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Competition in Portfolio Management: Theory and Experiment

Supplementary Online Material (SOM)

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Appendix A: Quadratic Utility and the CAPM

In all variations of the theory we had first-order conditions for optimality of investors given by

$$u_i'\left(z_s^i\right) = \lambda \frac{\tilde{p}_s}{\pi_s},$$

where z_s^i is always the investor's final wealth after subtracting possible fee payments, and $\tilde{p}_s$ is the state price, possibly "fee-adjusted".

Assume, as in the CAPM, that all investors hold a quadratic utility over post-fee wealth, $u_i\left(z_s^i\right) = z_s^i - \frac{b_i}{2}\left(z_s^i\right)^2$. The above FOC becomes

$$1 - b_i z_s^i = \lambda_i \frac{\tilde{p}_s}{\pi_s}.$$

Solving first-order-conditions with the Lagrange multiplier λ_i, the following optimal demands obtain:

$$z_s^i = \frac{1}{b_i} - \frac{\lambda_i}{b_i}\frac{\tilde{p}_s}{\pi_s} = z_c^i + z_{e,s}^i.$$

Notice that demands can be decomposed in terms of a constant, z_c^i, and a term that depends on the states only through the state price probability ratio $\tilde{p}_s/\pi_s$, $z_{e,s}^i$. We call the part of the demand that is state dependent "risk-exposed" demand. This property is referred to as (two-fund) separation. The constant in the demands, z_c^i, can be accommodated by purchasing risk-free securities. Isolating the risk-exposed demand we get:

$$\frac{z_{e,s}^i}{z_{e,s'}^i} = \frac{\frac{p_s}{\pi_s}}{\frac{p_{s'}}{\pi_{s'}}} = \frac{z_{e,s}^j}{z_{e,s'}^j},$$

for any two states s and s' and any other agent j (with quadratic utility) in the economy. Thus, the vector of risk-exposed components, $\{z_{e,s}^i\}_{s=1}^S$, is the same for all investors, up to a constant of proportionality that depends on individual risk tolerance.

Two-fund separation implies that individual demands aggregate, and one can work with a representative agent with a quadratic utility with risk parameter $B = \frac{1}{\sum_i \frac{1}{b_i}}$. The aggregate demands $z_s = \sum_i z_s^i$ satisfy

$$z_s = \frac{1}{B} - \frac{\lambda}{B}\frac{\tilde{p}_s}{\pi_s} = z_c + z_{e,s}.$$

These aggregate demands are those of a representative agent with the same preferences and risk aversion coefficient B. That is aggregate demands are optimal as well. They satisfy the second important property of CAPM, which is that the market portfolio is mean-variance optimal. This means that the aggregate portfolio of all AD securities available in the marketplace is optimal for some agent with quadratic utility. Hence, its Sharpe ratio (expected excess return divided by return standard deviation) is maximal, or equivalently, that the well-known "beta" pricing relationship holds (expected excess returns on all risky assets are strictly proportional to their "betas;" see Roll (1977)).

Imposing $\sum_s \tilde{p}_s = 1$, we can solve for the Lagrange multiplier (of the representative agent) after multiplying the optimal (aggregate) state-security demands by state probabilities (π_s) and summing:

$$\lambda = 1 - B\sum_s \pi_s z_s.$$

It is easy to show that $\lambda > 0$ as long as the representative agent is not satiated at optimal demands (i.e., marginal utility is still positive).

In equilibrium, demands should equal supplies ($z_s = z_s^0 = z_s^0 = \sum_i z_s^{0,i}$), and hence, the state price probability ratios should satisfy the following restriction:

$$\frac{\tilde{p}_s^*}{\pi_s} = \frac{1}{\lambda^*} - \frac{B}{\lambda^*} z_s^0, \tag{1}$$

where $\lambda^* = 1 - B\sum_s \pi_s z_s^0$. While not immediately transparent, this is the CAPM pricing equation. It implies that the market portfolio is mean-variance optimal, and hence, that its Sharpe ratio is maximal, and that expected excess returns on individual securities are strictly proportional to their "betas."

Hence, with the added assumption of quadratic utility, in all variants of our theory, the fee-adjusted wealth and fee-adjusted prices, jointly satisfy CAPM properties. In the baseline with limited liability, also the trading prices, p_s^d, satisfy CAPM, while this is not the case when expected payoffs are used to compute fees and shares. However, it will still be approximately true, as illustrated in the examples that follow.

Appendix B: Numerical Examples

For the numerical examples we use the pricing equation for a representative investor with quadratic utility over wealth, which we derived in the previous section.

Aggregate gross state wealth is assumed equal to the parameters used (on average) in our experiment. There are three states of the world, $s = 1, 2, 3$, corresponding to X, Y, and Z in the experiment. Per capita aggregate wealth is thus

$$\frac{1}{I}\left(x_1^0, x_2^0, x_3^0\right) = (2000, 11600, 7100)\,.$$

All states are equally likely, implying $\pi_s = 1/3$, and $1/\pi_s = 3$. We assume a *reasonable* value of aggregate risk aversion, $B = \frac{2\times 10^{-5}}{I}$. We now consider each one of the variants of our theory, appropriately replacing values of z_s^0 and $\tilde{p}_s^d$ for each case.

