (Bjornlund (2003), Grafton and Peterson (2007)). In this article, we focus exclusively on the role that such a system could play in the management of short-term water shortage risks, leaving aside the other benefits listed above which concern mainly the management of long-term uncertainties. The arguments relating to differentiated water rights can be summarized as follows:

Firstly, Freebairn and Quiggin (2006) argue that multiple security levels for water rights can improve the cost-effectiveness of water allocation by enabling users to constitute the best-adapted portfolio of rights to each weather scenario, thus reducing the need to trade on the allocation market and limiting corresponding transactions costs. Indeed, despite the existence of trade-facilitating solutions such as electronic market places or brokers, trading water remains costly. Transactions costs are incurred in searching for a trading partner, ascertaining the characteristics of the water commodity, negotiating a price and other terms of transfer and obtaining legal approval for the transfer (Colby (1990), Goodman and Howe (1997), Carey et al. (2002), Bjornlund (2003), Allen Consulting Group (2006)). Freebairn and Quiggin's argument is nevertheless controversial because it relies on the assumption that transactions costs in the allocation market are always greater than transactions costs in the rights market. Instead, most water markets seem to display greater transactions costs on the latter, first because water right transactions are more heavily taxed than water trading in the allocation market, and second because it is more administratively and legally complex. Bjornlund (2003) and Brennan (2006) examine this issue for Australian water markets. Libecap (2011) also mentions the reluctance to trade senior rights in the western US because of the increasing number of protests and litigation procedures launched by junior rights holders. As a result, if transactions costs in the rights market are prohibitive, they might offset the benefits of constituting a well-balanced portfolio of rights.

Secondly, a differentiated system can improve both the opportunities of risk management for risk averse farmers, as well as overall risk allocation within the group of water users. Even though water markets help in reducing the risk born by farmers by converting a quantity risk into a price risk (Calatrava and Garrido (2005)), they fail to share the remaining risk efficiently (Howitt (1998)). As highlighted by Quiggin (2008), "the quest to eliminate uncertainty is futile but uncertainty can be managed, allocated and sometimes mitigated". 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 water market or conditional leases of water: risk-averse users can trade-off lower expected gains for lower variability of gains; more risk-tolerant users may be willing to support a greater share of water variability in exchange for lower prices. We know from field studies that farmers have heterogeneous willingness to pay for the security or reliability of water supply (Rigby et al. (2010)).[3] Bjornlund and Rossini (2008) have studied Australian water markets at length, and they suggest that the risk differential between high value water users (eg. farmers with perennial crops) and low value water users (eg. producers of annual crops) is sufficiently large to enable sophisticated risk-sharing instruments to operate. Water rights with different levels of security can mimic these risk-sharing contracts and may be easier to implement.

A multiple security levels system could thus display two major advantages, compared to a single security system: transactions costs saving on the water market; and improved risk allocation. On the negative side however, it may increase the management cost for market administrators and the complexity of water market participation for farmers (Hughes and Goesch (2009), Shi (2006)). Overall, the benefits of water rights differentiation will depend on the strength of these positive and negative effects.

Based on the above discussion, we formulate the following research questions:

1. Does a water market with differentiated water rights increase total profits from water use and water trading?

2. Do differentiated water rights improve the risk management properties of water markets?

These two questions are addressed in the context of short-term (intra-seasonal) water management. The next section describes the experiment designed to compare two market structures: a two vs a single security level system for water rights.

Experimental design

Our experimental design captures the main characteristics of mature water markets where agricultural users participate both in the water rights market and in the allocation market in order to manage the risk of water shortage within a given production year. Each water right entitles its owner to a water allocation, i.e. a share of available seasonal water, which varies stochastically and is only known with certainty at a certain time of the year (when water levels in dams have stabilized). Water is used as an input in the agricultural production process with a decreasing marginal productivity.

To prevent prior attitudes about environmental policy from influencing subjects' behaviors, a neutral terminology is used: in particular, water rights are called "shares" and water allocations are called "coupons". A share gives the right to a pre-specified, scenario-dependent, number of coupons. At the end of each period, coupons held are converted into ECU benefits, the ECU being an experimental monetary unit convertible at a (known) fixed rate into cash.

Our experimental design simplifies the market structure observed in the field. In the field, water rights can be retained year after year and the market for water rights is open all year round. In the experiment, we implement stationary repetitions of the same market to enhance learning of the subjects. Subjects trade shares and coupons in two successive non overlapping stages. Shares and coupons have the same time frame: both are held for one period only and decisions do not spill over from one period to the other. This design choice allows us to preclude trading motives associated with long-term strategies such as banking and speculation on the future value of water rights. It therefore enables us to observe trading strategies uniquely associated with the need to reduce transactions costs and to manage short-term risk better, both in a single security system (only one level of security for shares) and in a two security levels system (two security levels for shares).

Treatments

We conduct four treatments. The treatment variables are (i) the number of levels of security for shares and (ii) transactions costs in the shares and coupons market. We use a between-subject design with 6 observations per cell, where each subject participates in only one of four treatments. *Table 1* summarizes the treatments' characteristics.

The first treatment dimension that we examine is the number of security levels. In the one security level treatments, there is only one type of share called "shares". In the two security levels treatments, high security ("shares A") and low security shares ("shares B") are traded sequentially, with the high security shares traded first.[4]

The second treatment dimension is transactions costs. In the first set of treatments we assume that transactions costs are higher when trading coupons. It follows Freebairn and Quiggin (2006) who suggest that seasonal allocation trading is likely to be associated with larger transactions costs. However Brennan (2006) indicates that the financial and administrative costs of allocation trade are relatively small compared to water rights trading. This is confirmed by the field interviews that we conducted in northern Victoria (Australia) in 2010. This constitutes our next set of treatments in which transactions costs are higher when trading shares. This alternative is more empirically relevant and hence improves the external validity of our results.

In the remainder of the article, we will use the following notation for the identification of our four treatments. The letter indicates the market in which the transactions costs are higher (C when transactions costs are higher in the Coupons market, and S when transactions costs are higher in the Shares market). The number indicates whether shares have only one security level (1) or two security levels (2).

This article mainly focuses on the comparison of the first treatment dimension (number of security levels). We use the second treatment dimension in order to test whether our results are consistent under alternative configurations of transactions costs.[5] We therefore do not directly compare C1 with S1 and C2 with S2 as these are just two different states of the world where transactions costs are higher in one or the other market. In the experiment, when one market entails low transactions costs, we normalize them to 0 (for the trading of shares in treatments C1 and C2 and for the trading of coupons in treatments S1 and S2). The higher transactions costs are captured in the experiment by a fee of 2 ECUs per coupon (in C1 and C2) or per share (in S1 and S2) traded, paid both by the buyer and the seller.[6]

Game structure

Figure 1 presents the game structure. At the beginning of each period, each subject is endowed with an equal number of shares: 9 shares in the treatments with a single level of security (C1 and S1) and 3 shares A (high security) and 12 shares B (low security) in the treatments with two security levels (C2 and S2). Each subject is also given an initial cash amount of 50 ECUs which enables him to buy shares and coupons if he wishes, without running a deficit.

In stage 1, subjects can choose to modify the number of shares they hold by buying and selling in the shares market. Once the shares market has closed, subjects obtain summary information on the following: the number of shares held; their gains and spending in this market; the transactions costs incurred and their remaining cash.

Between stages 1 and 2, a random draw selects a scenario that determines the number of coupons obtained from the shares (*table 2*). There are two equally likely scenarios, which are a simplified representation of the climatic variability. A wet season is described by the "blue scenario" whereas a dry season is called the "yellow scenario" and corresponds to a volume of available water which is three times lower than in the blue scenario: 54 coupons are available in the blue scenario, and 18 coupons in the yellow scenario. Both the probability of each scenario and *table 2* are common knowledge. Subjects are told the outcome of the scenario draw and the number of coupons they get from their shares, before the opening of the coupons market.

In stage 2, subjects can trade coupons in the coupons market: they can choose to hold on to their coupons, sell them or buy more, provided they have sufficient cash to do so. At the end of stage 2, coupons are converted into ECUs according to a benefit function (*table 3*) displaying diminishing marginal gains. The total gains in the period are the sum of ECUs held after the trading stages plus the ECUs generated by coupons held. Then a new period starts.

