How tournament incentives affect asset markets: A comparison between winner-take-all tournaments and elimination contests

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Abstract: We investigate the impact of fund managers' tournament incentives on investment strategies and market efficiency, distinguishing between winner-take-all tournaments (WTA), where a minority wins, and elimination contests (EC), where a majority wins. Theoretically, we show that fund managers play heterogeneous strategies in WTA and homogeneous strategies in EC, and markets are more prone to mispricing in WTA than in EC. Experimentally, we find that fund managers play more heterogeneous strategies in WTA than in EC, but this does not trigger significant differences in prices. Moreover, prices in WTA and EC do not differ significantly from markets composed of linearly incentivized subjects.

Keywords: tournament incentives, investment behavior, market efficiency, experimental finance

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1 Introduction

This paper explores how tournament incentives for fund managers affect investment strategies and aggregate market outcomes. On the one hand, mutual fund managers are engaged in a *winner-take-all tournament* (WTA) in real-world financial markets, where they aim to achieve a top performance ranking, since they often have asset-based compensation schemes (Khorana, 1996; Deli, 2002; Ma et al., 2015) and only top performing funds succeed in capturing significant capital inflows (Chevalier and Ellison, 1997; Sirri and Tufano, 1998; Huang et al., 2007). On the other hand, fund managers are exposed to an *elimination contest* (EC) and want to avoid being bottom performers, since bottom performers face a high risk of being "eliminated," i.e., having their positions terminated (Chevalier and Ellison, 1999; Qiu, 2003; Kempf et al., 2009).

These tournament incentives may affect fund managers' risk-taking behavior and thus the risk-exposure of financial institutions and the stability of financial markets.[1] Moreover, the U.S. mutual fund industry was worth $12.7 trillion at the end of 2014 (Hanouna et al., 2015). Distorted incentives of mutual fund managers may therefore have detrimental effects on aggregate capital allocation.

Our main research question is whether investment behavior and market efficiency differ between WTA and EC. To circumvent the difficulty of disentangling the effects of one type of tournament from the other when investigating them with empirical data, we use two alternative approaches, theory and experiment, that are complementary to each other and both enable us to isolate the effects of each type of tournament.

We first build a parsimonious model of a competitive market with a single risky asset. This asset produces a random terminal value, whose distribution is known to all traders. There are two types of traders in the market. The first type is *fund managers*. They have tournament incentives and aim to maximize the probability of winning the competition, i.e., the probability of outperforming a certain proportion of peer managers. The second type is *ordinary traders*. They have no tournament incentives and aim to maximize the terminal portfolio value.

Our theoretical model shows that, in WTA, in which a minority of fund managers win, man-

[1] See Rajan (2006) for a discussion of how tournament incentives for fund managers might lead to financial instability. See also Allen and Gorton (1993) and Allen (2001) for discussions of how other non-linear incentives for fund managers, such as convex compensation schemes, can create moral hazard problems and price inefficiencies.

agers follow heterogeneous strategies, with one group fully cashing into the risky asset and the other group fully cashing out. These aggressive strategies result in large trading volume. The equilibrium asset price is unique and weakly increases in managers' cash endowments. When managers have sufficiently large cash endowments, the equilibrium asset price exceeds the fundamental value, generating asset overpricing. In contrast, in EC, in which a majority of managers win, managers play the same strategy that need not be aggressive. There may exist multiple equilibrium prices, but the fundamental value is the unique equilibrium price that satisfies the security principle, an equilibrium selection principle based on the "riskiness" of an equilibrium following the concept of maximin introduced by Von Neumann and Morgenstern (1972).

Second, to complement our theoretical approach, which identifies tournament structure (WTA or EC) as a key determinant of investment behavior and market outcomes but does not allow us to explore the dynamic interactions among boundedly rational traders, we further investigate the effects of tournament incentives by running asset market experiments in the laboratory. Within a market, half of the experimental subjects act as fund managers, all of whom face the same tournament compensation scheme, and the other half act as ordinary traders receiving linear incentives. We use two tournament treatments, WTA, in which a minority of managers win, and EC, in which a majority of managers win. We also conduct a third treatment, LINEAR, where all subjects are ordinary traders. This treatment serves as a benchmark and allows us to relate our findings to previous experimental studies which typically concentrate on traders with linear incentives.

In the experiment, fund managers' trading behavior is indeed affected by the tournament structure applied. First, we find that, in Treatment WTA, managers invest more in the risky asset and trade more. In contrast, in Treatment EC, managers are more passive and trade less than ordinary traders. These results are, in general, consistent with the theoretical implications that managers play aggressive strategies to gain a chance of standing out in WTA, whereas they become more conservative to be less exposed to the risk of elimination in EC. Second, we compare fund managers' trading behavior across treatments. Consistent with the theoretical implications, we find that the standard deviation of asset holdings among fund managers is significantly lower in Treatment EC than in WTA. This implies that fund managers behave more heterogeneously in WTA. We also show that fund managers invest significantly less in the risky asset in Treatment EC than in WTA, implying that managers are more conservative in risk taking in EC.

Importantly, the significant differences in fund managers' trading strategies between Treatment WTA and EC do not result in significant differences in aggregate market outcomes between the two treatments. We find that, when fund managers have large cash endowments, the market is slightly more prone to overpricing in Treatment WTA than in EC. This result is consistent with the implication from theory, but the treatment differences are not significant. Moreover, the market price in these two treatments does not differ significantly from the price in the markets of Treatment LINEAR, composed of ordinary traders only. It thus appears that endowing half of the traders with tournament incentives is not sufficient to create a substantial impact on market prices in the laboratory. This might be rooted in subjects' boundedly rational behavior as they behave broadly in line with the theoretical implications, but not perfectly so, adding considerable noise to the aggregate market-level data.

The rest of the paper is organized as follows. In the next section, we review the related literature. Section 3 presents the theoretical model and draws implications. Section 4 describes the experimental design and presents the experimental results. Section 5 concludes. All the proofs are relegated to Appendix A. Appendix B includes some additional figures. Appendix C contains the instructions of the experiment.

2 Relation to earlier literature

Our paper relates to two strands of literature. First, our paper relates to the theoretical literature studying how tournament incentives affect investment strategies and market outcomes. Like our model, some studies adopt a tournament setting in which agent payoffs are rank-based. Most of these studies assume a single winner and thus abstract from the issue of different tournament structures (e.g., Taylor, 2003; Chen et al., 2015).[2] An exception is Gaba et al. (2004), which also dis-

[2] Taylor (2003) studies a tournament between two funds with different interim performances and finds that the interim winner is more likely to gamble than the interim loser. Chen et al. (2015) extend Taylor (2003) to a multi-period multi-fund setting and find that the interim winner reduces portfolio risk when she has a large lead.

tinguishes WTA from EC. Gaba et al. (2004) find that, when a strategic agent can modify both performance variance and correlations with other nonstrategic agents' performance, the strategic agent prefers higher variance and lower correlation in WTA, whereas in EC, her preference is reversed. Their analysis of correlation preference is made under a decision-theoretic framework and they abstract from the mean-variance and mean-correlation tradeoffs by imposing a common-mean assumption. In contrast, in our model, the risky asset can be mispriced, which can create such tradeoffs, and all agents are strategic. More importantly, all the papers mentioned above abstract from the tournament effect on asset prices. In contrast, we endogenize asset prices and show that different tournament structures can have different effects on portfolio choices and asset prices.

Some other theoretical papers investigating the impact of tournament incentives on asset markets use a cardinal setting in which an agent's payoff is a function of the ratio of her portfolio performance relative to a certain benchmark. Some of these papers abstract from the tournament effect on asset prices (e.g., Chen and Pennacchi, 2009; Basak and Makarov, 2012, 2014), while others endogenize asset prices (e.g., DeMarzo et al., 2007, 2008; Kaniel and Kondor, 2013). Specifically, DeMarzo et al. (2007, 2008) show that, when traders are risk averse and consumption goods are scarce, each trader's ability to consume depends on her relative wealth. This relative-wealth concern induces a herding incentive, which eventually leads to asset bubbles. Kaniel and Kondor (2013) assume that investors can decide on whether to delegate their trading decisions to fund managers. They find that, when the share of delegation is low, fund managers follow the same trading strategy, whereas when the share of delegation is high, managers employ heterogeneous trading strategies. In contrast to these papers, we focus on the effects of different tournament structures and we show that the heterogeneity/homogeneity of managers' trading strategies depends on the tournament structure. We find that managers play the same strategy only in EC and this strategic homogeneity need not induce mispricing.

Second, our paper relates to asset market experiments in which traders have non-linear incentives.[3] James and Isaac (2000) and Isaac and James (2003) document that tournament incentives lead to moderately larger price bubbles compared to markets with only linearly incentivized traders.

[3]For a recent experimental paper on how different tournament structures affect agents' effort decisions, see Dutcher et al. (2015).