B.1. No Delegation

No fees are paid and, therefore, $z_s^0 = x_s^0$ and $p_s = \tilde{p}_s$ for all s. Therefore,

$$\lambda = 1 - 2\times 10^{-5}\frac{1}{3}\sum_s \frac{x_s^0}{I} = 0.8620,$$

and equilibrium prices are

$$(p_1, p_2, p_3) = (0.3712, 0.2970, 0.3318)\,.$$

B.2. Delegation with Standard Liability

Consider a fee per unit of acquired contract of 8%, $f = 0.08$. Notice that this is not the same as the fee implemented in the experiment, which corresponds to ϕ in the theory. The total per capita fee payment is therefore $0.08 \times \sum_s \frac{x_s^0}{I} = 1656$, making the state wealth net of fees equal to

$$\frac{z^0}{I} = (344, 9944, 5444)\,.$$

With these values, we obtain $\lambda = 0.8951$, and fee-adjusted prices are immediately computed to be

$$\tilde{p} = (0.3698, 0.2983, 0.3318)\,.$$

Recall from section **??** that with standard liability, fee-adjusted inter-manager prices are $\tilde{p}_s^d = (1 - Sf)p_s^d + f$, and hence

$$p^d = \frac{\tilde{p}^d - f}{1 - Sf} = (0.3813, 0.2873, 0.3314)\,.$$

Notice that in this case, $\sum_s \tilde{p}_s^d = 1 \Leftrightarrow \sum_s p_s^d = 1$, so we need not re-normalize gross prices.

As expected, since it holds generally when states are equally likely, state prices satisfy CAPM, which also implies weak CAPM. Indeed, prices are ranked inversely to wealth in each state (both before and after fee adjustment). In this example all three state prices move farther away from the state probability, but this is not a general result. In general, state prices of states with below-average wealth increase in the economy with delegation and standard liability (this is the case here), but nothing general can be said about states with above-average wealth.

B.3. Delegation with Limited Liability

Using the same 8% fee as before, we now have state wealth net of fees given by $z_s^0 = x_s^0(1-f)$, yielding

$$\frac{z^0}{I} = (1840, 10672, 6532)\,.$$

Consequently, $\lambda = 0.8730$, and fee-adjusted prices are

$$\tilde{p}^d = (0.3678, 0.3003, 0.3319)\,.$$

In this case, fee-adjusted prices are defined to be $\tilde{p}_s^d = \frac{p_s^d}{1-f}$. We solve for gross prices, and obtain $p^d = (0.3997, 0.3264, 0.3608)$. If we normalize these prices so that they add up to one, we get back $\tilde{p}^d$, hence we use $\tilde{p}^d$ for comparison to the case without delegation. Notice that all three prices get closer to state probabilities, implying that state price probability ratios are closer to 1 with delegation. This reflects higher risk tolerance under delegated portfolio management. The intuition behind this result is simple. Notice that with delegation we have

$$\frac{p_s^d}{\pi_s} = \frac{1}{\lambda} - \frac{B}{\lambda} z_s^0 = \frac{1}{\lambda} - \frac{B}{\lambda}(1-f)x_s^0 = \frac{1}{\lambda} - \frac{\tilde{B}}{\lambda} x_s^0,$$

where $\tilde{B} = B(1-f)$. Hence, the aggregate investor has a lower risk aversion with than without delegation (of course, also λ is lower, but not enough to counter the decrease in expressed risk aversion).

B.4. Shares And Fees Based On Expected Payoff

Take, as in the experiment, $\phi = 0.4$. We solve the following system obtained from the representative investor's optimization, budget constraints, and market clearing:

$$\begin{aligned}
&\lambda \frac{p_s^d}{1/3\,(1-f_s)} = 1 - B x_s^0\,(1-f_s)\,, \quad s = 1,2,3,\\
&f_s = \frac{p_s^d \phi P}{\sum_t p_t^d x_t^0}, \quad s = 1,2,3, \text{ and}\\
&\lambda = 1 - \frac{IB}{3} \sum_t (1-f_t)\,\frac{x_t^0}{I}.
\end{aligned}$$

We obtain $\lambda = 0.8804$. The state-specific per-contract fees are

$$f = (f_1, f_2, f_3) = (0.1502, 0.1273, 0.1384)\,,$$

and gross prices, after re-normalizing so that $\sum_s p_s^d = 1$, are

$$p^d = (0.3611, 0.3062, 0.3327)\,.$$

The above prices, while satisfying weak CAPM, do not satisfy strong CAPM. The fee-adjusted prices, on the other hand, do satisfy CAPM (for fee-adjusted state wealth). These prices are

$$\tilde{p}^d = (0.3657, 0.3020, 0.3323)\,.$$

It is easily seen that the difference between the CAPM prices (fee-adjusted) and the equilibrium prices is very small, in fact, it equals

$$\tilde{p}^d - p^d = (0.0046, -0.0042, -0.0004)\,.$$

This means that investors with quadratic utility, facing prices that closely resemble CAPM prices, will also hold holdings that are close to CAPM. Hence, mean-variance efficiency of the market portfolio and two-fund separation hold approximately.

Appendix C: Shares And Fees Based On Expected Payoff

We must show that when shares and fees are computed based on expected payoff, weak CAPM holds for **gross prices,** p^d, and not only for fee-adjusted prices, $\tilde{p}^d$.

