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ARBITRAGE, ASSET PRICES and RISK ALLOCATION in EXPERIMENTAL MARKETS*

by

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ABSTRACT

I report the results of nine experimental asset market sessions. The traded assets were contingent claims on two "states" with known state probabilities and identical aggregate payoffs across states. Since subjects could diversify away all idiosyncratic risks, this results in prices predicted to equal expected values *regardless* of risk preferences. In addition, no-arbitrage restrictions lead to precise predictions for the sum of the individual asset prices. Thus, in these single-period asset markets, price bubbles are well defined without knowing risk preferences. Bubbles regularly form. Subjects seldom exploit the resulting arbitrage opportunity. Bubbles arise even when subjects have gained experience in 15 periods, when subjects can trade directly in the "unit portfolio" of all contingent claims and when subjects can sell claims short. However, direct portfolio trading may force subjects to recognize the assets' interdependence and price them accordingly. Expected utility maximizing models cannot explain these results. Non-expected utility models (for example, models of decision regret) may explain them.

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Arbitrage, Asset Prices and Risk Allocation in Experimental Markets

I. Introduction

General equilibrium asset pricing theory relies on weakly risk averse, expected utility maximizing agents acting in efficient, competitive markets (for examples, see Sargent [1987]). In a simple and appealing manner, these models attempt to relate levels of expected asset returns to real economic variables which affect market participants. However, econometric test results for these models have been mixed at best. The anomalies we find using U.S. financial data to test asset pricing models are too numerous to list here.[1] Various attempts to reconcile the data with the models have met with mixed success as well.[2]

However, econometric tests of asset pricing models are subject to a number of drawbacks. First, most models predict expected returns. We observe only one actual return per year. Second, though it may play an important role (see Rietz [1988] for example), we do not know the distribution of future asset returns. We only observe one realized set of past returns under past conditions. In a changing economy, we never observe multiple returns for an identical asset under identical conditions. Third, if heterogeneity across agents (for example, various tax bases, heterogeneous information, liquidity constraints, etc.) plays any important role, we cannot test the models appropriately. To do so we would have to observe relevant information for all agents under all relevant states of the world. Finally, even if all of these difficulties were overcome, the modelling and testing assumptions themselves are quite restrictive and may not be realized in the U.S. data. Models with revised or relaxed assumptions may fit the data better. However, how can we tell which assumptions need revision?

As an alternative to econometric analysis of field data, I use experimental markets to test a very simple result that serves as the basis for general equilibrium asset pricing models as well as risk sharing arrangements, insurance and portfolio theory: that risk averse people use markets to diversify away as much idiosyncratic risk as possible. In context, the proposition leads to precise predictions about asset prices and distributions in simple laboratory markets. The advantage of experimental economics is that, in the laboratory, we can create environments that match the fundamental assumptions underlying the predictions as closely as possible. Thus, we can test asset pricing models appropriately and determine exactly what factors influence prices in an understandable, controllable and replicable environment with known distributions of future asset values.

The particular result I will test was first discussed by Borch [1960] when analyzing reinsurance markets. It states that, acting in complete and competitive contingent claims markets, risk averse individuals will completely

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[1]For examples, see the variance bounds violations literature started by Shiller [1981] and Grossman and Shiller [1982]; the equity risk premium literature started by Mehra and Prescott [1985]; and the bounds violations discussed in Hansen and Jagannathan [1990]. Also see the entire June/September 1978 issue of the Journal of Financial Economics.

[2]For examples, see Kleidon [1986] who relaxes stationarity assumptions, Rietz [1988] who studies different probability structures, Kocherlakota [1990] who relaxes restrictions on discount rates, Marshall [1990] who introduces costly consumption variation and Epstein and Zin [1991] who use non-von Neumann-Morgenstern utility functions.

eliminate individual risks across states of the world in which the total endowment is fixed. The intuition is that individuals use the markets to divide a future "pie" of unknown size. If two states lead to the same size pie, they will divide it in exactly the same manner. Caspi [1974] derives this result assuming only complete, competitive markets and individuals with increasing, concave utility functions.[3] Malinvaud [1974] shows that relative prices for contingent claims across these states will reflect only relative state probabilities. Further, a no-arbitrage restriction implies that, properly normalized, prices of contingent claims must sum to 1 across these states. Hence, in the absence of arbitrage, normalized prices should equal state probabilities. Intuitively, this result says that people minimize risk, eliminating it when they can. Asset prices then reflect expected values. The assumptions that drive the result are the same as those that drive all Arrow-Debreu type models: individuals maximizing utility in perfectly functioning markets. Models that use these assumptions include models of individual behavior (e.g., von Neumann and Morgenstern [1944]), insurance (e.g., Borch [1960]), general risk bearing (e.g., Arrow [1974]) and asset pricing (e.g., Lucas [1978]), among others.

In laboratory markets, I find that subjects do diversify away some idiosyncratic risk, but not all of it. While relative prices often reflect relative state probabilities, absolute prices regularly exceed the predictions. Subjects seldom exploit the resulting arbitrage opportunities. This holds even when subjects have gained experience in 15 independent replications in one session or 28 independent replications across two sessions; when subjects can trade directly in the "unit portfolio" of one of each asset; and when subjects can make short sales. Finally, these results held in a session in which instructions explained how exploiting the arbitrage opportunity would result in a certain profit. However, few inter-market arbitrage opportunities arise when I allow subjects to trade in the portfolio directly. In addition, portfolio trading was allowed in the only markets in which individual asset prices did not regularly violate the no-arbitrage restriction.

These results are difficult to explain if subjects all maximize expected utility as traditionally defined. Because subjects seldom face binding constraints, risk seeking subjects or subjects with heterogeneous subjective state probabilities cannot explain these results. Since there is no opportunity cost to exploiting an arbitrage opportunity when short sales are allowed, subjects gambling on other subjects' out-of-equilibrium bids and offers also cannot explain these results. Non-expected utility models that produce a status quo bias may explain the results.

II. Theory

Suppose there is an economy with many individuals (denoted by $i=1,2,\ldots,N$), a single type of "good" and random "states of nature" drawn from a finite set, Ω. Let π^{ω} be the probability of state ω occurring. Define x_i^{ω} as

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[3]Formally, Caspi [1974] shows that any two states of the world in which the total endowments are identical will have identical sets of Pareto optimal distributions supported by competitive equilibria. If we construct a case in which there is only one Pareto optimal distribution for a given total endowment, competitive equilibria in the contingent claims markets will result in this distribution regardless of the initial individual endowments under each state.

individual i's endowment of the good in state ω. The total endowment is then $\sum_{i=1}^{N} x_i^\omega$. Let y_i^ω represent individual i's contingent consumption of the good in state ω. Finally, let P^ω be the price of a contingent claim for one unit of the good in state ω.

Suppose individuals have von Neumann-Morgenstern utility functions for consumption in each state that are increasing, concave and once-differentiable. Then, Caspi [1974] proves that if states ω' and ω'' have the same total endowments, the set of Pareto optimal allocations under ω' and ω'' will be identical. Competitive equilibria should result in $y_i^{\omega'} = y_i^{\omega''}$ for all individuals *regardless of the initial endowments* in the two states. That is, individuals will hold an equal number of contingent claims for consumption across states characterized by the same total endowment. Further, Malinvaud [1974] shows that the price ratios for contingent claims for consumption across these states should equal the ratios of the state probabilities. These relative prices will hold *regardless of the level of risk aversion* even though risk attitudes will affect absolute prices.

Now suppose that the total endowment is the same *in every state*. That is, the states only differ by the distribution of the endowments. Then, simple no-arbitrage arguments imply that prices must sum to one. Thus, in the absence of arbitrage, the properly normalized price for a contingent claim for the good in state ω is π^ω.[4] In this case, both relative and absolute prices are independent of the level of risk aversion.

These are the four propositions to be tested. Concisely, they are:

P1: (Risk Allocation) Each individual will hold contingent claims giving rights to the same consumption level in all states, i.e.: $y_i^\omega = \bar{y}_i \quad \forall \omega \in \Omega$.

P2: (Consistent Relative Prices) The ratio of prices for contingent claims for consumption in states ω and ω' equals to the ratio of the probabilities of state ω and ω' occurring, i.e.: $\frac{P^\omega}{P^{\omega'}} = \frac{\pi^\omega}{\pi^{\omega'}} \quad \forall \omega, \omega' \in \Omega$.

P3: (No Arbitrage) Contingent claim prices always sum to one, i.e.: $\sum_{\omega \in \Omega} P^\omega = 1$.

P4: (Consistent Prices under No Arbitrage) The normalized price of a contingent claim for consumption in state ω is equal to the probability of state ω, i.e.: $P^\omega = \pi^\omega \quad \forall \omega \in \Omega$.

Proposition P1 should hold for all individuals who have concave utility functions, regardless of their specific levels of risk aversion. Proposition P2 should hold as long as some individuals trade in all contingent claims, regardless of risk preferences. Proposition P3 should hold as long as individuals value more of the good to less.

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[4] If individuals assign subjective probabilities to states that differ from the true probabilities, then normalized prices will equal these subjective probabilities.

Finally, Proposition P4 follows directly from Propositions P1 and P3. It should hold as long as individuals prefer more of the good to less and some can trade in all claims, regardless of risk preferences.

Though existing experimental research was not designed to test these propositions, there is some related work. Dickhaut, Martin, Senkow and Sevick [1988] study risk sharing by asking whether individuals with the highest levels of induced risk aversion end up with risky assets in sealed bid auction markets. However, they must induce risk preferences and the markets are not competitive by design. O'Brien [1988] also studies risk sharing in oral, double auction markets. However, he also induces risk preferences. A variety of researchers have studied asset pricing predictions. Most competitive asset market experiments have involved informational conditions under which uncertainty could be resolved by the markets.[5] (For examples see Forsythe, Palfrey and Plott [1982], Plott and Sunder [1982 and 1988] and Forsythe and Lundholm [1990].) In equilibrium, these markets can resolve all uncertainty about asset values, making pricing trivial and risk sharing meaningless. Markets without sufficient information to determine asset values exactly have not had complete contingent claims which are necessary to make predictions independent of risk preferences and expectations about future values. (For example, see Smith, Suchanek and Williams [1988] and O'Brien [1988].) Finally, O'Brien and Srivastava [1989, 1990 and 1991] study arbitrage relationships on relative prices. However, they use an information structure sufficient to determine the state and the absolute values of assets. They do not study simple arbitrage restrictions on absolute prices.

In some ways, the propositions studied and the markets run for this paper are simpler than those in each previous line of research. The oral-double-auction design reliably gives competitive outcomes. The nature of the optimal risk-sharing arrangement is very simple: no one faces any risk in equilibrium. Equilibria do not require the aggregation of private information. The complete contingent claims markets provide precise distribution and price predictions that are independent of risk preferences. Finally, the arbitrage restrictions are on absolute price levels and seem very transparent.

III. Experimental Design

The experiment consisted of eleven sessions, three under each three slightly different treatments and two additional sessions using modifications of the first treatment. Table I summarizes the design and treatment features. Here, I will discuss the features common to all treatments. Then, I will discuss treatment specific features.

Subjects were drawn from a large volunteer subject pool of M.B.A. and undergraduate students recruited from classes at the University of Iowa. Each cohort of 10 subjects was exposed to only one treatment.[6] Except for session OPI-5(e) which used experienced subjects , subjects could not participate in more than one session. In each

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[5]That is, while no individuals have enough information to determine the state, the market's information (the union of all individuals' information) is sufficient to determine the state and, hence, the value of assets.

[6]This avoids hysteresis affects that may arise when switching between treatments within a cohort.

session, subjects participated in a series of 15 oral double auction asset market periods lasting 5 to 7 minutes.[7] Each session lasted two and one half to three hours.[8] Subjects earned an average of $30.00 each.

Upon arriving, subjects sat apart from each other in a classroom and received copies of the instructions and their own information and record sheets. (Appendix I contains these instructions.) After all subjects had arrived, the experimenter read the instructions aloud and answered any questions, making the instructional information commonly known. Except for making bids and offers or their acceptance, subjects were not allowed to speak to each other. They could ask the experimenter questions at any time.

In each period, subjects participated in at least two simultaneous oral double auctions markets with all bids, offers and acceptances publicly recorded. They used "francs" for currency in the markets. Each franc earned was worth $0.0005 at the end of the experiment. Subjects could not make short sales except under a treatment labeled OPIS (discussed later). In these markets, subjects traded units of two contingent claim assets ("Green Certificates" and "Blue Certificates") separately. Subjects could make bids or offers in any market at any time. They could also accept bids or offers in any market or all markets simultaneously. In addition, under a treatment labeled OPIP (discussed later), subjects could trade a "unit portfolio" security consisting of one of each of the contingent claims.

At the end of each market period, trading ceased and a random draw determined the "state". Specifically, without looking, a subject drew a marble from a bucket which contained 6 blue marbles and 14 green marbles of identical size. Subjects knew in advance how many marbles were of each color. The color of this marble determined the state: either "Blue" or "Green". The subject returned the marble to the bucket after determining the state. In the Blue state, each Blue certificate paid its owner 1,000 francs, while Green certificates paid 0. In the Green state, each Green certificate paid its owner 1,000 francs, while Blue certificates paid 0. Since the aggregate quantities of Blue and Green certificates were equal, aggregate payoffs were fixed.[9]

At the beginning of each period, subjects received initial amounts of francs on hand and inventories of Blue and Green certificates. Subjects knew their initial endowments for all periods at the beginning of the session. Subjects began each period with 40,000 francs that they could use for trading.[10] This cash was subtracted at the end of the period as a fixed cost. Subjects also began each period with unequal numbers of the two certificate types. Unless subjects were risk neutral, these were not Pareto optimal distributions. Hence, there were incentives for trade between non-risk neutral subjects.[11] Each period, subjects alternated between holding a portfolio of two Blue and

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[7]Session OPI-5(e) only ran for 13 periods.

[8]Subjects were recruited for three hours. Session OPIP-1 ran somewhat longer than three hours with the consent of all subjects.

[9]As discussed below, subjects could sell certificates short under the OPIS treatment. However, the method by which short selling was allowed insured that end of period aggregate quantities of Blue and Green certificate remained equal and aggregate payoffs were fixed.

[10]At equilibrium prices, this is enough currency to buy all the certificates in a period. Though prices often exceeded predictions, subjects never had binding liquidity constraints.

[11]Risk averse subjects will want to hold equal quantities of the two certificate types to insure themselves against risk. Risk seeking subjects will want all of their certificates to be of one type to maximize their risk. Risk neutral subjects will be indifferent between holding certificates or buying and selling them at equilibrium prices.

six Green certificates and a portfolio of six Blue and two Green certificates. Five subjects began each period holding each type of portfolio.[12] Subjects were endowed with a total of forty Blue certificates and forty Green certificates.

1. The OPI, OPI(e) and OPI(m) Treatments

The OPI (Oral double auction with Private Information about endowments) treatment is the baseline. Under this treatment, short sales were not allowed. Each initial endowment effectively included two unit portfolios. Though subjects could not trade directly in the unit portfolio, they could accept bids or offers in both markets simultaneously. Hence, when the sum of bids across markets exceeded 1,000 francs or 1,000 francs exceeded the sum of offers, subjects could exploit the resulting arbitrage opportunity without risk.

The OPI(m) treatment was the same as the OPI treatment except for two modifications in the instructions. First, the dividend tables contained an extra row that was explained in the text. This explained how the dividend to a "unit portfolio" consisting of one of each certificate would always be 1,000 francs regardless of the marble drawn. Second, additional instructions were distributed between periods 8 and 9 (after certificates had been trading at prices that totalled more than 1,000 francs for several periods). These explained how selling one of each certificate type at prices that totaled more than 1,000 francs always resulted in a certain profit. Similarly, they explained how buying one of each certificate type at prices that totaled less than 1,000 francs always resulted in a certain profit. This session is labeled OPI-4(m).

Except for the experience level of subjects, the OPI(e) treatment was the same as the OPI treatment. All subjects who participated in session OPI-5(e) had participated previously in one of the other sessions conducted for this paper. Further, all subjects were told that all other subjects had participated in exactly one previous session. Except under this treatment, all sessions used subjects who had not participated in previous sessions. In addition, session OPI-5(e) only ran for 13 periods because of one subject's time limitations.

2. The OPIP Treatment

The OPIP treatment added a unit Portfolio market to the OPI treatment. Short sales were not allowed. However, subjects could trade the unit portfolio directly in a third market called "Both". Subjects could sell separately purchased certificates as a unit portfolio in this market. Similarly, subjects could buy certificates as a unit portfolio and trade them separately later. Each initial endowment effectively included two unit portfolios. Subjects could accept bids or offers in any two or all three markets simultaneously. Hence, when the sum of bids across the Blue and Green markets exceeded the offer in the portfolio market or the bid in the portfolio market exceeded the sum of the offers in the Blue and Green markets, subjects could exploit the resulting arbitrage opportunity without risk.

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[12]A total of 10 subjects, 5 with each endowment type, should be sufficient for competitive outcomes. See Smith, Williams, Bratton and Vannoni [1982].

3. The OPIS Treatment

The OPIS treatment added a controlled form of Short sales to the OPI treatment. Again, each initial endowment effectively included two unit portfolios. Though subjects could not trade directly in the unit portfolio, they could still accept bids or offers in the Blue and Green markets simultaneously. However, under this treatment, subjects could effectively sell certificates short. During trading, individual inventories were allowed to fall below zero. At the end of trading, subjects had to "purchase" enough unit portfolios from the experimenter to bring their inventories of both certificate types up to zero. For each unit portfolio purchased, they had to pay 1,000 francs. They received this 1,000 francs back as a dividend if the certificate type they did not sell short paid a dividend. They lost this 1,000 francs if the certificate type they sold short paid a dividend. In this way, allowing negative inventories and then requiring the unit portfolio purchases is equivalent to short selling. Also, if subjects recognized the opportunity, this effectively created a perfectly elastic supply of unit portfolios at a price of 1,000. However, it did not change the aggregate payoffs across states. Thus, propositions P1-P4 should still hold.

