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« Do Security-differentiated Water Rights  
Improve Efficiency? »

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# Do security-differentiated water rights improve efficiency?

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## Abstract

Most existing water markets combine water rights trading and water allocation trading. Offering different levels of security for rights can make the market more sophisticated and allow water users to manage the risks of supply uncertainty better. We compare results from a laboratory experiment with two water right designs, one with a unique security level and another with two security levels. We find that a two security levels system improves both allocative efficiency and risk management, but only when transactions costs are higher in the market for water allocation than in the market for water rights.

*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 trading mechanisms to re-allocate water, there is an ongoing debate on how to improve the trading process. The existing literature has mainly focused on two aspects of water trading: trading constraints and transactions costs which reduce efficiency gains (Gardner and Fullerton (1968), Colby (1990), Allen Consulting Group (2006), Carey et al. (2002)); and third party impacts when trade might affect other users who are not involved in the transaction (Productivity Commission (2006, 2010), Bourgeon et al. (2008)). However, another important issue that deserves attention is the role that water markets can play to mitigate the risk of water shortage for farmers.<sup>1</sup>

The co-existence of both a market for water rights and a market for water allocation has been recognized as a useful risk management tool for irrigating farmers (Bjornlund (2006)). In most countries where water can be traded, farmers can buy or sell water rights, which entitle them to a given share of total available water within a season. The water volume that each right holder gets is called his allocation. When needed, farmers can also buy or sell water on the seasonal allocation market. Water markets improve the efficiency of water allocation and reduce farmers' exposure to risk as they transform the risk related to the availability of the water input into a risk on input prices (Calatrava and Garrido (2005)). Moreover, farmers are better able to manage their risks by shifting from the right market to the allocation market (and vice-versa) according to production conditions.

Under increasing pressure to manage water more efficiently, water trade institutions are being progressively strengthened, as the benefits of doing so (in terms of property rights being well-defined and markets becoming more complete) can offset the inherent costs involved (Bjornlund and Rossini (2008), Libecap (2011)). Under most statutory water right laws, as in Chile, Mexico and most of Australia, water rights are all identical in terms of security. They are defined as a proportion of stream flow or storage capacity and the total available water in a season is shared between water right holders in proportion to the number of rights they own. In other countries and states however, 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 low security allocations. As a result, low security water right holders bear the bulk of the risk of low water supply. Such hierarchy of rights is also the basis of the prior appropriation doctrine, much in use in western 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. Since 1994, some Australian states (New South Wales and Victoria) have created a differentiated water right system. Farmers can constitute a portfolio of water rights of two security levels. It is expected that a differentiated water rights system would improve the efficiency of resource and risk allocation across farmers. However such reforms are administratively complex and can lead to substantial transaction and learning costs for water users. 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, in Australia, little activity is observed yet in the market for low security rights (National Water Commission (2009)) and in the western United States, the trading of senior water rights is restricted by regulations controlling third party effects (Libecap (2011)). As a result, there are too few 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 of the performance across the systems difficult. This article therefore uses data from laboratory experiments. It presents an experimental design that captures the main characteristics of existing water markets.

The design is noteworthy in two respects. First, we introduce two markets in our experiment: a market for water rights and a market for water allocation. While other experimental studies have explored one market in isolation (for example, Cristi and Alevy (2009) and Garrido (2007) focus on the allocation market, whereas Hansen et al. (2007) include the allocation market and an option market but no rights market), this article is the first to consider both markets. In the emission trading experimental literature, Godby et al. (1997) designed an experiment mimicking the Canadian emissions trading market, including both a share and a coupon 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 future periods. Our experiment is inspired by this design. Subjects first participate in a “share market” (corresponding to the water rights market) without knowing the allocation of “coupons” (corresponding to water allocation) they will get from their shares. In a second stage, they can trade their coupons on the coupon market (corresponding to the market for

water allocation).

The second novelty of our design is the introduction of different levels of security for shares which enables us to compare the proportional rights system with the priority system. While Calatrava and Garrido (2006) compared these two definitions of water rights using simulation data, they do not consider water rights trading in their analysis. To our knowledge this design feature has not been examined systematically using experimental methods.<sup>2</sup>

The two main treatment variables of our experiment are the number of security levels for shares (1 or 2) and the presence of transactions costs in the share and coupon markets. With these treatments, we examine the role of transactions costs which are recognized as an important feature of water markets and 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 efficiency of water allocation and 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 reports the experimental results and Section 5 concludes with some implications for policy.

## Rationale for differentiated water rights

The benefits from a water market with differentiated rights rely on the existence and efficiency of the water rights market itself. Most of the countries that are engaging in water market reforms are investing into the creation or the enhancement of water rights markets, for example through the formal separation of water rights from land rights, mainly to facilitate real structural change within the irrigation industry. If the water market is perfectly competitive and transaction-cost free, and if water users are risk-neutral, then it is well-known that trading on the seasonal allocation market is sufficient to reach an efficient allocation of water amongst users (Freebairn and Quiggin (2006)). In theory, trading on the water rights market should not occur since all water users have the same expected value for water rights

(expected value of the corresponding allocation on the allocation 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. Nevertheless, it is observed that farmers are showing growing interest in water rights trading and water rights markets are slowly picking up (Young (2010)). 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. Some irrigators 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)). A system with differentiated water rights allows users to hold a sophisticated portfolio of rights with different levels of security, therefore potentially improving their management of water and the associated risks.<sup>3</sup> The arguments 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 allowing users to hold rights which match their water needs in each climatic scenario better, thus reducing trade on the allocation market and the 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 of the transfer (Colby (1990), 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 greater than transactions costs in the water 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, 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 active trading in the water rights market, which is required to constitute a portfolio of rights matching water needs.

Secondly, a differentiated system can improve both the risk management opportunities for risk averse farmers, as well as overall risk allocation. 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

underlined 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 of lower prices or higher water volumes in wet seasons. Bjornlund and Rossini (2008) have studied Australian water markets at length, and they suggest that the risk differential between high value water users (eg. perennial crops) and 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. It has been observed that uncertainty relating to water allocation motivates farmers to hold more rights than necessary (Brennan (2006)). With differentiated rights, they can instead buy more 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 (2008)). Some users will therefore bear more risks but they will also benefit from lower water prices.

A two security levels system thus displays two major advantages, compared to a single security system: transactions costs saving and improved risk allocation. On the negative side however, it increases the complexity of water market management for the administrators and the complexity of water market participation for the 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. The next section describes the experiment designed to compare the two market designs.

## 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. Each water right entitles its owner to a share of available seasonal water, which varies stochastically (with a known distribution) and is only known with certainty at a certain time of year (usually at the end of spring, when water levels in dams have stabilized). Water is used as an input in the agricultural production process with a decreasing marginal productivity. To mimic the relevant features of water markets for the research question we wish to address,



the experimental design simplifies the market structure. Subjects trade water rights and water allocation in two successive non overlapping phases. Water rights and allocation are only traded within a period and not across periods. This choice precludes trading motives associated with long-term strategies such as banking and speculation on the future value of water rights. It enables us to observe trading strategies associated with the need to reduce transactions costs and manage risk better, and to compare these strategies for a single security system (which has only one level of security for shares) with a two security levels system (that has two security levels for shares).