In both studies, traders' payoff functions have both convex and tournament features—i.e., a trader's payoff consists of a fixed payment and a bonus payment if her performance is above average. Holmen et al. (2014) and Kleinlercher et al. (2014) use convex payment schemes where the bonus payment depends on fixed return targets. Both studies involve markets in which linearly incentivized traders interact with traders with convex incentives and both show no difference in overpricing and mispricing between these markets and markets with only linearly incentivized traders. Schoenberg and Haruvy (2012) report that, holding the payment structure fixed, experimental asset markets in which traders receive feedback about the top performer display larger asset bubbles than when information is given about the bottom performer, implying the existence of status concerns.

Our experimental setup differs from the experimental studies mentioned above in several aspects. First, none of these studies explicitly imposes a rank-dependent monetary payoff as we do. Second, we extend the analysis of Holmen et al. (2014) and Kleinlercher et al. (2014) to a setting in which traders with tournament incentives interact with linearly incentivized traders. In both these two earlier studies, non-linear incentives are modeled without tournament components but with fixed return targets. Third, we distinguish between the two major types of tournaments, WTA and EC, which are both relevant in the mutual fund industry. Fourth, James and Isaac (2000), Isaac and James (2003), and Schoenberg and Haruvy (2012) use the Smith et al. (1988) multi-period market design, which is prone to bubbles even without tournament incentives. We use a more efficient one-period setting. Finally, we refrain from investigating the impact of social comparison and status incentives on trading behavior (Schoenberg and Haruvy, 2012; Dijk et al., 2014) and solely focus on the monetary aspect of tournament incentives.

Our paper also innovates by using two complementary approaches, theory and experiment, to investigate the impact of tournament incentives on investment behavior and market outcomes. All of the studies mentioned above use either a theoretical or an experimental approach.[4] These two approaches have their own pros and cons. On the one hand, our static competitive market model allows

[4] Agranov et al. (2013) also use both theory and laboratory experiment for their investigation of how the competition for fund inflows impacts risk-taking behavior of laboratory portfolio managers who are compensated with option-like incentives. One major difference between their study and ours is that they apply a principal-agent framework where the agents invest funds of their (laboratory) clients. A second major difference is that they study variants of option-like compensation schemes, whereas we focus on different tournament structures.

us to derive sharp theoretical implications based only on very few parameters, but it abstracts from bounded rationality of individuals and the dynamic nature of real-world markets where continuous double auction is commonly adopted. On the other hand, our experimental asset markets enable us to incorporate the real-world trading mechanism and the dynamic interactions among boundedly rational traders into our analysis, but due to laboratory capacity, the size of our experimental markets is much smaller than the size of the real-world market. By combining both approaches, we can compare the theoretical results with the experimental ones to learn to what extent our theoretical implications hold in a much more complex setting, to identify the factors that might contribute to the difference, and to provide policy implications that can be drawn from both approaches.

3 The theoretical framework

Consider a two-period model ($t = 1,2$). There exists a risky asset which pays a nonnegative random terminal value of $\tilde{v}$ at $t = 2$. This terminal value, $\tilde{v}$, has a continuous and symmetric distribution. Let F be its cumulative distribution function (CDF) and F^{-1} be the associated quantile function. Let $v^* > 0$ be the expected value of $\tilde{v}$. Since the distribution is symmetric, its median equals its mean, i.e., $F^{-1}(1/2) = E(\tilde{v}) = v^*$.

There are two types of risk-neutral traders in the market: a continuum of fund managers with a unit measure and a continuum of ordinary traders. Fund managers and ordinary traders differ in their objective functions. Specifically, an ordinary trader consumes individual wealth at $t = 2$. Given risk neutrality, each ordinary trader thus maximizes the expected wealth. In contrast, a fund manager does not consume the fund's wealth at $t = 2$. Rather, she competes against other managers in fund performance: she wins a fixed prize, with value normalized to 1, if her fund's wealth at $t = 2$ is among the top θ proportion of all funds, where $\theta \in (0,1)$ denotes the winner proportion among fund managers, and she earns 0 if otherwise. Ties are broken randomly.[5] Given this payoff structure, each fund manager maximizes the probability of winning a prize.

At $t = 1$, fund managers have the same endowments, each with $C_m > 0$ units of cash and $S_m > 0$

[5]Given risk neutrality, it makes no difference whether we assume a random resolution of ties or an equal division of tie-related prize(s) among tied winners.

units of the risky asset.[6] Given the unit measure of fund managers, the total cash and asset endowments held by fund managers are C_m and S_m, respectively. Let $C_o > 0$ and $S_o > 0$ be, respectively, the total cash and asset endowments held by ordinary traders. We do not further specify each ordinary trader's endowments, since such specification does not affect any result.

Trading takes place at $t = 1$. All the traders in the market are competitive and are thus price takers. Shorting assets and borrowing money are not allowed. A price p is an equilibrium market price if and only if, at p, each trader's demand is optimal given the other traders' demand levels and the market can be cleared, i.e., the total aggregate excess demand can take the value of 0 at p.

3.1 Model analysis and implications

Given risk neutrality, ordinary traders' strategy is clear: they maximize demand when $p < v^*$, minimize demand when $p > v^*$, and are indifferent between all levels of feasible demand when $p = v^*$. In contrast, fund managers compete in a constant-sum game and their strategies depend on the winner proportion, θ. We call this competition a *winner-take-all tournament* (WTA) when $\theta < 1/2$ and an *elimination contest* (EC) when $\theta \geq 1/2$.[7]

Given the simple strategy of ordinary traders, the equilibrium can be derived in two steps. The first step is to search for equilibrium candidates, with the market price fixed: for every price level, p, find all the profiles of fund managers' strategies that are mutually best responses. Then, given the solutions derived from the first step, the second step is to filter these solutions and endogenize the market price: for every p, check if there exists a solution obtained from the first step such that, when combined with the ordinary traders' strategy, can clear the market. To save space, we relegate the detailed derivation to Appendix A. Instead, in what follows, we illustrate the basic logic and intuition behind a formal derivation, followed by the presentation of the equilibrium solutions.

In WTA, the winner proportion, θ, is strictly less than 1/2. This implies that, for an individ-

[6] We assume identical fund manager endowments for the purpose of comparing their performance. Otherwise, to compare performance, we would have to impose an initial price on the risky asset, unless all fund managers' initial cash to asset ratios were the same so that their performance can be compared based on rate of returns. There is no change of any qualitative result if we assume heterogeneous endowments with identical cash to asset ratio for fund managers.

[7] There exists a knife-edge case where $\theta = 1/2$. The equilibrium feature of this case is closer to the case where $\theta > 1/2$ than to the case where $\theta < 1/2$. Thus, for ease of exposition, we merge this knife-edge case with the case where $\theta > 1/2$.

ual manager, if her demand is between the demand levels of two groups of managers, each with a measure of at least θ, she will be outperformed by at least θ proportion of all the managers no matter whether $\tilde{v} > p$ or $\tilde{v} < p$. In this case, she can never win. In addition, a manager can garner a more-than-average probability of winning by either minimizing or maximizing her demand unless there are a sufficient number of managers who also play such a strategy that creates ties. As long as p is neither too high nor too low, i.e., $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$, the disadvantage of being "in the middle," combined with the advantage of being "at the corner," generically results in one group of managers minimizing and the other group maximizing asset demand. The proportion of each group is determined in a way to make a manager indifferent between minimizing and maximizing demand. Everything else being equal, an increase in p increases the probability that the terminal value, $\tilde{v}$, falls below p and thus increases a manager's expected payoff from minimizing asset demand. This induces more managers to minimize demand, thus eliminating the extra payoff from demand minimizing. When price is sufficiently high, i.e., when $p > F^{-1}(1-\theta)$, the probability that $\tilde{v} > p$ is less than θ. In this case, betting on the upside gives a winning probability less than the average winning probability, θ. Thus, all the managers bet on the downside by minimizing demand, each thus obtaining an average probability of winning. Analogously, when price is sufficiently low, i.e., when $p < F^{-1}(\theta)$, all the managers bet on the upside by maximizing demand. An interior level of demand is submitted by some managers *only* in the two borderline cases where $p = F^{-1}(1-\theta)$ or $p = F^{-1}(\theta)$, in which a continuum of profiles of mutually best-response strategies exist. Specifically, when $p = F^{-1}(1-\theta)$ ($p = F^{-1}(\theta)$), given a proportion $1-\theta$ of managers minimizing (maximizing) demand, the rest of the managers are indifferent between all feasible demand levels.

These observations imply a continuous and downward-sloping managers' aggregate excess demand curve in WTA that is negative when $p > F^{-1}(1-\theta)$ and positive when $p < F^{-1}(\theta)$. Such a curve, combined with ordinary traders' excess demand curve, produces a continuous and downward-sloping total aggregate excess demand curve that is negative when $p > F^{-1}(1-\theta)$ and positive when $p < F^{-1}(\theta)$. Hence, there exists a unique asset price that clears the market. This equilibrium market price lies on the interval $[F^{-1}(\theta), F^{-1}(1-\theta)]$ and is weakly increasing (decreasing) in fund managers' cash (asset) endowments. These results are formalized as follows.