The share and coupons markets are organized as a continuous double auction (CDA) in order to mimic the electronic clearing houses used by farmers to trade water (Brooks and Harris (2008), Productivity Commission (2010)). Moreover, CDA is a useful mechanism in the lab because multiple trading opportunities are important in experimental markets to improve efficiency (Cason and Friedman (2008)). Subjects can place their price bids to buy extra shares or coupons, and/or price offers to sell them.

All these strategies, namely buy, sell and keep, can be pursued simultaneously, letting the market price allocate the goods to the most efficient use. Each trading stage is open for 2 minutes.

Subject types

Subjects' marginal benefit functions are parametrized in order to mimic two types of farmers (*table 3*). In each market group, we randomly assign marginal benefit functions to subjects so as to have three type-1 subjects and three type-2 subjects. Subjects retain the same type during the whole experiment. The marginal benefit function of a type-1 subject mimics a mixed crop producer, with relatively low value for water and elastic water demand. Parameters are chosen so that the equilibrium price in the yellow scenario is greater than the marginal value of the first unit of water for type 1, and therefore type-1 subjects sell their total water allocation and do not use water when it is scarce and expensive. Type-2 subjects represent farmers with high-value crops such as orchards or vineyards, who are highly sensitive to irrigation restrictions. They need a minimum volume of irrigation water to preserve the long term productivity of their plantations or to avoid catastrophic harvest losses. Type-2 subjects therefore display a high marginal value for water, a rather inelastic water demand, and a minimum water requirement. The first three coupons have no value for a type-2 subject because they are insufficient to ensure production, but the fourth coupon yields a high marginal value.

Experimental procedure

The experiment was programmed and conducted at the University of Montpellier experimental lab (LEEM), using the software z-Tree (Fischbacher (2007)). The subjects were drawn from the undergraduate student population. Subjects interacted anonymously in 6-person fixed groups. For each treatment, we conducted 2 sessions of 3 groups each, thus obtaining 6 independent observations per treatment, with a total of 144 subjects. Each session lasted 3 hours.

At the beginning of each session, subjects participated in an individual lottery task that helped us elicit their risk preferences (Brown and Stewart (1999)). The switch point of this lottery task was used as a relative indicator of elicited risk aversion (ERA). In our sample, 57% of the subjects can be classified as risk averse (switch point from 1 to 4), 40% as risk neutral (switch point of 5 or 6) and 3% as risk lovers (switch point from 6 to 10).[7]

After the lottery task, subjects were invited to read the instructions of the experiment explaining the different stages of the game, the trading software and the monetary incentives. They also answered a quiz which tested their understanding of the game. Subjects played two practice periods (with the same parameters as the rest of the experiment but which did not count towards earnings), followed by several periods, one of which could potentially be selected for payment. The number of periods played varied across treatments due to time constraints: 9 periods (C2), 10 (S2) and 12 (C1-S1). The succession of scenarios was randomly drawn in advance and is identical across treatments and groups. This ensures that we can compare behavior across treatments keeping the climatic distribution constant. The blue scenario was drawn in periods 1, 2, 5, 7, 8 and 12 and the yellow scenario in periods 3, 4, 6, 9, 10, 11. Subjects earned 18.50 Euros on average and received an additional 1, 3.5 or 6 Euros, depending on their choice and the outcome of the lottery task. In order to control for wealth effects, earnings from the lottery were only revealed at the end of the session. At the end of each session, qualitative and quantitative information was collected from the participants using survey questions. The instructions are available in the online supplementary appendix.

Theoretical predictions

This section presents the theoretical predictions on quantities and prices in the share and the coupons markets in each treatment. We solve the model for a two-agent market (with one agent of each type), assuming that agents are risk neutral. 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 are simply multiplied by 3. The model is solved by backward induction: the equilibrium of the coupons market is computed first, then the equilibrium in the shares market is derived. We conclude this section by presenting some intuition on the effect of risk aversion, which can potentially explain differences between theoretical predictions and experimental results.

A risk neutral agent chooses the number of shares as well as the number of coupons in order to maximize his net expected benefit from trading and coupon holding. The maximization problem can be written as follows:

$$\underset{S_i, c_{i,t}}{Max} \sum_{\mathrm{t}=1,2} \pi_{\mathrm{t}} \left[B(c_{i,t}) + p_{ct}. \left(W_t.S_i - c_{i,t} \right) - Tc.dc_{i,t}. \left(W_t.S_i - c_{i,t} \right) \right]$$
$$+ p_s. \left(Q_i - S_i \right) - Ts.ds_i. \left(Q_i - S_i \right) \tag{1}$$

Share: Q_i is the initial allocation of shares to agent i, S_i is the number of shares held in equilibrium, p_S is the equilibrium price of a share.

Allocation of coupons: t indexes the scenario ($t = 1, 2$ for the two scenarios: yellow and blue), π_t is the probability of occurrence of scenario t (with $\pi_1 + \pi_2 = 1$), W_t is the number of coupons received per share under scenario t. This value is known before the opening of the coupons market.

Coupon: $c_{i,t}$ is the number of coupons held by agent i in scenario t, $B(c_{i,t})$ is the total benefit from holding $c_{i,t}$ coupons, which is type-dependent, p_{ct} is the equilibrium price of a coupon under scenario t.

Transactions costs: Tc is the transaction cost to buy and to sell in the coupons market, Ts is the transaction cost to buy and to sell in the shares market, $dc_{i,t}$ is the net position of agent i in the coupons market under scenario t and ds_i in the shares market (1 for a net seller, -1 for a net buyer).

Equilibrium in the coupons market

Trading of coupons takes place until the marginal benefits of coupons, net of transactions costs, are equal for the two agents. Equilibrium prices and quantities of coupons are found where total demand is equal to total supply in each scenario (*table 4*).

$$\begin{cases} B'(c_{i,t}) - p_{c,t} + Tc.dc_{i,t} = 0 \\ \sum_{i=1,2} c_{i,t} = W_t \sum_{i=1,2} S_i \\ \forall t = 1, 2 \ ; \forall i = 1, 2 \end{cases} \tag{2}$$

We note that type-1 sells all his coupons to type-2 as the equilibrium price is higher than his marginal benefit from the first unit. The equilibrium price is between the minimum price the type-1 user is willing to sell at and the maximum price the type-2 user is willing to buy at. The bargaining power of each type in the game determines the equilibrium price within this range.

Equilibrium in the shares market

The maximum willingness to pay for the purchase of one share (or the minimum willingness to accept for the sale of one share) is its expected value: it is equal to the expected number of coupons obtained from this share multiplied by the expected price of coupons (including transactions costs).

$$\begin{cases} p_s + Ts.ds_i = \sum_{\mathrm{t}=1,2} \pi_{\mathrm{t}} W_t \left[p_{c,t}. - Tc.dc_{i,t} \right] \\ \sum_{i=1,2} S_i = \sum_{i=1,2} Q_i \\ \forall i = 1,2 \end{cases} \tag{3}$$

In the absence of transactions costs in the coupons market (in the S1 and S2 treatments), the expected value of a share is equal for all risk-neutral agents. As a result, no trade should take place in the shares market under the S1-S2 treatments. The incentives to trade shares in S1 and S2 are further reduced by the presence of transactions costs in the shares market.

On the contrary, transactions costs in the coupons market (in the C1 and C2 treatments) create heterogeneity in the expected value of a share across subjects if they anticipate to have different positions in the coupons market. Buyers of coupons have a higher value for shares, whereas sellers of coupons have a lower value. As a result, trading of shares occurs in equilibrium in treatments C1 and C2. In that case, the equilibrium price of a share is an interval, with the lower bound being the minimum price at which a net seller in the coupons market is willing to sell a share and the higher bound being the maximum price at which a net buyer of coupons is willing to buy a share: $p_S \in \left[\sum_{\mathrm{t}=1,2} \pi_{\mathrm{t}} W_t \left[p_{c,t} - Tc \right] ; \sum_{\mathrm{t}=1,2} \pi_{\mathrm{t}} W_t \left[p_{c,t} + Tc \right] \right]$.