IV. Specific Hypotheses and Results

In this experimental environment, Propositions P1-P4 imply the following: Proposition P1 implies that, at the end of trading, each subject should hold a portfolio with equal numbers of Blue and Green certificates. Proposition P2 implies that the ratio of Blue and Green prices should equal 6/14=0.4286. Alternatively, Proposition P2 implies that $\frac{1{,}000\times P^B}{P^B+P^G}=300$ and $\frac{1{,}000\times P^G}{P^B+P^G}=700$. Proposition P3 implies Blue and Green prices should sum to 1,000 (i.e. $P^B+P^G=1{,}000$). Finally, Proposition P4 implies that $P^B=300$ and $P^G=700$. Since the markets run for this paper were discrete, oral double auctions, propositions P1-P4 must be adapted slightly. Here, I will describe specific hypothesis derived from propositions P1-P4, summarize each session briefly and discuss the results in terms of these specific hypotheses.

Since the markets were hand run, the records do not show the clock times when events occurred within a period. Therefore, I will measure time in units of "events". Each bid, offer or acceptance will constitute an event. A subscript t will denote the outstanding bid, offer or price when the t^{th} event occurred within a market period. Let B^i_t, O^i_t and P^i_t denote the outstanding bid, offer and trading price for security i at the time of event t. Let superscripts of B, G and P denote the Blue certificate, the Green certificate and the "unit portfolio" of one of each type of certificate, respectively.

Recall that sessions labeled OPI were run with two markets, the ability to make acceptances in both markets simultaneously and no short sales. Session OPI-4(m) was run with the modified instruction set. Session OPI-5(e) was run using experienced subjects. Sessions labeled OPIP were run with three markets (one in the unit portfolio), the ability to make acceptances in any two or all three markets simultaneously and no short sales. Sessions labeled OPIS were run with two markets, the ability to make acceptances in both markets simultaneously and the ability to short sell (as discussed above).

A. Risk Allocation Hypotheses and Results

At the beginning of each period, subjects each held 40,000 francs and one of two initial certificate portfolios. The portfolios consisted of either (1) six Blue certificates and two Green certificates or (2) two Blue certificates and six Green certificates. After subtracting the fixed costs of 40,000 francs, these portfolios have expected values of 3,200 and 4,800 francs, respectively. They each have a standard deviation of 1,833 francs. Since there are always an equal number of Blue and Green certificates in the market, all subjects could attain portfolios with zero variance. If P4 always holds, they should be able to attain a zero variance portfolio with the same expected value as their initial portfolio.

1. Risk Sharing at the Market Level

If each subject is risk averse, each will try for a zero variance portfolio. For each subject to attain this portfolio, the minimum number of transactions overall in the Blue and Green markets must be twenty units. This leads to the first hypothesis:

H1: Efficient Distribution With Risk Averse Agents

To achieve zero variance portfolios for each subject, the volume across the Blue and Green markets must exceed twenty units. Risk averse subjects will then hold portfolios with equal numbers of each certificate type (zero variance portfolios).

Alternatively, if each subject is risk seeking, each will hold only one type of certificate in order to increase his or her portfolio's variance given its expected value. For each subject to attain this type of portfolio, the minimum number of transactions overall in the Blue and Green markets again must be twenty units. This leads to the alternative hypothesis:[13]

H2: Efficient Distribution with Risk Seeking Subjects

To achieve the highest variance portfolios for each subject, the volume across the Blue and Green markets must exceed twenty units. Risk seeking subjects will then hold portfolios consisting of only one certificate type (maximum risk portfolios).

These hypotheses make precise predictions about the final distributions of certificates in the market. If subjects are risk averse, they should diversify away all idiosyncratic risk and hold equal numbers of both certificates. If subjects are risk seeking, they should hold only one certificate type. The total volume in both markets was sufficient to attain these portfolios in only 26.38% of the periods overall (46 of 163 periods).

Because distributions never conformed exactly to either of these hypotheses, I ask which hypothesis better fits the final distributions of certificates. To do this, I define the market's risk sharing efficiency as the final percent

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[13]The distribution in H2 may result under another condition. If subjects have heterogeneous subjective probabilities on the states and if subjects are not too risk averse, the subjects with the highest subjective probabilities on each state will corner the market for the certificate corresponding to that state.

of the certificates that are distributed consistently with risk averse subjects (i.e. with Hypothesis H1). There are 80 certificates in each market all of which can be held in zero risk portfolios. Efficiency can be calculated by subtracting from 80 the absolute difference in the numbers of certificates of each type held by each subject and dividing by 80. (That is, subtracting from 100% the percentage of "exposed" certificates held in portfolios without certificates of the other type present to offset risk.) Figuring efficiency in this manner, the endowed distributions represented 50% risk sharing efficiency.[14] Efficiency reaches 100% when all 80 certificates are held in zero risk portfolios. Efficiency reaches 0% if all subjects only hold one certificate type each. Thus, efficiencies above 50% represent movements in the direction predicted by Hypothesis H1 while efficiencies below 50% represent movements in the direction predicted by Hypothesis H2.

Table II shows the final market risk sharing efficiency for each period in each session. Efficiencies ranged from 32.5% to 87.5% in a single period with average efficiencies ranging from 53% to 69% across sessions. The overall average was 64.05%. Thus, while the markets were never consistent with all risk seeking or risk averse subjects, they facilitated some risk sharing on average.

2. Risk Sharing at the Individual Portfolio Level

If subjects are risk seeking or risk averse and their risk preferences do not change over the course of the experiment, we would expect them to always either try to increase or decrease the variance in the portfolios. This leads to the hypothesis:

H3: Individually Consistent Risk Preferences Across Initial Endowments.

All of the final portfolios of an individual subject have either a higher variance (risk seeking subjects) or a lower variance (risk averse subjects) than their initial portfolios. That is, the quantities of the certificate types always differ by more or less than four in the final portfolio.

Overall, subjects tended to decrease the variance in their portfolios. Table III gives the average number of subjects who held only one certificate type or held a higher variance portfolio than the one with which they started the period. It also gives the average number of subjects who held zero variance portfolios. Finally, it gives the average number of subjects who held portfolios with lower variance than the one with which they started the period. Subjects seldom held only one certificate type. While subjects usually decreased the risk in their portfolios, they

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[14]In each endowment, four certificates (two Blue and two Green) are consistent with risk averse subjects because holding these two "unit portfolios" exposes the subject to no risk. The four remaining certificates are consistent with risk seeking subjects because holding them exposes the subject to unnecessary risk. In treatments with short sales, efficiency can be negative, though it never was.

seldom attained zero variance portfolios. Tests on all final portfolios show that, overall, subjects were significantly more likely to decrease the variance in their final portfolio than to increase it from their initial portfolio.[15]

Analysis of individual subject portfolios shows that some subjects consistently decreased their risk, a few consistently increased it and some consistently increased or decreased it depending upon their initial endowment. Table A.II.II in Appendix II gives binomial statistics testing whether individual subjects consistently increased or decreased their portfolio variances. It also gives χ^2 statistics testing whether the initial endowments affected subjects' tendencies to increase or decrease their portfolio variances. According to one sided tests using all the data at the 95% level of confidence, 50.91% of the subjects (56 of 110) consistently decreased the variance in their portfolio. Three subjects (2.73%) consistently increased the variance of their portfolio. Of the 51 remaining subjects, 45.10% (23) consistently increased the variance after receiving one endowment and decreased it after receiving the other endowment. Of these 23 subjects, 56.52% (13) consistently increased their portfolio's risk after receiving the high expected value endowment, while 43.48% (10) consistently increased it after receiving the low expected value endowment.

Finally, Table A.II.II gives χ^2 statistics testing the endowment's influence on whether subjects consistently held end of period portfolios with higher or lower variance than their own average end of period variance. There was an apparent endowment effect for nearly half of the subjects (46.36% using data from all periods and 44.55% using data from the last 10 periods). Of these subjects, just over half consistently held higher variance end of period portfolios after receiving the high expected value endowment (52.94% using data from all 15 periods and 53.06% using data from the last 10 periods). The rest of these subjects consistently held higher variance end of period portfolios after receiving the low expected value endowment. In session OPI-5(e), only two subjects displayed significant endowment effects. This was the smallest number in any session. Thus, experience may have decreased subject's susceptibility to endowment effects.

Thus, most subjects behaved consistently with Hypothesis H3, usually adjusting their portfolios in directions consistent with risk aversion. However, some consistently adjusted their portfolios as if they had endowment dependent risk preferences. Even among subjects who consistently decreased their portfolio's risk, the endowment appeared to affect systematically the level of risk in of period portfolios. Twenty three subjects (including 4 subjects from OPI-5(e) who may have been counted in both of their sessions) displayed none of these systematic portfolio adjustment patterns. This behavior is consistent with risk neutrality.

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[15]Assign a dummy variable the value of 1 if a subject increased the final variance of his or her portfolio, 0.5 if the variance was unchanged and 0 if it decreased. This allows a test on the hypothesis that subjects were equally likely to increase or decrease the variance in their portfolio. With 150 observations each, the standardized test statistics are -4.24578, -6.45032, and -4.57238 for the OPI sessions; -2.36784 in OPI-4(m); -2.77609, -6.94022, and -2.53114 for the OPIP sessions; and -8.65486, -6.53197 and -5.55218 for the OPIS sessions. With 130 observations, the standardized test statistic is -5.35005 in OPI-5(e). All are significant at the 95% level of confidence.

B. Relative Pricing Hypotheses and Results

Proposition P2 implies that relative prices should reflect only relative (subjective) state probabilities. I will state the hypotheses here in terms of prices normalized to be on the same scale as the absolute price hypotheses in the following sections. Thus, I will discuss normalized prices instead of price ratios directly.

The probability measure (π) can be any subjective probability measure upon which subjects who trade in both certificate types agree. If it is the objective probability measure, then, in equilibrium, prices should reflect the true state probabilities according to the hypothesis:

H4: Objective Probability Relative Pricing.

Prices are such that $1{,}000 \times P_t^B/(P_m^B + P_n^G) = 300$ and $1{,}000 \times P_s^G/(P_m^B + P_n^G) = 700$ for all m, n, t and s.

Alternatively, marginal subjects may not assign the objective probabilities to each event. Assuming that they use subjective probabilities leads to the weaker hypothesis:

H5: Subjective Probability Relative Pricing.

Prices are such that $1{,}000 \times P_m^B/(P_t^B + P_s^G) = \pi^B \times 1{,}000$ and $1{,}000 \times P_n^G/(P_t^B + P_s^G) = \pi^G \times 1{,}000$ for all m, n, t and s and $\pi^B + \pi^G = 1$.

Figure 1 shows the volume and average normalized prices in each period of each session. Table A.II.I in Appendix II also gives this information. Normalized prices in each period are found by dividing absolute prices by a constant. The constant makes the sum of the average normalized prices equal to 1,000 in that period. Thus, while the average normalized prices reflect only relative prices, they are on the same scale as the average absolute prices.

Overall, normalized prices were relatively close the objective probability predictions of H4 (with the possible exception of session OPIP-3 which will be discussed later). However, they showed a slight bias with normalized Blue prices generally averaging more than 300 and normalized Green prices generally averaging less 700 in these sessions (114 times out of 161 observations each or 70.81% of the time). However, normalized Blue prices were within two standard deviations of 300 in 60.25% of the observations overall (97 of 161). Normalized Green prices were within two standard deviations of 700 in 59.01% of the observations overall (95 of 161). These percentages were 55.96% and 57.80% during the last 10 periods. Thus, the majority of the time, relative prices were near the predictions. The slight bias was in the direction of subjects overweighting the lower probability event.

C. Arbitrage Hypotheses and Results

The portfolio consisting of one Blue certificate and one Green certificate will always pay its owner 1,000 francs at the end of the period. In equilibrium, subjects should not expect to be able to buy or sell this unit portfolio at prices that do not sum to 1,000. This leads to the first arbitrage hypothesis:

H6: Equilibrium No Arbitrage Pricing.

Bids, offers and prices are such that $B^B_t + B^G_t < 1{,}000$, $O^B_t + O^G_t > 1{,}000$ and $P^B_t + P^G_t = 1{,}000$ for all t.

Hypothesis H6 may not hold if subjects do not view holding the unit portfolio of certificates while the market is open as equivalent to receiving the certain final payoff of 1,000 francs after the market closes. This may be true if, because of out-of-equilibrium bids, offers and prices, subjects anticipate the possibility of selling the portfolio for more than 1,000 francs before the end of the period. The possibility of risk seeking subjects cornering the market in either certificate type could lead to similar expectations. Finally, non additive or heterogeneous subjective probabilities over states could also explain why the prices would not add to 1,000. Nevertheless, a no-arbitrage condition should still hold across markets in OPIP treatment sessions that include a market for the unit portfolio. This leads to the second arbitrage hypothesis:

H7: Instantaneous No Arbitrage Pricing.

Bids, offers and prices are such that $B^B_t + B^G_t < O^P_t$, $O^B_t + O^G_t > B^P_t$ and $P^B_t + P^G_t = P^P_t$ for all t.

1. Existence of Arbitrage Opportunities

Table IV summarizes the arbitrage opportunities that existed in each session. It lists the number of events in each session and the fraction that were non-trade events.[16] It also lists the number of times bids or offers were outstanding simultaneously in the Blue and Green markets and number of these events that represented arbitrage opportunities. Finally, it shows the arbitrage opportunities that existed across the three markets in the OPIP sessions. Figure 3 also shows the fraction of times simultaneous bids or offers resulted in potential equilibrium arbitrage opportunities and the fraction of these times that actually resulted in profitable equilibrium arbitrage opportunities. When arbitrage opportunities existed, unconstrained subjects could always exploit the opportunities risklessly by simultaneously accepting the bids or offers that created the opportunity. Thus, the ability to exploit arbitrage opportunities was independent of other trades that occurred during the market period.

There were many apparent arbitrages opportunities between Blue and Green bids and the certain portfolio payoff of 1,000 francs. Blue and Green bids were outstanding simultaneously during up to 44.86% of the non-trade events. During most of these events, the sum of the bids exceeded 1,000. While only 15.89% of these events represented arbitrage opportunities in OPIP-3, the fraction during which arbitrage opportunities existed in the other sessions ranged from 44.44% (OPI-2) to 100% (OPI-1).

While there were many apparent arbitrage opportunities between outstanding bids and the certain portfolio payoff of 1,000, there were very few between outstanding offers and the portfolio payoff. Offers were outstanding

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[16]A transaction would eliminate any arbitrage opportunity that existed.

in the Blue and Green markets simultaneously during up to 39.26% of the non-trade events. During all but three of these events, the sum of the offers exceeded 1,000 as expected.

There were also few arbitrage opportunities across the three markets in OPIP sessions. Blue and Green bids and a unit portfolio offer were outstanding during up to 12.98% of the non-trade events in these sessions. Arbitrage opportunities existed during only 9 of these events (which all occurred within a 10 event range of one period). Blue and Green offers and a unit portfolio bid were outstanding during up to 3.96% of the non-trade events. None of these represented arbitrage opportunities. Thus, while Hypothesis H6 was regularly violated when two bids were outstanding, Hypothesis H7 was seldom violated. Bids, offers and prices were almost always consistent with each other across markets.

2. Exploitation of Arbitrage Opportunities

In all treatments, subjects could accept bids or offers in all markets simultaneously. Hence, they could take advantage of the sum of Blue and Green bids exceeding 1,000 or the unit portfolio offer without risk. Similarly, they could take advantage of 1,000 or the unit portfolio bid exceeding the sum of the Blue and Green offers. While arbitrage opportunities often appeared to exist, only one subject made acceptances in more than one market simultaneously. That subject (Trader 8 in OPIS-3) accepted both bids at one time when the bids summed to 1,100.[17] Thus, most subjects never took advantage of apparent arbitrage opportunities in this completely risk free manner.

However, subjects sometimes made purchases or sales sequentially in both or all three markets. They also often purchased or sold certificates in all markets over the course of a period. Sometimes these non-synchronous trades were at prices that gave the subject a sure profit, sometimes a sure loss. Table V summarizes this non-synchronous trading and its profitability.[18] Sales of the two certificate types generally resulted in profits while purchases generally resulted in losses. Overall, profits from non-synchronous portfolio transactions were not significantly different from zero. Thus, there was no strong tendency for subjects to take advantage of the generally high certificate prices.

D. Absolute Pricing Hypotheses and Results

The hypotheses here are closely related to the relative pricing and arbitrage hypotheses above. Given relative prices, the summed prices determine the absolute prices for each security. If there is no arbitrage, prices must sum to 1,000. If subjects use the objective probability measure, then prices should equal 1,000 times the true state probabilities according to the hypothesis:

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[17]OPIS-3, Period 13, Event 43.

[18]When subjects had multiple trades in both markets, trades are matched to give the highest profit within the period first. Then, they were matched in order of occurrence within the period.

H8: Objective Probability Pricing.

Prices are such that $P_t^B=300$ for all t and $P_s^G=700$ for all s.

Hypotheses H4 (objective probability relative pricing) and H6 (no arbitrage) directly imply Hypothesis H8.

Again, marginal subjects may not assign the objective probabilities to each event. Assuming that the subjective probability measures are additive leads to the weaker hypothesis:

H9: Additive Subjective Probability Pricing.

Prices are such that $P_t^B=\pi^B\times 1{,}000$ for all t, $P_s^G=\pi^G\times 1{,}000$ for all s and $\pi^B+\pi^G=1$.

Hypotheses H5 (subjective probability relative pricing) and H6 (no arbitrage) directly imply Hypothesis H9.

Finally, assuming arbitrage restrictions are violated and that the subjective probability measures are not additive[19] leads to the still weaker hypothesis:

H10: Non-additive Pricing.

Prices are such that $P_t^B=\pi^B\times 1000$ for all t, $P_s^G=\pi^G\times 1000$ for all s and $\pi^B+\pi^G\neq 1$.

If Hypothesis H5 (subjective probability relative pricing) holds and H6 (no arbitrage) does not, then prices should conform to Hypothesis H10. Non-additive prices violate arbitrage restrictions. Hence, we should observe non-additive prices only if subjects cannot or will not take advantage of arbitrage opportunities. I will discuss possible reasons for this in the next section.