Proposition 1 (WTA)**.** *When $\theta < 1/2$, there exists a unique equilibrium market price p, which is weakly increasing in fund managers' cash endowments, C_m, and weakly decreasing in fund managers' asset endowments, S_m. There exist two cutoff points, C_m^l and C_m^h (defined by Equations* (A-1) *and* (A-2)*, respectively, in the proof of Proposition 1 in Appendix A) such that*

i. if $C_m \le C_m^l$, then $p = F^{-1}(\theta)$ and a proportion $1-\theta$ of fund managers maximize demand while the rest of managers can play different strategies with a sufficient proportion of them submitting negative excess demand to clear the market;

ii. if $C_m \in (C_m^l, C_m^h)$, then $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$ and a proportion $F(p)$ of fund managers minimize demand while the rest of managers maximize demand;

iii. if $C_m \ge C_m^h$, then $p = F^{-1}(1-\theta)$ and a proportion $1-\theta$ of fund managers minimize demand while the rest of managers can play different strategies with a sufficient proportion of them submitting positive excess demand to clear the market.

There is overpricing, i.e., $p > v^*$, if

$$C_m > (2S_o + S_m)v^*. \tag{1}$$

There is underpricing, i.e., $p < v^*$, if

$$S_m > \frac{2C_o + C_m}{v^*}. \tag{2}$$

Proposition 1 implies that, generically, in WTA, fund managers play aggressive and heterogeneous trading strategies by either fully cashing in or cashing out of the market. Whether and how their activism affects the asset price depends on their endowments. When managers have sufficiently large cash endowments, the cash supplied by the group of managers who maximize asset demand is large enough to absorb all the asset supplied by the rest of the traders at price above the expected asset value, v^*. In this case, overpricing exists and all the risky asset is finally held by the group of managers who maximize asset demand. Analogously, when managers have sufficiently large asset endowments, the asset supplied by the group of managers who minimize asset demand is large enough to meet all the cash supplied by the rest of the traders at price below the fundamental value. In this case, underpricing exists and all the cash is finally held by the group of managers who minimize asset demand. In both these two cases, all the traders end up with only cash or asset. Thus, trading volume is large.

Now we turn to EC, where the winner proportion, θ, is weakly greater than 1/2. Note that, when $\theta \geq 1/2$, the loser proportion, $1-\theta$, is weakly less than 1/2. This implies that, if a manager's demand is between the demand levels of two groups of managers, each with a measure of at least $1-\theta$, the manager will never lose. Thus, in contrast to WTA, in which being "in the middle" brings disadvantage to a manager, in EC, a middle demand position brings advantage. Since managers are strategic and the competition they face is a constant-sum game, equilibrium generically requires every manager to play the same strategy so that no manager is able to exploit the other managers by "hiding herself in the middle." When $p \in (F^{-1}(1-\theta), F^{-1}(\theta))$, the probability that $\tilde{v} > p$ and the probability that $\tilde{v} < p$ are both greater than $1-\theta$. In this case, for a given manager, as long as all her competitors play the same strategy, by deviating from the crowd, she will lose with certainty either when $\tilde{v} > p$ or when $\tilde{v} < p$. Thus, her probability of losing will be more than $1-\theta$, the average probability of losing, and she thus has no incentive to deviate from the crowd. Hence, when $p \in (F^{-1}(1-\theta), F^{-1}(\theta))$, there is a continuum of strategy profiles consistent with the best-response condition and, in all these profiles, fund managers submit the same demand. Such a continuum of strategy profiles shrinks to a single profile when price is sufficiently high or sufficiently low, i.e., when $p > F^{-1}(\theta)$ or $p < F^{-1}(1-\theta)$. This is because, when price is sufficiently high (low), a manager will find it profitable to bet on the downside (upside) by minimizing (maximizing) demand even when all the other managers demand at a different level. The only strategy profile that satisfies the best-response condition when price is sufficiently high (low) is the one with all the managers minimizing (maximizing) demand. Since such a strategy is in the same direction as ordinary traders' strategy, the market cannot be cleared. Thus, the equilibrium market price must be on the interval $[F^{-1}(1-\theta), F^{-1}(\theta)]$.[8]

Since when $p \in [F^{-1}(1-\theta), F^{-1}(\theta)]$, there is a continuum of strategy profiles consistent with

[8] In the two borderline cases where $p = F^{-1}(1-\theta)$ or $p = F^{-1}(\theta)$, with $\theta > 1/2$, equilibrium only requires a proportion θ of managers to submit the same demand, while the rest can play other strategies. These two borderline cases merge when $\theta = 1/2$, in which case $p = F^{-1}(1/2) = v^*$ and all demand levels are optimal for a manager at $p = v^*$.

the best-response condition, there is a continuum of aggregate excess demand levels consistent with the best-response condition. This leads to an interval of equilibrium market prices.

To arrive at sharp implications for EC given the multiplicity of equilibrium prices, we use *security* as our equilibrium selection principle. This selection principle is based on the "riskiness" of an equilibrium following Von Neumann and Morgenstern's (1972) concept of maximin and receives experimental support from Van Huyck et al. (1991). A manager's maximin strategy is a strategy that maximizes the manager's minimum possible payoff. For a given manager, we can determine her maximin strategy by treating all her competing managers as if they acted collectively to minimize her payoff. An equilibrium satisfies the security principle if it is supported by maximin strategies. Note that, when $p > v^*$, the terminal asset value is more likely to be below p instead of above p. Thus, a manager's maximin strategy is to bet on the downside by minimizing asset demand. However, given that ordinary traders also minimize asset demand when $p > v^*$, if managers play the maximin strategy, the market cannot be cleared. Thus, $p > v^*$ is not consistent with the security principle. Analogously, $p < v^*$ is not consistent with the security principle either, because a manager's maximin strategy when $p < v^*$ is to bet on the upside by maximizing demand and then the market again cannot be cleared. The only price consistent with the security principle is $p = v^*$. When $p = v^*$, the terminal asset value has an equal probability of being above or below p. Thus, given $\theta \geq 1/2$, any feasible demand is a maximin strategy for a manager that produces a maximin value equal to 1/2 probability of winning.

Proposition 2 (EC)**.** *When $\theta \geq 1/2$, $p = v^*$ is the unique equilibrium market price consistent with the security principle. At this price, in equilibrium, fund managers demand the same if $\theta > 1/2$.*[9]

In contrast to WTA, in which fund managers play heterogeneous and aggressive trading strategies, Proposition 2 implies that, in EC, fund managers play the same trading strategy that need not be aggressive. Regarding market price, the price in EC does not differ from the price in a market with only ordinary traders. In contrast, in WTA, if fund managers have sufficiently large cash en-

[9]When $\theta = 1/2$, at the equilibrium market price $p = v^*$, each fund manager is indifferent between buying and selling, in which case homogeneous and heterogeneous strategies can both sustain an equilibrium. Without the application of the security principle, the full range of equilibrium prices in the case of $\theta > 1/2$ is given in the proof of Proposition 2 in Appendix A.

dowments, there will be overpricing and all the risky asset will finally be held by a group of fund managers. We thus obtain the following key implications of our model.

Implication 1: Fund managers play more heterogeneous and aggressive trading strategies in WTA than in EC. When fund managers' cash endowments exceed the threshold specified in Condition (1), fund managers on average hold more units of the risky asset in WTA than in EC and, in WTA, fund managers on average hold more units of the risky asset than ordinary traders.

Implication 2: Market price exhibits no difference between EC and a market with only ordinary traders. In contrast, when fund managers' cash endowments exceed the threshold specified in Condition (1), market price in WTA is higher than the price in a market with only ordinary traders.

4 The experiment

4.1 Market architecture

In the above section, based on a static competitive market model, we derived two key implications, one on the tournament effects on managerial investment behavior and the other on the tournament effects on market price. In this section, we run experimental asset markets with a real-world trading mechanism. Our purpose is to see to what extent the implications derived from a simple competitive market model are consistent with the experimental results from a more complex setting.

In each experimental market, eight subjects interact in a sequence of 12 independent periods of 150 seconds each. The common-value asset lives for one period and is bought back by the experimenter at the end of each period at the *buy-back value* (BBV). This BBV serves as the terminal value of the asset and is determined through a random draw from a uniform distribution over the values between 0 and 100 (with one decimal place) in each period. Thus, the fundamental value (FV) equals 50. In each market, one period is randomly drawn to be relevant for payout for all subjects.

Each subject is initially endowed with 20 units of the asset and with 4000 Taler (the virtual currency), resulting in each subject's initial expected wealth of $20 \times 50 + 4000 = 5000$ Taler. Asset and Taler holdings are not carried over from one period to the next. No interest is paid on Taler holdings. There are no transaction costs. Shorting assets and borrowing money are not allowed.