To prevent prior attitudes about environmental policy from influencing subjects' behavior, a neutral terminology is used: in particular, water rights are called "shares" and water allocations are called "coupons". A share is thus an entitlement to a pre-specified fraction of the total available coupons to be issued. At the end of each period, coupons held are converted into ECU benefits, the ECU being an experimental monetary unit convertible at a fixed rate into cash.

### *Treatments*

We use a 2x2 factorial design with 6 observations per cell. The treatment variables are the number of levels of security for shares (1 or 2) and the presence or absence of transactions costs (TC) in the share and coupon market. We use a between subject design where each subject participated in one of four treatments.

	One level of security	Two security levels
TC in the coupon market only	C1	C2
TC in the share market only	S1	S2

The first treatment dimension is the number of security levels. In C1 and S1, there is only one type of shares called "shares". In the two security levels treatment (C2 and S2), high security ("shares A") and low security shares ("shares B") are traded sequentially, with the high security shares traded first.<sup>4</sup>

The second treatment dimension is the transactions costs. Our first set of treatments (C1 and C2), follow Freebairn and Quiggin (2006) who suggest that seasonal allocation trading is likely to be associated with larger transaction costs. However Brennan (2006) suggests that the financial and administrative costs of allocation trade are relatively small. Field

interviews that we conducted in northern Victoria (Australia) also largely provide evidence of higher transactions costs in the water rights market. This constitutes our second set of treatments (S1 and S2).<sup>5</sup> 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 if our results are consistent with an alternative configuration of transactions costs. This alternative is seen to be more empirically relevant and hence improves the external validity of our results. We 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 transaction costs, we normalize them to 0 (for shares trading in C1 and C2 and coupons in S1 and S2). The higher transaction 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 by the seller.<sup>6</sup>

## *Game structure*

*Figure 1* presents the game structure. At the beginning of each period, each of the subject is endowed with an equal number of shares: 9 shares in the treatments with a single level of security and 3 shares A (high security) and 12 shares B (low security) in the treatments with two security levels. Each subject is also given an initial cash amount of 50 ECUs which enables him to buy shares and coupons if he wishes.

In stage 1, subjects can choose to modify the number of shares they hold by buying and selling in the share market. Between stage 1 and stage 2, a random draw selects the scenario (blue or yellow, both of which are equally likely) that determines the number of coupons subjects get from their shares (*table 1*). Both the probability of each scenario and *table 1* are common knowledge. The scenarios 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 three times less water available: 54 coupons are available in the blue scenario, and 18 coupons in the yellow scenario. 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. In treatments C1 and S1, 54 shares are distributed, corresponding to 54 coupons under the blue scenario and 18 coupons under the yellow scenario. In treatments C2 and S2, 18 high security shares (A) are distributed corresponding to a guaranteed allocation of 18

coupons in both the blue and yellow scenarios; and 72 low security shares (B) corresponding to 36 coupons in the blue scenario and no coupon allocation in the yellow scenario.

In stage 2, subjects can trade coupons in the coupon 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 2*). 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.<sup>7</sup>

The share and coupon markets are organized according to continuous double auction (CDA) rules in order to mimic the electronic clearing houses used by farmers to trade water. Farmers in the field post, buy or sell bids for a 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 trading platforms work on the basis of a continuous double auction (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 have marginal benefit functions parametrized to mimic two types of farmers (*table 2*). Type 1 subjects' marginal benefits mimic a mixed crop producer, with relatively low value for water and an elastic water demand. Parameters are chosen so that in equilibrium, type 1 subjects sell their total water allocation (coupons) and do not use water when it's scarce and expensive (in the yellow scenario). This is because the equilibrium price is greater than the marginal value of even the first unit of water (the first coupon held) for type 1. Type 2 subjects represent farmers with high-value crops such as orchards or vineyard, 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. 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.

## *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 risk aversion. In our sample, 57% of the subjects are risk averse (switch point from 1 to 4), 40% are risk neutral (switch point of 5 or 6) and 3% risk lovers (switch point from 6 to 10). The random assignment of subjects to types was successful as we do not observe any significant correlation between type and elicited risk aversion (coefficient of correlation  $r = -0.0837$ ;  $p$  value = 0.3437). This will enable us to compare the relative impact of type and risk aversion on behavior in the game.

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), which did not count toward subjects' earnings, followed by a series of 9 (C2), 10 (S2) and 12 (C1-S1) periods, one of which could potentially be selected for payment. 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, subjects' gains from the lottery were only revealed at the end of the session. At the end of each session, qualitative and quantitative information was collected in the form of questionnaires from the participants. Instructions for treatment C2 are available in the appendix.

## Theoretical predictions

This section presents the theoretical predictions on quantities and prices in the share and the coupon markets in each treatment. We first solve the model under the risk neutrality assumption and then present some intuition on the effect of risk aversion. We solve the model for a two-agent market (with one agent of each type). For a market of 6 participants (3 type-1 and 3 type-2), 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 coupon market is computed first, then the equilibrium in the share market is derived. In the experiment, share trading takes place first, followed by coupon trading, once the scenario is drawn.

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.

$$\underset{S_i, c_{i,t}}{\text{Max}} \sum_{t=1,2} \pi_t [B(c_{i,t}) + p_{c,t} \cdot (W_t \cdot S_i - c_{i,t}) - Tc \cdot dc_{i,t} \cdot (W_t \cdot S_i - c_{i,t})] + p_s \cdot (Q_i - S_i) - Ts \cdot ds_i \cdot (Q_i - S_i)$$

**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),  $\pi_t$  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 coupon market.

**Coupon:**  $c_{i,t}$  is the number of coupons held by agent  $i$  in scenario  $t$ ,  $B(c_{i,t})$  is the marginal benefit function of agent  $i$ , which depends on the number of coupons held.

$B'_i(c_{i,t}) = a_i - 2b_i c_{i,t}$ ,  $a_{type1} < a_{type2}$  and  $b_{type1} < b_{type2}$ ,  
 $p_{c,t}$  is the equilibrium price of a coupon under scenario  $t$ .

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

We note here that the market for shares is unaffected by the scenario. This is explained in the sections below.