Figure 2 shows the volume and average absolute prices in each period of each session. Table A.II.I in Appendix II also gives this information.

In each session under the OPI and OPIS treatments, average absolute prices in both markets were generally above the equilibrium prices of 300 and 700, often with an extremely small standard deviation (sometimes zero). With only three exceptions, the sum of average absolute prices exceeded the prediction of 1,000.[20] With only two exceptions, the averages of both absolute prices exceeded the predictions during the last 10 periods of each session.[21] Blue prices were within two standard deviations of 300 during only 21.90% of the 105 periods in the sessions without portfolio trading and without experienced subjects. Green prices were within two standard deviations of 700 during 30.48% of these periods. These percentages were 20.00% and 12.86% during the last 10 periods of each session. With experienced subjects, Blue prices were closer to the predictions, but Green prices generally stayed above the predictions. Average Blue prices were within two standard deviations of 300 during

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[19]See Schmeidler [1989], who generalizes expected utility to non-additive subjective probability measures.

[20]The exceptions were OPI-4(m), period 2 and OPIS-2, periods 2 and 4.

[21]The exceptions were Blue prices in OPI-4(m), period 14 and OPI-5(e), period 11 (in which blue prices averaged 300 exactly).

69.23% of the 13 periods in OPI-5(e). However, average Green prices always exceed 700 by more than two standard deviations.

Results were similar in all periods of OPIP-1 and in the last 6 periods of OPIP-2. During these periods, average absolute prices in all three markets were always above the equilibrium prices (with the average price in the portfolio market equal to 1,000 in period 2 of OPIP-1). Average Blue and Green prices were within two standard deviations of the predictions during only 33.33% and 9.05% of these periods, respectively. The sum of the Blue and Green average prices always exceeded the prediction of 1,000. Again, relative prices were closer to the predictions with average normalized Blue and Green prices within two standard deviations of the predictions during 76.19% and 71.43% of these periods respectively.

Results in the first 9 periods of OPIP-2 and the last 14 periods of OPIP-3 differed. During these periods, the summed absolute mean prices were generally within two standard deviations of 1,000 francs. They summed to within 25 francs half of the time (12 of 24 periods) and within 50 francs two thirds of the time (16 of 24 periods). In OPIP-2, both absolute and normalized prices were generally within two standard deviations of 300 and 700. However, in OPIP-3, Blue prices were generally below 300 while Green prices were generally above 700.[22] Average absolute and normalized Blue and Green prices were within two standard deviations of the predictions only two times each in the last 10 periods of OPIP-3.

While individual and summed absolute certificate prices often exceeded predictions in all treatments, the sum of the average prices was generally within two standard deviations of the average portfolio price in sessions with portfolio markets. Further, as discussed above, there were seldom arbitrage opportunities across markets under in these sessions. Thus, again, while absolute prices did not fit the predictions well, relative prices appeared consistent.

V. Potential Explanations for the Results

The observed distributions, prices and arbitrage opportunities are difficult to explain. Most simple explanations can easily be ruled out. For example, Smith, Suchanek and Williams (1988) cite subjects's lack of previous experience to explain bubbles in their experiments. However, the potential arbitrage profits here do not depend on expectations about how other subjects will behave. Subjects here often ignored these extremely simple arbitrage opportunities across dozens of events in 15 independent trials per session. Further, bubbles arose in a session in which all subjects commonly knew that they had all participated in previous sessions.

Non-competitive markets or low volumes may explain prices that do not sum to 1,000 because of non-synchronous trade. However, this cannot explain un-exploited arbitrage opportunities. Other markets with similar numbers of traders generally have resulted in competitive outcomes (see Smith, Williams, Bratton and Vannoni [1982]). Overall volumes approached the competitive predictions with a median of 17 units traded across the two

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[22]Note, a green marble was drawn in each of the first 12 periods of OPIP-3.

contingent claim markets. Finally, subjects could exploit arbitrage opportunities regardless of other volume in the markets.

Insufficient motivation or understanding cannot easily explain the results. The arbitrage opportunities here seem exceptionally transparent and continued to exist even after subjects were told explicitly how to exploit them. Further, subjects drawn from similar pools for asset markets with similar payoff levels seem to be sufficiently motivated and understand the markets (e.g., Forsythe and Lundholm [1990]). Finally, generally consistent relative prices in all treatments and the inter-market consistency of prices the most complex, three market treatment (OPIP) argues against this explanation.

Subjects seldom hit binding constraints, so neither risk seeking subjects nor heterogeneous subjective probabilities can explain prices. Neither can binding constraints explain the un-exploited arbitrage opportunities. Finally, bubbles formed in a treatment that allowed a form short sales that should have created a perfectly elastic supply of unit portfolios at the equilibrium price. Under this treatment, subjects did not give up opportunities to sell at later times when they exploited an arbitrage opportunity. Since subjects generally did not exploit the arbitrage opportunity under this treatment, high prices cannot be explained by subjects anticipating still higher prices later in the period.

While many simple explanations fail, non-expected utility maximizing subjects may explain the results. Subjects will not take advantage of arbitrage opportunities if they anticipate being worse off after exploiting them. That is, non-additive prices may arise if each subject views exploiting the arbitrage opportunity as leaving them worse off in spite of the resulting sure increase in wealth. This will only occur if subjects are not maximizing the expected utility of final wealth alone. Instead, they must have some preference for the status quo that offsets the sure profits possible from exploiting the arbitrage opportunities.

There is both direct and indirect evidence that not all subjects were expected utility maximizers with wealth as the only argument in the utility function. Some subjects consistently increased or decreased their portfolio's variance conditional on their initial endowment. Further, subjects' endowments appeared to affect the absolute level of risk in final portfolios even for subjects who consistently decreased their portfolio risk. These observations are consistent with endowment dependent preferences or framing effects. Finally, even when they could, subjects seldom, if ever, exploited arbitrage opportunities that would have led to a sure profit. This is clearly inconsistent with expected utility maximization if the only argument in each subject's utility function is final wealth. (Note that the propositions regularly violated (P3 and P4) are those that depend on subjects who always prefer more wealth to less.)

In these experiments, subjects are seldom constrained and appear to understand the trading mechanism well. That is, they seem *able* to exploit the arbitrage opportunities. However, they seldom do exploit these opportunities even after the opportunities are carefully explained to them. Further, though subjects usually adjust their portfolios through trade, the seldom alter their holding sufficiently to attain the optimal portfolio for either risk seeking or risk averse preferences. Thus, to some degree, subjects seem *unwilling* to trade. This is consistent with previous experimental evidence that shows individuals are often subject to a status quo bias.

An abundance of other research documents that individuals often do not maximize expected utility when making individual decisions under uncertainty. In particular, much of it shows that subjects are reluctant to make decisions that change their status quo.[23] Thaler (1980) labels this the endowment effect, noting that individuals are averse to giving up any objects they are endowed with (e.g. coffee cups, candy bars, gambles, etc.). Kahneman, Knetsch and Thaler [1990], show that individuals are often unwilling to sell items in markets even when the values of the items are known with certainty and the prices exceed this known value. Tversky and Kahneman [1991] attribute this effect to loss aversion, a property of Kahneman and Tversky's [1979] prospect theory. Loomes and Sugden [1982] and Bell [1982 and 1983] both develop models of decision regret that would lead to a status quo bias if the status quo served as a reference point against which all decisions are judged. Further, as Bell [1988] points out, "perhaps the most influential reference point is the status quo of the decision maker. It has been widely observed that a decision maker will make significant economic trade-offs to remove the possibility of a net loss on a transaction."

An endowment effect would easily explain the results here and the relationships between these results and other experimental asset markets. First, unexploited arbitrage opportunities, failures to reach optimal portfolios and somewhat low volumes (relative to equilibrium) suggest a reluctance to trade or an endowment effect. Kahneman, Knetsch and Thaler [1990] discuss a variety of bargaining and market situations in which the number of trades consistently fell significantly short of the predictions. They cite this as evidence for an endowment determined status quo bias.

Second, prices are bid up, consistent with Tversky and Kahneman's [1991] observation "that the reluctance to sell is much greater than the reluctance to buy" as evidenced by Kahneman, Knetsch and Thaler [1990].

Third, arbitrage opportunities because of over-pricing arise in these markets and those of Smith, Suchanek and Williams [1988]. In both market sets, the assets traded are truly prospects in the sense that their final values are never know with certainty during trade. However, over-pricing seldom arises in markets in which the asset values can be known with certainty (e.g. Forsythe, Palfrey and Plott [1982], Plott and Sunder [1982 and 1988] and Forsythe and Lundholm [1990]). This is consistent with Kahneman, Knetsch and Thaler's [1990] observation that endowment effects are minimized when objects of known value (e.g. induced value tokens) are traded. When their value becomes know, assets cease to be prospects and become such simple tokens.

Fourth, arbitrage opportunities are quickly exploited in markets in which traders must purchase their assets instead of being endowed with assets (e.g. the Iowa Political Securities Market (IPSM) of Forsythe, Nelson,

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[23]Samuelson and Zeckhauser [1988] give evidence for the status quo bias in both laboratory and naturally occurring choices, in choosing among investment alternatives, in consumer choice, in evaluating mortality risks and other situations. Knetsch and Sinden [1984 and 1987], Knetsch [1989], Kahneman, Knetsch and Thaler [1990] and Hartman, Doane and Woo [1991] also give evidence for the endowment effect and status quo bias in a variety of situations.

Neumann and Wright [1992]). In the IPSM, participants are not endowed with any assets. Instead they must create all positions by purchasing the assets for resale from the market makers at exactly the no arbitrage price. This is consistent with Kahneman, Knetsch and Thaler's [1990] observation that "there is no reason in general to expect reluctance to resell goods that are held especially for that purpose." That is, the endowment effect will be reduced when individuals specifically purchase items for resale.

Finally, the results here reconcile two apparently contradictory lines of research: that of Smith, Suchanek and Williams [1988] and O'Brien and Srivastava [1989, 1990 and 1991]. In Smith, Suchanek and Williams [1988], asset markets seen inefficient because of absolute over-pricing and the pure arbitrage opportunities that sometimes result. O'Brien and Srivastava [1989, 1990 and 1991] find that asset markets are relatively efficient in the sense that arbitrage opportunities based on relative prices seldom arise and are quickly exploited. Here, arbitrage opportunities based on relative prices seldom arise and relative prices track the predictions relatively well. Concurrent absolute prices exceed the predictions and violate arbitration restrictions based on absolute prices. Thus, market trading can result in both relative price efficiency and absolute over-pricing simultaneously.

VI. Summary and Conclusions

The results can be grouped into three areas: risk allocation results, price results and arbitrage results.

First, subjects seldom perfectly insured themselves against risk. They also generally did not use the markets to gamble as much as they could. Thus, the observed final distributions of certificates never conformed exactly to predictions. However, the markets did facilitate some risk sharing. Most subjects appeared risk averse, consistently reducing the risk of their portfolios. A few subjects consistently increased their portfolio risk. Finally, some appeared to have endowment-dependent risk preferences, consistently increasing their portfolio risk after receiving one endowment and decreasing it after receiving the other endowment. Many systematically exposed themselves to different levels of risk conditional on their endowment.

Second, while relative prices often reflected relative state probabilities, absolute market prices generally differed from the predictions, usually exceeding them. Price bubbles regularly formed in which prices and, often, joint bids exceeded the certain final payoff of the unit portfolio. Allowing short sales did not eliminate this phenomenon. Neither did bringing subjects back for a second session. However, having subjects trade in the unit portfolio directly may have mitigated price bubbles. The only sessions in which price bubbles did not regularly form were sessions that included direct portfolio trading.

Finally, high prices and bids often resulted in apparent arbitrage opportunities between the unit portfolio and its certain final payoff. Subjects seldom, if ever, exploited these arbitrage opportunities though they seldom faced short sale constraints that might have prevented the exploitation. Allowing short sales did not eliminate this phenomenon. Neither did special instructions which explained the arbitrage opportunities. Finally, bringing subjects back for a second session did not eliminate arbitrage opportunities. While arbitrage opportunities often arose between the unit portfolio and its certain final payoff, inter-market arbitrage opportunities seldom arose between prices in individual asset markets and prices in the unit portfolio market when subjects could trade in the unit portfolio directly. Further, the only sessions in which prices did not regularly exceed the no-arbitrage predictions were sessions that included direct portfolio trading.

The failure of subjects to exploit arbitrage opportunities and the endowment effects on their apparent risk preferences indicate that subjects were not all expected utility maximizers. Instead, their behavior indicates that many subjects have an endowment induced status quo bias. Price bubbles that expected utility maximizing subjects could not explain were remarkably robust. Nevertheless, the relative prices and the inter-market consistency of prices in three-market sessions indicate that subjects were highly adept at determining the relative values of assets. The results add to the body of evidence supporting efficient relative pricing and the scarcity of inter-market arbitrage. However, it also shows that, at least in some contexts, absolute prices consistently differ from predictions and arbitrage opportunities based on absolute prices can persist without being exploited. Thus, asset pricing models that predict relative prices (e.g. APT or the standard CAPM) may out perform those that try to relate absolute prices to economic fundamentals (e.g. consumption based CAPM) because market participants react to relative value more and more capably than they react to absolute value. In addition, models relaxing assumptions about expected utility maximization may have a better chance of explaining behaviors observed in financial markets than current models or those relaxing other assumptions.

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Table I: Experimental Design Parameters

General Parameters

Subjects:	University of Iowa Undergraduates. All sessions except OPI-5(e) used subjects without previous experience in other markets run for this paper. Session OPI-5(e) used subjects with previous experience in one previous session run for this paper. Subjects commonly knew this experience level. 10 Subjects per Session.
Time and Payments:	Subjects were recruited for 3 hours. Experiments lasted for approximately 2.5 hours.* Earnings averaged $30.00 and ranged from $17.70 to $40.50. Francs were exchanged at the rate of $0.0005 per franc.
Endowments and Fixed Costs:	Subjects began each period with 40,000 francs and either 1) 2 Blue Certificates and 6 Green Certificates or 2) 6 Blue Certificates and 2 Green Certificates. A Fixed cost of 40,000 francs was subtracted after each period.
Number And Time of Periods:	There were 15 periods in each experiment. Subjects began each experiment with record sheets for 15 periods. Each period lasted 5-7 minutes (with period times announced in advance).
Dividend Structure:	Dividends each period were determined by a marble drawn randomly from a bucket containing 20 marbles according to the following table:

Color	Number	Blue Certificate Dividend	Green Certificate Dividend
Blue	6	1,000 Francs	0 Francs
Green	14	0 Francs	1,000 Francs

Treatment Variables

OPI Treatment:	2 Markets Simultaneous Acceptances in Both Markets. No Short Sales Expanded Payoff Table and Instructions in OPI-4(m) Experienced Subjects Participated in OPI-5(e)
OPIP Treatment:	3 Markets (One in the Unit Portfolio). Simultaneous Acceptances in any Two or All Three Markets. No Short Sales
OPIS Treatment:	2 Markets Simultaneous Acceptances in Both markets. Short Sales Allowed

*Experiment OPIP-1 ran for over 3 hours with all the subjects' consent.

Table II: Market Risk Sharing Efficiency*

Period	Session										
	OPI-1	OPI-2	OPI-3	OPI-4(m)	OPI-5(e)	OPIP-1	OPIP-2	OPIP-3	OPIS-1	OPIS-2	OPIS-3
1	65.00%	52.50%	62.50%	57.50%	52.50%	50.00%	67.50%	65.00%	62.50%	55.00%	52.50%
2	60.00%	60.00%	77.50%	70.00%	60.00%	55.00%	67.50%	75.00%	70.00%	70.00%	42.50%
3	82.50%	55.00%	67.50%	70.00%	55.00%	45.00%	70.00%	70.00%	75.00%	67.50%	65.00%
4	67.50%	65.00%	60.00%	55.00%	67.50%	52.50%	67.50%	52.50%	70.00%	70.00%	55.00%
5	70.00%	62.50%	52.50%	57.50%	72.50%	57.50%	70.00%	65.00%	70.00%	80.00%	57.50%
6	62.50%	67.50%	65.00%	60.00%	60.00%	50.00%	57.50%	55.00%	75.00%	60.00%	60.00%
7	57.50%	72.50%	67.50%	55.00%	70.00%	65.00%	72.50%	52.50%	65.00%	77.50%	62.50%
8	62.50%	60.00%	62.50%	67.50%	62.50%	62.50%	77.50%	45.00%	82.50%	60.00%	70.00%
9	60.00%	75.00%	57.50%	62.50%	72.50%	70.00%	75.00%	55.00%	67.50%	82.50%	67.50%
10	57.50%	72.50%	67.50%	52.50%	87.50%	57.50%	60.00%	47.50%	67.50%	62.50%	67.50%
11	52.50%	80.00%	55.00%	55.00%	57.50%	57.50%	65.00%	45.00%	70.00%	62.50%	70.00%
12	57.50%	72.50%	55.00%	55.00%	80.00%	65.00%	60.00%	45.00%	60.00%	55.00%	67.50%
13	65.00%	72.50%	55.00%	52.50%	67.50%	62.50%	75.00%	40.00%	55.00%	75.00%	72.50%
14	57.50%	77.50%	65.00%	55.00%	--	47.50%	72.50%	47.50%	65.00%	67.50%	62.50%
15	52.50%	75.00%	32.50%	45.00%	--	60.00%	72.50%	40.00%	62.50%	62.50%	70.00%
Average:	62.00%	68.00%	60.17%	58.00%	66.54%	57.17%	68.67%	53.33%	67.83%	67.17%	62.83%

*Efficiency is defined as $\frac{80 - \sum_i |Q_i^* - Q_i^a|}{80}$ where i indexes the subjects and Q_i^j represents subject i's holdings of certificate type j at the end of the period.