The trading mechanism is a continuous double auction with open order books. Subjects are allowed to freely place limit and market orders. Any order size, the partial execution of limit orders, and the deletion of posted limit orders are possible.[10] At the start of each trading period, order books are empty. During a trading period, subjects are continuously informed about all open limit orders, their own asset and cash holdings, and a chart containing all trading prices in the current period (see Figure C1 in Appendix C for further details on the trading screen).

4.2 Treatments

We conduct two tournament-relevant treatments and one linear treatment as a benchmark. In both tournament-relevant treatments, there are eight subjects, half of them facing one of the two tournament incentive schemes (either WTA or EC) and the other half facing linear incentives (ordinary traders). Note that our parameter choices in the experiment satisfy Condition (1) under which theory implies overpricing and large end-of-period asset holdings of fund managers in WTA.[11] Subjects know that there are two types of traders in the market—four ordinary traders and four fund managers—and that their incentive scheme depends on their type. However, subjects are not informed about the exact incentive scheme of the subjects of the other type. The specific characteristics of the treatments are as follows.

In Treatment WTA, fund managers are ranked according to *final wealth* after each period. Final wealth is calculated as units of the asset times BBV plus cash holdings. Only the best performing fund manager among the four managers receives a prize of 40 Euro as payout, while the other three fund managers receive zero. The four ordinary traders in each market receive their final wealth converted into Euro at a rate of 500 Taler equaling 1 Euro.

Treatment EC differs from Treatment WTA only in the number of winners and the winner prize.

[10] A limit order enables a trader to specify price and quantity. Price is given priority over time for the execution of limit orders. In contrast, for a market order, the price is given and one can only specify the quantity. Market orders are executed immediately.

[11] Under our parameter choices, managers' total cash endowments, C_m, equal $4 \times 4000 = 16000$, managers' total asset endowments, S_m, equal $4 \times 20 = 80$, ordinary traders' total asset endowments, S_o, equal $4 \times 20 = 80$, and FV, v^*, equals 50. Thus, $C_m = 16000 > 12000 = (2 \times 80 + 80) \times 50 = (2S_o + S_m)v^*$ and, hence, Condition (1) is satisfied.

Specifically, in Treatment EC, only the worst performing fund manager receives zero while all the other three fund managers get a prize of 13.33 Euro each.[12] In both treatments, in case of a relevant tie, tied winners split the tie-related prize(s).

In Treatment LINEAR, all subjects play the role of ordinary traders and face the same linear compensation structure. Their final wealth is exchanged at a rate of 500 Taler equaling 1 Euro, which is the same as the exchange rate for ordinary traders in Treatments WTA and EC.

4.3 Implementation of the experiment

Nine markets were run for each treatment. All 27 markets were conducted in the Innsbruck_EconLab at the University of Innsbruck with a total of 216 bachelor and master students in business administration and economics. Each subject participated in only one market and we made sure that subjects did not participate in earlier asset market experiments with a comparable design. The markets were programmed and conducted with z-Tree 3.4.7. developed by Fischbacher (2007). Subjects were recruited using HROOT developed by Bock et al. (2014). Each experimental session lasted for approximately 80 minutes, including 20 minutes for reading the written instructions.

We conducted a risk elicitation task before running the main experiment. To test for subjects' risk attitudes, we employed a mechanism based on Crosetto and Filippin (2013), where subjects are asked to choose out of 25 cards how many and which cards they want to reveal. If they do not reveal the bomb which is behind one card, they receive 30 eurocent for each card revealed. When they select the bomb, they get nothing. Thus, the fewer cards a subject reveals, the higher is her degree of risk-aversion.

After the risk elicitation task, we conducted two trial periods and then the main experiment.

4.4 Results

4.4.1 Individual behavior

We start by investigating whether different tournament structures affect individual trader behavior differently. We refrain from incorporating Treatment LINEAR into this comparative analysis, be-

[12]The total price value in Treatment EC is $13.33 \times 3 \approx 40$ Euro, which equals the total price value in Treatment WTA.

cause Treatment LINEAR differs in too many aspects from the two tournament treatments and most analyses require the existence of fund managers in the market for the comparison with ordinary traders' behavior.[13] To investigate the differences in behavior between fund managers and ordinary traders, in Table 1, we report GLS random-effects regressions with standard errors clustered at the market level. We use subjects' average final WEALTH across all periods, the average end-of-period ASSET HOLDINGS, the corresponding average final CASH HOLDINGS, and the average total TRADING VOLUME. TRADING VOLUME is defined as the average number of assets traded by the subject across all periods. FUND_MANAGER is a binary dummy indicating whether a subject is a fund manager or not. We control for risk attitudes by including an individual risk measure, RISK. The more cards a subject selects, the higher is her value of the variable RISK, and thus the more risk a subject takes. Ordinary traders are captured by the intercept.

We find that fund managers and ordinary traders behave differently and the differences in their behavior depend on the tournament structure. Consistent with the theoretical implication, fund managers in Treatment WTA take significantly more risks compared to ordinary traders in the same treatment. Managers invest significantly more in the risky asset and, accordingly, hold significantly less cash than ordinary traders. The qualitative results reverse for fund managers in Treatment EC, where they hold more cash and less risky asset compared to ordinary traders, but the effect is not significant. We also find a tendency that fund managers in WTA end up with lower levels of final wealth than ordinary traders—however the differences are insignificant. The cautious behavior of fund managers in Treatment EC is also shown with the variable TRADING_VOLUME. Fund managers in EC trade significantly less than ordinary traders, which is in stark contrast to fund managers in Treatment WTA, who trade significantly more by 8 units. Note that risk attitudes only partly explain behavior in one out of the eight regressions in Table 1.[14] This implies that incentives shape behavior more strongly than individuals' risk attitudes.

[13]Treatment LINEAR differs from the two tournament treatments in many aspects. For example, the number of ordinary traders equals 8 in Treatment LINEAR but equals 4 in Treatments WTA and EC. Also, in Treatments WTA and EC, each ordinary trader knows the existence of fund managers.

[14]Risk attitudes only significantly affect trading volume in EC at the 10 percent level. There, the positive sign of the RISK coefficient implies that less risk-averse subjects trade more in EC.

Table 1: GLS regressions for differences in behavior between fund managers and ordinary traders.

WEALTH	WTA	EC
α	5060.707***	4883.526***
	(57.549)	(59.522)
FUND_MANAGER	−45.666	109.675
	(−1.355)	(1.061)
RISK	−0.268	9.449
	(−0.057)	(1.168)
N	72	72

ASSET_HOLDINGS	WTA	EC
α	15.577***	17.080***
	(4.657)	(4.109)
FUND_MANAGER	4.957**	−2.585
	(2.002)	(−0.878)
RISK	0.190	0.402
	(0.479)	(1.005)
N	72	72

CASH_HOLDINGS	WTA	EC
α	4292.768***	4094.220***
	(19.919)	(15.837)
FUND_MANAGER	−304.390*	214.267
	(−1.875)	(0.924)
RISK	−13.752	−19.227
	(−0.531)	(−0.725)
N	72	72

TRADING_VOLUME	WTA	EC
α	16.632***	10.737
	(6.375)	(1.547)
FUND_MANAGER	8.272***	−9.174**
	(3.469)	(−2.035)
RISK	0.264	1.619*
	(1.396)	(1.845)
N	72	72

WEALTH, ASSET_HOLDINGS, CASH_HOLDINGS, and TRADING_VOLUME serve as dependent variables. WEALTH is the average final wealth of the subjects across all periods, ASSET_HOLDINGS stands for the average number of end-of-period asset holdings of the subject, CASH_HOLDINGS indicates the average end-of-period cash holdings of the subject, and TRADING_VOLUME is the average number of assets traded by the subject across all periods. FUND_MANAGER equals one if the subject is a fund-manager and zero otherwise. RISK indicates subject risk attitudes (higher levels indicating more risk-taking behavior). Ordinary traders are captured by the intercept. N is the number of observations, with each observation indicating the subject average across all periods. Coefficients and z-values (in parentheses) are provided.
*, ** and *** represent the 10%, 5% and the 1% significance levels of a double-sided test.

In Table 2, we analyze whether fund managers differ in trading behavior *across* the two tournament treatments. We use subjects' average final wealth, the average end-of-period asset holdings, the corresponding average final cash holdings, and the average total trading volume for all fund managers. We apply a GLS random-effects regression with standard errors clustered at the market level. EC is a binary treatment dummy and WTA is captured by the intercept. Again RISK is included as an independent variable. The qualitative nature of the results in Table 2 is consistent with the theoretical implication and is in line with Table 1. Fund managers in Treatment WTA take significantly more risks than those in EC by investing more in the risky asset and holding less cash.

Table 2: GLS regressions for differences in fund manager behavior *across* treatments.