The marginal benefits of coupons have no impact on the willingness to pay for shares because the coupons market plays the role of a reconciliation market: agents can buy more or sell extra coupons in the coupons market. Nevertheless type matters as it determines the net position of subjects in the coupons market. Being net buyers in the coupons market, type-2 subjects are willing to pay more for shares than type-1 subjects when there are transactions costs in the coupons market. As a result, type-1 subjects will sell shares to type-2 subjects in the C1 and C2 treatments. The equilibrium allocation of shares in C1 and C2 is such that the need for costly trade in the coupons market is minimized. When there is only one level of security for shares (C1), the equilibrium number of shares held by each subject is such that coupon trading is required only in the yellow scenario. Each subject holds a number of shares corresponding to his need for coupons in the blue scenario. A simple calculation shows that any other allocation of shares is less efficient as it requires more trade in the coupons market. When two security levels for shares are available (C2), the experiment is parametrized in a way which leads to the absence of trade in the coupons market in both scenarios, provided efficient portfolio of shares have been constituted. High security shares are bought in order to cover the anticipated need for coupons in the yellow scenario, and low security shares are bought to obtain and supplement the anticipated need of coupons in the blue scenario.

From the equilibrium predictions in the shares market, one can compute the number of coupons that will be received by each type in each treatment and scenario. This needs to be compared to the equilibrium number of coupons held by each type to determine the equilibrium number of trades in the coupons market. Equilibrium predictions for the number of trades in each market are presented in *table 4*.

Impact of risk aversion on trading patterns

The theoretical predictions presented above are calculated under the assumption of risk neutrality. Introducing risk aversion of subjects does not have an impact on the theoretically-calculated final allocation of coupons since uncertainty is resolved before coupons are traded. However, risk aversion potentially impacts the willingness of subjects to participate in one market rather than the other. This effect is ambiguous when subjects can be both buyers and sellers and can trade both in the coupon and the shares market. Most of the previous models examining decisions in water markets (Howitt and Taylor (1993), Calatrava and Garrido (2006b)) have ignored this issue.

Risk aversion can potentially have two effects. On the one hand, risk averse subjects may prefer to trade in the coupons market as more information is available at this stage. Even if coupon trading is costly (treatments C1-C2), they may be willing to trade-off greater transactions costs for a gain in information. On the other hand, risk averse subjects may be willing to buy shares as an insurance against a small allocation of coupons (if the scenario is yellow), in order to secure a minimum number of coupons. This is particularly true for type-2 subjects because they need at least 4 coupons to get benefits from coupons. As a result, if the first (second) effect is stronger, the trading activity in the shares market is expected to be lower (higher) under risk aversion compared to the risk neutral prediction. Risk aversion can therefore have an impact on the performance of the market.

We know from the risk preference elicitation task that subjects are risk averse on average, with relatively high heterogeneity (average switch point = 6.20, std. deviation = 2.26). This pattern of individual risk preferences is likely to affect experimental outcomes and explain departure from theoretical predictions. However, it is unclear to what extent decisions will be impacted by individual risk preferences of subjects (elicited before the market experiment with the lottery task) as compared to type characteristics. Indeed, the shape and slope of the benefit functions change the magnitude of potential losses faced by subjects and are likely to influence them when facing risky decisions. We assume that subjects' behavior is influenced more by the shape of their benefit functions (their types) than by individual elicited risk aversion (ERA) (see Bowles (1998) for a discussion on how economic circumstances can influence preferences and Schoemaker (1993) for a review of the difference between elicited risk aversion and observed risk taking behavior).[8] We therefore expect type-2 subjects to behave in a less risk-tolerant way (because of their discontinuous and highly inelastic water demand function) than type-1 subjects (as they display a more elastic or concave demand function). Therefore, to simplify, we will describe type-2 subjects as less risk-tolerant and type-1 subjects as more risk-tolerant. The word "risk-tolerance" encompasses here the risk-related behavior of subjects, driven by their type. The results section provides evidence in favor of this assumption.

Hypotheses

From these theoretical predictions on trading and conjectures on the effect of risk, we draw two hypotheses related to the two research questions stated above, concerning profits and risk management.

Hypothesis 1: Profits are higher under the two security system than under the one security system.

Theoretical predictions show that under the assumption of risk neutrality, profits are on average higher in C2 than C1, because subjects can take advantage of the two security levels system to constitute a diversified portfolio of shares matching their need for coupons in each scenario. Subjects can thus avoid trading in the coupons market and save transactions costs. The transactions costs are on average lower in C2 than C1 at equilibrium. Profits do not change under S2 compared to S1 because no trade of shares is expected to take place either in S1 or in S2, precluding the possibility to save transactions costs. *Table 4* presents equilibrium profits under the assumptions of risk neutrality and equal bargaining power of buyers and sellers (the latter assumption helps in avoiding interval predictions for profits).

With risk averse subjects, the picture is less clear since profits will depend on the way subjects choose to manage risks. The experimental results will help determine how risk tolerance modifies the impact of market structure on profits.

Hypothesis 2: The two security system improves risk management: it decreases the overall variability of profits (H2a) and it enables a re-allocation of risk with a reduced variability of profits for less risk-tolerant subjects (H2b)

Theoretical results for the risk-neutral case show that the variability of profits at the group level (measured as the difference between equilibrium profits in the blue scenario and in the yellow scenario) is reduced under C2 as compared to C1, as stated in H2a. Disaggregated at the individual level, this effect is type-dependent: C2 reduces the variability of profit for type-2 subjects and increases it for type-1 subjects (H2b). The intuition for this prediction is as follows: both type-1 and type-2 subjects gain from a system with differentiated shares but type-1 subjects gain more in the blue scenario (therefore increasing the difference between profits in the blue and yellow scenario) and type-2 subjects gain more in the yellow scenario (thereby reducing the difference between profits in the blue and yellow scenario). This theoretical result is only driven by transactions costs since we assume risk neutrality. Both H2a and H2b do not hold for the S1-S2 comparison in theory because no trade of shares is expected in these treatments.

We conjecture that risk-related behavior will reinforce the predicted effect of a differentiated system on profits variability. Indeed, when shares have different levels of security, less risk-tolerant subjects can more easily trade off "less variability" for "less average profit", whereas more risk-tolerant subjects accept "greater variability" in return for "higher average profit". Therefore, assuming that type-2 subjects are less risk-tolerant than type-1 subjects because of the shape of their benefit functions, we expect a reduction in the variability of profits for type-2 subjects and an increase in profit variability for type-1 subjects. If this result holds, risk allocation will be improved, as efficient risk sharing theory suggests that agents should bear a share of the risk proportional to their risk tolerance (Borch (1962), Wilson (1968), Eeckhoudt et al. (2005)). However, because efficient risk sharing requires trading in the shares market, the gains of risk re-allocation might be countervailed by additional transactions costs paid on share trading and therefore lower profits when it is costly to trade shares (in S1 and S2).

The lack of clear theoretical predictions concerning the impact of risk reinforces the reason for conducting experiments in order to investigate the validity of these assumptions.

Experimental results

We first present an overview of market activity (in particular, quantities traded and prices). Then, we provide evidence relating to the two hypotheses. For each hypothesis, we first analyze the results from the treatments for which the gains of the two security level system are theoretically expected to be higher (in situations where transactions costs are higher in the coupons market: C1 and C2). We then present the results for the treatments that better reflect empirical reality (when transactions costs are higher in the shares market: S1 and S2) and examine how higher transactions costs in the shares market impact the performance of the two security level system.

We examine the differences across treatments using nonparametric Mann-Whitney U tests with exactly one summary statistic value for each of the six independent groups in each treatment. We present the p-values of the two-sided tests. Unless specified, we compute the descriptive statistics for the last four periods of the experiment common to all the treatments (periods 6 to 9), as we are interested in the performance in the later part of the sessions after an initial learning and equilibration phase. The results show similar patterns when all periods are considered. When relevant, we also report results from multivariate regression models which evaluate the contribution of different factors on the decisions made by subjects. For the regressions, we use the data from periods 1 to 9. Unless stated otherwise, we use random effects at the subject level to capture the unobserved heterogeneity between subjects. Moreover, errors are clustered at the group level to capture any unobserved heterogeneity in the group.

Overview of market activity

Quantities traded

Both the coupons market and the shares market are observed to be active. On average, over periods 6 to 9, 80% of the subjects participated in the shares market (trading at least one share) and 74% traded in the coupons market. As expected, transactions costs reduce the level of participation: more subjects participate in the shares market and more shares are traded in C1 and C2 than in S1 and S2, whereas the opposite is true for the coupons market (*table* 5). There are no significant differences between types in the rate of market participation (Mann-Whitney U test for the difference between participation rates of types 1 and types 2: p-value=0.39 for coupons and 0.84 for shares).