### *Equilibrium in the coupon market*

Trading of coupons takes place until coupons' marginal benefits, net of transaction costs, are equal for the two agents. *Figure 2* represents the demand functions for coupons of type 1 and type 2 subjects. The total demand is drawn for two subjects (multiplying by 3 gives the total demand in a 6-subjects market). Equilibrium prices and quantities of coupons are found where total demand is equal to total supply in each scenario. When the scenario is yellow, type 1 sells all his coupons to type 2 as the equilibrium price is higher than the marginal benefit from the first unit. The equilibrium price is between the minimum price type 1 is willing to sell at and the maximum price type 2 is willing to buy at. The bargaining power of each type in the game determine the equilibrium price. In treatments C1 and C2 (compared to S1 and S2) in the blue scenario, the final number of coupons held is greater for a type 1 net seller (because he sells less in the presence of transactions costs) and lower for a type 2 net buyer (because he buys less). *Table 3* summarizes the equilibrium prices and quantities in the coupon market in each scenario.

### *Equilibrium in the share 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. The marginal benefits of coupons have no impact on the willingness to pay for shares because the coupon market plays the role of a reconciliation market: agents can buy more or sell extra coupons in the coupon market.

In the absence of transactions costs in the coupon market (S1 and S2), the expected value of a share is equal for all risk-neutral agents. As a result, no trade should take place in the share market. The presence of transactions costs in the share market reinforces this result. On the contrary, transactions costs in the coupon market (C1 and C2) create heterogeneity in the expected value of a share across subjects if they anticipate that they will have a different position (buyer or seller) in the coupon market. As a result, trading of shares occurs in equilibrium in treatments C1 and C2. The equilibrium price of a share is an interval, with the lower bound the minimum price at which a net seller in the coupon 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:  $p_S \in [E[W \times (p_c - TF_c)]; E[W \times (p_c + TF_c.)]]$  (see *table 3*).

Being net buyers in the coupon market, type 2 subjects are 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 C1 and C2 is such that the need for costly trade in the coupon market is minimized. When only one level of security shares are available (C1), the equilibrium number of shares held by each subject is such that coupon trading is required only in the yellow scenario. Each subject will hold shares such that it corresponds to his needs 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 coupon market.<sup>8</sup> When two security levels for shares are available (C2), the experiment is parametrized such that, by constituting an efficient portfolio of shares, no trade is required in the coupon market in either scenario. High security shares are bought to cover the need for coupons in the yellow scenario. Low security shares are bought to complement the allocation from high security shares in the blue scenario.

From the equilibrium predictions in the share 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 coupon market. Equilibrium predictions for the number of trades in each market are presented in *table 3*.

### ***Impact of risk aversion***

In theory, there is no impact of risk aversion on the number of coupons held at the end of the experiment since uncertainty is resolved when decisions on coupons are taken. 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 share market. Risk aversion can potentially have two effects. On the one hand, risk averse subjects may prefer to trade in the coupon market as more information is available at this stage. Even if coupons 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 share market is expected to be lower (higher) under risk aversion as compared to the risk neutral prediction. The lack of clear theoretical predictions reinforces the reason for conducting experiments..

## *Profits*

Theoretical profits are different across treatments as they are dependent on transactions costs (*table 3*). Under the risk neutrality assumption, profits are in theory equal in S1 and S2 because no trade is expected in the share market, thus no transactions costs are paid in equilibrium. Profits are on average higher in C2 than C1, because the two security levels system offers the possibility to subjects to hold a portfolio of shares which matches their needs for coupons in each scenario perfectly. Subjects can thus avoid trading in the coupon market and therefore save transactions costs in C2 compared to C1. Table 3 presents equilibrium profits under the assumptions of risk neutrality and equal bargaining power of buyers and sellers (the latter assumption helps avoid the problem of having interval predictions).

The variability of profits - measured by the difference between equilibrium profits in the blue scenario and profits in the yellow scenario, is different across types and across treatments. By definition of the variability of profits, it is lower for type 1 subjects as they have lower profits in absolute value. The interesting prediction that arises however is that the effect of treatment is type-dependent: type 2 has less variable gains in C2 than C1 but it is the opposite for type 1. How can we relate this result to the efficient risk sharing theory? 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)). An improved risk allocation decreases the variability of profits for the less risk-tolerant and increases it for the more risk-tolerant (risk tolerance is equal to the inverse of risk aversion). Type 2 subjects do not display significantly different intrinsic risk aversion than type 1 (due to randomization), but they face a more concave benefit function in the experiment. This may induce more reluctance to adopt risky decisions by type 2 subjects, or more “induced risk aversion”. We assume that subjects’ behaviors are influenced more by induced risk aversion (through type) than by intrinsic risk aversion (ERA, elicited in the lottery game) (see Schoemaker (1993) for a review of the difference between elicited risk aversion and observed risk taking behavior). If this assumption holds, an efficient allocation of risk is such that type 2 subjects, who have lower induced risk tolerance, transfer part of their risk to type 1 subjects. In equilibrium, the allocation of risk is therefore improved in C2 as compared to C1. This result does not hold when transactions costs are higher in the shares market (S2-S1), as there is no difference in the variability of profits between S1 and S2 .



## *Hypotheses*

From the theoretical predictions discussed above, we draw the following hypotheses:

**Hypothesis 1:** A share system with two security levels increases overall profits when the transactions costs are higher on the coupon market (H1a). However, when it is more costly to trade shares than to trade coupons, there are no profit gains from a system with two security levels (H1b).

**Hypothesis 2:** The two security level system improves risk management: the overall variability of profits is decreased (H2a) and risk allocation is improved (H2b). Since the two security level system offers better options to subjects to adjust their portfolio of rights to their preferences, more “risk-averse” subjects (type 2) will have less variable profits and less “risk-averse” subjects (type 1) more variable profits. Hypothesis 2 holds under the condition that trade occurs in the share market. Therefore, we expect hypothesis 2 to be verified only in treatments C2 vs C1 (and not in S2 vs S1).

## **Results**

We compare the market performance of treatments C1 and S1, with treatments C2 and S2, in terms of profits, efficiency and variability of profits, in order to test our hypotheses.<sup>9</sup>

For each hypothesis, we first present the results from the treatments for which the gains of the two security level system are theoretically expected to be higher (C1 and C2). Then, we present the results for the treatments that better reflect empirical reality (S1 and S2) and examine how higher transaction costs in the share 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 one-sided tests in most comparisons as it provides more power to detect an effect when there is a specific hypothesis about the direction of the effect. When relevant, we also report results from multivariate regression models which evaluate the contribution of different factors on the decisions made by subjects. Unless specified, we compute the 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 last four periods include 2 blue periods (7 and 8) and 2 yellow periods (6 and 9). The results show similar patterns when all periods are considered.

### ***Hypothesis 1: Profits***

Hypothesis H1a is supported by the experimental results: when transactions costs are greater in the coupon market, average profits are significantly higher under a two security level system (C2 compared to C1, *table 4*). The lower number of coupons traded and therefore the lower transactions costs paid in C2 compared to C1 explain this result (*figure 3* and *table 5*). Theory predicts that in equilibrium no trade of coupons should occur in C2. In the experiment, 39.6% of subjects in C2 reach the equilibrium portfolio of shares and hence do not have to trade coupons and pay transactions costs.