Fund managers	WEALTH	ASSET_HOLDINGS	CASH_HOLDINGS	TRADING_VOLUME
α	4984.113***	22.101***	3822.155***	21.507***
	(40.700)	(4.306)	(12.541)	(3.656)
EC	84.908	−3.543**	246.281**	−8.382
	(0.915)	(−2.022)	(1.974)	(−1.429)
RISK	2.693	0.040	2.163	0.589
	(0.313)	(0.085)	(0.078)	(0.921)
N	72	72	72	72

WEALTH, ASSET_HOLDINGS, CASH_HOLDINGS, and TRADING_VOLUME serve as dependent variables. WEALTH is the average final wealth of the subjects across all periods, ASSET_HOLDINGS stands for the average number of end-of-period asset holdings of the subject, CASH_HOLDINGS indicates the average end-of-period cash holdings of the subject, and TRADING_VOLUME is the average number of assets traded by the subject across all periods. RISK indicates subject risk attitudes (higher levels indicating more risk-taking behavior). EC equals one if the observation is from an elimination contest and zero otherwise. WTA is captured by the intercept. N is the number of observations, with each observation indicating the subject average across all periods. Coefficients and z-values (in parentheses) are provided. *, ** and *** represent the 10%, 5% and the 1% significance levels of a double-sided test.

In Table 3, we investigate whether, as implied by theory, fund managers play more heterogeneous strategies in WTA than in EC. We calculate the standard deviations of asset holdings and of wealth of the four fund managers (FUND_MANAGER) and of the four ordinary traders (ORDINARY_TRADER) in each period and investigate differences between treatments. We set up a GLS random-effects panel regression model with standard errors clustered at the market level and with a binary dummy for Treatment EC. Low values of standard deviations suggest that fund managers tend to have similar asset holdings and similar wealth levels, which indicates a relatively homogeneous investment behavior. High values of standard deviations indicate more diverse asset holdings and thus more diverse trading behavior among fund managers.

Table 3: GLS panel regressions of standard deviations of asset holdings and wealth for fund managers and ordinary traders per period.

	S.D. of asset holdings		S.D. of wealth	
Treatment	FUND_MANAGER	ORDINARY_TRADER	FUND_MANAGER	ORDINARY_TRADER
α	23.658***	14.584***	590.106***	381.542***
	(12.084)	(6.309)	(9.014)	(5.876)
EC	−13.254***	0.682	−283.201***	93.746
	(−5.983)	(0.253)	(−3.625)	(1.014)
N	216	216	216	216

S.D. of asset holdings and S.D. of wealth serve as dependent variables. S.D. of asset holdings FUND_MANAGER (ORDINARY_TRADER) is the standard deviation of asset holdings among fund managers (ordinary traders) in each period. S.D. of wealth FUND_MANAGER (ORDINARY_TRADER) indicates the standard deviation of wealth among fund managers (ordinary traders) in each period. EC equals one if the observation is from an elimination contest and zero otherwise. WTA is captured by the intercept. N is the number of observations, with each observation indicating the standard deviation for one type of traders in one period of a market. Coefficients and z-values (in parentheses) are provided. *, ** and *** represent the 10%, 5% and the 1% significance levels of a double-sided test.

The first column of Table 3 shows that the standard deviation of asset holdings among fund managers is significantly lower in Treatment EC than in WTA. This result indicates that fund managers act more heterogeneously in WTA than in EC. The second column of Table 3 displays no significant differences in the standard deviations of asset holdings among ordinary traders across both treatments. Columns three and four support these results by showing a significantly higher standard deviation of wealth for fund managers in WTA than in EC and no significant differences for ordinary traders. Again, this result hints at more diverse trading strategies among fund managers in Treatment WTA than in EC, which is consistent with the theoretical implication.

4.4.2 Aggregate market outcomes

In Figure 1 and Table 4, we investigate whether different tournament structures affect market prices differently as implied by theory. Figure 1 shows the volume-weighted mean prices of individual markets and the mean treatment prices, and figures for the individual markets are reported in Appendix B. From Figure 1, we can see that in Treatment WTA, in almost all the individual markets, the volume-weighted mean price is constantly above the fundamental value (FV) of 50 for all periods and, in most of the individual markets, the volume-weighted mean price is constantly close to or above 60. In contrast, in Treatment EC, in most of the individual markets, the volume-weighted mean price is constantly below 60. However, there are two markets in Treatment EC in which the volume-weighted mean price is constantly high (around 75). As a result, the mean treatment prices between WTA and EC do not exhibit much difference. In Treatment LINEAR, there is considerable variation in the volume-weighted mean prices across individual markets. Some individual markets exhibit large overpricing whereas some exhibit underpricing. However, similar to Treatments WTA and EC, the mean treatment price in Treatment LINEAR is also constantly above the FV of 50.

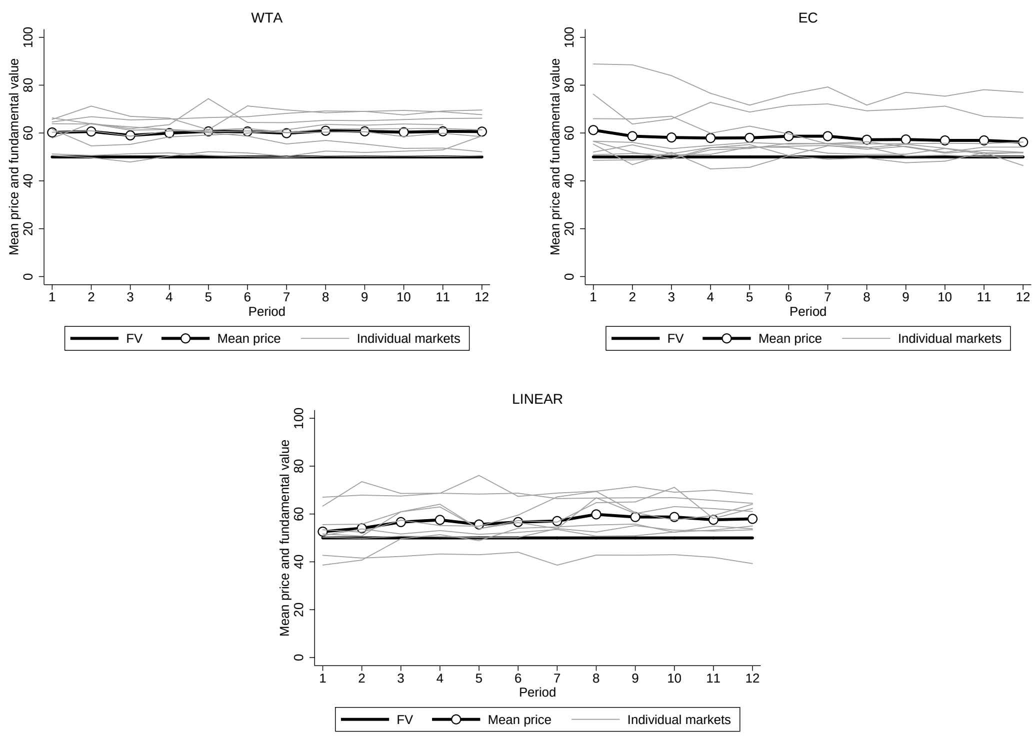

Figure 1: Market data across the three treatments: Fundamental value (FV, bold line), mean treatment prices (bold line with circles) and volume-weighted mean prices of individual markets (grey lines) as a function of period.

Table 4 reports GLS random-effects panel regressions with markets as cross-section and periods as observations over time. As dependent variables, we use RAD (relative absolute deviation), which is calculated as the percentage absolute deviation of the mean price from the FV of 50 in each period of each market, and RD (relative deviation), which measures the percentage of overvaluation of mean prices relative to FV (see Stöckl et al. (2010) for details on RAD and RD). In addition, we examine other market variables, such as volatility of market prices (VOLA), which is calculated as the standard deviation of all log-returns within a period, the average bid-ask spread (SPREAD) within a period, which is expressed as a percentage of the FV, and share turnover (ST), which is calculated as trading volume divided by shares outstanding.[15] The variables WTA and EC are binary dummies for the respective treatments and thus Treatment LINEAR is captured by the intercept. We cluster standard errors on a market level to account for non-independence of observations within a market.

Table 4: Regression results for treatment differences in mispricing (RAD), overpricing (RD), intra-period volatility (VOLA), bid-ask spread (SPREAD), and share turnover (ST).