Under the assumptions made for the feasible variation derivation (all investors have equal expected payoff and market value of their initial portfolio), we obtained that

$$\frac{u'(z_s^0)}{u'(z_t^0)} = \frac{\tilde{p}_s^d/\pi_s}{\tilde{p}_t^d/\pi_t},$$

where $\tilde{p}_s^d = \frac{p_s^d}{1-f_s}$, and therefore, $p_s^d = (1-f_s)\tilde{p}_s^d$. For the representative investor, $\alpha_s = \frac{p_s^d x_s^0}{\sum_t p_t^d x_t^0}$, and the fee-adjusted wealth in state s is $z_s^0 = x_s^0 - \phi\alpha_s P$. Letting $W = \sum_t p_t^d x_t^0$, we obtain that

$$1 - f_s = 1 - \frac{p_s^d \phi P}{W}.$$

Therefore, gross state-price probability ratios are given by

$$\frac{p_s^d}{\pi_s} = \left[1 - \frac{p_s^d \phi P}{W}\right] \frac{\tilde{p}_s^d}{\pi_s}.$$

Solve the above for p_s^d/π_s, to obtain

$$\frac{p_s^d}{\pi_s} = \frac{\tilde{p}_s^d/\pi_s}{1 + \frac{\phi P}{W}\tilde{p}_s^d}.$$

Assume that all states are equally likely (as in our experimental setup), to obtain the following expression for the relative (gross) price of two given states, s and t:

$$\frac{p_s^d}{p_t^d} = \frac{\tilde{p}_s^d}{\tilde{p}_t^d}\left[\frac{1 + \frac{\phi P}{W}\tilde{p}_t^d}{1 + \frac{\phi P}{W}\tilde{p}_s^d}\right].$$

Assume that the fee-adjusted prices are such that $\tilde{p}_s^d < \tilde{p}_t^d$, which will be the case if the fee-adjusted wealth of state s is larger than that of state t. We want to show that in this case, also $p_s^d < p_t^d$. With the above expression, this will be the case if and only if

$$\frac{1 + \frac{\phi P}{W}\tilde{p}_t^d}{1 + \frac{\phi P}{W}\tilde{p}_s^d} < \frac{\tilde{p}_t^d}{\tilde{p}_s^d}.$$

Work with the above expression to see that it holds if and only if

$$1 + \frac{\phi P}{W}\tilde{p}_t^d < \frac{\tilde{p}_t^d}{\tilde{p}_s^d} + \frac{\phi P}{W}\tilde{p}_t^d \Leftrightarrow$$
$$1 < \frac{\tilde{p}_t^d}{\tilde{p}_s^d},$$

and the latter holds by the original assumption. Hence, we conclude that whenever $\tilde{p}_s^d < \tilde{p}_t^d$, it will also hold that $p_s^d < p_t^d$.

Table 1 State-Dependent Liquidating Dividends (in US Cents Per Unit).

	State		
	X	Y	Z
Asset A	5	80	0
Asset B	0	30	80
Bond	100	100	100

Appendix D: Computational Details Behind Experimental Results

D.1. Payoffs

Below we provide formal definitions of the payoff functions for the investors and managers in our experiment.

In the set I of investors, let I_A and I_B be the subsets of those of type A (who initially hold only risky asset A, in addition to cash) and type B (with B only, and cash) and let x_A^0 and h_A^0 denote the individual initial endowments of asset A and cash for type A investors, while x_B^0 and h_B^0 denote individual initial endowments of asset B and cash for type B investors. All investors of one type have identical initial endowments. Let $\alpha^i = (\alpha_1^i, \ldots, \alpha_{32}^i)$ denote investor i's distribution of his initial endowment among the 32 managers. The initial portfolio of manager m is composed of $x_A^{m,0}$ units of asset A, and $x_B^{m,0}$ units of asset B, where

$$x_A^{m,0} = x_A^0 \sum_{i \in I_A} \alpha_m^i, \qquad x_B^{m,0} = x_B^0 \sum_{i \in I_B} \alpha_m^i.$$

Manager m's initial cash endowment is given by

$$h^{m,0} = \sum_{i \in I_A} \alpha_m^i h_A^0 + \sum_{i_B \in I_B} \alpha_m^i h_B^0.$$

Letting $\bar{D}_A$ ($\bar{D}_B$) denote the expected payoff of asset A (B), the expected payoff of manager m's initial portfolio is $\bar{D}^m = \bar{D}_A x_A^{m,0} + \bar{D}_B x_B^{m,0} + h^{m,0}$.

Manager m's payoff is 40% of the expected payoff of her initial portfolio. That is,

$$Pay^m = 0.4 \times \bar{D}^m. \tag{2}$$

Investor i's share in fund m is defined as

$$\sigma_m^i = \frac{\alpha_m^i \left(\bar{D}_A x_A^0 + h_A^0\right)}{\bar{D}^m}, \text{ and } \sigma_m^i = \frac{\alpha_m^i \left(\bar{D}_B x_B^0 + h_B^0\right)}{\bar{D}^m},$$

for investors of type A and B, respectively.

Given her initial portfolio of risky assets, $x^{m,0} = \left(x_A^{m,0}, x_B^{m,0}\right)$, and cash, $h^{m,0}$, manager m can trade to a final portfolio, (x^m, h^m), with $x^m = (x_A^m, x_B^m)$.[1] The final holdings and the realized state of the world, $s \in \{X, Y, Z\}$ determine manager m's realized payoff, Π^m, as follows:

$$\Pi^m\left(x^m, h^m; s\right) = D_A\left(s\right) x_A^m + D_B\left(s\right) x_B^m + h^m,$$

where $D_A(s)$ and $D_B(s)$ denote, respectively, the payoff of security A and security B in state of the world s (table 1 summarizes the dollar payoffs for each asset/state of the world).

[1] h^m includes both cash and bond holdings (the dividend on the Bond is always \$1).

Manager m's *residual* payoff is $\max\{\Pi^m - Pay^m, 0\}$, i.e. it is the positive part of the realized payoff of manager m after her "fees" (Pay^m) are subtracted from it. Investor i's payoff from manager m equals his share in this manager's residual payoff, i.e., it is equal to $\sigma_m^i \max\{\Pi^m - Pay^m, 0\}$.