Although we observe high trading activity in both markets, the exchange of shares and coupons between type-1 and type-2 subjects remains lower than theoretically predicted under risk neutrality. We observe that type-1 subjects are net sellers and type-2 are net buyers on average. However, a significant proportion of trades occurs between subjects of the same type: 41% in the general security shares market, 29% in the high security shares market, 40% in the low security market and 24% in the coupons market. These trades between subjects of the same type contribute to market inefficiency (though some of these trades may also help subjects in learning the trading process).

Theory under risk neutrality predicts no gains from trade in the shares market in S1 and S2, as well as in the low security shares market and the coupons market in C2. However, only 30% of subjects do not trade shares in S1 and 25% in S2, 15% of subjects do not trade low security shares in C2 and 40% do not trade coupons in C2. No significant difference between types is observed. Risk-related behaviour (the impact of which we conjecture in the hypotheses section) can potentially explain the gap between observed behaviour and the no-trade theoretical prediction.[9]

Prices

One measure of market performance is the extent to which observed prices converge towards the risk-neutral theoretical predictions. We find that, average prices of shares are in the upper part of the interval prediction. Average prices of coupons are not significantly different from the equilibrium prediction in the blue scenario (p-value: 0.228 in S1 and 0.613 in S2) and lie within the lower part of the interval prediction in the yellow scenario. There is little fluctuation in prices over periods.

In theory, the price of shares should reflect the expected price of coupons. However, because uncertainty is not resolved when subjects are trading shares, we can expect the average observed price of shares to deviate from the average price of coupons. To examine this more closely, we compute, for each group and period, the price markup, defined as the difference between the observed average price of a share divided by the number of coupons obtained from this share, and the average price of a coupon in the same period. We include transactions costs in the price paid. In theory, the markup should be zero if subjects are risk neutral and are able to perfectly anticipate what the price will be in the coupons market in each scenario: indeed, under such assumptions, they should trade shares at a price equal to their expected value. In the experiment, the average markup is significantly positive in all treatments but C2 (4.98 ECUS in C1, 0.03 in C2, 9.27 in S1 and 5.73 in S2), indicating that in all treatments but C2, buyers overpay for shares. Low price markup is an indicator of market efficiency, which seems only reached for treatment C2, in which transactions costs are higher on the coupons market and which proposes a two security levels system for shares.

After having presented these general features of our experimental data, we examine the specific hypotheses concerning profits and risk management.

Hypothesis 1: Profits

Descriptive statistics on profits are presented in *table 6*. When transactions costs are greater in the coupons market, average profits are significantly higher under a two security level system (C2 compared to C1). On the other hand, we observe that profits are significantly lower in S2 than in S1. These results also hold when considering efficiency ratio instead of total profits.[10] *Table 7* presents results with random effects generalized least squares regressions with clustering, where the dependent variable is the profit made at the individual level. Two separate regression models are estimated for C1-C2 and S1-S2. Explanatory variables include treatment dummies (labeled C2 and S2), a scenario dummy (labeled yellow which takes a value of 1 when the scenario is yellow), type dummies (Type2=1 when subject's type is type 2) as well as period and elicited risk aversion (ERA). As expected, profits are lower under the yellow scenario and higher for type 2 subjects. We also observe a significant and positive effect of period, revealing a learning effect. Elicited risk aversion (ERA) does not significantly explain variation in profits. Consistent with the non-parametric results, the coefficient of the treatment dummy is significant and positive for C2 (*column 1,table 7*) and negative for S2 (*column 3, table 7*).

In *columns 2 and 4* of *table 7*, we also report regression specifications with interaction variables. The impact of treatment, type, scenario, period and ERA is unchanged. The total effect of the treatment is large and statistically significant (C2: coefficient = 5.988; p-value = 0.009 and S2: coefficient = -4.715; p-value= 0.030; see footnote of *table 9* for an explanation on the computation of the total effect). While the interaction variable between type 2 and treatment is not significant in C1-C2, it is significantly negative in S1-S2, suggesting that type-2 subjects are worse off in a differentiated system (*column 4, table 7*). Hence, the reduction in profits due to differentiated shares is mainly endured by type-2 subjects when transactions costs are higher in the shares market, whereas both types gain from differentiated shares when transactions costs are higher in the coupons market

To understand the observed asymmetry between type-1 and type-2 subjects better, we estimated a random effects generalized least squares regression model with clustering, where the dependent variable is the average price paid for a share by a subject in one period (general security shares in C1-S1 and high security shares in C2-S2). We observe that controlling for treatment dummies, elicited risk aversion of buyers and sellers and period, the price paid for a share is significantly higher if the buyer is of type 2 and/or if the seller is of type 1 (the p-values associated with the relevant coefficients are less than 0.05). Type 2 have a greater willingness to pay for shares because they want to be sure to get a minimum of coupons to avoid catastrophic losses, and type 1 are willing to sell only at high prices because they prefer to keep their shares and sell coupons. Both elements explain the positive price markup for shares on average and the consequent lower profit made by type-2 subjects since they are usually net buyers of shares. These results are available in the online supplementary appendix.

The observed pattern of profits and efficiency in the treatments with differentiated rights described in this section, i.e., higher in C2 (lower in S2), can be explained by the following factors: i) a more (less) profitable allocation of coupons at the end of the trading round and ii) lower (higher) transactions costs paid, therefore better cost-effectiveness. In the rest of this section, we explore the relative impacts of these two factors.

Impact of inefficiencies in coupon allocation on profits

As mentioned before, the increased complexity of water markets with different types of water rights may reduce farmers' participation in the market or increase their confusion and therefore be detrimental to water allocation. In the lab, we may therefore find that the complexity of treatments C2 and S2 could lead to an inefficient allocation of coupons and hence lower total benefits from coupons held.[11] To examine this, we test whether the deviation from the efficient allocation of coupons differs across treatments.

Columns 1 and 2 of table 8 present random effects generalized least squares regression models with clustering, where the dependent variable is the difference in absolute terms between the observed number of coupons held and the theoretical prediction. In both sub-samples, the treatment dummy has no significant impact. Subjects do not significantly deviate more in the two security levels treatments (C2 and S2) as compared to the single-security treatments (C1 and S1). This suggests that the complexity of a two security levels system does not affect the capacity of subjects to reach the equilibrium allocation of coupons.

Impact of transactions costs on profits

The cost-effectiveness of the market depends on the number of trades that are necessary to reach an efficient allocation, when these trades are costly. Theory predicts that market cost-effectiveness is higher in treatment C2 as no trade of coupons should occur. In the experiment, there are no trade of coupons in C2 in 40% of the observations averaged across subjects and periods. The average total transactions costs paid at the group level are significantly lower in C2 than C1 (*table 6*).

When transactions costs are higher in the shares market, there are theoretically no potential savings since no trade should occur for shares in S1 or in S2. In the experiment, the differentiated system reduces cost-effectiveness: average transactions costs paid in a group are significantly higher in S2 than S1. As mentioned in the overview section, subjects do not reach the predicted no-trade equilibrium in the shares market. They therefore pay more transactions costs than the optimal level calculated under risk-neutrality assumptions. We compute a ratio of extra-trades, which is equal to (total number of trades - net number of trades)/ net number of trades, where net number of trades is the difference between the number of units held after and before the trading stage for each subject. Therefore these "extra-trades" are capturing the difference between the total number of units traded and the final "net number of trades". We observe significantly more extra-trades of shares in S2 than S1 (8% in S1 and 49% in S2, p-value=0.00).[12] Note that extra-trades do not necessarily lead to an inefficient final allocation, because they can enable to correct mistakes. However, they reduce profits since unnecessary transactions costs are paid. *Table 8 (columns 3 and 4)* confirms these results with random effects generalized least squares regressions, where the dependent variable is the transactions costs paid by a subject. Transactions costs paid are significantly lower under C2 (compared to C1) and significantly higher under S2 (compared to S1). We also observe a significant and negative effect of period, revealing a learning effect.

Our results confirm hypothesis 1 when transactions costs are higher in the coupons market, but invalidate it when transactions costs are higher in the shares market. While there is no difference between treatments in the efficiency of final allocation of coupons, the second factor -transactions costs- explains why profits are higher in C2 (as compared to C1) and lower in S2 (as compared to S1). These results underline the important role of transactions costs, and therefore further justify our treatments. We now analyze the impact of the differentiated system on risk management.