We can measure the share of the potential gain realized by using an efficiency ratio. The max-gain efficiency ratio is defined as the observed profits over the maximum attainable profits (equilibrium prediction assuming equal bargaining power of the subjects). Efficiency ratios are high in all treatments (*table 4*). This is partly due to the fact that, given the parameters of the experiment, even if agents do not trade at all during the experiment (i.e., they keep their initial allocation of shares and coupons), they can reach an average efficiency level of more than 85%. We nevertheless observe differences across treatments: the max-gain efficiency ratios are on average lower in C1 than C2. We also compute the no-trade efficiency ratio, defined as the observed profits over the profits if subjects do not trade at all, for each treatment. The no-trade-efficiency ratios are higher than 100%, which indicates that subjects increase their profits by trading in the different markets, even if they do not reach the maximum potential gains (as defined by the max-gain efficiency ratio). The no-trade-efficiency ratios are also on average significantly lower in C1 than C2. These results suggest that the complexity of the two security level market is not detrimental to efficiency.<sup>10</sup>

Profits are theoretically identical under treatments S1 and S2, but in the experiment, we observe that profits are significantly lower in S2 (*table 4*). This can be explained by the fact that subjects fail to reach the predicted no-trade equilibrium in the share market: only one quarter of the subjects do not trade shares (in S1, 29.9% do not trade any shares; in S2, 25.6% do not trade low security shares and 25% do not trade high security shares). However, there is evidence that subjects learn to approach the no-trade equilibrium as the transactions costs paid in S1 and S2 decrease over time (*figure 3*). The failure to reach the

no-trade equilibrium could be the result of an experimental demand effect, which is higher in S2 than S1, since there are two opportunities to trade shares in S2 (Zizzo (2010)). As a consequence, the number of shares traded (as a sum of high and low security shares) and the total transaction costs paid in a group are significantly higher in S2 than S1 (*table 5*). Max-gain efficiency and no-trade efficiency are reduced in S2 as compared to S1 because subjects trade more shares than necessary. This leads to the lower performance of the two security levels treatment in terms of average profits when there are higher transactions costs associated with share trading. Hypothesis H1b (equality of profits in S1 and S2) is thus not supported by our data.<sup>11</sup>

*Table 6* confirms these results with random effects generalized least squares regressions, where the dependent variable is the profit made at the individual level in periods 1 to 9. Errors are clustered at the group level to capture any unobserved heterogeneity in the group. Two separate regressions are run for C1-C2 and S1-S2. Explanatory variables are treatment dummies, scenario dummies, type dummies as well as period and elicited risk aversion (ERA). As expected, profits are lower under the yellow scenario and for type 1 subjects. In the first regression, the parameter of the treatment dummy (C2) is significant and positive, confirming the non parametric test results that profits are higher under C2 (thus providing additional support for H1a). In the second regression, the treatment dummy (S2) is negative and significant. H1b can therefore be rejected. We also observe a significant and positive effect of period, revealing a learning effect. The elicited risk aversion (ERA) is not significant.

## ***Hypothesis 2: Risk management***

Table 4 shows that the standard deviation of profits (which can be interpreted as a proxy for overall risk) is not significantly different across treatments. This initial test invalidates hypothesis 2a which postulated that overall risk could be reduced with a two security levels system.

Even though a two security levels system does not seem to reduce overall risk, data show that it helps to share risk more efficiently. We argued before that the shape of the benefit functions suggests that type 2 subjects may display a greater “induced” risk-aversion than type 1 subjects. Therefore type 1 subjects are expected to favor trading decisions that may increase the variability of their profits but increase their average profits, whereas 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.

Table 4 shows that the standard deviation of profit is significantly greater in C2 than in C1 for type 1 and lower in C2 than C1 for type 2. Contrary to theoretical predictions, the same results hold for S1 and S2 (*table 4*). A two security level system therefore leads to an increase in the risk for type 1 and to a decrease for type 2 irrespective of the transactions costs. Table 7 presents regressions of the difference between average profits in the blue scenario and average profits in the yellow scenario for each subject type in each treatment comparison. The treatment variable (C2 and S2) has a positive sign for type 1 (statistically significant for C2 and marginally significant for S2) and negative sign for type 2. While the statistical significance is not uniformly strong in tables 4 and 7, the direction of the effect is clear, hence providing some support for hypothesis 2b. Elicited risk aversion mostly does not have an impact (except for type 1 in S1-S2) and this indicates that type is more relevant than elicited risk aversion in explaining variability of profits.

The results concerning risk allocation are similar whatever the configuration of transactions costs. It suggests that a two security levels system does not reduce risk but it can improve risk allocation if the share market is active (even if there are no gains from trading shares as in S2).

*Table 8* summarizes all the experimental results and compares them to the theoretical predictions.

## 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 variability. In this article we focus on the design of markets for water rights by analyzing the relative benefits of having rights with different levels of security. This research can provide the first step towards designing water markets that can simultaneously achieve an efficient and cost-effective allocation of water and risk. While there are on-going policy debates for improving the risk management potential of water markets, no previously reported laboratory experiment has studied the impact of introducing water rights with different security levels. We show in this article that security-differentiated water rights can improve the performance of water markets but the outcome is also dependent on market transactions costs.

Our results suggest that being allowed to hold and trade water rights with different levels of security increases water users' profits, provided that transactions costs in the rights market

are lower than in the allocation market (treatments C1 and C2). If instead the allocation market is efficient and trading in this market is costless, the profits from trading rights are reduced, as well as the gains from a differentiated water rights market. This system offers nevertheless interesting opportunities in terms of risk allocation, irrespective of the transactions cost scenario.

Our findings indicate that there is a trade-off between water allocation and risk allocation. In the absence of perfect information about the preferences of farmers and water managers with respect to these two objectives (efficient water allocation and risk allocation), the potential benefits of differentiated markets for water rights cannot be overlooked. As risk becomes a major concern for farmers, differentiated markets may become a valuable water policy option as they can improve the allocation of risk by decreasing the variability of profits for less risk-tolerant water users. This analysis 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 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 rights differentiation.

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 level 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 future market may be less dependent on the number of trades and transactions costs as compared to a differentiated water market. Further research could also include field experiments with farmers, trained in water trading to examine if farmers can take better advantage of a two security levels system than subjects in a laboratory (Herberich et al. (2009)).

# Notes

<sup>1</sup>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 is seen to increasingly fluctuate with climatic change.

<sup>2</sup>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 coupon market is a kind of reconciliation market in case the allocation is not efficient after the share market), hence efficient allocation is the result of both the coupon and the share market.

<sup>3</sup>In this paper, 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.

<sup>4</sup>In field settings (for example in the Australian context), both markets could operate simultaneously but the high security market tends to be more active. Theoretically, the order of the two markets will not impact the equilibrium of both markets. Experimentally, some order effects may be observed. To limit the number of treatments, we choose to run the experiment with the high security share market first then the low security market as it is more intuitive to trade first the more secure assets.