Investor i's total payoff is the sum of his payoffs from all managers and depends on the realized state of the world, as given in the expression below:

$$Pay^i(s) = \sum_{m=1}^{32} \sigma_m^i \left[\max\left\{\Pi^m(x^m, h^m; s) - Pay^m, 0\right\}\right]. \tag{3}$$

D.2. Disclosure of Information

Trading always took place on a Tuesday. Indicators of management performance were published online on the following Friday and appeared in the newspaper (*The California Tech*) the subsequent Monday.

For all managers, we announced four performance indicators, specified below, and compared those to the same indicators for an index called the *Dow-tech* Index, composed of one unit of asset A, one unit of asset B, and \$1. The following performance indicators were used: *Portfolio Return, Market Share*[2]*, Residual,* and *Risky Share*. In what follows we describe these indicators in detail.

Given prices $p^d = (p_A^d, p_B^d, 1)$ for assets A, B and the Bond, the *value*, V^m, of manager m's initial portfolio is defined as

$$V^m\left(p^d\right) = p_A^d x_A^{m,0} + p_B^d x_B^{m,0} + h^{m,0}.$$

In continuous markets such as the ones in our experiment, assets rarely trade at constant prices. In computing the valuations V^m, we take p^d to be the vector of average prices over the last five minutes of trading in a period.

Portfolio Return. This measure captures the realized rate of return for manager m when the state of the world is s and the average trading price is p^d. Namely,

$$R^m = \frac{\Pi^m(x^m, h^m; s) - V^m(p^d)}{V^m(p^d)}. \tag{4}$$

Market Share. (We report the realized market shares in the experiment in table 2 below). This measure is meant to capture the relative size of mutual fund m. It is equal to the ratio of the expected dividend of manager m's initial portfolio and the expected dividend of the portfolio comprised of all assets and cash available to all investors. Specifically,

$$MS^m = \frac{\bar{D}^m}{\sum_{k=1}^{32} \bar{D}^k}. \tag{5}$$

Residual. The residual for manager m is the payoff net of fees,

$$Re^m = \max\{\Pi^m - Pay^m, 0\}. \tag{6}$$

Risky Share. This measure for a manager m equals the value of the risky portion of m's final portfolio.

$$Ri^m = \frac{p_A^d x_A^m + p_B^d x_B^m}{p_A^d x_A^m + p_B^d x_B^m + h^m}, \tag{7}$$

where p^d is again taken to be the average price for the last five minutes of trade in a period.

[2] The *Market Share* indicator was referred to as "Volume" in the published reports.

D.3. News Page

The news page of the experimental webpage had a brief explanation of each one of the announced indicators, as follows:

The table below reports the results from the experiment on Oct 17. The three statistics computed are Volume, Return, and Proportion Invested in Risky Assets. Volume represents the proportion of the total assets (the sum of all assets given to all investors) that went to each of the managers. Return is the (Final payoff - Value of initial portfolio delegated to the manager) divided by the Value of initial portfolio delegated to the manager. Final value is based on the actual realization of the state. Initial value is based on average transaction prices. Proportion invested in risky assets is the value of the final risky holdings (computed at average transaction prices) divided by the value of the entire final portfolio. Notice that a manager can invest more than 100% of the assets under management in risky assets. This is done by borrowing cash and investing it in the assets A and/or B.

Additionally, in the university newspaper we also reported the index *Residual* with its description.

Starting with the second experimental period, we included a page for each manager where investors could graphically follow the returns of each manager across all past periods. This was also updated weekly.

D.4. Terminal Session Payoffs

The experiment concluded with an additional pseudo-period. This period was like other periods with the exception of the payoffs for the managers and investors. As in the main session, investors allocated their assets among managers and managers participated in a thirty-minutes trading period. However, each manager received a payoff (fee) equal to 40% of her payoff after trade, given the realized state of the world s. Investors were paid the sum of their share of each manager's realized dividend after the management fee. In other words, manager m's payoff in the *end* session equaled $0.4 \times \Pi^m\left(x^m, h^m; s\right)$ in state s. Investor i's payoff equaled $\sum_{m=1}^{32} \sigma_m^i \left[0.6 \times \Pi^m\left(x^m, h^m; s\right)\right]$.

The terminal session was implemented to maintain the incentives that up to the last period had been enforced through the existence of future periods. Prices and portfolio choices from this period were not part of the experiment. In our experiment, managers did not announce the nature of their contracts (the weights, θ_s^m) before investors made their choices of managers. Instead, we counted on the reputation established across periods to signal managers' commitment to certain contracts. Clearly, this could not be sustained in the last period. With this concluding period we provided all managers equal incentives to: *i*) maximize the funds they received at the beginning of the concluding period, presumably by establishing good reputation in previous periods; *ii*) behave like investors themselves and, in this way, give investors no good reason to change their choice of manager with respect to what they would have chosen had there been more periods. However, *ex-post* the incentives in the concluding period were of little importance as an accounting mistake in the software corrupted the data from periods 7 and 8. Instead of revealing *Returns* it computed $k \times Returns$, where k was period-dependent. Thus, investors received inaccurate information about previous period returns in periods 7 and 8. The experimental website contains the numbers reported in those periods and the interested reader is referred to it (http://clef.caltech.edu/exp/dp). Periods 7 and 8 could thus no longer be used in our data, while period 6 could safely be used with no concerns regarding possible last-period effects.