Hypothesis 2: Risk management

Hypothesis 2a

We consider two related but distinct measures of overall risk (at the group level): (i) the difference between profits in the blue and yellow scenarios, and (ii) the standard deviation of profits. The last panel of *table 6* shows that both indicators do not differ significantly between the two market structures. In addition, we also examined the hypothesis of reduced overall risk under the assumption that subjects would rather adopt a maximin strategy, i.e. they would seek to maximize the lowest profit level. The average minimum profit obtained over periods 6 to 9 is significantly greater in C2 as compared to C1 (74.47 in C2 compared to 69.55 in C1, p-value = 0.00), and therefore the overall risk is lower. However, we observe the reverse in the S1-S2 comparison. This is mainly due to the fact that transactions costs paid in S2 are greater and weigh more on the minimum profit. Therefore, hypothesis 2a is only supported when profit management is interpreted as a maximin strategy, and only when transactions costs are paid on the coupons market.

Hypothesis 2b

Even though a two security levels system does not seem to reduce overall risk at the group level, data show that it helps to share risk more efficiently. We argued before that the shape of the benefit functions suggest that type-2 subjects may be less risk-tolerant than type-1 subjects. Therefore type-2 subjects are expected to take decisions which contribute to a reduction in the variability of their profits, even if this reduction of risk has a cost in terms of lower average profits. On the contrary, type-1 subjects are expected to accept an increase in the variability of their profits in exchange of higher average profits.

We find that the difference in profits between blue and yellow scenarios, when comparing across a one security system and a two security system, tend to significantly increase for type-1 subjects and to decrease for type-2 subjects. The same results hold with the standard deviation of profits (*table 6*). We also present regression models on the difference between average profits in the blue scenario and yellow scenario for each type and each treatment comparison *(table 9)*. The total treatment effect (C2 and S2), reported in the bottom panel of *(table 9)*, is positive and significant for type-1 subjects and negative for type-2 subjects though not significant. The joint test of significance for the interaction terms shows that the treatment variable (C2 or S2) has a significant impact on the variability of profits, for all regressions but the last (S1-S2, type 2). While the statistical significance is not uniformly strong for both types, the direction of the effect is clear, hence providing support for hypothesis H2b.

Table 9 also controls for the effect of elicited risk aversion (ERA). The variability of profits is lower for subjects of both types with higher elicited risk aversion in all treatments, though it is never statistically significant. In addition, the total effect of ERA is never significant (except for type 1 in S1-S2), suggesting that ERA has less explanatory power for risk allocation outcomes, as compared to type. We also include another dummy called "risk taking" in the regression, which captures the perception that subjects had of their risk-related behavior.[13] We observe that subjects who declare having taken risks during the experiment have more variable profits but the total effect of "risk taking" is significant only for type 2 in S1-S2.

The results confirm our intuition on the effect of risk tolerance presented in hypothesis 2. As the differentiated system offers more opportunities to adapt behavior in response to risk, we observe gains in terms of risk allocation both in C2 and S2. The difference is that this risk-reallocation is more costly in S2 than C2 because it is costly to trade shares.

How does this re-allocation of risk work? We find that risk re-allocation is a "win-win" situation as those who increase their risk are compensated by higher average profits. Type-1 subjects increase their profits in S2 as compared to S1, whereas type-2 subjects have significantly lower profits. Both types increase their average profits in C2 as compared to C1 but the relative increase of profits is higher for type-1 subjects. In both cases, we can see that type-1 subjects are compensated for the higher risk taken. They "sell security" to type-2 subjects in C2 and S2.

Overall, the results concerning risk are similar whatever the configuration of transactions costs. It suggests that a two security levels system does not always reduce risk at the group level but it can improve risk allocation.

Conclusion

There is a major impetus for water reforms around the world. Much is expected from the development of sophisticated water markets to improve the economic efficiency of water allocation, especially in times of increasing scarcity and rainfall variability. In this article we focus on the design of markets for water rights by analyzing the relative benefits of designing rights with different levels of security. While there are on-going policy debates for improving the risk management potential of water markets, no previously reported research has systematically studied the impact of introducing water rights with different security levels. We find that security-differentiated water rights can improve the performance of water markets but the outcome is dependent on market transactions costs.

Our results provide the first step towards designing water markets that can simultaneously achieve an efficient and cost-effective allocation of water and risk. Translating our experimental results into water terminology, our findings suggest that the differentiated system offers interesting opportunities in terms of risk allocation, irrespective of the transactions cost scenario: less risk-tolerant farmers can trade-off lower average profits for lower variability of profits, by constituting the right portfolio of high security and low security shares. Hence, as risk becomes a major concern for farmers, differentiated markets may become a valuable water policy option. The differentiated system can also increase farmers' profits, provided that transactions costs in the rights market are lower than in the allocation market. When transactions costs in the rights market are higher, our results underline the trade-off between the ability of differentiated rights to provide better risk-management solutions to farmers, and the possibility to make more mistakes in the transaction due to the increased complexity of the market.

Our research focuses on decision making in a static framework, for intra-seasonal trade among farmers with different risk tolerance. It does not include the other benefits of creating a water right system with several security levels: for example, since water rights are permanent assets, whose value depends on the level of security attached to them, farmers may be willing to hold high security rights in order to improve the management of their long-term risks. These arguments would reinforce our case in favor of a differentiated right system. Another policy recommendation is to ensure that transactions costs on the market for water rights be minimized so that participants can take the full advantage of the differentiation in security levels.

It would be useful to replicate these results using field experiments with key market participants (for example, farmers), and include more features of water markets (for example, a dynamic game where rights can be held over many periods). Farmers may relate more to the context of a two security levels system than subjects in a laboratory (Herberich et al. (2009)) and allowing the banking of shares may lead subjects to attain the no-trade equilibrium in the rights market, hence improving the performance of the differentiated system.

Alternative mechanisms, such as option markets, have been proposed by policy makers in order to improve the tools available to farmers to hedge the risk of water availability. Under an annual dry-year option, a water user pays a premium for the right to purchase water at a later date, contingent on the pre-specified strike price (Howitt (1998), Hansen et al. (2008)). Future research in this area could compare both policies using experimental methods: water rights markets to trade rights with different levels of security or an option market for future allocation. In order to compare these two alternative systems, the trade-off between potential efficiency of the scheme and the necessary level of participation in the markets would need to be considered. For example, it is possible that the performance of a futures market may be less dependent on the number of trades and transactions costs as compared to a differentiated water market.

Notes

[1]While this problem is particularly crucial for unregulated river systems where there is no water storage through reservoir dams, it also exists for regulated systems because the probability of reserve replenishment from one year to another fluctuates with climatic change.

[2]Noussair and Porter (1992) ran an auction experiment, inspired by the priority service literature, on proportional versus priority rationing systems (Wilson and Chao (1987), Wilson (1989)). As there is no reconciliation market in their design, the only way to achieve efficient allocation is through the auction and the rationing scheme. Our article on the contrary has a reconciliation mechanism (the market for water allocation is a kind of reconciliation market in case the allocation is not efficient after the market for water rights), hence efficient allocation is the result of both the allocation and the rights market, as we describe in the next paragraph.

[3]Water users' willingness to pay for reliability has been studied extensively but mainly in the context of potable water. These studies aim at measuring the optimal capacity for potable water distribution given the trade-off between the additional cost of upgrading the infrastructure and risk of water restriction (see Griffin and Mjelde (2000) for example).

[4]In practice (for example, in the Australian context), both markets could operate simultaneously but the high security market tends to be more active. In theory, the order in which trading takes place does not impact the equilibrium of both markets. Experimentally, some order effects may be observed. To limit the number of treatments, we chose to run the experiment with the high security shares market first followed by the low security market, as it is more intuitive to trade the more secure assets first.

[5]We could also have run complementary and intermediary treatments with no transactions costs or equal transactions costs in both markets. However, under these two configurations of transactions costs, we can show that the incentives to trade shares are reduced, thus limiting the gains from a two security levels system. Due to budget limitations, we concentrated our data collection efforts on the two treatments for which the gains from a two security levels system are theoretically the highest (C1-C2) and the lowest (S1-S2).