Treatment	RAD	RD	VOLA	SPREAD	ST
α	0.176***	0.133**	0.082***	0.159***	0.422***
	(4.762)	(2.502)	(4.437)	(5.983)	(7.901)
WTA	0.030	0.073	−0.025	−0.004	0.170*
	(0.566)	(1.102)	(−1.171)	(−0.110)	(1.926)
EC	−0.010	0.024	0.017	0.061	0.154
	(−0.135)	(0.296)	(0.661)	(1.470)	(1.274)
N	323	323	323	323	323
Pairwise Wald-tests:					
WTA vs. EC	0.31	0.43	4.13**	2.23	0.02

RAD, RD, VOLA, SPREAD, and ST serve as dependent variables. RAD is the percentage absolute deviation of the mean price from the fundamental value. RD stands for the percentage of overvaluation of mean prices relative to fundamental value. VOLA measures the standard deviation of all log-returns within a period. SPREAD indicates the average bid-ask spread per period as a percentage of fundamental value. ST is the number of traded shares per period divided by shares outstanding. EC equals one if the observation is from an elimination contest and zero otherwise. WTA equals one if the observation is from a winner-take-all tournament and zero otherwise. Treatment LINEAR is captured by the intercept. N is the number of observations, with each observation indicating the market-level average in one period of a market. Top panel: Coefficients and z-values (in parentheses) are provided. Bottom panel: Pairwise Wald-tests: Chi2-values are given.
*, ** and *** represent the 10%, 5% and the 1% significance levels of a double-sided test.

Table 4 shows that Treatment WTA has the highest degree of overpricing (RD) with 20.6 percent (intercept plus the WTA coefficient), followed by Treatment EC with 15.7 percent (intercept

[15]These variables and variations of them are frequently used in the literature (see, e.g., Kirchler et al., 2011, 2012; Huber et al., 2015).

plus the EC coefficient) and Treatment LINEAR with 13.3 percent. However, pairwise Wald coefficient tests reveal no significant differences between Treatment WTA and EC. The pattern is similar for all variables, showing mainly insignificant differences between coefficients, with the exception of a marginally significantly higher trading volume (ST) in Treatment WTA compared to Treatment LINEAR and a significantly higher volatility measure (VOLA) in Treatment EC compared to Treatment WTA.[16] Thus, although different tournament structures affect individual trader behavior differently, they do not lead to significantly different aggregate market outcomes.

The moderate overpricing in Treatment LINEAR is not unusual and is backed by the literature. In their multi-period markets with constant fundamental values and linearly incentivized traders, Holmen et al. (2014) and Kleinlercher et al. (2014) show moderate levels of RD of 12 and 8 percent (in asset LOW_RISK), respectively.[17] Similarly, Cueva and Rustichini (2015) report moderate overpricing of 3 and 5 percent in their female-only and male-only markets, respectively, with constant fundamentals inspired by the multi-period markets of Noussair et al. (2001). The results of our tournament treatments WTA and EC can be interpreted in light of the HYBRID-treatments in Holmen et al. (2014) and Kleinlercher et al. (2014). In the former, half of the traders in the market are endowed with linear and half with convex incentives (with fixed return targets). In the latter, the mixed markets are composed of traders with convex, linear, and penalty-like incentives (with fixed return targets). In both studies, these markets show no difference in the degree of mispricing compared to markets with only linearly incentivized traders.

5 Summary and conclusion

In this paper, we investigate the impact of tournament incentives of fund managers on investment behavior and market efficiency, distinguishing between *winner-take-all tournaments* (WTA), in which a minority of fund managers win, and *elimination contests* (EC), in which a majority of fund managers win. For this investigation, we use two complementary approaches, theory and laboratory

[16] The significantly higher VOLA in Treatment EC is due to two outlier markets.

[17] Whereas the overpricing in Treatment LINEAR in Holmen et al. (2014) can partly be explained by the positive skewness of asset fundamentals, asset LOW_RISK in Kleinlercher et al. (2014) has a symmetric distribution of the buyback values.

experiment, to get a comprehensive picture of the effects.

Our theory implies that, in WTA, fund managers play heterogeneous strategies by either fully buying into or cashing out of the market. Furthermore, assets are overpriced if managers have sufficiently large cash endowments. In contrast, in EC, managers play the same strategy, and the fundamental value is the unique equilibrium market price consistent with the security principle.

We contribute to the theoretical literature on mutual fund tournaments in two aspects. First, our theoretical model differs from the earlier ones (e.g., Taylor, 2003; Chen et al., 2015) by distinguishing between different tournament structures. We show that different tournament structures can affect fund managers' trading strategies and market outcomes differently. Second, we endogenize asset prices and analyze how tournament incentives affect asset prices. This is in contrast to many earlier studies that focus on portfolio choices under exogenous asset prices (e.g., Taylor, 2003; Gaba et al., 2004; Chen and Pennacchi, 2009; Basak and Makarov, 2014; Chen et al., 2015).

Our experimental results can be summarized as follows. First, consistent with the theoretical implications, we observe more aggressive and more diverse trading behavior of fund managers in Treatment WTA than in Treatment EC. Second, these experimental differences in trading behavior do not result in significant differences in the aggregate market outcomes. Market prices do not differ significantly between Treatment WTA and EC and they do not differ from prices in the markets composed solely of ordinary traders (Treatment LINEAR). Such a difference between the theoretical implications and the experimental results on the aggregate market level might be explained by the fact that, in our experiment, boundedly rational subjects behave broadly in line with the theoretical implications but not perfectly so. Given that our experimental markets are small, if an individual subject behaves "peculiarly," this peculiar behavior may "churn" the market, adding considerable noise into our aggregate market-level data. Thus, although we find a slightly higher average price in Treatment WTA than in EC, because of noise, this price difference is not significant.

We extend the previous laboratory asset market research along two dimensions. First, our results differ from James and Isaac (2000) and Isaac and James (2003) who document moderate bubble and crash patterns when all traders have tournament incentives compared to a baseline case where all traders are linearly incentivized. This discrepancy in results between their studies and ours may be explained by the fact that, in our markets, at least half of the traders are linearly incentivized. It may also be due to the differences in trading horizons (multi-period asset markets in their studies versus one-period markets in ours) and the differences in the asset market models. Both James and Isaac (2000) and Isaac and James (2003) apply a multi-period setting with the bubble-prone model of Smith et al. (1988), making bubbles much more likely. It is well documented that bubbles and crashes can emerge in asset markets with long trading horizons even when all traders are linearly incentivized, particularly in the presence of cash or trader inflows (Smith et al., 1988, 2014; Kirchler et al., 2015). In our case, we use a baseline market which runs for one period, making speculation less likely. With our design, however, we cannot predict whether the relatively efficient pricing observed in our markets will prevail in multi-period settings where stronger mispricing is more likely in general. Second, we extend the set of insights gained from markets with subjects with different incentives interacting with each other. Such market experiments are pioneered by Holmen et al. (2014) and Kleinlercher et al. (2014). We find that tournament incentives per se do not necessarily exacerbate overvaluation when a sufficiently large fraction of ordinary traders is present in laboratory asset markets.

The results in this paper have at least two real-world implications. The first relates to the policy discussion about the regulation of investment managers' incentive schemes (Turner, 2009; Walker, 2009). Given that, in our experiment, markets with only linearly incentivized traders show similar levels of overvaluation and mispricing compared to markets containing tournament incentivized traders, it appears as if instabilities of financial markets on an aggregate level may not originate from tournament incentives. Our theory also partially supports this view by showing that, in EC where managers aim to avoid being a bottom performer, market efficiency is the same as the efficiency of markets with only linearly incentivized traders. There are two caveats here. First, our theory implies that market efficiency may depend on the tournament structure and EC is less prone to mispricing than WTA. Thus, our first implication may be more likely to hold for EC than for WTA. Second, in Treatments WTA and EC in our experiment, half of the traders have linear incentives and there are only eight traders in an individual market. Whether our first implication can be drawn from laboratory markets with most traders having tournament incentives, with more traders, and with multi-period markets which can make speculation more likely is difficult to judge and open for future research.

The second implication relates to individual financial institutions. Here, it is important to be aware of the effects of tournament incentives (or aspects of them) for fund managers. As suggested by both theory and laboratory experiments, these incentives appear to affect fund managers' investment strategies, which may lead to, depending on the tournament structure predominantly applied, increased or decreased risk-taking. As a consequence, individual financial institutions may experience undesired risk exposure triggered by fund managers' tournament incentives.

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References

Agranov, Marina, Alberto Bisin, Andrew Schotter. 2013. An experimental study of the imact of competition for other people's money: The portfolio manager market. *Experimental Economics* **17**(4) 564–585.

Allen, Franklin. 2001. Do financial institutions matter? *Journal of Finance* **56**(4) 1165–1175.

Allen, Franklin, Gary Gorton. 1993. Churning bubbles. *Review of Economic Studies* **60**(4) 813–836.

Basak, Suleyman, Dmitry Makarov. 2012. Difference in interim performance and risk taking with short-sale constraints. *Journal of Financial Economics* **103** 377–392.

Basak, Suleyman, Dmitry Makarov. 2014. Strategic asset allocation in money management. *Journal of Finance* **69** 179–217.

Bock, Olaf, Ingmar Baetge, Andreas Nicklisch. 2014. hroot: Hamburg registration and organization online tool. *European Economic Review* **71** 117–120.

Chen, Hsiu-lang, George G. Pennacchi. 2009. Does prior performance affect a mutual fund's choice of risk? theory and further empirical evidence. *Journal of Financial and Quantative Analysis* **44** 745–775.