Table III: Summary of Portfolio Holdings

Session	Events Summarized	Average Number of Subjects (out of 10) Who: Held Only One Certificate Type (Std. Dev.)	Held Portfolios with Higher than Initial Variance (Std. Dev.)	Held Equal Numbers of Both Certificate Types (Std. Dev.)	Held Portfolios with Lower than Initial Variance (Std. Dev.)
OPI-1	All Events	0.9473 (1.07868)	1.7522 (1.3725)	0.6736 (0.9844)	4.3632 (2.2061)
	End of Period	2.4000 (0.9856)	2.7333 (1.2799)	2.0000 (1.1339)	6.2000 (1.2649)
OPI-2	All Events	0.2134 (0.4099)	0.8509 (0.8938)	0.6864 (0.9583)	5.5257 (2.4631)
	End of Period	0.6667 (0.4880)	1.5333 (1.0601)	1.4000 (1.3522)	6.8000 (1.6987)
OPI-3	All Events	0.6450 (1.2144)	1.8464 (1.3870)	0.6870 (0.9562)	4.8044 (2.2107)
	End of Period	1.6667 (1.7182)	2.4667 (1.2459)	1.4667 (0.8338)	6.2000 (1.1464)
OPI-4(m)	All Events	0.7931 (0.7830)	1.1255 (0.7748)	0.6909 (0.8825)	4.7004 (1.9496)
	End of Period	1.4667 (1.0601)	1.8000 (0.6761)	1.4667 (1.0601)	5.2667 (1.0998)
OPI-5(e)	All Events	0.7569 (0.8293)	1.4213 (1.1705)	0.4834 (0.8001)	4.8936 (2.1457)
	End of Period	1.7692 (0.7250)	1.8462 (1.3445)	1.846154 (1.4051)	6.5385 (1.4500)
OPIP-1	All Events	0.7075 (1.0864)	1.9665 (1.2433)	0.4962 (0.7061)	4.2984 (2.2446)
	End of Period	2.0000 (1.3093)	3.2000 (1.3732)	1.2667 (0.9612)	5.4667 (1.4573)
OPIP-2	All Events	0.1941 (0.4618)	1.0233 (0.7410)	0.5359 (0.7569)	5.5652 (2.0927)
	End of Period	0.5333 (0.7432)	1.5333 (0.5164)	1.6000 (1.0556)	7.2000 (0.7746)
OPIP-3	All Events	0.7404 (1.0102)	2.2330 (1.6069)	0.5429 (0.7734)	4.6861 (1.9424)
	End of Period	2.0000 (1.1952)	3.2667 (1.6242)	1.1333 (0.8338)	5.3333 (1.4960)
OPIS-1	All Events	0.0545 (0.2272)	0.4876 (0.6955)	0.1411 (0.3889)	5.1535 (2.7809)
	End of Period	0.2000 (0.4140)	0.5333 (0.7432)	0.5333 (0.5164)	7.6000 (1.6818)
OPIS-2	All Events	0.3525 (0.4922)	1.0686 (1.0473)	0.3964 (0.8107)	4.8505 (2.3878)
	End of Period	0.8667 (0.5164)	1.5333 (1.1255)	1.5333 (1.2459)	6.8667 (1.4075)
OPIS-3	All Events	0.2674 (0.4759)	1.3861 (0.9942)	0.4595 (0.7889)	4.9548 (2.3363)
	End of Period	1.0000 (0.6547)	2.0000 (0.7559)	1.2000 (0.9411)	6.5333 (1.7265)

Table IV: Summary of Equilibrium and Instantaneous Arbitrage Opportunities

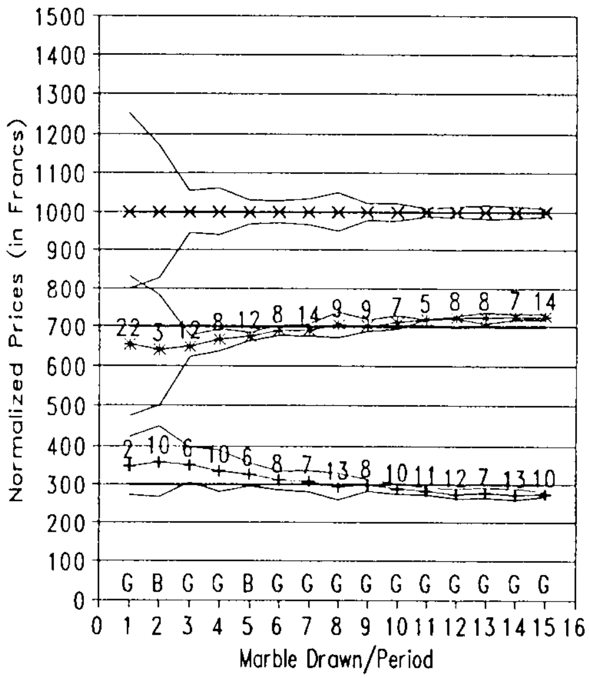
	Session										
	OPI-1	OPI-2	OPI-3	OPI-4(m)	OPI-5(e)	OPIP-1	OPIP-2	OPIP-3	OPIS-1	OPIS-2	OPIS-3
Events:	1005	778	1048	1155	724	1193	989	1043	404	729	531
Non-Trade Events	726	561	754	815	500	883	740	701	265	535	328
(% of Events):	(72.24)	(72.11)	(71.95)	(70.56)	(69.06)	(74.02)	(74.82)	(67.21)	(65.59)	(73.39)	(61.77)
Both Blue and Green Bids Outstanding	149	36	177	221	129	152	332	214	33	181	79
(% of Non-Trade Events):	(20.52)	(6.42)	(23.47)	(27.12)	(25.80)	(17.21)	(44.86)	(30.53)	(12.45)	(33.83)	(24.09)
Blue Plus Green Bids Exceed 1,000	149	16	174	172	123	132	188	34	31	133	66
(% of Both Outstanding):	(100.0)	(44.44)	(98.31)	(77.83)	(95.35)	(86.84)	(56.63)	(15.89)	(93.94)	(73.48)	(83.54)
Both Blue and Green Offers Outstanding	285	188	177	94	108	154	22	118	28	58	55
(% of Non-Trade Events):	(39.26)	(33.51)	(23.47)	(11.53)	(21.60)	(17.44)	(2.97)	(16.93)	(10.57)	(10.84)	(16.77)
Blue Plus Green Offers Less than 1,000	0	0	0	0	0	0	1	2	0	0	0
(% of Both Outstanding):	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(4.55)	(1.69)	(0.00)	(0.00)	(0.00)
Blue and Green Bids and "Both" Offer	--	--	--	--	--	95	0	91	--	--	--
Outstanding (% of Non-Trade Events):						(10.76)	(0.00)	(12.98)			
Blue Plus Green Bids Exceed "Both"	--	--	--	--	--	9	0	0	--	--	--
Offer (% of All Three Outstanding):						(9.47)	(N.A.)	(0.00)			
Blue and Green Offers and "Both" Bid	--	--	--	--	--	35	3	18	--	--	--
Outstanding (% of Non-Trade Events):						(3.96)	(0.41)	(2.57)			
Blue Plus Green Offers Less than "Both"	--	--	--	--	--	0	0	0	--	--	--
Bid (% of All Three Outstanding):						(0.00)	(0.00)	(0.00)			

Table V: Summary of Non-Synchronous Portfolio Transactions within a Period

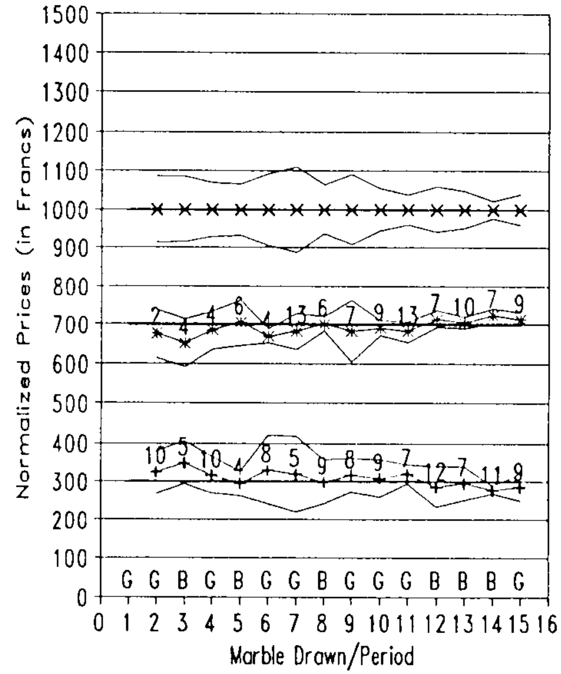
	Non-Synchronous Portfolio Purchases (Blue and Green Markets)			Non-Synchronous Portfolio Sales (Blue and Green Markets)			All Non-Synchronous Portfolio Transactions (Blue and Green Markets)		
Session	# of Subs	# of X-actions	Average Profit Std Dev	# of Subs	# of X-actions	Average Profit Std Dev	# of Subs	# of X-actions	Average Profit Std Dev
OPI-1	5	26	-202.11 (31.44)	7	32	261.25 (90.94)	9	58	53.53 (242.83)
OPI-2	7	13	-171.15 (134.18)	7	26	207.31 (130.49)	9	39	81.15 (222.61)
OPI-3	6	15	-335.00 (63.95)	8	29	352.59 (85.92)	9	44	118.18 (338.87)
OPI-4(m)	8	58	-176.72 (114.60)	8	44	202.27 (95.21)	10	102	-13.24 (216.46)
OPI-5(e)	5	22	-164.55 (39.12)	7	33	171.06 (34.20)	9	55	36.82 (169.77)
OPIP-1	5	28	-283.04 (177.44)	8	19	363.68 (215.93)	9	47	-21.60 (373.69)
OPIP-2	6	28	-32.14 (141.24)	6	24	83.13 (140.53)	9	52	21.06 (151.11)
OPIP-3	5	18	-52.78 (113.08)	6	29	88.79 (150.24)	9	47	34.57 (152.65)
OPIS-1	3	10	-250.00 (100.00)	3	6	283.33 (87.56)	4	16	-50.00 (282.25)
OPIS-2	4	18	-179.17 (139.92)	3	10	45.00 (144.24)	6	28	-99.11 (176.71)
OPIS-3	4	11	-163.64 (77.75)	5	21	146.43 (85.25)	7	32	39.84 (170.37)

	Non-Synchronous Portfolio Purchases (Blue and Green Markets) and Sales in the Portfolio Market			Non-Synchronous Portfolio Sales (Blue and Green Markets) and Purchases in the Portfolio Market			All Non-Synchronous Portfolio Transactions (Blue and Green Markets) with Offsetting Portfolio Market Transactions		
Session	# of Subs	# of X-actions	Average Profit Std Dev	# of Subs	# of X-actions	Average Profit Std Dev	# of Subs	# of X-actions	Average Profit Std Dev
OPIP-1	2	11	-100.00 (125.50)	4	9	120.56 (120.12)	5	20	-0.75 (164.03)
OPIP-2	0	0	0	0	0	0	0	0	0
OPIP-3	0	0	0	0	0	0	0	0	0

Session OPI-1



Session OPI-2



Session OPI-3

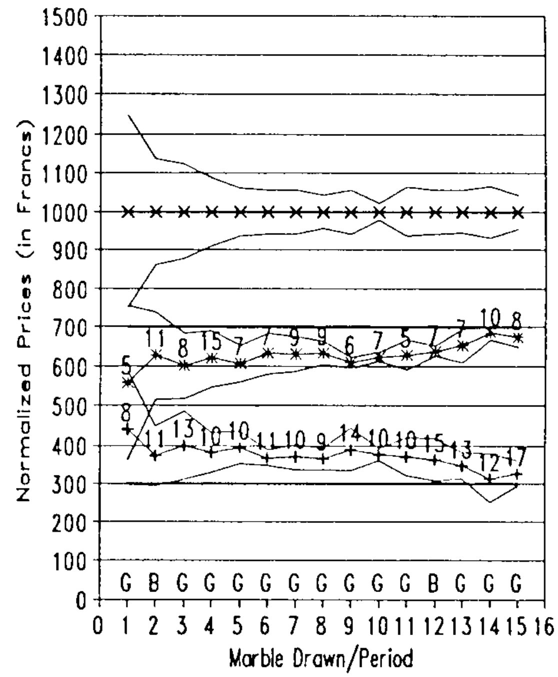
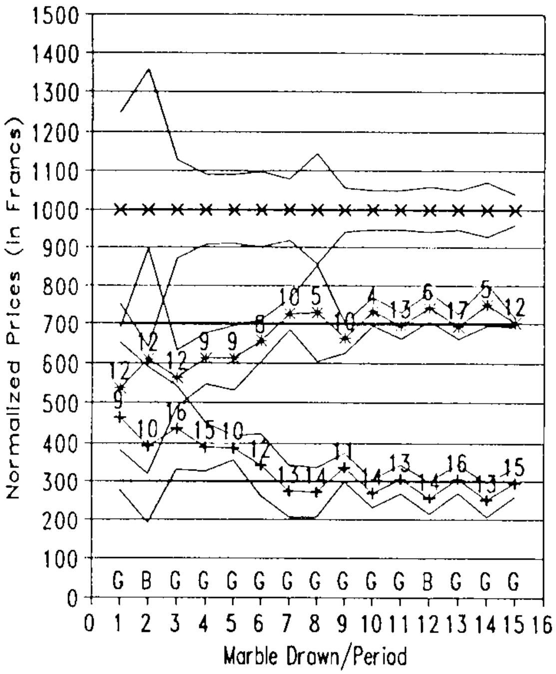


Figure 1.a: Treatment OPI Sessions, Blue (+), Green (✱) and Summed (✕) Average Normalized Prices and Volumes and ±1.96 Standard Deviation Confidence Intervals.

Session OPI-4(m)



Session OPI-5(e)

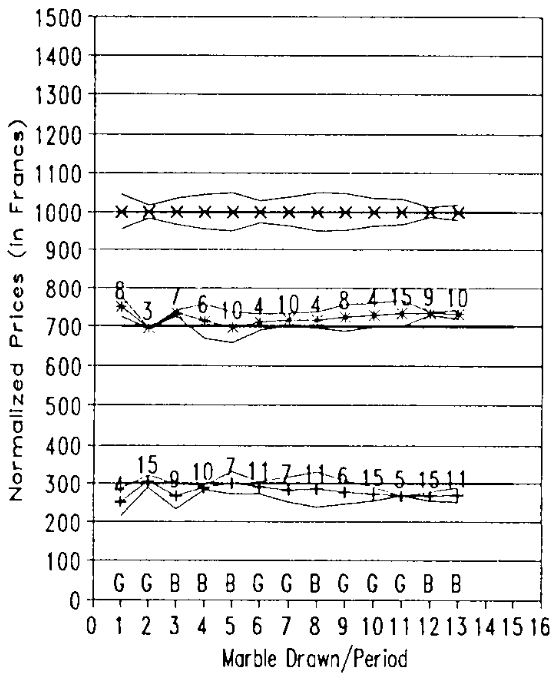


Figure 1.b: Treatment OPI(m) and OPI(e) Sessions, Blue (+), Green (✱) and Summed (⋆) Average Normalized Prices and Volumes and ± 1.96 Standard Deviation Confidence Intervals.

Session OPIP-1 | Session OPIP-2 | Session OPIP-3

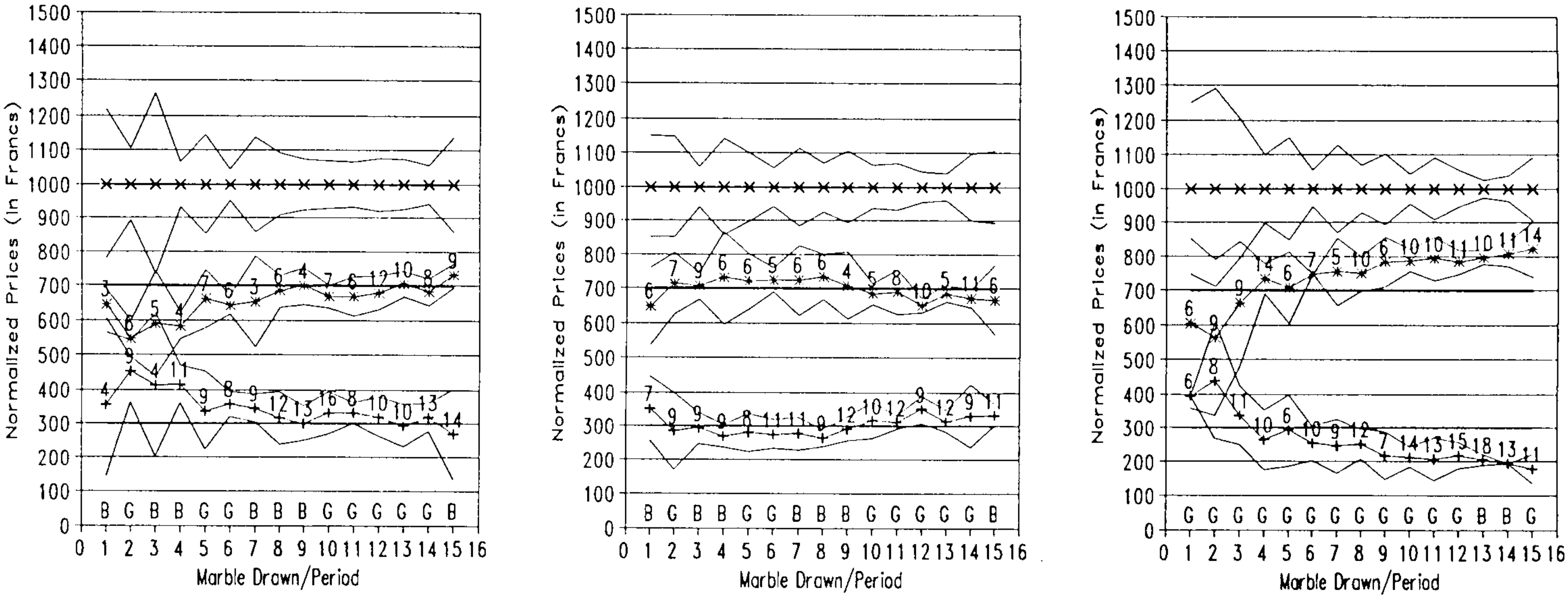


Figure 1.c: Treatment OPIP Sessions, Blue (+), Green (✱) and Summed (⋇) Average Normalized Prices and Volumes and ± 1.96 Standard Deviation Confidence Intervals.