<sup>5</sup>We could also have run complementary and intermediary treatments with no transactions costs or equal transactions costs in both markets. However, under these 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 focus 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).

<sup>6</sup>This fee is 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, it may be unusual for buyers and sellers to pay the same transaction cost although theoretically the burden of the cost should be shared equally if the market is competitive.

<sup>7</sup>In one treatment of Godby et al. (1997), shares are kept from one period to the other (banking). This design feature could be relevant for water markets as water rights are equivalent to an asset yielding returns every season. As this design places substantial cognitive demands on the subjects, Godby et al. provided computerized advice on intertemporal optimization of shares and coupons holding. We want to avoid such complexity. Moreover, banking of shares is not necessary to observe the types of market gains we are interested in (transaction costs saving and better risk allocation). As a result, our design is simpler: each period starts with the same initial number of shares.

<sup>8</sup>Assume type 1 holds 6 shares. He will receive 2 shares in the yellow scenario and 6 shares in the blue scenario. He will have to sell 2 coupons if the scenario is yellow and 0 coupons if the scenario is blue. If he

holds less than 6 shares, he will have to sell less than 2 coupons in the yellow scenario but will have to buy coupons in the blue scenario. He will on average pay more transactions costs to trade coupons. If he holds more than 6 shares, he will have to sell more than 2 coupons in the yellow scenario and will also have to sell coupons in the blue scenario. He will pay more transactions costs to trade coupons. The same reasoning applies for type 2 with 12 shares.

<sup>9</sup>Profits are a function of market prices and quantities traded, which are presented in table 5. However, in this article, we focus on aggregate results in order to provide a clearer message in terms of comparison of policy options.

<sup>10</sup>We mentioned in section 1 that the increased complexity of water markets with different types of water rights may reduce farmers' participation in the market. In the lab, we may therefore find that the complexity of treatments C2 and S2 could lead to less trades and hence lower efficiency. To examine this, we define the deviation from the efficient portfolio of shares (the one that minimizes their needs to buy and sell coupons in stage 2) and coupons (the one that maximizes their gains) as a measure of the effect of complexity on the market performance of each treatment. The complexity of a two security levels system does not have any impact on the capacity of subjects to reach the equilibrium portfolio of shares and coupons as they do not deviate more in the two security levels treatments (C2 and S2) as compared to the single-security treatments (C1 and S1). In addition, we also estimated random effects generalized least squares regression models with clustering, where the dependent variable is the difference (in absolute terms) between the observed variable (number of coupons received and number of coupons held) and the theoretical prediction over periods 6 to 9. Consistent with the results from the other tests, the treatment dummy has no significant impact. These results are not presented here but they suggest that subjects did not find the trading setup in C2 and S2 more complex. We tried to ensure that complexity or confusion was reduced to the extent possible, for example subjects participated in a quiz after the instructions were read out to ensure that they understood the experiment. In the post experimental questionnaire, subjects did not indicate any confusion with any aspect of the experiment.

<sup>11</sup>This could partly be due to a design feature in our experiment that introduces the high and low security share markets sequentially. With simultaneous trading of high and low security shares, we may not observe more share trading in the two security levels treatment as compared to the treatment with a single type of shares.