[6]This fee is relatively high compared to the fee/water price ratio observed in operational water trading platforms. We chose to set a high transaction fee in the lab to capture all the non-monetary but time-consuming transactions costs born by farmers including writing contracts, locating and identifying trading partners. Moreover, in the field, buyers and sellers do not pay the same transaction cost. But theoretically the burden of the cost should be shared equally if the market is truly competitive. Therefore, we have an equal fee for buyers and sellers in the experiment. Lastly, we chose to set the same transactions costs on the coupons market (in C1-C2) and on the shares market (S1-S2). In water markets in the field, it is much more costly to trade rights but, since water rights are long term assets, transactions costs paid to acquire a right are amortized over several years. Our experimental setup is based on the assumption that transactions costs that need to be paid for each

trade of water allocation is approximately equal to the annual value of transactions costs paid for rights trading (since shares have only a one-period lifetime in our experiment).

[7]Seven subjects out of 144 switched more than once. Seven other subjects never switched even though it is more profitable and riskless to switch to option Y in the last lottery (choice 10). We have dropped these 14 subjects from the data set used for the regressions (*tables 7 to 9*). The results are robust to their inclusion.

[8]In our experimental setting, as we have randomly assigned subjects to types, we do not observe any significant correlation between type and elicited risk aversion (coefficient of correlation r= -0.0837; p value=0.3437).

[9]Experimenter Demand effect could also be an explanation. It has been observed in some experimental markets that the very act of placing subjects in a laboratory experimental market and asking them to set prices probably creates some presumption that they should trade (Zizzo (2010), Angrisani et al. (2011))

[10]Efficiency ratio can be used to compare the observed profits with the maximum attainable profits under risk neutrality (this is the equilibrium prediction assuming equal bargaining power of subjects). In order to correct for the high efficiency ratio that can be obtained without trade (efficiency levels are close to 85% even if subjects hold on to their initial allocation of shares and coupons), we compute the following ratio: (observed total profits - profits without trade)/(maximum theoretical profits - profits without trade).

[11]We made sure that complexity or confusion was reduced to the extent possible. For example, we conducted pilots to ensure that our instructions and software were easy to understand. In addition, subjects participated in a quiz after the instructions were read out. This gave them an opportunity to review the instructions on their own, answer questions and clarify any existing concerns with the experimenter. In the post experimental questionnaire, subjects did not indicate any confusion with any aspect of the experiment.

[12]This could be potentially due to a higher experimenter demand effect in S2 than S1, since there are two opportunities to trade shares in S2. However, we argue that this effect is limited due to the following reasons: Firstly, we conducted practice periods, where subjects could learn the workings of the market. Secondly, we have only used the last four periods in the descriptive statistics, as unnecessary trades decrease with repetitions. Thirdly, if these extra-trades were the result of a higher experimenter demand effect, we should also observe more extra-trades in C2 as compared to C1. This is not the case: there is no significant difference in the number of extra-trades in C2 compared to C1 (p-value=0.40). Therefore, we can conclude with some confidence that the experimenter demand effect is not responsible for the extra-transactions costs paid in S2 as compared to S1.

[13]This dummy corresponds to the answer given by subjects at the end of the experiment to the question "Do you think that you have taken risks during the experiment?" This response was coded 1 when they responded yes and 0 otherwise. 60% of the subjects reported to have taken risk during the experiment. There is no significant correlation between type and reported risk taking

(r= 0.0158 p value=0.8588), nor between elicited risk aversion and reported risk taking (r= 0.0125 p value=0.8882).

References

Allen Consulting Group (2006). Transaction costs of water markets and environmental policy instruments. Technical report, Productivity Commision, Australia.

Angrisani, M., Guarino, A., Huck, S., and Larson, N. C. (2011). No-trade in the laboratory. *The B.E. Journal of Theoretical Economics (Advances)*, 11(1).

Bjornlund, H. (2003). Farmer participation in markets for temporary and permanent water in southeastern Australia. *Agricultural Water Management*, 63:57–76.

Bjornlund, H. (2006). Can water markets assist irrigators managing increased supply risk? some Australian experiences. *Water International*, 31(2):221–232.

Bjornlund, H. and Rossini, P. (2008). Are the fundamentals emerging for more sophisticated water market instruments ? In *Proceedings from the 14th Annual Conference of the Pacific Rim Real estate Society, Kuala Lumpur, Malaysia*.

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

Bourgeon, J.-M., Easter, K. W., and Smith, R. B. (2008). Water markets and third-party effects. *American Journal of Agricultural Economics*, 90(1):902–917.

Bowles, S. (1998). Endogenous preferences: The cultural consequences of markets and other economic institutions. *Journal of Economic Literature*, 36:75–111.

Brennan, D. (2006). Water policy reform in Australia: lessons from the Victorian seasonal water market. *Australian Journal of Agricultural Economics*, 50:403–423.

Brooks, R. and Harris, E. (2008). Efficiency gains from water markets: Epirical analysis of watermove in Australia. *Agricultural Water Management*, 95:391–399.

Brown, P. M. and Stewart, S. (1999). Avoiding severe environmental consequences: Evidence on the role of loss avoidance and risk attitudes. *Journal of Economic Behavior and Organization*, 38:179–198.

Calatrava, J. and Garrido, A. (2005). Spot water markets and risk in water supply. *Agricultural Economics*, 33:131–143.

Calatrava, J. and Garrido, A. (2006a). Difficulties in adopting formal water trading rules within users' associations. *Journal of Economic Issues*, XL(1):27–44.

Calatrava, J. and Garrido, A. (2006b). *Risk aversion and gains from water trading under uncertain water availability*, pages 43–67. Frontiers in Water Resource economics. Goetz and Berga, Springer edition.

Carey, J., Sunding, D. L., and Zilberman, D. (2002). Transaction costs and trading behavior in an immature water market. *Environment and Development Economics*, 7(4):733–750. Special Issue: The economics of water: environment and development.

Cason, T. N. and Friedman, D. (2008). *A comparaison of Market Institutions*, volume 1 of *Handbook of Experimental Economic Results*, pages 264–272. North Holland.

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

Colby, B. G. (1990). Transaction costs and efficiency in western water allocation. *American Journal of Agricultural Economics*, 72(5):1184–92.

Cristi, O. (2007). *The influence of 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.

Eeckhoudt, L., Gollier, C., and Schlesinger, H. (2005). *Economic and Financial Decisions under Risk.* Princeton University Press.

Fischbacher, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2):171–178.

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

Gangadharan, L. (2000). Transactions costs in pollution markets: An empirical study. *Land Economics*, 76(4):601–614.

Gardner, B. D. and Fullerton, H. H. (1968). Transfer restrictions and misallocations of irrigation water. *American Journal of Agricultural Economics*, 50(3):556–571.

Garrido, A. (2007). Water markets design and evidence from experimental economics. *Environmental and Resource Economics*, 38(3):311–330.

Godby, R., Mestelman, S., Muller, R. A., and Welland, J. D. (1997). Emissions trading with shares and coupons when control over discharges is uncertain. *Journal of Environmental Economics and Management*, 32:359–381.

Goodman, D. J. and Howe, C. W. (1997). Determinants of ditch company share prices in the south platte river basin. *American Journal of Agricultural Economics*, 79:946–951.

Grafton, R. Q. and Peterson, D. (2007). *Water trading and pricing*, pages 73–84. Managing Water for Australia. CSIRO Publishing.

Griffin, R. and Mjelde, J. W. (2000). Valuing water supply reliability. *American Journal of Agricultural Economics*, 82:414–426.

Hansen, K., Howitt, R., and Williams, J. (2008). Valuing risk: Options in Californian water markets. *American Journal of Agricultural Economics*, 90(5):1336–1342.

Hansen, K., Kaplan, J., Kroll, R., and Howitt, R. (2007). Valuing options in Californian water markets: A laboratory investigation. *Working Paper*.

Herberich, D. H., Levitt, S. D., Ogden, W. B., and List, J. A. (2009). Can field experiments return agricultural economics to the glory days ? *American Journal of Agricultural Economics*, 91(5):1259–1265.

Howe, C. W. and Goesmans, C. (2003). Water transfers and their impacts: Lessons from three Colorado water markets. *Journal of the A*, pages 1055–1065.

Howitt, R. E. (1998). Spot prices, option prices and water markets: An analysis of emerging markets in California. In Easter, Rosegrant, D., editor, *Markets for water: Potential and Performance*. Kluwer Academic Publisher.

Howitt, R. E. and Taylor, C. R. (1993). *Some microeconomics of agricultural resource use*, pages 28–68. Agricultural and Environmental Resource Economics. Oxford University Press.

Hughes, N. and Goesch, T. (2009). Management of irrigation water storages: carry-over rights and capacity sharing. Technical report, ABARE research report 09.10.