Table 2 Portfolio Manager Market Shares (in %), Per Period

	1 (061017)	2 (061024)	3 (061030)	4 (061107)	5 (061114)	6 (061121)
Albite	2.02[3]	0.34	8.14	4.28	2.42	2.53
Alexandrite	2.38	11.61	10.36	19.95	20.34	8.67
Allanite	2.42	1.96	1.16	2.03	2.91	2.74
Alunite	2.34	2.27	5.69	1.88	1.78	2.21
Amazonite	4.62	6.68	6.19	3.71	5.65	6.80
Amblygonite	5.31	4.38	2.58	6.60	5.48	11.69
Amosite	2.33	0.98	3.89	1.81	0.77	1.29
Andalusite	3.36	0.84	1.22	1.08	2.27	0.85
Anthophyllite	2.78	1.70	0.89	2.03	0.86	0.63
Atacamite	3.38	4.39	2.72	1.25	1.74	0.74
Barite	2.93	2.19	1.12	0.46	0.84	0.57
Bassanite	2.84	3.18	2.11	1.09	5.66	2.68
Beidellite	3.17	1.83	2.06	1.37	0.89	0.74
Bementite	2.96	0.64	4.66	3.20	2.23	5.27
Bentonite	2.31	0.69	1.62	1.12	0.78	0.76
Bertrandite	2.01	10.57	2.98	0.90	4.54	6.27
Biotite	2.48	1.09	1.56	1.19	1.36	1.07
Birnessite	2.47	7.71	0.99	1.04	0.58	0.51
Bloedite	3.44	0.28	3.72	1.86	0.79	0.46
Boracite	3.06	1.44	1.67	3.30	3.77	2.44
Calcite	3.35	1.80	2.90	3.80	1.41	0.71
Carnallite	3.29	0.62	3.90	2.32	6.53	10.80
Celestite	2.78	1.82	1.64	1.23	0.89	0.50
Chalcopyrite	4.41	1.58	1.54	2.94	0.49	2.65
Chlorite	4.42	2.21	2.96	2.67	2.09	1.33
Colemanite	3.52	0.97	2.99	15.66	4.82	6.26
Cornadite	2.74	3.62	6.65	4.42	9.08	13.42
Cristobalite	3.12	1.87	3.07	1.55	2.22	0.69
Cryolite	3.42	6.15	2.82	0.91	1.13	0.70
Dolomite	4.02	12.36	2.28	1.20	1.97	1.18
Dumortierite	2.84	1.53	1.52	1.82	0.91	1.07
Dunite	3.48	0.70	2.38	1.34	2.80	1.77

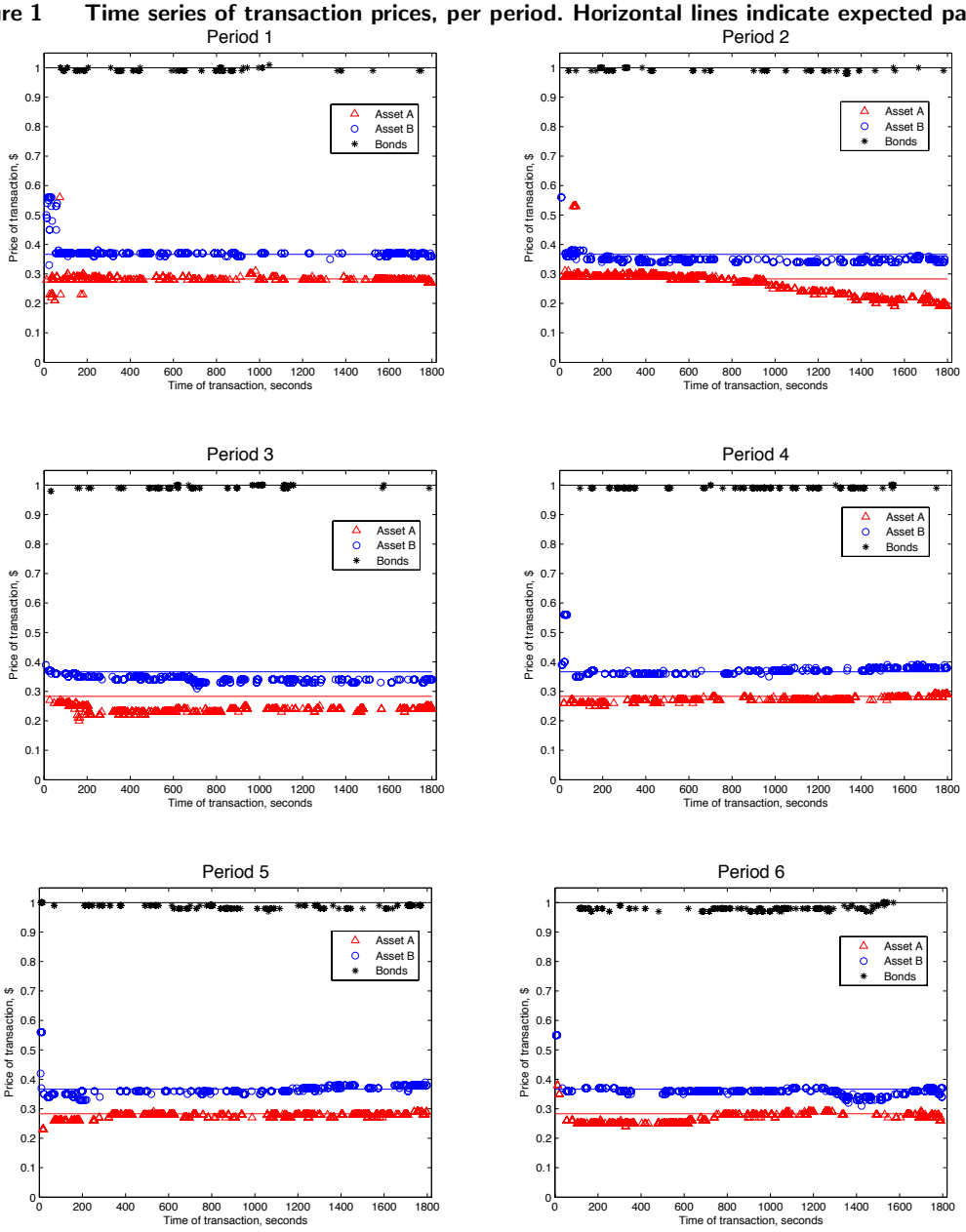
Appendix E: Manager Pseudonyms And Market Shares