Chen, Joseph, Eric Hughson, Neal Stoughton. 2015. Strategic mutual fund tournaments. *Working Paper* .

Chevalier, Judith, Glenn Ellison. 1997. Risk taking by mutual funds as a response to incentives. *Journal of Political Economy* **105** 1167–1200.

Chevalier, Judith, Glenn Ellison. 1999. Career concerns of mutual fund managers. *Quarterly Journal of Economics* **114** 389–432.

Crosetto, Paolo, Antonio Filippin. 2013. The "bomb" risk elicitation task. *Journal of Risk and Uncertainty* **47** 31–65.

Cueva, Carlos, Aldo Rustichini. 2015. Is financial instability male-driven? gender and cognitive skills in experimental asset markets. *Working Paper* .

Deli, Daniel N. 2002. Mutual fund advisory contracts: An empirical investigation. *Journal of Finance* **57** 109–134.

DeMarzo, Peter M., Ron Kaniel, Ilan Kremer. 2007. Technological innovation and real investment booms and busts. *Journal of Financial Economics* **85** 735–754.

DeMarzo, Peter M., Ron Kaniel, Ilan Kremer. 2008. Relative wealth concerns and financial bubbles. *Review of Financial Studies* **21** 19–50.

Dijk, Oege, Martin Holmen, Michael Kirchler. 2014. Rank matters. the impact of social competition on portfolio choice. *European Economic Review* **66** 97–110.

Dutcher, E Glenn, Loukas Balafoutas, Florian Lindner, Dmitry Ryvkin, Matthias Sutter. 2015. Strive to be first or avoid being last: An experiment on relative performance incentives. *Games and Economic Behavior* **94** 39–56.

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

Gaba, Anil, Ilia Tsetlin, Robert L. Winkler. 2004. Modifying variability and correlations in winner-take-all contests. *Operations Research* **52** 384–395.

Hanouna, Paul, Jon Novak, Tim Riley, Christof Stahel. 2015. Liquidity and flows of u.s. mutual funds. *SEC Staff Papers, Available at https://www.sec.gov/dera/staff-papers/white-papers/liquidity-white-paper-09-2015.pdf* .

Holmen, Martin, Michael Kirchler, Daniel Kleinlercher. 2014. Do option-like incentives induce overvaluation? evidence from experimental asset markets. *Journal of Economic Dynamics and Control* **40** 179–194.

Huang, Jennifer, Kelsey D. Wei, Hong Yan. 2007. Participation costs and the sensitivity of fund flows to past performance. *Journal of Finance* **62** 1273–1311.

Huber, Jürgen, Michael Kirchler, Daniel Kleinlercher, Matthias Sutter. 2015. Market vs. residence principle: Experimental evidence on the effects of a financial transaction tax. *Economic Journal* **Forthcoming**.

Isaac, Mark R., Duncan James. 2003. Boundaries of the tournament pricing effect in asset markets: Evidence from experimental markets. *Southern Economic Journal* **69**(4) 936–951.

James, Duncan, Mark R. Isaac. 2000. Asset markets: How they are affected by tournament incentives for individuals. *American Economic Review* **90** 995–1004.

Kaniel, Ron, Péter Kondor. 2013. The delegated lucas tree. *Review of Financial Studies* **26** 929–984.

Kempf, Alexander, Stefan Ruenzi, Tanja Thiele. 2009. Employment risk, compensation incentives, and managerial risk taking: Evidence from the mutual fund industry. *Journal of Financial Economics* **92** 92–108.

Khorana, Ajay. 1996. Top management turnover: An empirical investigation of mutual fund managers. *Journal of Financial Economics* **40** 403–429.

Kirchler, Michael, Caroline Bonn, Jürgen Huber, Michael Razen. 2015. The "inflow-effect" - trader inflow and price efficiency. *European Economic Review* **77** 1–19.

Kirchler, Michael, Jrgen Huber, Daniel Kleinlercher. 2011. Market microstructure matters when imposing a tobin tax - evidence from laboratory experiments. *Journal of Economic Behavior & Organization* **80**(3) 586–602.

Kirchler, Michael, Jürgen Huber, Thomas Stöckl. 2012. Thar she bursts - reducing confusion reduces bubbles. *American Economic Review* **102**(2) 865–883.

Kleinlercher, Daniel, Jürgen Huber, Michael Kirchler. 2014. The impact of different incentive schemes on asset prices. *European Economic Review* **68** 137–150.

Ma, Linlin, Yuehua Tang, Juan-Pedro Gómez. 2015. Portfolio manager compensation in the u.s. mutual fund industry. *Working Paper* .

Noussair, Charles N., Stephane Robin, Bernard Ruffieux. 2001. Price bubbles in laboratory asset markets with constant fundamental values. *Experimental Economics* **4** 87–105.

Qiu, Jiaping. 2003. Termination risk, multiple managers and mutual fund tournaments. *European Finance Review* **7** 161–190.

Rajan, Raghuram G. 2006. Has finance made the world riskier? *European Financial Management* **12**(4) 499–533.

Schoenberg, Eric, Ernan Haruvy. 2012. Relative performance information in asset markets: An experimental approach. *Journal of Economic Psychology* **33** 1143–1155.

Sirri, Erik R., Peter Tufano. 1998. Costly search and mutual fund flows. *Journal of Finance* **53** 1589–1622.

Smith, Alec, Terry Lohrenz, Justin King, Read Montague, Colin Camerer. 2014. Irrational exuberance and neural crash warning signals during endogenous experimental market bubbles. *Proceedings of the National Academy of Science* **111**(29) 10503–10508.

Smith, Vernon L., Gerry L. Suchanek, Arlington W. Williams. 1988. Bubbles, crashes, and endogenous expectations in experimental spot asset markets. *Econometrica* **56**(5) 1119–1151.

Stöckl, Thomas, Jürgen Huber, Michael Kirchler. 2010. Bubble measures in experimental asset markets. *Experimental Economics* **13** 284–298.

Taylor, Jonathan. 2003. Risk-taking behavior in mutual fund tournaments. *Journal of Economic Behavior & Organization* **50** 373–383.

Turner, Adair. 2009. *A Regulatory Response to the Global Banking Crisis*. Financial Services Authority, London.

Van Huyck, John B., Raymond C. Battalio, Richard O. Beil. 1991. Strategic uncertainty, equilibrium selection, and coordination failure in average opinion games. *Quarterly Journal of Economics* **106** 885–910.

Von Neumann, John, Oskar Morgenstern. 1972. *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton University Press.

Walker, David. 2009. *A Review of Corporate Governance in UK Banks and Other Financial Industry Entities: Final Recommendations*. Online Archive.

Appendix A Proofs of results

To prove Propositions 1 and 2, we first make several definitions that will be used throughout the proofs. Then we develop several auxiliary results. The proof of Proposition 1 is provided after we establish Lemma A-8, which shows the managers' mutually best-response strategies and their corresponding aggregate excess demand conditional on p in WTA. The proof of Proposition 2 is provided after we establish Lemma A-9, which shows the managers' mutually best-response strategies and their corresponding aggregate excess demand conditional on p in EC.

The following definitions will be used throughout the proofs. Let Z_m and Z_o be fund managers' and ordinary traders' aggregate excess demand for the risky asset, respectively. Let $Z = Z_m + Z_o$ be the total aggregate excess demand. Let $\mathscr{M}$ be the set of fund managers with a unit measure. For manager $i \in \mathscr{M}$, let z_i be manager i's individual excess demand. Let $\mathscr{M}_l \subset \mathscr{M}$ represent a set of managers with a measure of $1-\theta$ such that, for every manager $i \in \mathscr{M}_l$ and $j \in \mathscr{M} \backslash \mathscr{M}_l$, $z_i \leq z_j$. Let $\mathscr{M}_h \subset \mathscr{M}$ represent a set of managers with a measure of $1-\theta$ such that, for every manager $i \in \mathscr{M}_h$ and $j \in \mathscr{M} \backslash \mathscr{M}_h$, $z_i \geq z_j$. Thus, $\mathscr{M}_l$ ($\mathscr{M}_h$) represents a proportion $1-\theta$ of managers who demand weakly less (more) units of the asset than the rest of the managers.