Session OPIS-1 Session OPIS-2 Session OPIS-3

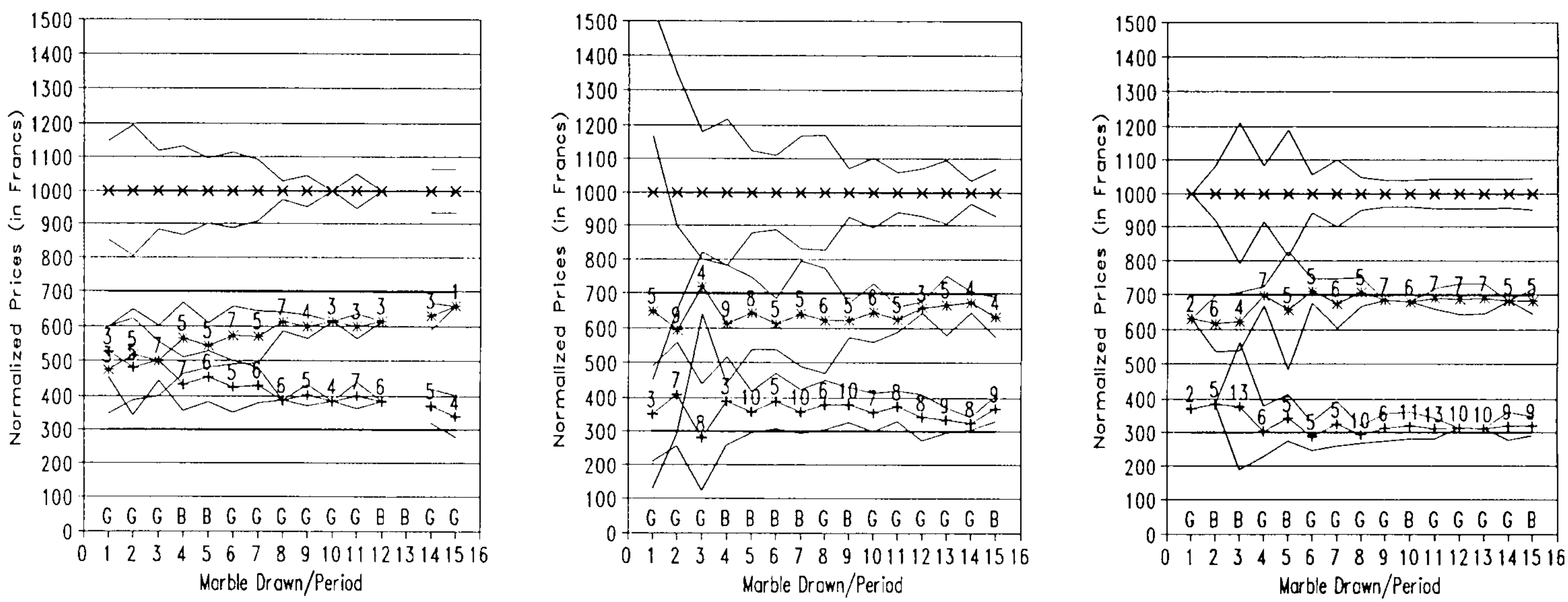
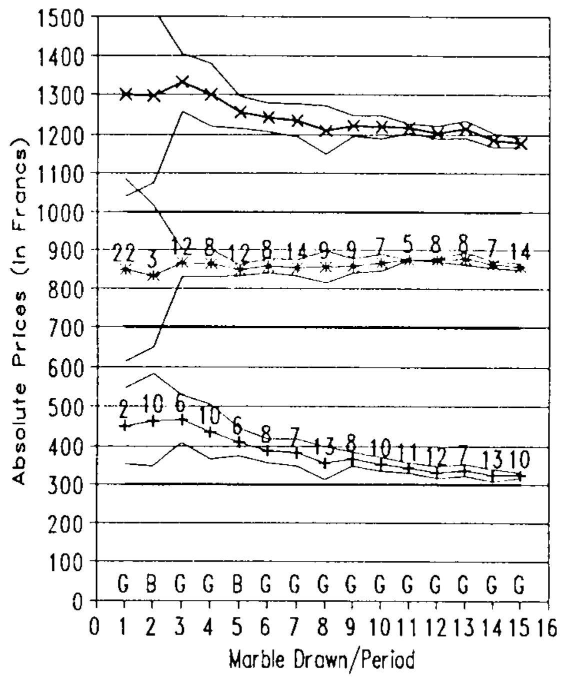
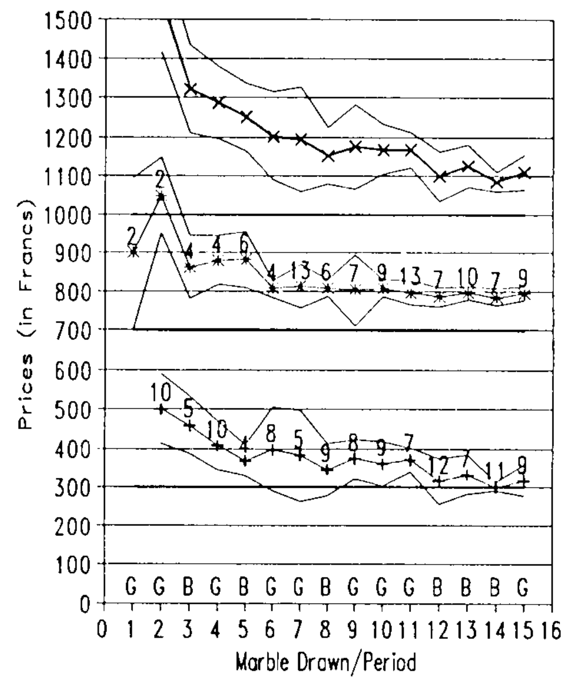


Figure 1.d: Treatment OPIS Sessions, Blue (+), Green (✳) and Summed (×) Average Normalized Prices and Volumes and ±1.96 Standard Deviation Confidence Intervals.

Session OPI-1



Session OPI-2



Session OPI-3

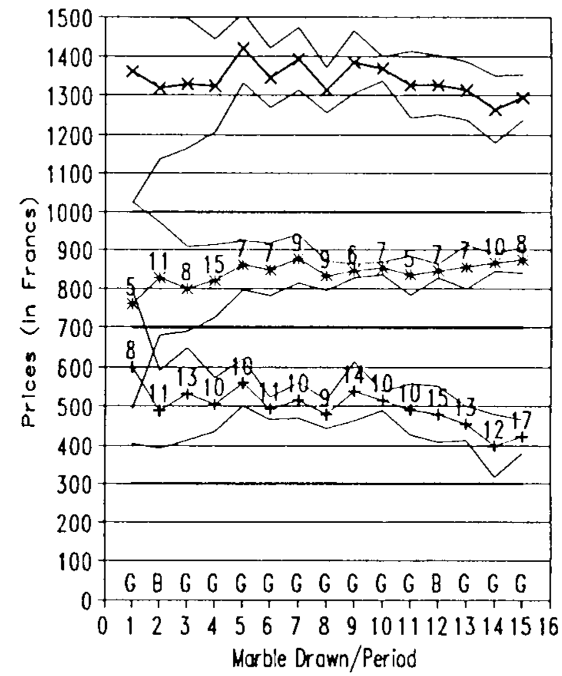
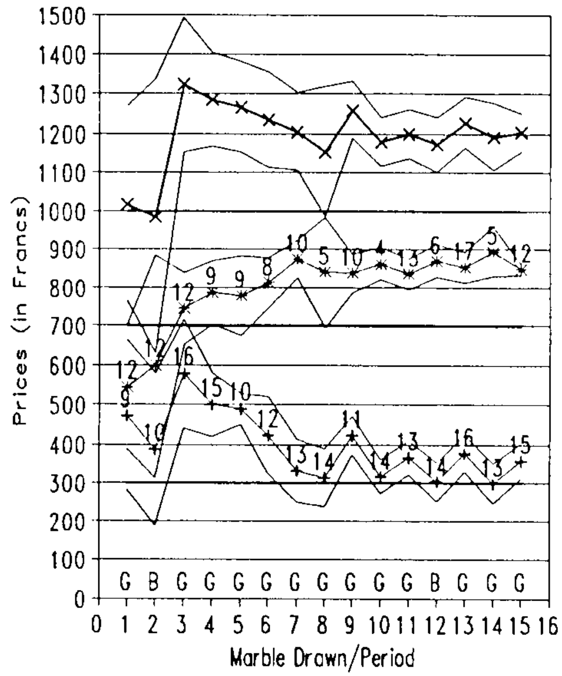


Figure 2.a: Treatment OPI Sessions, Blue (+), Green (✳) and Summed (✕) Average Absolute Prices and Volumes and ±1.96 Standard Deviation Confidence Intervals.

Session OPI-4(m)



Session OPI-5(e)

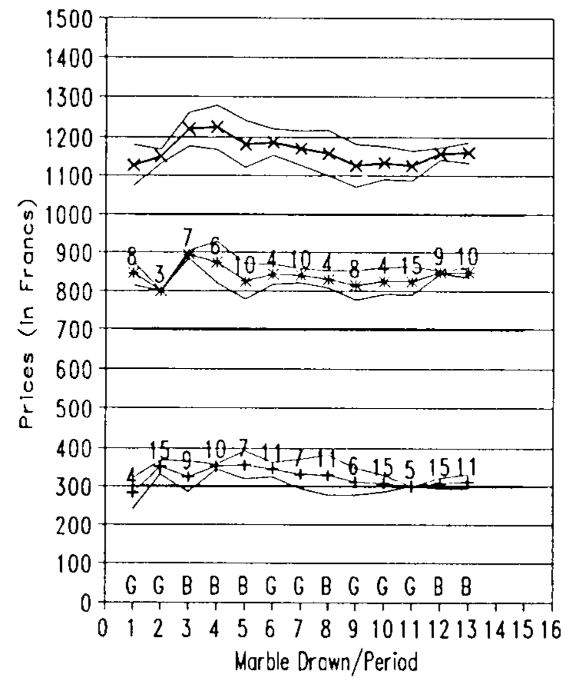
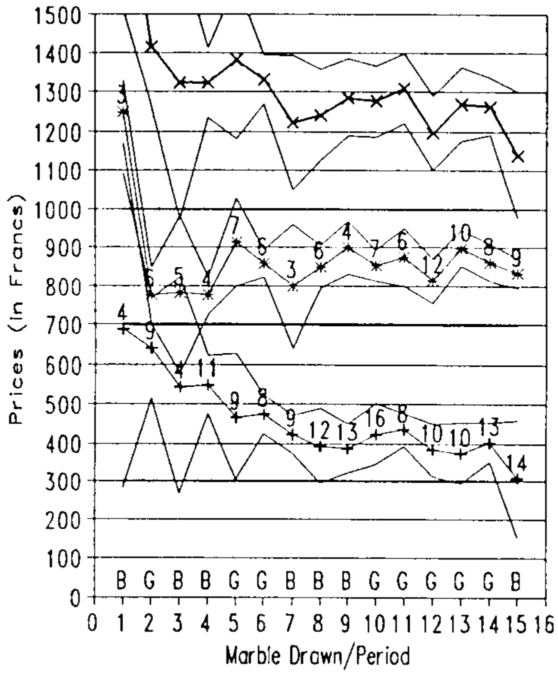
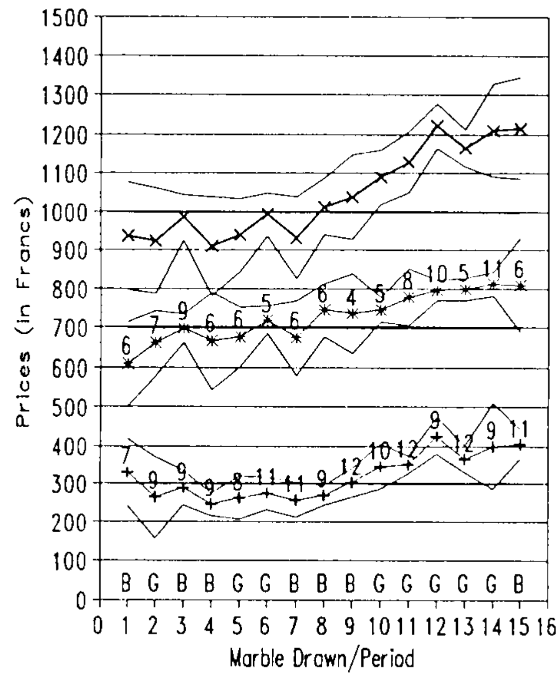


Figure 2.b: Treatment OPI(m) and OPI(e) Sessions, Blue (+), Green (✱) and Summed (✕) Average Absolute Prices and Volumes and ±1.96 Standard Deviation Confidence Intervals.

Session OPIP-1



Session OPIP-2



Session OPIP-3

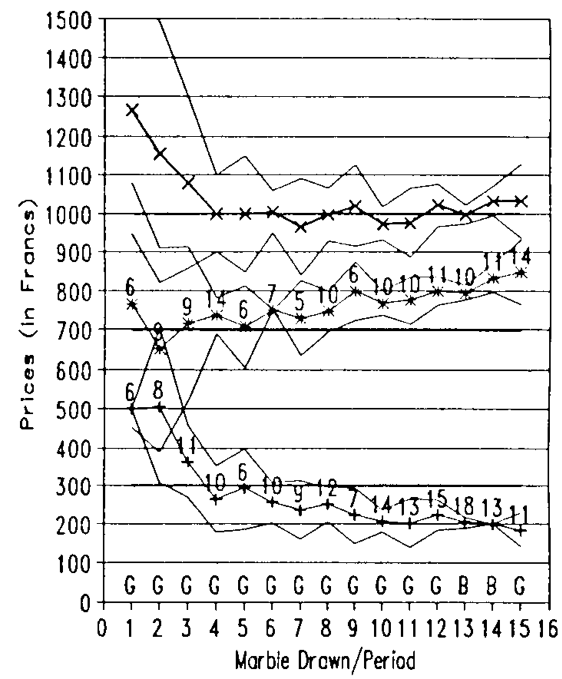


Figure 2.c: Treatment OPI Sessions, Blue (+), Green (✳) and Summed (✕) Average Absolute Prices and Volumes and ± 1.96 Standard Deviation Confidence Intervals.

Session OPIS-1 Session OPIS-2 Session OPIS-3

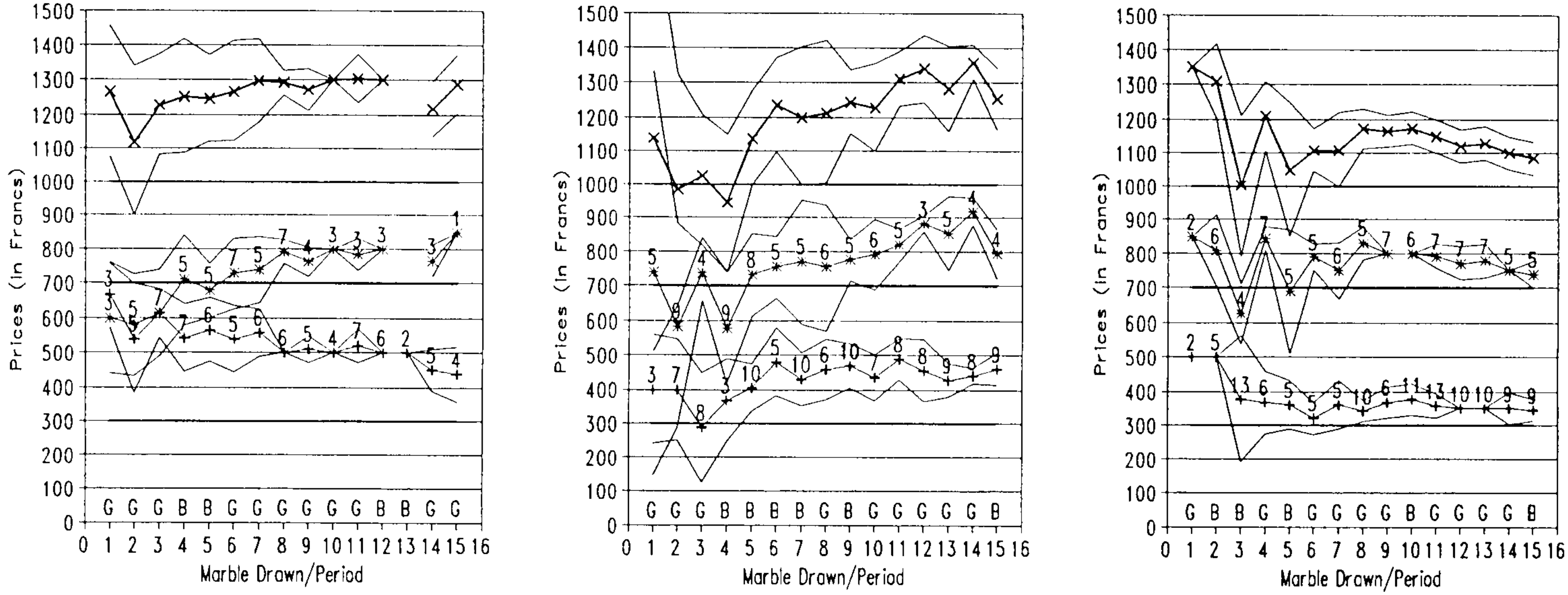


Figure 2.d: Treatment OPIS Sessions, Blue (+), Green (✳) and Summed (×) Average Absolute Prices and Volumes and ±1.96 Standard Deviation Confidence Intervals.