Below we list the pseudonyms used to identify different managers throughout the experiment. In parenthesis we state the manager number used to identify managers in the body of the article.

Alexandrite (11), Allanite (12), Alunite (13), Amazonite (14), Amblygonite (15), Amosite (16), Andalusite (17), Anthophyllite (18), Atacamite (19), Anthophyllite (20)Barite (21), Bassanite (22), Beidellite (23), Bementite (24), Bentonite (25), Bertrandite (26), Biotite (27), Birnessite (28), Bloedite (29), Boracite (30), Calcite (31), Carnallite (32), Celestite (33), Chalcopyrite (34), Chlorite (35), Colemanite (36), Cornadite (37), Cristobalite (38), Cryolite (39), Dolomite (40), Dumortierite (41), Dunite (42).

Appendix F: Plot of All Transaction Prices

Figure 1 Time series of transaction prices, per period. Horizontal lines indicate expected payoffs.



Appendix G: Construction of τ Statistic

Following Bossaerts and Plott (2004), we construct a statistic, called τ, that measures the frequency with which state-price probability ratios $u_S(t)$ (states $S = X, Y, Z$; t indexes time) move in the right direction to restore ranking according to weak CAPM when ranking is incorrect. Specifically, τ is the average across transactions of a variable that assigns a value of 1 to a change in state prices in the direction of weak CAPM, and 0 otherwise. For each possible ranking of the state-price probabilities ($u_S(t)$) after transaction t, Table 3 presents the required subsequent changes (at transaction $t+1$) for the indicator variable determining τ to take the value of 1. To avoid bias, we eliminate observations where prices do not change (these would otherwise automatically be assigned a value of 1).

Table 3 List Of Changes That Suggest Rankings Of State-Price Probabilities $u_S(t)$ (states $S = X, Y, Z$, all time t) Drift Back To Satisfying Weak CAPM.

Ranking at t	Correct Subsequent Change In State-Price Probability Ratios
$u_X(t) > u_Z(t) > u_Y(t)$	Any Change
$u_X(t) > u_Y(t) > u_Z(t)$	$u_Z(t+1) - u_Y(t+1) \geq u_Z(t) - u_Y(t)$
$u_Z(t) > u_X(t) > u_Y(t)$	$u_X(t+1) - u_Z(t+1) \geq u_X(t) - u_Z(t)$
$u_Z(t) > u_Y(t) > u_X(t)$	$u_X(t+1) - u_Y(t+1) \geq u_X(t) - u_Y(t)$
$u_Y(t) > u_X(t) > u_Z(t)$	$u_X(t+1) - u_Y(t+1) \geq u_X(t) - u_Y(t)$
$u_Y(t) > u_Z(t) > u_X(t)$	$u_X(t+1) - u_Z(t+1) \geq u_X(t) - u_Z(t)$
	or $u_Z(t+1) - u_Y(t+1) \geq u_Z(t) - u_Y(t)$
	or $u_X(t+1) - u_Y(t+1) \geq u_X(t) - u_Y(t)$

Appendix H: Experimental Instructions

H.1. Instructions for Investors

1. Situation

In this experiment there are managers who invest assets to generate profits for **investors** who delegate the management of their assets.

As an **investor** you will need to decide which managers should manage your assets. Upon sign-up you will be assigned an initial portfolio of assets. Then you will allocate your initial portfolio among managers whom you will pick from a list of 32 managers. These managers will then trade on your behalf the assets you allocate them.

As an **investor** you will earn the returns on your final portfolio, resulting from managers' trades, minus a fee that you will pay to the managers. The managers will be compensated proportionally to the amount of assets you gave them, and *not according to how well they trade.*

Investors' only task will be to allocate their assets to managers.

After managers complete their trading session, you will be informed how well the managers did and what your returns are.

2. Timing

- Sign up for the experiment before the deadline on Tuesday 4am.
- You receive initial portfolio of assets and a link to the online form by Tuesday 7am.
- Assign your portfolio to the managers via the online form by Tuesday at 6pm.
- Tuesday night: the managers trade and the state of the world is realized.
- Thursday morning: your earnings are reported to you.
- Next Monday 10/23: you can observe the performance of the managers in *The Tech* and on the CLEF website.

3. The Securities and Initial Portfolio

In this experiment, there are risky assets, A and B, and a riskless asset, cash. The risky assets pay randomly, depending on the draw of the state of the world which is realized at the end of the trading period. There are 3 different states of the world, the table below summarizes the asset payoffs in cents, in different states of the world.

	X	Y	Z
A	5	80	0
B	0	30	80
Bond	100	100	100

For example, if the state of the world is X then asset A pays 0.05, and asset B pays 0.

The states of the world are drawn randomly, with equal probabilities.