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## Figures and tables

Figure 1: Game structure

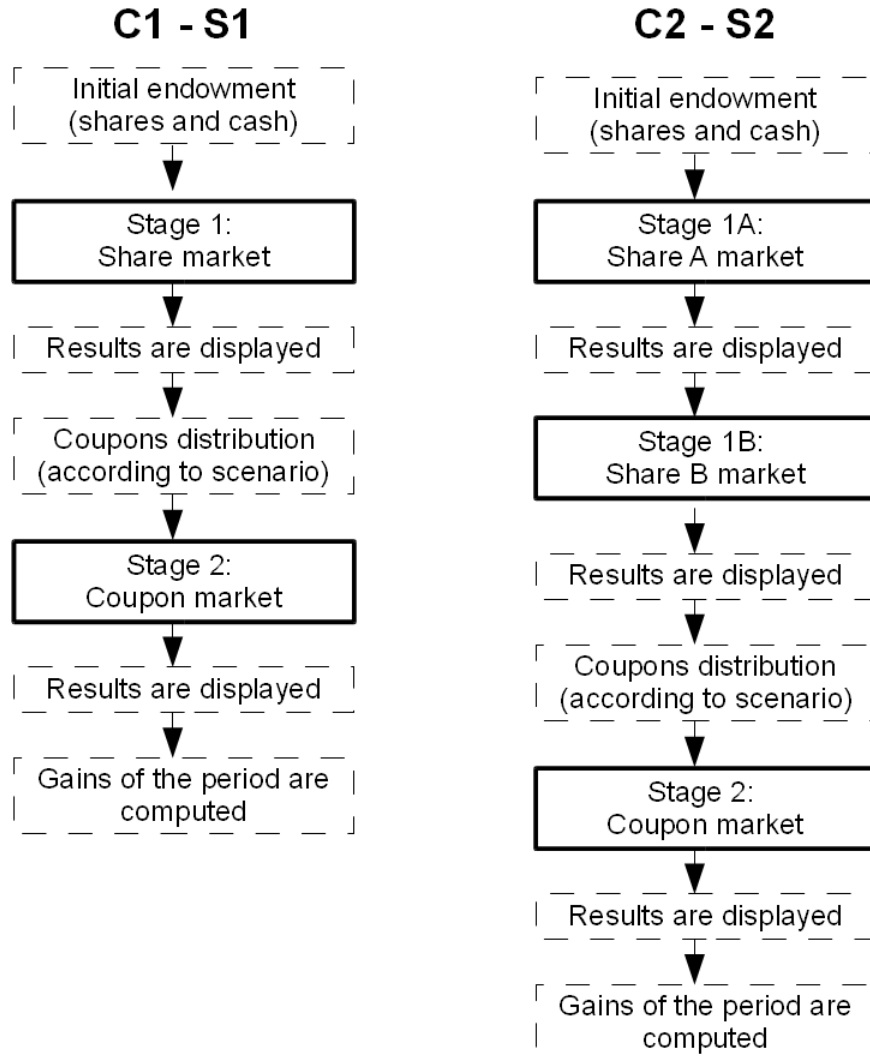


Figure 2: Equilibrium in the coupon market

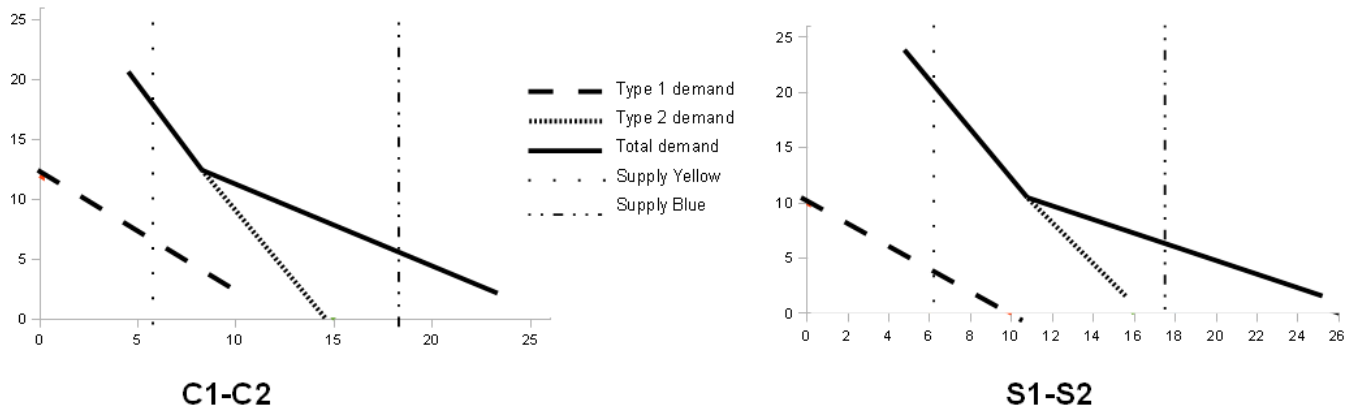


Figure 2 presents the equilibrium for a 2-subjects market. For a 6-subjects market, the supply is multiplied by 3 and the equilibrium price and quantities remain the same.

Figure 3: Transactions costs paid by each subject

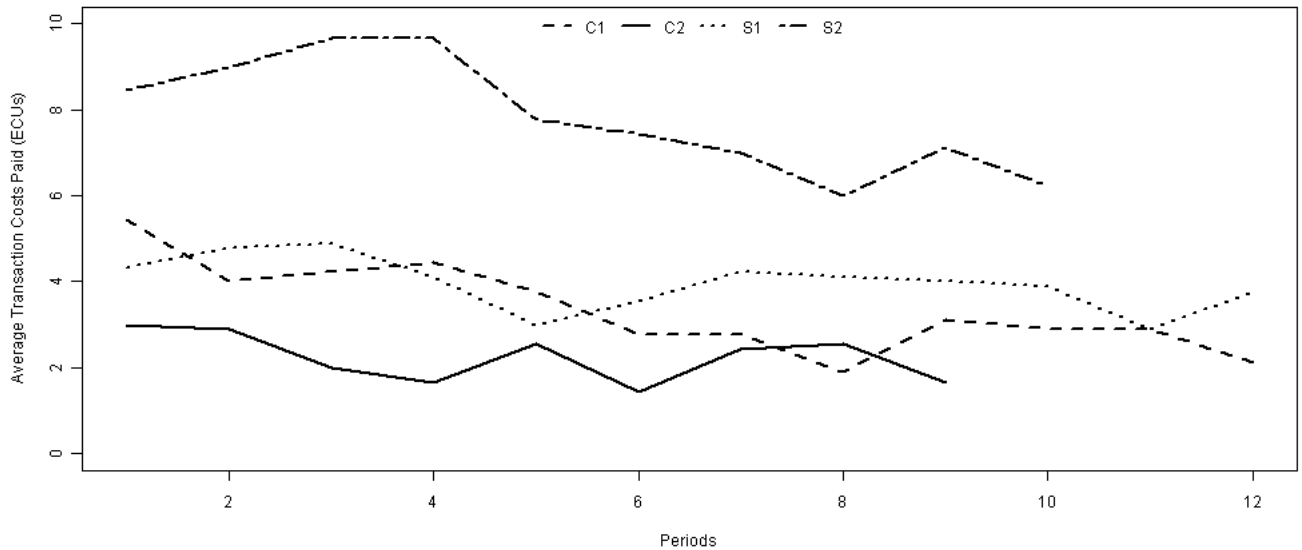


Table 1: Coupons allocation

	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

Table 2: Marginal and total benefits (in ECUs) for coupons held at the end of a period

Coupons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	$\geq 16$
<i>Type 1</i>																
Unit benefits	10	9	8	7	6	5	4	3	2	1	0	0	0	0	0	0
Total benefits	10	19	27	34	40	45	49	52	54	55	55	55	55	55	55	55
<i>Type 2</i>																
Unit benefits	0	0	0	24	22	20	18	16	14	12	10	8	6	4	2	0
Total benefits	0	0	0	24	46	66	84	100	114	126	136	144	150	154	156	156

Table 3: Equilibrium Predictions

	C1	C2	S1	S2
<b>Shares</b>		<b>(A;B)</b>		<b>(A;B)</b>
Number held by Type 1	6	(0;12)	9	(3;12)
Number held by Type 2	12	(6;12)	9	(3;12)
Number of trades in a group	9	(9;0)	0	(0;0)
Equilibrium price*	[4.67;6.33]	([8;13]; )		
<b>Coupons</b>				
<i>Blue scenario</i>				
Coupons held by Type 1	6	6	5	5
Coupons held by Type 2	12	12	13	13
Number of trades in a group	0	0	12	12
Equilibrium price	6	6	4.67	4.67
<i>Yellow scenario</i>				
Coupons held by Type 1	0	0	0	0
Coupons held by Type 2	6	6	6	6
Number of trades in a group	6	0	9	9
Equilibrium price	[10;20]	[10;20]	[12;18]	[12;18]
<b>Total TC paid in a group</b>				
<i>Blue scenario</i>	0	0	0	0
<i>Yellow scenario</i>	12	0	0	0
<b>Profits (assuming equal bargaining power of subjects)</b>				
<i>Blue scenario</i>				
Type 1	111.5	126.5	109	109
Type 2	177.5	162.5	181	181
<i>Yellow scenario</i>				
Type 1	92.5	81.5	95	95
Type 2	65.5	84.5	71	71
<i>Difference of profits between scenarios</i>				
Type 1	19	45	14	14
Type 2	112	78	110	110

(A;B) Shares A are the high security shares and shares B the low security shares.

\* When no trade is expected at equilibrium, there is no equilibrium price

Table 4: Observed Profits

	C1	C2	<i>p-value</i> *	S1	S2	<i>p-value</i> *
<b>Average profits</b> in ECUs (H1)	626	656	<i>0.04+</i>	655	629	<i>0.04</i>
<b>Efficiency Ratio (%)</b> (H1)						
Max-gain efficiency	93.25	96.10	<i>0.12</i>	95.80	91.96	<i>0.02</i>
No-trade efficiency	102.46	107.43	<i>0.04</i>	105.78	101.53	<i>0.02</i>
<b>Standard Deviation of Profits</b> (H2)						
All subjects	35.45	35.93	<i>0.70</i>	36.74	36.96	<i>0.82</i>
Type 1	18.58	21.05	<i>0.07</i>	17.79	21.27	<i>0.12</i>
Type 2	52.33	50.81	<i>0.24</i>	55.69	52.66	<i>0.15</i>

\* 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.