Kerr, S. and Mare, D. (1995). Efficient regulation through tradable permit markets: The United States lead phasedown. University of Maryland Department of Agricultural and Resource Economics Working Paper 90-06.

Libecap, G. (2011). Institutional path dependence in climate adaptation: Coman's "some unsettled problems of irrigation". *American Economic Review*, 101:1–19.

National Water Commission (2009). Australian water market report 2008-2009. Technical report, National Water Commission, NWC, Canberra.

Noussair, C. and Porter, D. (1992). Allocating priority with auctions: An experimental analysis. *Journal of Econonomic Behavior and Organization*, 19:169–195.

Productivity Commission (2010). Market mechanisms for recovering water in the murray darling basin. Technical report.

Quiggin, J. (2008). *Uncertainty, Risk and Water management in Australia*, chapter 5. Water policy in Australia : the impact of change and uncertainty. Resources for the Future.

Rigby, D., Alcon, F., and Burton, M. (2010). Supply uncertainty and the economic value of irrigation water. *European Review of Agricultural Economics*, 37(1):97–117.

Schoemaker, P. J. H. (1993). Determinants of risk-taking: behavioral and economic views. *Journal of Risk and Uncertainty*, 6:49–73.

Shi, T. (2006). Simplifying complexity: Rationalising water entitlements in the southern connected river murray system, Australia. *Agricultural Water Management*, 86:229–239.

Tisdell, J. (2011). Water markets in Australia: an experimental analysis of alternative market mechanisms. *The Australian Journal of Agricultural and Resource Economics*, 55:500–517.

Wilson, R. (1968). The theory of syndicates. *Econometrica*, 36:113–132.

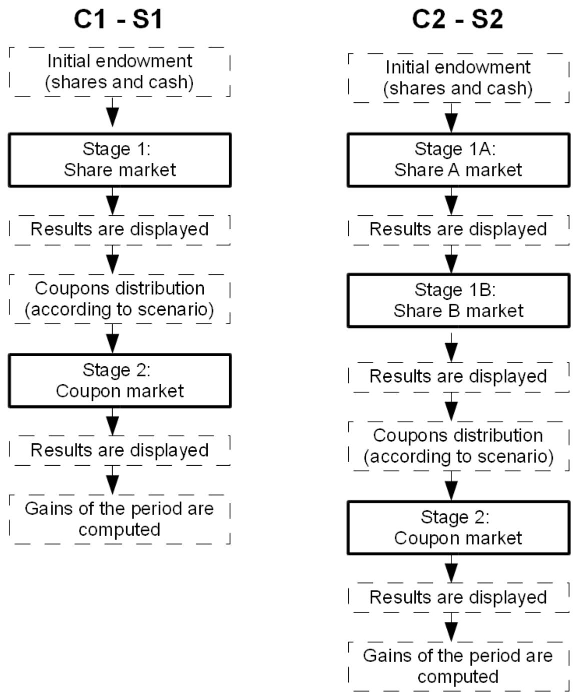
Wilson, R. (1989). Efficient and competitive rationing. *Econometrica*, 57(1):1–40.

Wilson, R. and Chao, H. (1987). Priority service : pricing, investment and market organization. *American Economic Review*, 77:899–916.

Young, M. (2010). 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.

Zizzo, D. (2010). Experimenter demand effects in economic experiments. *Experimental Economics*, 13:75–98.

Figure 1: Game Structure



Notes:
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Shares: Water Rights. Shares A are the high security shares and shares B the low security shares.
C1: Treatment with higher TC in the coupons market and one level of security
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S2: Treatment with higher TC in the shares market and two levels of security

Table 1: Treatments

	One Security level	Two security levels
TC are higher in the coupon market	C1	C2
TC are higher in the share market	S1	S2

Table 2: Coupons Allocation

	Blue scenario	Yellow scenario
Number of coupons received from 1 Share	1	0.33
Number of coupons received from 1 Share A	1	1
Number of coupons received from 1 Share B	0.5	0
Total number of coupons allocated in a group	54	18

Notes:
Yellow: Dry
Blue: Wet
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Table 3: Marginal and Total Benefits (in ECUs) for Coupons Held at the End of a Period

#coupons held	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	≥16
Type 1																	
per unit	0	10	9	8	7	6	5	4	3	2	1	0	0	0	0	0	0
total	0	10	19	27	34	40	45	49	52	54	55	55	55	55	55	55	55
Type 2																	
per unit	0	0	0	0	24	22	20	18	16	14	12	10	8	6	4	2	0
total	0	0	0	0	24	46	66	84	100	114	126	136	144	150	154	156	156

Notes:
Type 1: More Risk Tolerant
Type 2: Less Risk Tolerant
Coupons: Water Allocations

Table 4: Equilibrium Predictions (Risk Neutrality)

	C1	C2	S1	S2
Shares		**(A;B)**		**(A;B)**
Shares held by Type 1	6	(0;12)	9	(3;12)
Shares held by Type 2	12	(6;12)	9	(3;12)
Total trades in a group #	9	(9;0)	0	(0;0)
Equilibrium price ##	[4.67;6.33]	([8;13];–)	–	–
Coupons				
Blue scenario				
Coupons held by Type 1	6	6	5	5
Coupons held by Type 2	12	12	13	13
Total trades in a group#	0	0	12	12
Equilibrium price ##	–	–	4.67	4.67
Yellow scenario				
Coupons held by Type 1	0	0	0	0
Coupons held by Type 2	6	6	6	6
Total trades in a group #	6	0	9	9
Equilibrium price ##	[10;20]	–	[12;18]	[12;18]
Total TC paid in a group				
Blue scenario	0	0	0	0
Yellow scenario	12	0	0	0
Profits ###				
Average over all periods				
Group	670.5	682.5	684	684
Type 1	102	104	102	102
Type 2	121.5	123.5	126	126
Blue scenario				
Group	867.5	867	870	870
Type 1	111.5	126.5	109	109
Type 2	177.5	162.5	181	181
Yellow scenario				
Group	474.5	498	498	498
Type 1	92.5	81.5	95	95
Type 2	65.5	84.5	71	71
Difference in average profits between scenarios				
Group	393.5	369	372	372
Type 1	19	45	14	14
Type 2	112	78	110	110

The total number of trades is divided by three to obtain the number of goods traded by a subject. At equilibrium, type 1 are net sellers and type 2 are net buyers.
When no trade is expected at equilibrium, there is no equilibrium price.
We assume equal bargaining power of subjects.

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Table 5: Experimental Data: Allocation and Trade

Average statistics over last four periods (6 to 9)

	C1	C2	S1	S2
Shares market		**(A;B)**		**(A;B)**
Participation rate (%)				
Type 1	84	(89;78)	70	(67;77)
Type 2	90	(89;89)	72	(78;68)
Number of shares held				
Type 1	7.96	(1.56;11.14)	8.18	(2.18;11.75)
Type 2	10.04	(4.44;12.86)	9.82	(3.82;12.25)
p-value#	*0.031*	*(0.031;0.036)*	*0.059*	*(0.115;0.563)*
Quantities traded				
Total trades in a group	10.50	(6.88;10.46)	5.96	(5.21;4.38)
Net trades in a group##	8.33	(6.29;9.08)	5.42	(4.62;4.00)
Net trades for a subject###	1.04	(1.44;0.86)	0.82	(0.82;0.25)
Average price	7.9	(11.6;2.0)	6.9	(12.9;3.2)
Coupons market				
Participation rate (%)				
Type 1	73	56	88	80
Type 2	67	64	88	73
Blue scenario				
Number of coupons held				
Type 1	7.39	6.69	6.00	6.61
Type 2	10.61	11.81	12.00	11.92
p-value#	*0.156*	*0.054*	*0.058*	*0.031*
Quantities traded				
Total trades in a group	3.50	3.75	10.00	7.42
Net trades in a group##	2.83	3.17	9.42	5.75
Net trades for a subject###	0.61	0.86	2.36	1.75
Average price	7.3	6.6	7.3	6.6
Yellow scenario				
Number of coupons held				
Type 1	2.06	0.94	1.08	1.11
Type 2	4.06	5.06	5.08	4.89
p-value#	*0.036*	*0.031*	*0.036*	*0.059*
Quantities traded				
Total trades in a group	4.42	2.33	6.25	4.00
Net trades in a group##	4.08	2.17	5.75	3.92
Net trades for a subject###	0.64	0.58	1.69	1.06
Average price	10.2	12.5	11.0	11.7

We present the p-values of the two-sided Wilcoxon test where we compare the observed outcome with the theoretical predictions on number of shares and coupons held by a subject.
Net trades in a group= $\sum_{i=1}^{6}$|number of goods held after the market stage by i - number held before by i |
The average number of trades for a subject is equal for both types but type 1 are net sellers on an average and type 2 are net buyers.