When you sign up you will be given a portfolio of assets, for instance, your initial portfolio may consist of 5 A and 3 B.

4. Allocating your initial portfolio

You will allocate your initial portfolio via an online form, the link to the form will be sent to you after you

on Tuesday at 7am. There are 32 different managers, and they are identified by names of minerals. You will be able to split your portfolio among as many managers as you want, and you can use any criteria. However, you can only allocate the assets in integer amounts. Thus, if you started with the above portfolio, you might for example decide to give 3A to the manager Pyrite, 2A and 1B to Dunite, and 2B to Dickite.

5. Trading, portfolio returns, and managers' compensation

The managers will trade in a single 30-minute trading round on Tuesday night. You will not participate in the trading round. At the end of the trading round the state of the world will be drawn, and the returns' on the managers' final portfolios will be realized.

Your share of final returns with each manager will be computed according to the proportion that your investment represents in the starting portfolio of the manager. The manager's fee will be subtracted from your final returns. Managers' fees are the same for all managers, and they are a fixed fraction of your initial investment. Managers' fees are independent of the managers' final holdings, and are thus independent of their performance in the trading round.

Your earnings will be reported to you on Thursday morning, and will be calibrated so that you will in expected terms obtain roughly $20. Of course, your actual earnings will depend on how well your managers perform.

Next Monday, October 23, you will be able to observe the performance of all the managers in The Tech as well as on CLEF's website.

Good Luck!

H.2. Instructions for Managers

Overview:

I. The Experiment
II. The Markets Interface, jMarkets

I. THE EXPERIMENT

1. Situation

The experiment consists of a series of 30-minute sessions, one per week, over the next 9 weeks. As a **manager** you will have the opportunity to trade assets given to you by investors. The investors choose what fraction of their assets to give to each manager. You are free to trade any of the assets allocated to you. All assets pay dividends in the end of the session and expire worthless afterwards. The exact dividend payment depends on the realization of a random variable (described in detail below). Thus, in the end of each session you will collect a dividend payment for each asset in your final holdings. This payment is passed back to the investors who allocated assets to you.

Managers are paid a fraction of the value of the assets they are assigned by investors. When making the decision of how to allocate their assets among managers, investors have at their disposal the information on the past performance of all managers, and on the performance of a benchmark market index that is fixed (like an S&P500 index). **Managers** are identifiable by investors through a pseudonym assigned to them in the first session.

Managers are requested to participate in **all** sessions, covering the entire Fall Academic term. They will be **generously compensated** for a steady and reliable participation (independent of the performance). The first session will be held on a Monday, after which all sessions will be held on Tuesday nights. Please manage your schedule accordingly!!

Information on managers and index performance will be published in the **California Tech** and in the **News** section of this webpage. Only pseudonyms will be published.

2. The Securities

Investors will be given two types of stocks, Stock A and Stock B and some cash to allocate to managers. In addition managers will be able to use a type of security, called Bond, to lend and/or borrow money during the session. Bonds pay a fixed liquidating dividend, namely, 100 US cents. Stocks pay a liquidating dividend that is determined by the drawing of a **state**. The three possible states are X, Y, and Z. Stocks pay different dividends in each state. The table below shows how dividend payoffs (in cents) depend on the state.

	X	Y	Z
Stock A	5	80	0
Stock B	0	30	80
Bond	100	100	100

You won't be able to *buy* Stocks or Bonds unless you have the cash. You will be able to *sell* Stocks and Bonds (and get cash) even if you do not own any. This is called *short selling*. If you sell, say, one Stock A, then you get to keep the sales price, but 5(80) cents *will be subtracted from your period profits after the market closes and if the state is X(Y). If at the end of a period you are holding, say, -1 Bonds, £1.00 will be subtracted from your period profits.*

The trading system checks your orders against *bankruptcy*: you may not be able to submit orders which, if executed, generate negative period earnings in some state(s).

Investors who delegated assets to you will be paid according to the profit (equal to the sum of final dividend payments and cash you own) made by the *mutual fund* that you manage. You, as a **manager** will be paid regardless of your profit, according to the value of the assets and cash you were given by investors at the beginning of the session. Specifically, you will receive 60% of the value of assets given to you. This value is computed at the average price that the assets had over the last 10 seconds of trading in the previous session.