+ The data reject the hypothesis that average profits are the same with one or two security levels for shares but this effect is driven by the yellow periods. One cannot reject the hypothesis that total profits are equal in the blue scenario (one-tailed  $p$ -value=0.11 with alternative hypothesis  $C1 < C2$ ) but one can reject that they are equal in the yellow scenario (one-tailed  $p$ -value=0.03 with alternative hypothesis  $C1 < C2$ ).



Table 5: Trading Activity and Market Prices

	C1	C2	<i>p-value</i>	S1	S2	<i>p-value</i>
<b>Shares</b>		<b>(A;B)</b>			<b>(A;B)</b>	
Number of trades in a group	10.5	(6.9;10.5)		6	(5.2;4.4)	
Equilibrium price	7.9	(11.6;2.0)		6.9	(12.9;3.2)	
<b>Coupons</b>						
<i>Average</i>						
Number of trades in a group	4	3	<i>0.17</i>	8.1	5.7	<i>0.10</i>
Equilibrium price	8.7	9.6		9.2	9.2	
<i>Blue scenario</i>						
Number of trades in a group	3.5	3.8		10	7.4	
Equilibrium price	7.3	6.6		7.3	6.6	
<i>Yellow scenario</i>						
Number of trades in a group	4.4	2.3		6.2	4.0	
Equilibrium price	10.2	12.5		11.0	11.7	
<b>Total TC paid in a group</b>						
<i>Average</i>						
	15.8	12.2	<i>0.17</i>	23.8	41.3	<i>0.09</i>
<i>Blue scenario</i>						
	14	15		25	39	
<i>Yellow scenario</i>						
	17.7	9.3		22.7	43.7	

(A;B) Shares A are the high security shares and shares B the low security shares.

All the statistics presented are the average over the last 4 periods for the subjects in each treatment.

Table 6: Random effect model of individual profits

Explanatory variables	C1 - C2	S1 - S2
C2	4.931*** (1.604)	
S2		-4.386** (2.099)
Yellow scenario	-59.76*** (2.880)	-63.02*** (1.539)
Type 1	-18.63*** (3.667)	-17.90*** (3.187)
Period	0.556*** (0.204)	0.761*** (0.169)
ERA	1.193 (1.107)	0.315 (1.035)
Constant	133.4*** (7.072)	142.6*** (6.576)
Observations (periods 1 to 9)	576	594
Number of subjects	64	66
Wald Chi-squared (6)	94418	18710
Prob > Chi-squared	0.00	0.00

Robust standard errors in parentheses, clustered at the group level

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 7: Regression models for variability of profits between scenarios

Explanatory variables	C1-C2		S1-S2	
	Type 1	Type 2	Type 1	Type 2
ERA	-2.087 (1.273)	-2.681 (1.761)	-2.689** (1.219)	-0.934 (1.530)
C2	7.314** (3.138)	-7.067 (7.263)		
S2			3.927 + (2.419)	-2.772 (5.595)
Constant	39.51*** (10.09)	113.6*** (8.790)	49.00*** (8.341)	100.8*** (10.09)
Observations	33	31	32	34
F(2,11)	9.745	3.653	3.891	0.243
Prob>F	0.004	0.061	0.053	0.788

Robust standard errors in parentheses, clustered at the group level

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

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 only one data per subject and we run a linear regression.

+ The effect of treatment S2 for type 1 is close to being significant (p-value=0.133).

Table 8: Summary of results

Hypotheses	C2 compared to C1	S2 compared to S1
H1a: Increased Profits	supported ++	
H1b: Equal Profits		not supported
H2a: Decreased Variability of Profits	not supported	not supported
H2b: Improved Risk Allocation between Types	some support +	some support +

++ supported by both non-parametric and parametric analysis

+ in the expected direction but not always statistically significant

## Appendix: Experimental Instructions (not for publication)

*The instructions reported are for treatment C2. Instructions were modified slightly for the other treatments depending on the transaction costs scenario and the type and return of shares. Instructions are translated from French by native French speakers who are fluent in English. The text in italics has been added to make the instructions clearer for the reviewer, the participants did not see this.*

As a participant in this experiment, you will be asked to make decisions using a computer. This document gives you the instructions for the experiment. Please make sure you understand them correctly. This experiment has two parts You'll get the instructions of the second part after all of you have completed the first part. You will be paid according to your decisions for both parts. The computer will calculate your gains at the end of the experiment. They will be paid to you privately in cash at the end of the experiment.

### Part 1: Risk aversion elicitation

For each of the 10 choices, you have to choose your preferred option between X and Y. The gain is fixed for option X. There are two possible outcomes for option Y. The realized outcome will depend on the random draw of a number. One of you will be chosen by the experimenter to draw a ball from a bag with the balls numbered from 1 to 10.

Your gain in Euros for part 1 depends on your choice and the number drawn.

	Option X		Option Y	
	Payoff	Number	Payoff	Number
Choice 1	3.5	1-10	1 6	1-9 10
Choice 2	3.5	1-10	1 6	1-8 9-10
Choice 3	3.5	1-10	1 6	1-7 8-10
Choice 4	3.5	1-10	1 6	1-6 7-10
Choice 5	3.5	1-10	1 6	1-5 6-10
Choice 6	3.5	1-10	1 6	1-4 5-10
Choice 7	3.5	1-10	1 6	1-3 4-10
Choice 8	3.5	1-10	1 6	1-2 3-10
Choice 9	3.5	1-10	1 6	1 2-10
Choice 10	3.5	1-10	1 6	0 1-10

## Part 2

### General principles of the experiment

The server computer will form randomly 3 groups of 6 participants. You will be part of one group, fixed during the experiment. You can't identify the other members of your group and they can't identify you.

In this experiment, you will have the opportunity to realize transactions (buying or selling) of different goods: shares A, shares B and coupons. All transactions will be realized in ECUs.

You can only trade with participants of your own group.

You will play over a number of periods. You will not learn the number of periods until the end of the experiment.

The same rules apply to each period: You are endowed with an initial number of shares and an initial cash endowment of 50 ECUs. In stage 1, you can buy or sell shares A (stage 1A). Then, you can buy or sell shares B (stage 1B). In stage 1, shares will be converted into coupons according to their "return" and according to the draw of a scenario. In stage 2, you can buy or sell the coupons you received. At the end of stage 2, coupons are converted into ECUs, according to their "benefit".

The following explains the relation between shares, coupons and gains in ECUs. Each stage within a period is further explained.

### Shares, coupons and gain of the period

#### *Return of shares*

At the end of Stage 1, shares are converted into coupons according to a "return rate". The number of coupons you obtain from one share depends on the scenario, drawn in each period by the central computer. The scenario can be "Blue" or "Yellow". The scenario is the same for all participants in each period. Both scenario are equally likely (50% chance of being "Blue" and 50% of being "Yellow"). Table 1 (*same as the one reported in the paper*) gives the number of coupons received from each share according to the scenario.

The number of coupons you receive will always be an integer (nearest highest integer).