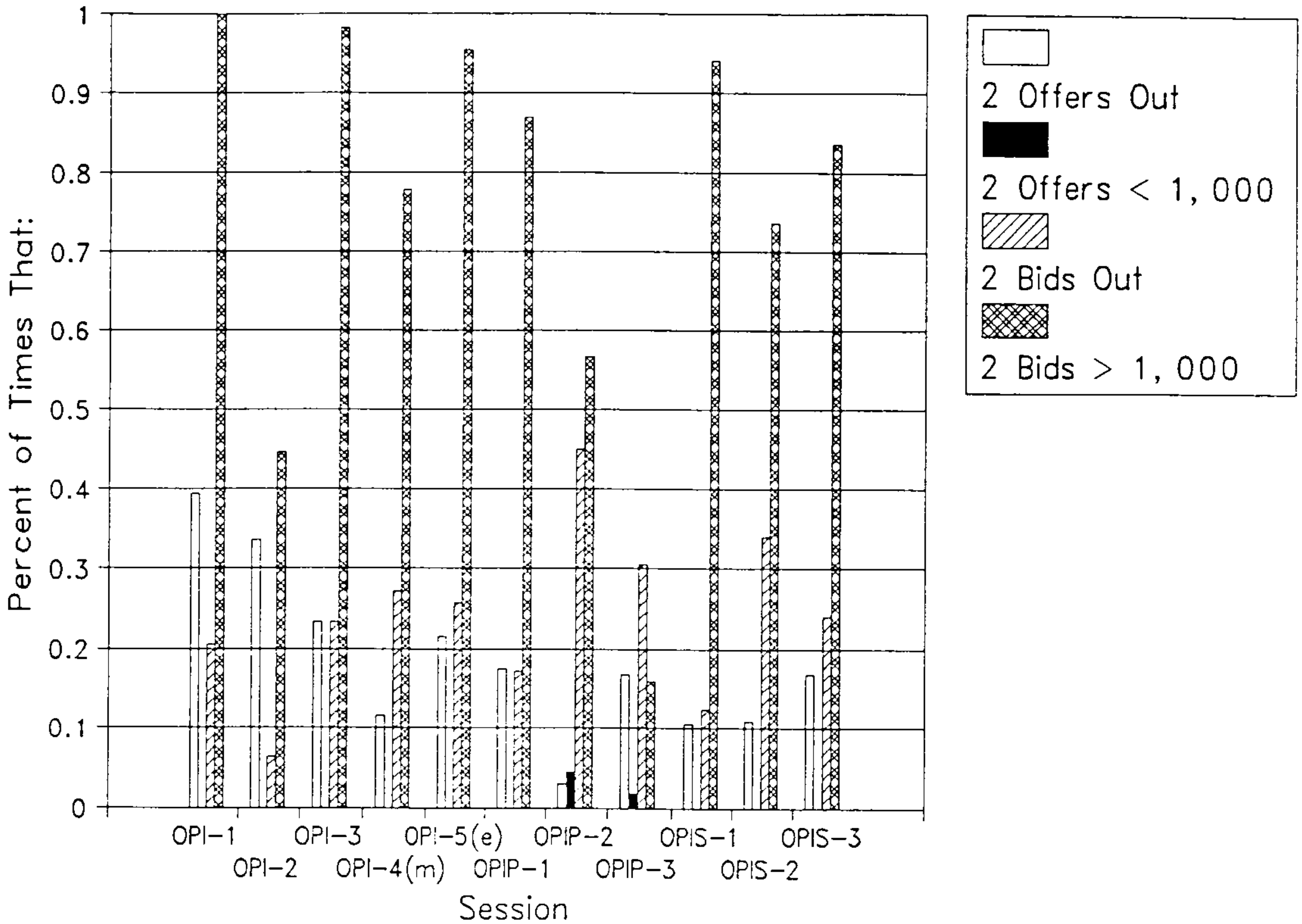


Figure 3: The Fractions of Non-Trade Events During which Bids or Offers Were Outstanding in the Blue and Green Markets Simultaneously and the Fraction of These Events During Which Equilibrium Arbitrage Opportunities Existed

Appendix I: Instruction Sets

This appendix gives the instructions sets used and sample record sheets. The text of instruction sets for specific treatments contained only the general text and passages marked for that specific treatment. It did not contain passages marked for other treatments. Each subject had a copy of the instructions. They were read aloud and all questions were answered before the sessions began.

GENERAL INSTRUCTIONS

This is an experiment in the economics of market decision making. The instructions are simple. If you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash at the end of the experiment. With these instructions you will find sheets labeled "INFORMATION AND RECORD SHEET" and "PROFIT SHEET AND RECEIPT". These will help you determine the value to you of any decisions you might make.

In this experiment we are going to conduct markets in which you will buy and sell two types of certificates in a sequence of market periods. In each period you will have both certificates and currency. You can use the currency to buy and sell certificates or you can save it.

The type of currency used in these markets is francs. All trading and earnings will be in terms of francs. At the end of the experiment, each franc will be worth $_________ to you. Do not reveal this number to anyone. At the end of the experiment, your francs will be converted to dollars at this rate, and you will be paid in dollars. Notice that the more francs you earn, the more dollars you will earn.

SPECIFIC INSTRUCTIONS

Your profits during this experiment come from two sources: (1) from collecting dividends on certificates you hold at the end of each period and (2) from buying and selling certificates.

There will be two types of certificates in this experiment, "Blue" certificates and "Green" certificates. During each market period you are free to purchase or sell as many certificates of each type as you wish, provided you follow the rules below. Each period, there will be *separate* markets for Blue and Green certificates. **[Treatment OPIP:** In addition, there will be a market called "Both" in which you can buy and sell both certificates simultaneously.] During each period, you may buy and sell certificates in **[Treatments OPI, OPI(m), OPI(e) & OPIS:** both] **[Treatment OPIP:** all three] markets. **[Treatment OPIS:** In addition, after trading ceases in these markets, there will be a market called "Both" in which you can buy both certificates simultaneously from the experimenter for a fixed price. We will discuss the reasons for the "Both" market and how it works in more detail later.]

For each certificate of each type you hold at the end of the period you will receive a dividend. The size of the dividend you will receive on each certificate will depend both on the certificate type and on the outcome of a random event. Specifically, we have a bucket which contains twenty (20) colored marbles of identical size. Six (6) of these marbles are blue and fourteen (14) are green. Each period, one of you will draw a marble from the bucket without looking. The dividend for each certificate type will be determined by the marble drawn according to the following DIVIDEND TABLE:

[Treatments OPI, OPI(e), OPIP and OPIS:

DIVIDEND TABLE		
	Color of Marble Drawn	
Certificate Type	BLUE (There are 6 blue marbles.)	GREEN (There are 14 green marbles.)
BLUE	1000 Francs	0 Francs
GREEN	0 Francs	1000 Francs

]

[Treatment OPI(m):

DIVIDEND TABLE		
	Color of Marble Drawn	
Certificate Type	BLUE (There are 6 blue marbles.)	GREEN (There are 14 green marbles.)
BLUE	1000 Francs	0 Francs
GREEN	0 Francs	1000 Francs
Unit Portfolio (1 Blue and 1 Green)	1000 Francs	1000 Francs

]

After the level of the dividend for each certificate type has been determined, the marble drawn will be returned to the bucket so they will all be there for the next draw.

Total certificate earnings are calculated by multiplying the dividend for each type of certificate by the number of certificates held of each type and adding the results. That is:

Total Certificate Earnings = (Dividend for Blue Certificates) × (Number of Blue Certificates Held)
+ (Dividend for Green Certificates) × (Number of Green Certificates Held).

Suppose, for example, that you hold five Blue certificates and two Green certificates at the end of a period. If a blue marble is drawn at the end of that period, you would receive dividends of 1000 francs for each Blue certificate and 0 francs for each Green Certificate. Your total certificate earnings in that period would be $1000 \times 5 + 0 \times 2 = 5000$ francs. If a green marble is drawn at the end of that period, you would receive dividends of 0 francs for each Blue certificate and 1000 francs for each Green Certificate. Your total certificate earnings in that period would be $0 \times 5 + 1000 \times 2 = 2000$ francs.

[Treatment OPI(m): Notice that, for each "unit portfolio" you hold consisting of one of each certificate type, you receive 1000 francs when either a blue or green marble is drawn. Thus, you always receive at least 2000 francs in the above example because you hold two unit portfolios. That is, holding five Blue certificates and two green certificates implies you hold two unit portfolios and three additional Blue certificates.]

Note, the DIVIDEND TABLES are the same for each participant. Thus, the dividend on each certificate does not depend on who owns it at the end of the period.

INVENTORIES OF CERTIFICATES AND CASH ON HAND

At the beginning of each period, you are provided with initial inventories of each type of certificate. These inventories are recorded in Row 0 of each period's INFORMATION AND RECORD SHEET. You may sell these if you wish, or you may hold them. You may also purchase certificates and increase your inventories. For each of the certificates of each type that you hold at the end of the period, you will receive the dividend corresponding to the certificate type and the marble drawn at the end of the period.

The amount of francs that you have at any particular time will be called "cash on hand". At the beginning of each period you are provided with an initial amount of cash on hand. This amount is given on your INFORMATION AND RECORD SHEET. Sales from your certificate inventories increase your cash on hand by the amount of the sale price. Similarly, purchases reduce your cash on hand by the amount of the purchase price. Thus you can gain or lose money on the purchase and resale of certificates. At the end of the period, you will be paid the earnings on your certificate inventories. This will be added to your cash on hand. Then you will figure your profits for the period and a new period will begin.

Thus, at the beginning of each period you will be endowed with initial inventories of certificates and with an initial amount of cash on hand. Do not reveal these amounts to anyone. They are for your own private information. You are free to buy and sell certificates as you wish according to the rules below. Your total francs at the end of the period are determined by your initial amount of cash on hand, earnings on certificate inventories at the end of the period and by gains and losses from purchases and sales of certificates. All of the cash on hand at the end of each period in excess of the "fixed cost" of __________ francs are yours to keep.

MARKET ORGANIZATION

The markets for certificates are organized as follows. The markets will be conducted in a series of periods. Each period will last for ___ minutes. Anyone wishing to buy a certificate is free to raise his or her hand and make a verbal bid in that certificate's market to buy one certificate at a specified price. Anyone **[Treatments OPI, OPI(m), OPI(e) & OPIP:** with certificates of that type to sell] **[Treatment OPIS:** is free to accept or not accept the bid.] Likewise, anyone wishing to sell a certificate is free to raise his or her hand and submit a verbal offer in that certificate's market to sell one certificate at a specified price. Anyone with enough cash on hand to buy that certificate is free to accept or not accept the offer.

[Treatment OPIP: In addition, anyone wishing to buy one of each type of certificates simultaneously is free to raise his or her hand and make a verbal bid in the "Both" market to buy both certificates at a specified price. Anyone with one of each type of certificates to sell is free to accept or not accept the bid. Likewise, anyone wishing to sell a certificate of each type simultaneously is free to raise his or her hand and submit a verbal offer in the "Both" market to sell both certificates at a specified price. Anyone with enough cash on hand to buy both certificates is free to accept or not accept the offer.]

If a bid or offer is accepted, a binding contract has is made for a single certificate **[Treatment OPIP:** (in the Blue or Green markets) or a "unit portfolio" of one of each certificate type (in the "Both" market)]. At that time, the contracting parties must record the transaction on their INFORMATION AND RECORD SHEETS and determine their new levels of cash on hand and certificate inventories. **[Treatment OPIS:** You are allowed to let your inventories of certificates fall below zero during trading.] Any ties in bids, offers or their acceptance will be resolved by random choice. After a contract has been made, you are free to submit any new bids or offers that you wish.

There are likely to be many bids and offers that are not accepted, but you are free to keep trying. You are free to make as much profit as you can.

[Treatment OPIS: If you have a negative inventory of either certificate type at the end of market trading in a period, you will have to purchases certificates from the experimenter. You must purchase the same number of certificates of each type from the experimenter. You will be charged 1,000 francs for each "unit portfolio" of one Blue and one Green certificate you purchase. You must purchase enough unit portfolios to increase your inventories of both types of certificate to at least zero. For example, if, when trading ceases, you have -2 Blue certificates and 3 Green certificates, you must purchase 2 unit portfolios from the experimenter. This will cost you 2,000 francs and add 2 certificates to both of your inventories. Then, your end of period inventories will be 0 Blue certificates and 5 Green certificates. You will be paid dividends on these end of period inventories.]

At the end of each period, one of you will draw a marble and determine the dividend for each certificate type for that period. You will use these dividends to calculate your total certificate earnings and your profits for the period. After all participants have calculated their profits, the next period will start. For the next period, use the INFORMATION AND RECORD SHEET with the appropriate period number in your packet.

Except for making bids, offers or acceptances and asking the experimenter questions, you are not to speak to anyone until this experiment is over. If you break silence, you will be given one warning. If you break silence again, you will lose any earnings you have and be asked to leave the experiment.

TRADING AND RECORDING RULES[23]

[Treatments OPI, OPI(m) & OPI(e): 1. All transactions are for one certificate at a time.]

[Treatment OPIP: 1. All transactions in the "Blue" or "Green" markets are for one certificate at a time. All transactions in the "Both" market are for one "unit portfolio" consisting of each certificate type at a time.]

[Treatment OPIS: 1. All transactions in the "Blue" or "Green" markets are for one certificate at a time. All purchases in the "Both" market are for equal numbers of each certificate type at a price of 1,000 for each "unit portfolio" of two certificates.]

2. BIDS (TO BUY) ARE SUBMITTED stating your ID number, that you are making a bid, the amount of the bid and the market in which you are bidding.

   For example, trader 4 would submit a bid to buy a Green certificate for 500 by stating: "4 Bids 500 for Green."

3. BIDS ARE ACCEPTED (SELLING A CERTIFICATE) by stating you ID number, that you are accepting a bid and the market(s) in which you are accepting the bid.

   For example, trader 7 would sell a Green certificate at the outstanding bid of 500 by stating: "7 accepts the Green bid." **[Treatment OPIP:** Trader 7 would accept the bid in the "Both" market by stating, "7 accepts the 'Both' bid."] Trader 7 could accept both the Green and Blue bids by stating: "7 accepts the Blue and Green bids."

4. Bids must be higher than the last outstanding bid unless a contract has just been made.

5. OFFERS (TO SELL) ARE SUBMITTED by stating your ID number, that you are making an offer, the amount of the offer and stating the market in which you are offering.

   For example, trader 6 would submit an offer to sell a Blue certificate for 500 by stating: "6 Offers Blue at 500.

6. OFFERS ARE ACCEPTED (BUYING A CERTIFICATE) by stating your ID number, that you are accepting an offer and the market(s) in which you are accepting the offer.

   For example, trader 2 would buy a Blue certificate at the outstanding offer of 500 by stating: "2 accepts the Blue offer." **[Treatment OPIP:** Trader 2 could accept the offer in the "Both" market by stating: "2 accepts the 'Both' offer."] Trader 2 could accept both the Blue and Green offers by stating: "2 accepts the Blue and Green offers."

7. Offers must be lower than the last outstanding offer unless a contract has just been made.

8. After each of your sales or purchases you must record the TRANSACTION PRICE in the appropriate column of your information and record sheet depending on the nature of the transaction. The first transaction is recorded on Row 1 and succeeding transactions are recorded on subsequent rows.

9. After each transaction you must calculate and record your new inventories of certificates and your new cash on hand. [Treatments OPI, OPI(m), OPI(e) & OPIP: Your inventories of certificates may NEVER GO

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[23]These rules appeared on one sheet in each set of instructions so that subjects could refer to them all at one time.

BELOW ZERO.] [Treatment OPIS: Your inventories of certificates MAY go below zero during the trading period. However,] Your francs on hand may NEVER GO BELOW ZERO.

10. At the end of the period you must:
    [Treatment OPIS: i. Purchase enough unit portfolios from the experimenter so that both of your certificate inventories are at least zero.]
    ii. Record your final inventories and cash on hand on row 25.
    iii. Record the dividends and your total certificate earnings in rows 26 and 27.
    iv. Find your total end of period cash on hand by adding your certificate earnings to your cash on hand. Place the result in row 28.
    v. Subtract from your cash on hand the amount listed in row 29 and enter this new amount on row 30. This is your profit for the market period and is yours to keep.
    vi. Finally, record your end of period net profits on your PROFIT SHEET.

11. At the end of the experiment add up your total profit on your PROFIT SHEET. To convert this number into dollars, multiply it by your conversion rate. Place the result in the receipt section and the experimenter will pay you this amount of dollars in cash.

[Additional Instructions Distributed and Explained after Period 8 in OPI-4(m):

ADDITIONAL INSTRUCTIONS

Because a unit portfolio will always pay you 1000 francs in dividends, you will always profit if you sell one Blue and one Green certificate at prices that total more than 1000 francs. Similarly, you will always profit if you buy one Blue and one Green certificate at prices that total less than 1000 francs.]

INFORMATION AND RECORD SHEET

Participant # ___ Period # 1

Row	TRANSACTION INFORMATION			INVENTORIES		Cash on Hand
	Cert. Type B and/or G	Sale Price (↑ Cash, ↓ Inv)	Purc. Price (↓ Cash, ↑ Inv)	Blue Certificates	Green Certificates	
0	INITIAL VALUES:					
1						
2						
⋮	⋮	⋮	⋮	⋮	⋮	⋮
24						
25	FINAL VALUES:					
26	Blue Cert. Earnings _______ × Final Blue Cert. Inventory _______ =					
27	Green Cert. Earnings _______ × Final Green Cert. Inventory _______ =					
28	Total Cash on Hand + Certificate Earnings =					
29	(-) Fixed Costs =					
30	End of Period Net Profits =					

Figure A.I.1: Sample Record Sheet

PROFIT SHEET AND RECEIPT PARTICIPANT #: ___	
Period	End of Period Net Profits (in Francs)
1	
2	
. . .	. . .
15	
Total Profits in Francs:	
Conversion rate:	×
Total Profits in Dollars:	

I received, from Thomas A. Rietz, the amount of $_________ in cash as payment in full for participation in a market experiment.