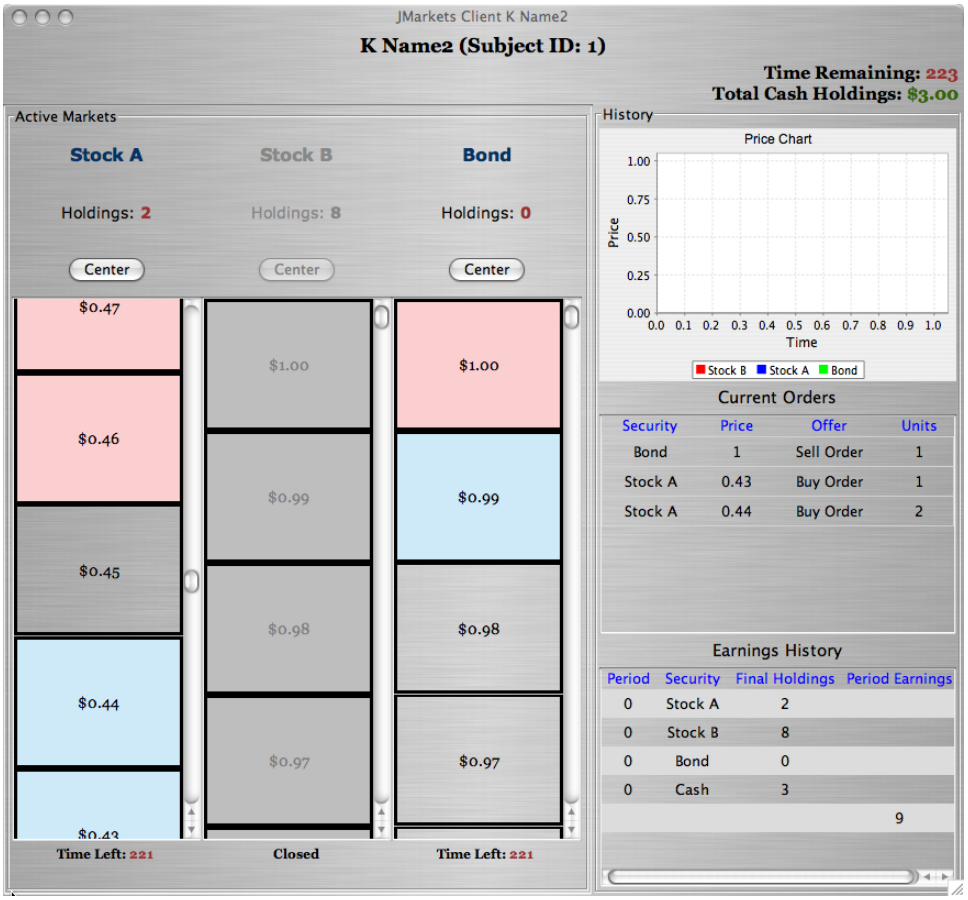
3. How The State Is Drawn

There are three possible states, X, Y and Z. Here is how states are drawn. *We start with an urn with 18 balls, 6 of which are marked X (X balls), 6 are marked Y (Y balls), and 6 are marked Z (Z balls).* We draw one ball from this urn. Imagine that we draw a Z ball. This will determine the liquidating dividends on the stocks. E.g., for each unit of Stock B you're holding, you will receive 80 cents. We then put the ball back in the urn and keep the urn for the next experimental session (next week). As a consequence, the next time we determine the liquidating dividends, we draw a state from an urn with the same composition: 6 X balls, 6 Y balls, and 6 Z balls.

We draw the state before you start trading with a fresh supply of securities and cash. This means that the state will not depend on your trading. Nobody will be told what the state is until the end of the period when the securities and cash expire.

II. THE MARKETS INTERFACE, jMARKETS

Once you click on the **Participate** link to the left, you will be asked to log into the markets, and you will be connected to the *jMarkets* server. After everybody has logged in, a markets interface like the one below will appear.



1. Active Markets

The **Active Markets** panel is renewed each period. In it, you'll see several scroll-down columns. Each column corresponds to a market in one of the securities. The security name is indicated on top. At the bottom, you can see whether the market is open, and if so, how long it will remain open. The time left in a period is indicated on the right hand side above the Active Markets panel.

At the top of a column, you can also find your current holdings of the corresponding security. Your current cash holdings are given on the right hand side above the Active Markets panel.

Each column consists of a number of price levels at which you and others enter offers to trade. Current offers to sell are indicated in red; offers to buy are indicated in blue. When pressing the **Center** button on top of a column, you will be positioned halfway between the best offer to buy (i.e., the highest price at which somebody offers to buy) and the best offer to sell (i.e., the lowest price that anybody offers to sell at).

When you move your **cursor** to a particular price level box, you get specifics about the available offers. On top, at the left hand side, you'll see the number of units requested for purchase. Each time you click on it, you send an order to buy one unit yourself. On top, at the right hand side, the number of units offered for sale is given. You send an order to sell one unit each time you yourself click on it. At the bottom, you'll see how many units you offered. (Your offers are also listed under **Current Orders** to the right of the Active Markets panel.) Each time you hit **cancel**, you reduce your offer by one unit.

If you click on the price level, a small window appears that allows you to offer multiple units to buy or to sell, or to cancel offers for *multiple* units at once.

2. History

The **History** panel shows a chart of past transaction prices for each of the securities. Like the *Active Markets* panel, it refreshes every period.

3. Current Orders

The **Current Orders** panel lists your offers. If you click on one of them, the corresponding price level box in the Active Markets panel is highlighted so that you can easily modify the offer.

4. Earning History

The **Earnings History** table shows, for each period, your final holdings for each of the securities (and cash), as well as the resulting period earnings.

5. How Trade Takes Place

Whenever you enter an offer to sell at a price below or equal to that of the best available buy order, a sale takes place. You receive the price of the buy order in cash. Whenever you enter an offer to buy at a price above or equal to that of the best available sell order, a purchase takes place. You will be charged the price of the sell order.

The system imposes strict price-time priority: buy orders at high prices will be executed first; if there are several buy orders at the same price level, the oldest orders will be executed first. Analogously, sell orders at low prices will be executed first, and if there are several sell orders at a given price level, the oldest ones will be executed first.

6. Restrictions On Offers

Before you send in an offer, *jMarkets* will check two things: the *cash constraint*, and the *bankruptcy constraint*.

The cash constraint concerns whether you have enough cash to buy securities. If you send in an offer to buy, you need to have enough cash. To allow you to trade fast, *jMarkets* has an automatic cancelation feature. When you submit a buy order that violates the cash constraint, the system will automatically attempt to cancel buy orders you may have at lower prices, until the cash constraint is satisfied and your new order can be placed.

The bankruptcy constraint concerns your ability to deliver on promises that you implicitly make by trading securities. We may not allow you to trade to holdings that generate losses in some state(s). A message appears if that is the case and your order will not go through.

Good Luck!

References

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