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S2: Treatment with higher TC in the shares market and two levels of security

Table 6: Experimental Data - Average Profits, Variability of Profits and Efficiency

Average statistics over last four periods (6 to 9)

	C1	C2	*p-value*	S1	S2	*p-value*
Profits(ECUs)						
Average over all periods						
Group#	626	656	*0.000*	655	629	*0.000*
Type 1	97	102	*0.087*	99	100	*0.253*
Type 2	111	117	*0.000*	120	110	*0.000*
Efficiency Ratio(%)						
Group	42.36	70.42	*0.000*	68.62	39.89	*0.000*
Type 1	57.25	83.64	*0.087*	70.05	81.64	*0.253*
Type 2	30.56	59.60	*0.022*	67.76	14.62	*0.000*
Transactions costs paid						
Group Average	15.8	12.2	*0.079*	23.8	41.3	*0.000*
Type 1	3.5	2.0	*0.315*	2.8	6.9	*0.000*
Type 2	3.7	2.5	*0.195*	5.4	9.2	*0.115*
Difference in average profits between scenario						
Group	341	361	*1*	368	372	*1*
Type 1	25.05	32.97	*0.00*	27.45	34.44	*0.01*
Type 2	88.75	87.53	*0.153*	92.25	89.5	*0.045*
Standard Deviation of Profits						
All subjects	35.45	35.93	*0.222*	36.74	36.96	*0.416*
Type 1	18.58	21.05	*0.043*	17.79	21.27	*0.022*
Type 2	52.33	50.81	*0.153*	55.69	52.66	*0.045*

In addition to the Mann-Whitney U tests reported above, we also conducted a robust-rank order test on average profits as the samples dispersions seem different between treatments (Feltovich (2003)). For C2-C1, with U=-6.25, the robust rank order test is significant at the 0.5% level (U left-tail critical value=-4.803): profits are significantly higher in C2 than C1. For S2-S1, with U=3.07, the test is significant at the 2.5% level (U right-tail critical value=2.55): profits are significantly lower in S2 than S1.

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Table 7: Individual Profits
- Random effects panel regression, with errors clustered at the group level-

Dependant variable	Individual profits			
Explanatory variables	C1 - C2		S1 - S2	
Yellow	-59.76***	-28.36***	-63.02***	-30.99***
	(2.880)	(2.388)	(1.539)	(1.878)
Type 2	18.63***	67.81***	17.90***	31.02
	(3.667)	(25.99)	(3.187)	(21.17)
Period	0.556***	0.556***	0.761***	0.761***
	(0.204)	(0.205)	(0.169)	(0.169)
ERA	1.193	4.279	0.315	-1.373
	(1.107)	(3.429)	(1.035)	(1.782)
C2	4.931***	30.36*		
	(1.604)	(16.67)		
Yellow x C2		3.267		
		(3.268)		
Type 2 x C2		-2.443		
		(7.950)		
ERA x C2		-3.687		
		(2.273)		
S2			-4.386**	-7.994
			(2.099)	(17.55)
Yellow x S2				-1.980
				(2.444)
Type2 x S2				-10.22*
				(5.895)
ERA x S2				1.380
				(2.519)
Yellow x Type 2		-68.20***		-60.30***
		(5.124)		(4.228)
ERA x Type 2		-2.372		2.734
		(3.443)		(3.074)
Constant	114.7***	78.27***	124.7***	119.9***
	(8.857)	(25.92)	(6.989)	(12.52)
Observations	576	576	594	594
Number of subjects	64	64	66	66
Wald Chi-squared	94418	1.100e+07	18710	78382
Prob>Chi-squared	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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ERA: Elicited Risk Aversion

Table 8: Deviation from Efficient Allocation of Coupons and Transactions Costs
-Random effects panel regression, with errors clustered at the group level-

Dependant variable	Deviation nb coupons held #		TC paid per subject	
Explanatory Variables	C1-C2	S1-S2	C1-C2	S1-S2
C2	-0.358		-1.515**	
	(0.262)		(0.765)	
S2		-0.143		3.397***
		(0.372)		(0.998)
Type 2	-0.667**	-0.145	0.146	2.138**
	(0.277)	(0.207)	(0.303)	(0.895)
ERA	0.00973	-0.0556	0.0695	-0.406*
	(0.0774)	(0.0672)	(0.103)	(0.234)
Yellow	-0.296	-0.0291	-0.125	0.614*
	(0.229)	(0.194)	(0.388)	(0.313)
Period	-0.0529***	-0.124***	-0.188**	-0.251**
	(0.0156)	(0.0260)	(0.0810)	(0.126)
Constant	2.711***	2.874***	4.098***	6.953***
	(0.689)	(0.605)	(0.764)	(1.531)
Observations	576	594	576	594
Number of subjects	64	66	64	66
Chi2	303.4	139.3	115.0	1575
Prob>Chi-squared	0.00	0.00	0.00	0.00

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Deviation nb coupons held is the difference in absolute terms between the observed number of coupons held and the theoretical prediction.

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S1: Treatment with higher TC in the shares market and one level of security
S2: Treatment with higher TC in the shares market and two levels of security
ERA: Elicited Risk Aversion

Table 9: Risk Allocation - Variability of Profits Between Scenarios

We take the absolute difference between average profit in the blue scenario (periods 7 and 8) and average profit in the yellow scenario (periods 6 and 9) as a measure of variability of profits. As a result, we have one observation per subject. We estimate linear regressions, with errors clustered at the group level.

Dependant variable	Variability of profits			
	C1 - C2		S1 - S2	
Explanatory variables	Type 1	Type 2	Type 1	Type 2
ERA	-2.470	-2.816	-1.011	-1.833
	(1.713)	(2.785)	(1.133)	(2.201)
Risk Taking	1.456	-9.962	-8.303**	8.778
	(8.594)	(9.159)	(3.519)	(7.191)
C2	0.0380	-27.89		
	(22.43)	(23.83)		
ERA x C2	0.849	0.301		
	(3.605)	(3.644)		
Risk Taking x C2	2.672	38.40***		
	(14.08)	(11.07)		
S2			15.24	-3.739
			(10.04)	(16.87)
ERA x S2			-2.765*	-0.339
			(1.425)	(3.627)
Risk Taking x S2			15.28**	5.472
			(5.015)	(11.92)
Constant	41.14**	119.1***	40.38***	100.0***
	(16.66)	(16.59)	(7.466)	(12.03)
Total effects # *(p-value)*				
Treatment (C2-S2)	7.81** *(0.021)*	-5.68 *(0.544)*	3.71** *(0.045)*	-0.66 *(0.797)*
ERA	2.04 *(0.281)*	-2.66 *(0.171)*	-2.39*** *(0.006)*	-2.00 *(0.293)*
Risk Taking	2.79 *(0.699)*	9.23 *(0.123)*	-0.66 *(0.797)*	11.51* *(0.080)*
Joint test of significance	F *(Prob>F)*			
C2 ERAxC2 RiskTakingxC2	4.64 *(0.025)*	13.51*(0.000)*		
S2 ERAxS2 RiskTakingxS2			9.85 *(0.002)*	0.18 *(0.905)*
Observations	33	31	32	34
R-squared	0.146	0.362	0.538	0.108
F(5,11)	7.710	26.52	10.51	3.212
Prob>F	0.00245	8.70e-06	0.000671	0.0496

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

#The total effects are computed as the sum of each effect, weighted by the mean of the interaction variable. For example, the total effect of C2 for type 1 is equal to C2+ERAC2*mean(ERA)+riskTakingC2*mean(riskTaking) = 0.0380+0.849*6.878+ 2.672 *0.722=7.81. The null hypothesis is that total effect is zero, the p-value reports if the null is rejected.

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S1: Treatment with higher TC in the shares market and one level of security
S2: Treatment with higher TC in the shares market and two levels of security
ERA: Elicited Risk Aversion
Risk Taking: =1 if the subject answers "yes" to the question Do you think that you have taken risks during the experiment ?, 0 otherwise

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