NAME (Please Print): ____________________

Address: ____________________

____

Social Security Number: ____________________

Signature: ____________________

Date: ____________________

Figure A.I.2: Sample Profit Sheet and Receipt

APPENDIX II: SUMMARY TABLES

Table A.II.I: Summary of Transaction Prices and Volume

			Blue Market			Green Market			Unit Portfolio Market	
Ses.	Per.	# of Events	# of X-Actions	$\bar{P}^B$ (Std Dev)	$\frac{1000\times\bar{P}^B}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# of X-Actions	$\bar{P}^G$ (Std Dev)	$\frac{1000\times\bar{P}^G}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# X-Actions	$\bar{P}^P$ (Std Dev)
	1	58	2	450 (50)	346 (38)	22	850 (120)	654 (92)		
	2	41	10	465 (60)	358 (47)	3	833 (94)	642 (73)		
	3	68	6	467 (31)	350 (23)	12	866 (19)	650 (14)		
	4	72	10	435 (36)	334 (27)	8	866 (17)	666 (13)		
	5	64	6	408 (19)	325 (15)	12	848 (7)	675 (6)		
	6	65	8	385 (16)	309 (13)	8	859 (9)	691 (7)		
	7	70	7	381 (18)	308 (14)	14	855 (11)	692 (9)		
OPI-1	8	81	13	356 (22)	294 (18)	9	856 (21)	706 (17)	N.A.	N.A.
	9	70	8	364 (9)	298 (7)	9	859 (10)	702 (8)		
	10	65	10	352 (10)	288 (8)	7	868 (11)	712 (9)		
	11	66	11	342 (6)	281 (5)	5	875 (0)	719 (0)		
	12	75	12	331 (8)	275 (7)	8	874 (2)	725 (2)		
	13	65	7	336 (7)	277 (6)	8	878 (8)	723 (7)		
	14	74	13	324 (8)	273 (7)	7	864 (4)	727 (4)		
	15	71	10	323 (4)	274 (3)	14	857 (5)	726 (4)		
	1	11	0	N.A.	N.A.	2	900 (100)	N.A.		
	2	29	10	500 (45)	323 (29)	2	1050 (50)	677 (32)		
	3	33	5	460 (37)	348 (28)	4	863 (41)	652 (31)		
	4	48	10	408 (32)	316 (25)	4	881 (32)	684 (25)		
	5	42	4	369 (21)	295 (17)	6	883 (37)	705 (30)		
	6	45	8	397 (55)	330 (46)	4	806 (11)	670 (9)		
	7	61	5	380 (60)	318 (50)	13	813 (29)	682 (24)		
OPI-2	8	55	9	344 (35)	299 (30)	6	808 (12)	701 (10)	N.A.	N.A.
	9	62	8	372 (26)	316 (22)	7	804 (47)	684 (40)		
	10	58	9	361 (29)	309 (25)	9	808 (12)	691 (10)		
	11	66	7	371 (16)	318 (14)	13	797 (16)	682 (14)		
	12	66	12	315 (30)	286 (27)	7	786 (12)	714 (11)		
	13	70	7	332 (26)	295 (23)	10	796 (9)	705 (8)		
	14	58	11	301 (6)	277 (6)	7	784 (11)	723 (10)		
	15	74	9	317 (20)	285 (18)	9	794 (9)	715 (8)		
	1	35	8	600 (100)	441 (74)	5	760 (136)	559 (100)		
	2	65	11	491 (51)	372 (39)	11	827 (75)	628 (57)		
	3	72	13	531 (61)	399 (46)	8	800 (56)	601 (42)		
	4	85	10	505 (35)	381 (26)	15	820 (48)	619 (36)		
	5	62	10	560 (30)	394 (21)	7	861 (32)	606 (23)		
	6	69	11	495 (14)	368 (11)	7	850 (35)	632 (26)		
	7	72	10	515 (23)	370 (16)	9	878 (32)	630 (23)		
OPI-3	8	70	9	481 (20)	366 (15)	9	833 (20)	634 (16)	N.A.	N.A.
	9	78	14	539 (39)	389 (28)	6	846 (9)	611 (7)		
	10	73	10	515 (12)	376 (9)	7	854 (9)	624 (6)		
	11	64	10	493 (34)	371 (25)	5	835 (25)	629 (19)		
	12	75	15	480 (37)	362 (28)	7	846 (9)	638 (7)		
	13	71	13	456 (22)	347 (17)	7	857 (29)	653 (22)		
	14	79	12	398 (41)	314 (33)	10	868 (11)	686 (9)		
	15	78	17	422 (22)	325 (17)	8	875 (18)	675 (14)		

Table A.II.I: Summary of Transaction Prices and Volume

			Blue Market			Green Market			Unit Portfolio Market	
Ses.	Per.	# of Events	# of X-Actions	$\bar{P}^B$ (Std Dev)	$\frac{1000\times\bar{P}^B}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# of X-Actions	$\bar{P}^G$ (Std Dev)	$\frac{1000\times\bar{P}^G}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# X-Actions	$\bar{P}^P$ (Std Dev)
	1	53	9	472 (97)	464 (96)	12	546 (80)	536 (79)		
	2	78	10	385 (100)	391 (102)	12	600 (146)	609 (148)		
	3	101	16	578 (71)	437 (53)	12	746 (48)	563 (36)		
	4	86	15	500 (41)	389 (32)	9	786 (43)	611 (33)		
	5	67	10	490 (20)	387 (16)	9	778 (53)	613 (42)		
	6	80	12	423 (50)	342 (41)	8	813 (33)	658 (27)		
	7	75	13	331 (42)	274 (35)	10	875 (25)	726 (21)		
OPI-4(m)	8	75	14	313 (39)	271 (34)	5	840 (73)	729 (64)	N.A.	N.A.
	9	75	11	423 (25)	335 (20)	10	838 (26)	665 (20)		
	10	70	14	316 (22)	268 (19)	4	863 (22)	732 (18)		
	11	86	13	365 (23)	304 (19)	13	835 (21)	696 (17)		
	12	78	14	302 (26)	257 (22)	6	871 (22)	743 (19)		
	13	88	16	377 (24)	306 (20)	17	853 (21)	694 (17)		
	14	68	13	298 (27)	250 (22)	5	895 (33)	750 (28)		
	15	75	15	357 (23)	296 (19)	12	848 (7)	704 (6)		
	1	42	4	281 (21)	250 (18)	8	845 (15)	750 (14)		
	2	58	15	350 (10)	305 (8)	3	800 (0)	695 (0)		
	3	54	9	324 (21)	266 (17)	7	896 (5)	734 (4)		
	4	54	10	351 (3)	286 (2)	6	874 (28)	714 (23)		
	5	49	7	356 (18)	301 (16)	10	826 (24)	699 (20)		
	6	48	11	343 (11)	289 (9)	4	844 (13)	711 (11)		
OPI-5(e)	7	55	7	331 (20)	283 (17)	10	840 (10)	717 (9)	N.A.	N.A.
	8	57	11	329 (27)	284 (23)	4	830 (12)	716 (10)		
	9	49	6	312 (18)	276 (16)	8	816 (20)	724 (18)		
	10	55	15	307 (11)	271 (10)	4	826 (18)	729 (16)		
	11	65	5	300 (0)	266 (0)	15	827 (19)	734 (17)		
	12	71	15	308 (7)	266 (6)	9	850 (2)	734 (2)		
	13	67	11	312 (10)	269 (9)	10	849 (7)	731 (6)		
	1	29	4	688 (207)	355 (107)	3	1250 (41)	645 (21)	4	2163 (96)
	2	45	9	642 (65)	453 (46)	6	775 (38)	547 (27)	3	1000 (356)
	3	58	4	544 (142)	411 (107)	5	780 (103)	589 (78)	5	1100 (245)
	4	69	11	550 (37)	415 (28)	4	775 (25)	585 (19)	5	1220 (147)
	5	73	9	467 (82)	338 (59)	7	914 (58)	662 (42)	5	1180 (40)
	6	80	8	475 (25)	356 (19)	6	858 (19)	644 (14)	4	1350 (87)
	7	75	9	422 (25)	345 (20)	3	800 (82)	655 (67)	5	1250 (45)
OPIP-1	8	95	12	393 (50)	316 (40)	6	850 (29)	684 (23)	5	1120 (24)
	9	83	13	387 (33)	300 (26)	4	900 (35)	700 (27)	4	1188 (89)
	10	99	16	423 (40)	332 (31)	7	854 (21)	668 (16)	3	1275 (20)
	11	92	8	434 (21)	332 (16)	6	875 (38)	668 (29)	5	1180 (75)
	12	102	10	383 (35)	320 (30)	12	815 (30)	680 (25)	4	1225 (109)
	13	93	10	373 (41)	293 (32)	10	898 (24)	707 (19)	4	1288 (65)
	14	97	13	402 (27)	318 (21)	8	863 (25)	682 (20)	4	1200 (61)
	15	103	14	307 (78)	269 (68)	9	833 (20)	731 (18)	4	1100 (35)

Table A.II.I: Summary of Transaction Prices and Volume

			Blue Market			Green Market			Unit Portfolio Market	
Ses.	Per.	# of Events	# of X-Actions	$\bar{P}^B$ (Std Dev)	$\frac{1000 \times \bar{P}^B}{\bar{P}^B + \bar{P}^G}$ (Std Dev)	# of X-Actions	$\bar{P}^G$ (Std Dev)	$\frac{1000 \times \bar{P}^G}{\bar{P}^B + \bar{P}^G}$ (Std Dev)	# X-Actions	$\bar{P}^P$ (Std Dev)
	1	36	7	329 (45)	351 (48)	6	608 (53)	649 (57)	0	N.A.
	2	50	9	264 (54)	285 (59)	7	661 (42)	715 (45)	0	N.A.
	3	53	9	288 (23)	293 (23)	9	697 (19)	707 (19)	0	N.A.
	4	69	9	244 (16)	268 (17)	6	667 (62)	732 (69)	0	N.A.
	5	67	8	263 (28)	280 (30)	6	677 (39)	720 (41)	0	N.A.
	6	53	11	274 (22)	275 (22)	5	720 (18)	725 (18)	0	N.A.
	7	63	11	257 (23)	276 (25)	6	675 (48)	724 (51)	0	N.A.
OPIP-2	8	74	9	268 (13)	265 (13)	6	745 (34)	735 (34)	1	950 (0)
	9	76	12	302 (19)	290 (18)	4	738 (52)	710 (50)	0	N.A.
	10	72	10	345 (30)	316 (28)	5	746 (17)	684 (15)	0	N.A.
	11	76	12	350 (12)	310 (11)	8	779 (37)	690 (33)	0	N.A.
	12	75	9	426 (25)	349 (20)	10	797 (13)	651 (11)	0	N.A.
	13	79	12	366 (19)	314 (16)	5	799 (14)	686 (12)	0	N.A.
	14	70	9	398 (58)	329 (48)	11	813 (16)	671 (13)	0	N.A.
	15	76	11	404 (20)	333 (17)	6	811 (62)	667 (51)	0	N.A.
	1	33	6	500 (0)	395 (0)	6	767 (160)	605 (126)	0	N.A.
	2	54	8	506 (101)	438 (88)	9	650 (133)	562 (115)	0	N.A.
	3	71	11	364 (48)	337 (45)	9	717 (100)	663 (93)	0	N.A.
	4	82	10	265 (45)	265 (45)	14	736 (23)	735 (23)	0	N.A.
	5	57	6	292 (53)	292 (53)	6	708 (53)	708 (53)	4	1050 (50)
	6	63	10	255 (27)	254 (27)	7	750 (0)	746 (0)	1	1000 (0)
	7	60	9	236 (39)	244 (41)	5	730 (48)	756 (50)	1	1000 (0)
OPIP-3	8	76	12	250 (23)	251 (23)	10	748 (26)	749 (26)	0	N.A.
	9	59	7	221 (36)	217 (36)	6	800 (38)	783 (37)	1	1000 (0)
	10	71	14	207 (15)	213 (15)	10	768 (16)	787 (16)	0	N.A.
	11	73	13	202 (32)	207 (32)	10	775 (32)	793 (32)	1	1100 (0)
	12	82	15	222 (20)	217 (20)	11	800 (18)	783 (18)	0	N.A.
	13	82	18	203 (8)	203 (8)	10	795 (10)	797 (10)	1	1000 (0)
	14	70	13	200 (0)	193 (0)	11	834 (19)	807 (19)	0	N.A.
	15	80	11	184 (22)	178 (21)	14	848 (43)	822 (41)	2	1000 (0)
	1	15	3	667 (47)	526 (37)	3	600 (82)	474 (64)	0	
	2	21	5	540 (80)	482 (71)	5	580 (75)	518 (67)	0	
	3	41	7	614 (35)	500 (28)	7	614 (64)	500 (52)	0	
	4	35	7	543 (49)	433 (39)	5	710 (66)	567 (53)	0	
	5	32	6	567 (47)	455 (38)	5	680 (40)	545 (32)	0	
	6	35	5	540 (49)	426 (39)	7	729 (52)	574 (41)	0	
	7	36	6	558 (34)	430 (26)	5	740 (49)	570 (38)	0	
OPIS-1	8	32	6	500 (0)	387 (0)	7	793 (17)	613 (14)	0	N.A.
	9	28	5	510 (20)	401 (16)	4	763 (22)	599 (17)	0	
	10	24	4	500 (0)	385 (0)	3	800 (0)	615 (0)	0	
	11	26	7	521 (25)	400 (19)	3	783 (24)	600 (18)	0	
	12	30	6	500 (0)	385 (0)	3	800 (0)	615 (0)	0	
	13	11	2	500 (0)	N.A.	0	N.A.	N.A.	0	
	14	19	5	450 (32)	370 (26)	3	767 (24)	630 (19)	0	
	15	19	4	438 (41)	340 (32)	1	850 (0)	660 (0)	0	

Table A.II.I: Summary of Transaction Prices and Volume

			Blue Market			Green Market			Unit Portfolio Market	
Ses.	Per.	# of Events	# of X-Actions	$\bar{P}^B$ (Std Dev)	$\frac{1000\times\bar{P}^B}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# of X-Actions	$\bar{P}^G$ (Std Dev)	$\frac{1000\times\bar{P}^G}{\bar{P}^B+\bar{P}^G}$ (Std Dev)	# X-Actions	$\bar{P}^P$ (Std Dev)
	1	19	3	400 (82)	351 (72)	5	740 (302)	649 (265)	0	
	2	37	7	400 (76)	407 (77)	9	583 (153)	593 (155)	0	
	3	41	8	288 (82)	280 (80)	4	738 (41)	720 (40)	0	
	4	42	3	367 (62)	388 (66)	9	578 (82)	612 (87)	0	
	5	55	10	405 (35)	356 (31)	8	731 (61)	644 (54)	0	
	6	52	5	480 (51)	389 (41)	5	755 (46)	611 (37)	0	
	7	65	10	430 (40)	358 (33)	5	770 (93)	642 (77)	0	
OPIS-2	8	53	6	458 (45)	378 (37)	6	754 (94)	622 (78)	0	N.A.
	9	59	10	470 (33)	378 (27)	5	775 (32)	622 (25)	0	
	10	51	7	436 (35)	355 (29)	6	792 (53)	645 (43)	0	
	11	50	8	491 (30)	374 (23)	5	820 (24)	626 (19)	0	
	12	47	8	456 (46)	341 (35)	3	883 (12)	659 (9)	0	
	13	52	9	428 (25)	333 (19)	5	855 (56)	667 (43)	0	
	14	51	8	441 (12)	324 (9)	4	919 (21)	676 (15)	0	
	15	55	9	461 (24)	367 (19)	4	794 (37)	633 (29)	0	
	1	12	2	500 (0)	370 (0)	2	850 (0)	630 (0)	0	
	2	27	5	500 (0)	382 (0)	6	808 (53)	618 (41)	0	
	3	40	13	377 (95)	376 (95)	4	625 (43)	624 (43)	0	
	4	31	6	367 (47)	303 (39)	7	843 (17)	697 (14)	0	
	5	27	5	360 (37)	343 (36)	5	690 (92)	657 (87)	0	
	6	28	5	320 (24)	288 (22)	5	790 (20)	712 (18)	0	
	7	31	5	360 (37)	324 (34)	6	750 (41)	676 (37)	0	
OPIS-3	8	40	10	343 (16)	292 (14)	5	830 (24)	708 (21)	0	
	9	37	6	367 (24)	314 (20)	7	800 (0)	686 (0)	0	
	10	47	11	375 (24)	319 (20)	6	800 (0)	681 (0)	0	
	11	52	13	358 (18)	311 (16)	7	793 (17)	689 (15)	0	
	12	39	10	350 (0)	312 (0)	7	771 (25)	688 (22)	0	
	13	46	10	350 (0)	310 (0)	7	779 (25)	690 (22)	1	1000
	14	39	9	350 (24)	318 (21)	5	750 (0)	682 (0)	0	
	15	35	9	344 (16)	318 (14)	5	740 (20)	682 (18)	0	