For example, if you hold 30 shares A and 9 shares B, you will get: if the scenario is blue,  $30*1+9*0.5=34.5$  coupons, which is rounded off to 35 coupons; if the scenario is yellow,  $30*1+9*0=30$  coupons.

#### *Benefits from coupons*

Each coupon you hold at the end of stage 2 gives you benefits, according to *table 2* (*The table 2 given to the subjects is slightly different as we only give them the total and marginal benefits of their type*). The benefit of each unit is given in the second line. The total benefit you get is the sum of the benefit of each coupon you hold. The total benefit is given in line 3.

The benefit of each coupon held is typically different from the benefits of other coupons held and your benefits may be different from the benefits of other participants.

For example, imagine your first coupon gives you a benefit of 50 ECUs, your second coupon gives you a benefit of 49, etc. If you hold 2 coupons, your total benefits would be  $50+49=99$ .

### ***Gains***

Your gains in ECUs for each period are determined as follows:  $\text{Gains} = \text{Benefits from coupons held at the end of the period} + \text{Cash left at the end of the period} (= \text{Initial endowment of 50 ECUS} + \text{Gains from shares and coupons trading} - \text{Expenses from shares and coupons trading})$ .

## **Detailed information on each stage within a period**

### ***Initial endowment***

Everyone starts each period with 3 Shares A and 12 Shares B. You also get an initial amount of cash of 50 ECUs at the beginning of each period. You can use this money to buy in the share and coupon market. You can buy shares or coupons only if you have enough cash to do so (no borrowing is allowed). This initial allocation is the same for all participants and for all periods.

### ***Stage 1: Share market***

Anyone can adjust their own holding of shares by buying and selling them in the share market in stage 1. This share market will operate over the computer network. You won't know the return of a share when trading shares as the scenario (blue or yellow) will be drawn only at the end of stage 1.

If you buy a share, you will have to spend ECUs to buy shares. Shares allow you to get some coupons in stage 2. You will get benefits from each coupon held or you can sell these coupons in stage 2.

If you prefer to buy coupons in the coupon market, you don't need to hold shares. You can get some gains from selling your shares.

You will be first allowed to trade shares A (Stage 1A) and then shares B (Stage 1B).

### ***Stage 2: Coupon market***

The coupon market (Stage 2) occurs after you learn the scenario and the number of coupons you get from one share. Anyone can adjust their own holding of coupons by buying and selling them in the coupon market in stage 2. This coupon market will operate over the computer network.

If you buy coupons and keep them until the end of the period, you will get some benefits from these coupons. If the price of a coupon in the market is lower than your benefit from this coupon, you will have a net gain from buying this extra coupon. If the price of a coupon in the market is higher than your benefit from this coupon, you will have a net gain from selling this coupon.

## **Transaction fee**

Each time you buy or sell a coupon, you will have to pay a transaction fee of 2 experimental dollars. This fee will automatically be withdrawn from your cash amount.

For example, if you find a buyer for one of your coupon at the price of 5 experimental dollars, your net gain from trade will be  $5-2=3$ . The buyer will pay a total of  $5+2=7$  experimental dollars for this coupon.

You pay no transaction fee to buy or sell a share

## **Period Results**

A summary of the results from the period are shown on the Period Results screen. At the end of the instructions you will find a sheet labeled Personal Record Sheet, which will help you keep track of your earnings. You can copy this information onto your Personal Record Sheet at the end of each period, and then click “continue” to begin the next period. You are not to reveal this information to anyone. It is your own private information.

## **Earnings**

You will play for several periods but you will be paid for only one period. This will be randomly determined at the end of the experiment, where one of the participants will pick a ball from a bag where there will be as many balls as periods played. Your final earnings will be the earnings of the period corresponding to the number of the ball drawn.

All earnings on your computer screens are in ECUs. These ECUs will be converted to real euros at the end of the experiment, at a rate of 1 ECU= 0.2 real Euro.

Before you begin making decisions for real money, we will conduct 2 practice periods for you to get comfortable with the trading software. These practice periods do not affect your earnings from the experiment.

## How to Buy and Sell

The trading software enables you to trade one share or one coupon at a time. At any time during either market stage, everyone is free to buy an extra unit:

- by making an offer to buy and choose the price offered,
- by buying at the best offer price specified by someone wishing to sell,

You can also sell a coupon or a share:

- by making an offer to sell and choose the price offered,
- by selling at the best offer price specified by someone wishing to buy.

You will enter offer prices and accept prices to execute transactions using your computer.

*A screen shot of the market stage is given to the subject.*

Some information is given on the upper right of the screen (for example, time left, cash, number of shares). This information is updated after each trade in the period.

Each time you enter an offer to buy or sell, this offer price is immediately displayed on all traders' computers on the part of the screen labeled "Buy Offers" or "Sell Offers". Once an offer price has been submitted, anyone can accept this price offer. Such an acceptance results in an immediate trade at that price. The previous trading prices in the current period are displayed in the "Trading Prices" list in the center of your computer screen.

If there are already buy offers displayed in the current period, then new buy offers submitted by anyone wishing to buy must provide better trading terms to the sellers. Sellers prefer higher prices, so any new buy offers must be higher than the current highest buy offer. Your computer will give you an error message if you try to offer a lower price than the best price currently available. If there are already Sell Offers displayed in the current period, then new sell offers submitted by anyone wishing to sell must provide better trading terms to the buyers. Buyers prefer lower prices, so any new sell offers must be lower than the current lowest sell offer. Your computer will give you an error message if you try to offer a higher price than the best price currently available.

Eventually, after your trade has been finalized, all your previous offers will be removed from the system. To trade another coupon or share, you will need to submit a new offer. For each share or coupon you want to sell or buy, the price you offer can be different.



## Summary

Figure 1 (*same as reported in the paper*) summarizes the different stages of the game. Note that you will make decisions only in the stages represented by solid lines boxes.

- Your gains in ECUs for each period is the sum of the cash you have at the end of a period and the benefits you get from the coupons you held.
- You can trade shares A in stage 1A and shares B in stage 1B, before knowing the scenario. You can then trade coupons in stage 2, once the scenario is known.
- The number of coupons you get from one share depends on the scenario (“Blue” or “Yellow”) and the type of share (A or B). see table 1
- Your benefits from holding coupons are shown in table 2 (in ECUs).
- You pay a transaction fee of 2 ECUs to buy or sell a coupon. There is no transaction fee to trade shares.
- Everyone starts the experiment with an initial endowment of 50 ECUs and some initial number of shares (3 shares A and 12 shares B). These numbers are the same for all the participants in the room.
- Shares are not kept from one period to the other. At the beginning of a period, you start with the initial number of shares.
- Your final earning will be the earnings from the period corresponding to the number drawn randomly from the bag at the end of the experiment. Your gains from this period in ECUs will be converted to Euros at the end of the experiment, at a rate of 1 ECU = 0.2 Euro.

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