Table A.II.II: Binomial and χ^2 Tests on Final Portfolios of Subjects

		Binomial Tests of Whether Subjects are More Likely to Increase or Decrease their Portfolio's Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and Whether the Subject Increased or Decreased the Portfolio Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and the Whether the Subject Held a Higher or Lower Variance Portfolio than His or Her Average at the End of the Period			
		All Periods		Last 10 Periods		All 15 Periods		Last 10 Periods		All Periods		Last 10 Periods	
Session	Sub. No.	Prob. Var. ↑'s	Norm. Stat.	Prob. Var. ↑'s	Norm. Stat.	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2
OPI-1	1	0.47	-0.2582	0.50	0.0000	9.5472†	0.008	10.0000†	0.002	8.0405†	0.005	10.0000†	0.002
	2	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	0.0446	0.833	0.0000	1.000
	3	0.17	-2.5820*	0.20	-1.8974#	4.2857	0.117	2.5000	0.114	11.4844†	0.003	6.6667†	0.010
	4	0.07	-3.3566*	0.10	-2.5298*	1.2245	0.268	1.1111	0.292	15.0000†	0.000	10.0000†	0.002
	5	0.47	-0.2582	0.60	0.6325	0.5788	0.447	0.0000	1.000	0.5788	0.447	0.0000	1.000
	6	0.57	0.5164	0.55	0.3162	8.1362†	0.017	10.0000†	0.007	8.0405†	0.005	10.0000†	0.002
	7	0.07	-3.3566*	0.10	-2.5298*	2.0192	0.155	2.5000	0.114	2.1429	0.143	1.6667	0.197
	8	0.60	0.7746	0.65	0.9487	0.9375	0.626	0.4762	0.490	0.0244	0.876	0.4762	0.490
	9	0.53	0.2582	0.70	1.2649	1.7267	0.189	0.4762	0.490	1.7267	0.189	0.4000	0.527
	10	0.33	-1.2910	0.50	0.0000	8.5714†	0.003	10.0000†	0.002	11.4844†	0.001	10.0000†	0.002
OPI-2	1	0.07	-3.3566*	0.00	-3.1623*	0.9375	0.333	N.A.	N.A.	3.6161‡	0.057	0.4762	0.490
	2	0.07	-3.3566*	0.00	-3.1623*	0.0103	0.919	N.A.	N.A.	1.6071	0.205	1.6667	0.197
	3	0.50	0.0000	0.45	-0.3162	12.3214†	0.002	7.3333†	0.026	8.7500†	0.003	4.2857†	0.038
	4	0.27	-1.8074#	0.30	-1.2649	2.9464	0.229	6.6667†	0.036	1.7267	0.189	6.6667†	0.010
	5	0.07	-3.3566*	0.00	-3.1623*	2.6374	0.104	N.A.	N.A.	0.0765	0.782	0.0000	1.000
	6	0.23	-2.0656*	0.15	-2.2136*	1.2500	0.535	4.2857†	0.038	0.1339	0.714	0.4000	0.527
	7	0.57	0.5164	0.50	0.0000	8.8776†	0.012	8.0000†	0.018	8.0405†	0.005	6.6667†	0.010
	8	0.33	-1.2910	0.25	-1.5811	3.0580	0.217	3.1429	0.208	0.0446	0.833	0.0000	1.000
	9	0.23	-2.0656*	0.25	-1.5811	2.2768	0.320	3.1429	0.208	0.5788	0.447	0.0000	1.000
	10	0.03	-3.6148*	0.00	-3.1623*	1.2245	0.268	N.A.	N.A.	0.5788	0.447	1.6667	0.197
OPI-3	1	0.43	-0.5164	0.50	0.0000	8.8776†	0.012	8.0000†	0.018	6.5625†	0.010	6.6667†	0.010
	2	0.17	-2.5820*	0.20	-1.8974#	1.3636	0.506	1.1429	0.565	1.0288	0.310	0.4762	0.490
	3	0.03	-3.6148*	0.05	-2.8460*	0.9375	0.333	1.1111	0.292	8.9732†	0.011	0.0000	1.000
	4	0.30	-1.5492	0.20	-1.8974#	2.3438	0.310	2.5000	0.114	2.2194	0.330	0.4000	0.527
	5	0.20	-2.3238*	0.20	-1.8974#	2.3438	0.310	1.1429	0.565	2.1429	0.143	0.4762	0.490
	6	0.77	2.0656*	0.80	1.8974#	3.8839	0.143	4.2857	0.117	5.4018†	0.020	6.6667†	0.010
	7	0.30	-1.5492	0.15	-2.2136*	2.3438	0.310	2.0000	0.368	2.1429	0.143	0.4762	0.490
	8	0.57	0.5164	0.60	0.6325	8.9732†	0.011	6.6667†	0.010	5.5293†	0.019	6.6667†	0.010
	9	0.17	-2.5820*	0.05	-2.8460*	4.2857	0.117	1.1111	0.292	3.2334‡	0.072	4.2857†	0.038
	10	0.20	-2.3238*	0.30	-1.2649	2.7638	0.251	2.6667	0.264	0.5357	0.464	1.6667	0.197

Table A.II.II: Binomial and χ^2 Tests on Final Portfolios of Subjects

Session	Sub. No.	Binomial Tests of Whether Subjects are More Likely to Increase or Decrease their Portfolio's Variance During a Period: All Periods, Prob. Var. ↑'s	All Periods, Norm. Stat.	Last 10 Periods, Prob. Var. ↑'s	Last 10 Periods, Norm. Stat.	χ^2 Tests of Independence of the Subjects' Initial Endowment and Whether the Subject Increased or Decreased the Portfolio Variance During a Period: All 15 Periods, χ^2 Stat.	All 15 Periods, Prob > χ^2	Last 10 Periods, χ^2 Stat.	Last 10 Periods, Prob > χ^2	χ^2 Tests of Independence of the Subjects' Initial Endowment and the Whether the Subject Held a Higher or Lower Variance Portfolio than His or Her Average at the End of the Period: All Periods, χ^2 Stat.	All Periods, Prob > χ^2	Last 10 Periods, χ^2 Stat.	Last 10 Periods, Prob > χ^2
OPI-4(m)	1	0.10	-3.0984*	0.10	-2.5298*	0.9375	0.626	1.1111	0.292	2.1429	0.143	0.0000	1.000
	2	0.77	2.0656*	0.65	0.9487	2.1429	0.343	2.2000	0.333	5.5293†	0.019	4.2857†	0.038
	3	0.40	-0.7746	0.50	0.0000	11.4286†	0.001	10.0000†	0.002	11.4286†	0.001	10.0000†	0.002
	4	0.50	0.0000	0.55	0.3162	0.5357	0.765	0.6667	0.717	0.1339	0.714	0.0000	1.000
	5	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	1.0288	0.310	0.0000	1.000
	6	0.20	-2.3238*	0.25	-1.5811	2.3438	0.310	2.0000	0.368	1.7267	0.189	1.6667	0.197
	7	0.53	0.2582	0.45	-0.3162	12.9911†	0.002	10.0000†	0.007	11.4286†	0.001	10.0000†	0.002
	8	0.47	-0.2582	0.45	-0.3162	3.9031	0.142	6.8000†	0.033	3.2334‡	0.072	3.6000‡	0.058
	9	0.53	0.2582	0.60	0.6325	5.5293†	0.019	1.6667	0.197	5.5293†	0.019	0.4000	0.527
	10	0.47	-0.2582	0.65	0.9487	6.1990†	0.045	6.6667†	0.036	5.5293†	0.019	6.6667†	0.010
OPI-5(e)	1	0.00	-3.6056*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	0.0344	0.853	0.0344	0.853
	2	0.08	-3.0509*	0.00	-3.1623*	0.0141	0.906	N.A.	N.A.	0.6268	0.429	1.1298	0.568
	3	0.35	-1.1094	0.35	-0.9487	0.7370	0.692	0.5333	0.766	0.0663	0.797	0.0663	0.797
	4	0.04	-3.3282*	0.05	-2.8460*	0.9286	0.335	1.1111	0.292	0.1238	0.725	0.1238	0.725
	5	0.38	-0.8321	0.20	-1.8974#	2.2363	0.135	2.5000	0.114	2.2363	0.135	0.7370	0.391
	6	0.42	-0.5547	0.35	-0.9487	9.5510†	0.008	6.6667†	0.036	9.5510†	0.002	9.5510†	0.002
	7	0.31	-1.3868	0.40	-0.6325	0.7609	0.684	0.5333	0.766	1.8866	0.170	0.6268	0.429
	8	0.50	0.0000	0.45	-0.3162	0.0344	0.983	1.1429	0.565	0.0141	0.906	0.0344	0.983
	9	0.23	-1.9415#	0.10	-2.5298*	3.3429‡	0.067	1.1111	0.292	4.9524†	0.026	3.8985†	0.048
	10	0.35	-1.1094	0.35	-0.9487	4.5692	0.102	2.5333	0.282	1.8866	0.170	1.8866	0.170
OPIP-1	1	0.10	-3.0984*	0.05	-2.8460*	0.2679	0.605	1.1111	0.292	0.0446	0.833	0.4000	0.527
	2	0.37	-1.0328	0.35	-0.9487	6.2946†	0.043	4.1333	0.127	5.5293†	0.019	3.6000‡	0.058
	3	0.70	1.5492	0.65	0.9487	4.2857	0.117	2.0000	0.368	5.4018†	0.020	1.6667	0.197
	4	0.20	-2.3238*	0.20	-1.8974#	6.5625†	0.038	4.2857	0.117	11.4286†	0.001	10.0000†	0.002
	5	0.20	-2.3238*	0.15	-2.2136*	2.0333	0.362	2.5000	0.287	3.2334‡	0.072	3.6000‡	0.058
	6	0.57	0.5164	0.65	0.9487	8.9732†	0.011	4.6667†	0.097	5.5293†	0.019	3.6000‡	0.058
	7	0.07	-3.3566*	0.00	-3.1623*	0.9375	0.333	N.A.	N.A.	1.0288	0.310	3.6000‡	0.058
	8	0.63	1.0328	0.55	0.3162	6.9643†	0.031	6.8000†	0.033	3.6161‡	0.057	3.6000‡	0.058
	9	0.67	1.2910	0.55	0.3162	2.0536	0.358	1.2000	0.549	0.7143	0.398	0.0000	1.000
	10	0.37	-1.0328	0.35	-0.9487	1.2500	0.535	1.3333	0.513	0.7143	0.398	0.0000	1.000

Table A.II.II: Binomial and χ^2 Tests on Final Portfolios of Subjects

		Binomial Tests of Whether Subjects are More Likely to Increase or Decrease their Portfolio's Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and Whether the Subject Increased or Decreased the Portfolio Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and the Whether the Subject Held a Higher or Lower Variance Portfolio than His or Her Average at the End of the Period			
		All Periods		Last 10 Periods		All 15 Periods		Last 10 Periods		All Periods		Last 10 Periods	
Session	Sub. No.	Prob. Var. ↑'s	Norm. Stat.	Prob. Var. ↑'s	Norm. Stat.	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2
OPIP-2	1	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	0.1339	0.714	2.2000	0.333
	2	0.10	-3.0984*	0.00	-3.1623*	2.0192	0.364	N.A.	N.A.	3.2334‡	0.072	4.2857†	0.038
	3	0.23	-2.0656*	0.20	-1.8974*	1.2500	0.535	4.2857	0.117	0.7143	0.398	6.0000†	0.050
	4	0.07	-3.3566*	0.10	-2.5298*	2.6374	0.104	2.5000	0.114	11.4286†	0.001	10.0000†	0.007
	5	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	0.7143	0.398	0.4000	0.527
	6	0.07	-3.3566*	0.00	-3.1623*	0.9375	0.333	N.A.	N.A.	0.7143	0.398	0.4000	0.527
	7	0.43	-0.5164	0.35	-0.9487	0.0446	0.978	0.4762	0.490	0.0244	0.876	0.4762	0.490
	8	0.33	-1.2910	0.50	0.0000	8.5714†	0.003	10.0000†	0.002	8.5714†	0.003	10.0000†	0.002
	9	0.47	-0.2582	0.50	0.0000	0.5788	0.447	3.6000‡	0.058	0.5788	0.447	4.8000‡	0.091
	10	0.47	-0.2582	0.50	0.0000	8.2079†	0.017	10.0000†	0.002	8.0405†	0.005	10.0000†	0.002
OPIP-3	1	0.50	0.0000	0.70	1.2649	6.9643†	0.031	10.0000†	0.007	0.5357	0.464	10.0000†	0.002
	2	0.40	-0.7746	0.45	-0.3162	5.7589‡	0.056	10.0000†	0.007	5.5293†	0.019	10.0000†	0.002
	3	0.03	-3.6148*	0.00	-3.1623*	1.2245	0.268	N.A.	0.000	0.0446	0.833	0.0000	1.000
	4	0.10	-3.0984*	0.15	-2.2136*	2.0192	0.364	2.5000	0.287	1.1384	0.566	1.6667	0.197
	5	0.60	0.7746	0.65	0.9487	6.2468†	0.044	2.5333	0.282	1.0288	0.310	1.6667	0.197
	6	0.57	0.5164	0.70	1.2649	5.6250‡	0.060	4.2857†	0.038	5.5293†	0.019	6.6667†	0.010
	7	0.67	1.2910	0.85	2.2136*	3.9509	0.139	2.5000	0.287	5.5293†	0.019	1.6667	0.197
	8	0.47	-0.2582	0.60	0.6325	3.2334‡	0.072	6.6667†	0.010	3.2334‡	0.072	6.6667†	0.010
	9	0.30	-1.5492	0.25	-1.5811	4.2857	0.117	4.2857	0.117	1.6071	0.205	4.2857†	0.038
	10	0.33	-1.2910	0.45	-0.3162	8.7500†	0.013	10.0000†	0.007	11.4286†	0.001	10.0000†	0.002
OPIS-1	1	0.27	-1.8074‡	0.30	-1.2649	3.9509	0.139	3.8000	0.150	4.4196	0.110	3.6000‡	0.058
	2	0.10	-3.0984*	0.05	-2.8460*	0.2679	0.605	1.1111	0.292	0.5357	0.464	2.5000	0.114
	3	0.07	-3.3566*	0.00	-3.1623*	1.2245	0.268	N.A.	N.A.	1.6071	0.205	0.4762	0.490
	4	0.17	-2.5820*	0.10	-2.5298*	1.3636	0.506	2.5000	0.114	1.7267	0.189	4.2857†	0.038
	5	0.13	-2.8402*	0.15	-2.2136*	4.2857	0.117	2.5000	0.287	4.2857†	0.038	2.5000	0.114
	6	0.37	-1.0328	0.35	-0.9487	3.3673	0.186	4.8000‡	0.091	3.2334‡	0.072	3.6000‡	0.058
	7	0.20	-2.3238*	0.25	-1.5811	3.6161‡	0.057	3.6000‡	0.058	5.6250‡	0.060	3.6000‡	0.058
	8	0.07	-3.3566*	0.10	-2.5298*	0.0103	0.919	0.0000	1.000	1.7267	0.189	0.4000	0.527
	9	0.07	-3.3566*	0.10	-2.5298*	2.0192	0.155	2.5000	0.114	0.1339	0.714	0.0000	1.000
	10	0.03	-3.6148*	0.05	-2.8460*	1.2245	0.268	1.1111	0.292	0.7143	0.398	0.4000	0.527

Table A.II.II: Binomial and χ^2 Tests on Final Portfolios of Subjects

		Binomial Tests of Whether Subjects are More Likely to Increase or Decrease their Portfolio's Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and Whether the Subject Increased or Decreased the Portfolio Variance During a Period				χ^2 Tests of Independence of the Subjects' Initial Endowment and the Whether the Subject Held a Higher or Lower Variance Portfolio than His or Her Average at the End of the Period			
		All Periods		Last 10 Periods		All 15 Periods		Last 10 Periods		All Periods		Last 10 Periods	
Session	Sub. No.	Prob. Var. ↑'s	Norm. Stat.	Prob. Var. ↑'s	Norm. Stat.	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2	χ^2 Stat.	Prob > χ^2
	1	0.20	-2.3238*	0.20	-1.8974	3.5491	0.170	4.2857	0.117	8.0405†	0.005	6.6667†	0.010
	2	0.13	-2.8402*	0.10	-2.5298*	1.2723	0.529	1.1111	0.292	5.5293†	0.019	6.6667†	0.010
	3	0.10	-3.0984*	0.10	-2.5298*	2.0192	0.364	1.1111	0.292	0.0244	0.876	0.0000	1.000
	4	0.07	-3.3566*	0.00	-3.1623*	1.2245	0.268	N.A.	N.A.	0.5357	0.464	1.6667	0.435
OPIS-2	5	0.33	-1.2910	0.35	-0.9487	4.4531	0.108	4.6667‡	0.097	0.5788	0.447	1.6667	0.197
	6	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	4.4196	0.110	1.6667	0.197
	7	0.37	-1.0328	0.30	-1.2649	8.7500†	0.013	10.0000†	0.007	8.5714†	0.003	10.0000†	0.007
	8	0.33	-1.2910	0.20	-1.8974	6.5625†	0.010	2.5000	0.114	6.5625†	0.010	3.6000‡	0.058
	9	0.30	-1.5492	0.45	-0.3162	4.2857	0.117	4.3333	0.115	1.6071	0.448	1.6667	0.197
	10	0.50	0.0000	0.70	1.2649	3.5204	0.172	4.2857†	0.038	3.2334‡	0.072	4.2857†	0.038
	1	0.23	-2.0656*	0.25	-1.5811	1.2500	0.535	1.3333	0.513	0.0446	0.833	0.0000	1.000
	2	0.03	-3.6148*	0.00	-3.1623*	0.9375	0.333	N.A.	N.A.	3.2334‡	0.072	1.6667	0.197
	3	0.67	1.2910	0.60	0.6325	3.3482‡	0.067	1.6667	0.197	3.3482‡	0.067	1.6667	0.197
	4	0.73	1.8074#	0.80	1.8974#	8.7500†	0.013	4.2857	0.117	8.7500†	0.003	7.3333†	0.026
OPIS-3	5	0.17	-2.5820*	0.05	-2.8460*	2.0942	0.351	1.1111	0.292	3.2334‡	0.072	3.6000‡	0.058
	6	0.20	-2.3238*	0.05	-2.8460*	2.7638	0.251	1.1111	0.292	3.3482‡	0.067	2.5000	0.114
	7	0.00	-3.8730*	0.00	-3.1623*	N.A.	N.A.	N.A.	N.A.	0.0446	0.833	1.6667	0.435
	8	0.03	-3.6148*	0.00	-3.1623*	0.9375	0.333	N.A.	N.A.	0.5788	0.447	2.5000	0.114
	9	0.10	-3.0984*	0.05	-2.8460*	3.2813‡	0.070	1.1111	0.292	3.2813‡	0.070	0.0000	1.000
	10	0.57	0.5164	0.50	0.0000	12.3214†	0.002	8.0000†	0.018	11.4844†	0.001	6.6667†	0.010

*Significant at the 95% and 97.5% levels of confidence in two sided and one sided tests, respectively.
#Significant at the 90% and 95% levels of confidence in two sided and one sided tests, respectively.
†Significant at the 95% level of confidence in two sided tests.
‡Significant at the 90% level of confidence in two sided tests.