Lemma A-1. *Ordinary traders' aggregate excess demand Z_o satisfies $Z_o = \frac{C_o}{p}$ if $p < v^*$, $Z_o = -S_o$ if $p > v^*$, and Z_o can take any value in $[-S_o, \frac{C_o}{v^*}]$ if $p = v^*$.*

Proof. Given risk neutrality, ordinary traders are expected wealth maximizers. Thus, given that the expected value of the asset is v^*, ordinary traders maximize demand when $p < v^*$, minimize demand when $p > v^*$, and are indifferent between all levels of feasible demand when $p = v^*$. Since borrowing and short selling are not allowed, Z_o is bounded below by $-S_o$ and bounded above by C_o/p, and the result thus follows. □

Lemma A-2. *In equilibrium, managers have the same probability of winning, equal to θ.*

Proof. Since managers are atomless, their payoff functions must be identical. Since managers are homogeneous, by playing a best reply to the same payoff function, they must have the same probability of winning. Since the winner proportion is θ, this probability of winning must equal θ. □

Lemma A-3. *For any two managers $i, j \in \mathscr{M}$, with $z_i < z_j$, i strictly outperforms j if $\tilde{v} < p$ while j strictly outperforms i if $\tilde{v} > p$.*

Proof. By buying z_i units of the asset, manager i finally holds $S_m + z_i$ units of the asset and $C_m - z_i p$ units of cash. Thus, manager i's final performance is $(C_m - z_i p) + (S_m + z_i)\tilde{v}$. Similarly, manager j's final performance is $(C_m - z_j p) + (S_m + z_j)\tilde{v}$. Thus, the performance difference between i and j equals $(z_i - z_j)(\tilde{v} - p)$, which, given $z_i < z_j$, is positive if $\tilde{v} < p$ and negative if $\tilde{v} > p$. $\square$

Lemma A-4. *In all equilibria with $p < F^{-1}(\theta)$, if there are any, all the managers in $\mathscr{M}_l$ demand the same amount of the asset.*

Proof. We prove by way of contradiction. Suppose, contrary to the lemma, that there exist managers $i, k \in \mathscr{M}_l$ such that $z_i < z_k$. Since $z_k \leq z_j$ for all $j \in \mathscr{M} \backslash \mathscr{M}_l$, we must have $z_i < z_j$ for all $j \in \mathscr{M} \backslash \mathscr{M}_l$. Thus, by Lemma A-3, when $\tilde{v} > p$, i will be strictly outperformed by all the managers in $\mathscr{M} \backslash \mathscr{M}_l$. This implies, given that the measure of $\mathscr{M} \backslash \mathscr{M}_l$ equals θ, that i cannot win when $\tilde{v} > p$. Note that, when $p < F^{-1}(\theta)$, we must have $\mathbb{P}(\tilde{v} > p) > 1 - \theta$. Thus, i's probability of losing is strictly greater than $1 - \theta$. This contradicts Lemma A-2 and the result thus follows. $\square$

Lemma A-5. *In all equilibria with $p > F^{-1}(1 - \theta)$, if there are any, all the managers in $\mathscr{M}_h$ demand the same amount of the asset.*

Proof. We prove by way of contradiction. Suppose, contrary to the lemma, that there exist managers $i, k \in \mathscr{M}_h$ such that $z_i > z_k$. Since $z_k \geq z_j$ for all $j \in \mathscr{M} \backslash \mathscr{M}_h$, we must have $z_i > z_j$ for all $j \in \mathscr{M} \backslash \mathscr{M}_h$. Thus, by Lemma A-3, when $\tilde{v} < p$, i will be strictly outperformed by all the managers in $\mathscr{M} \backslash \mathscr{M}_h$. This implies, given that the measure of $\mathscr{M} \backslash \mathscr{M}_h$ equals θ, that i cannot win when $\tilde{v} < p$. Note that $\tilde{v}$ is atomless, so given $p > F^{-1}(1 - \theta)$, we have $\mathbb{P}(\tilde{v} < p) = \mathbb{P}(\tilde{v} \leq p) = F(p) > 1 - \theta$. Thus, i's probability of losing is strictly greater than $1 - \theta$. This contradicts Lemma A-2 and the result thus follows. $\square$

Lemma A-6. *In all equilibria with $p < F^{-1}(1 - \theta)$, if there are any,*

i. all the managers in $\mathscr{M} \backslash \mathscr{M}_l$ demand the same amount of the asset;

ii. some managers in $\mathscr{M}_l$ also demand this amount of the asset.

Proof. (i): We prove by way of contradiction. Suppose, contrary to part (i) in the lemma, that there exist managers $j,k \in \mathscr{M} \setminus \mathscr{M}_l$ such that $z_j > z_k$. Since $z_k \geq z_i$ for all $i \in \mathscr{M}_l$, we must have $z_j > z_i$ for all $i \in \mathscr{M}_l$. Thus, by Lemma A-3, when $\tilde{v} > p$, j will strictly outperform all the managers in $\mathscr{M}_l$. This implies, given that the measure of $\mathscr{M}_l$ equals $1-\theta$, that j wins with certainty when $\tilde{v} > p$. Since, when $p < F^{-1}(1-\theta)$, we must have $\mathbb{P}(\tilde{v} > p) > \theta$. Thus, j's probability of winning is strictly greater than θ. This contradicts Lemma A-2 and the result thus follows.

(ii): The proof of part (ii) is similar to the proof of part (i). Specifically, if all the managers in $\mathscr{M}_l$ have strictly lower demand than those in $\mathscr{M} \setminus \mathscr{M}_l$, then the managers in $\mathscr{M} \setminus \mathscr{M}_l$ will win with certainty if $\tilde{v} > p$, which occurs with a probability strictly greater than θ if $p < F^{-1}(1-\theta)$. This contradicts Lemma A-2. □

Lemma A-7. *In all equilibria with $p > F^{-1}(\theta)$, if there are any,*

i. *all the managers in $\mathscr{M} \setminus \mathscr{M}_h$ demand the same amount of the asset;*

ii. *some managers in $\mathscr{M}_h$ also demand this amount of the asset.*

Proof. (i): We prove by way of contradiction. Suppose, contrary to part (i) in the lemma, that there exist managers $j,k \in \mathscr{M} \setminus \mathscr{M}_h$ such that $z_j < z_k$. Since $z_k \leq z_i$ for all $i \in \mathscr{M}_h$, we must have $z_j < z_i$ for all $i \in \mathscr{M}_h$. Thus, by Lemma A-3, when $\tilde{v} < p$, j will strictly outperform all the managers in $\mathscr{M}_h$. This implies, given that the measure of $\mathscr{M}_h$ equals $1-\theta$, that j wins with certainty when $\tilde{v} < p$. Since $\tilde{v}$ is atomless, when $p > F^{-1}(\theta)$, we must have $\mathbb{P}(\tilde{v} < p) > \theta$. Thus, j's probability of winning is strictly greater than θ. This contradicts Lemma A-2 and the result thus follows.

(ii): The proof of part (ii) is similar to the proof of part (i). Specifically, if all the managers in $\mathscr{M}_h$ have strictly higher demand than those in $\mathscr{M} \setminus \mathscr{M}_h$, then the managers in $\mathscr{M} \setminus \mathscr{M}_h$ will win with certainty if $\tilde{v} < p$, which occurs with a probability strictly greater than θ if $p > F^{-1}(\theta)$. This contradicts Lemma A-2. □

Lemma A-8. *When $\theta < 1/2$, if p is an equilibrium price, then in all equilibria associated with p, managers' strategies and their aggregate excess demand, Z_m, are as follows:*

i. *if $p < F^{-1}(\theta)$, all managers maximize demand, in which case $Z_m = C_m/p$;*

ii. if $p = F^{-1}(\theta)$, a proportion $1-\theta$ of managers maximize demand and, for each of the other managers, any feasible demand level is optimal, in which case Z_m can take any value in $[-\theta S_m + (1-\theta)C_m/F^{-1}(\theta), C_m/F^{-1}(\theta)]$;

iii. if $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$, a proportion $F(p)$ of managers minimize demand and all the other managers maximize demand, in which case $Z_m = -F(p)S_m + (1-F(p))C_m/p$;

iv. if $p = F^{-1}(1-\theta)$, a proportion $1-\theta$ of managers minimize demand and, for each of the other managers, any feasible demand level is optimal, in which case Z_m can take any value in $[-S_m, -(1-\theta)S_m + \theta C_m/F^{-1}(1-\theta)]$;

v. if $p > F^{-1}(1-\theta)$, all managers minimize demand, in which case $Z_m = -S_m$.

Proof. (i) and (v): First consider the case where $p < F^{-1}(\theta)$. Given $\theta < 1/2$, $p < F^{-1}(\theta)$ implies that $p < F^{-1}(1-\theta)$. Then Lemmas A-4 and A-6 imply that all the managers have the same asset demand in equilibrium. Note that this demand must be the maximal demand, since otherwise, a manager could obtain a probability of winning strictly greater than θ and thus be better off by demanding more than the peer managers. When all the managers maximize demand, $Z_m = C_m/p$. Next consider the case where $p > F^{-1}(1-\theta)$. Given $\theta < 1/2$, $p > F^{-1}(1-\theta)$ implies that $p > F^{-1}(\theta)$. Then Lemmas A-5 and A-7 imply that all the managers have the same asset demand. Note that this demand must be the minimal demand, since otherwise, a manager can obtain a probability of winning strictly greater than θ and thus be better off by demanding less than the peer managers. When all the managers minimize demand, $Z_m = -S_m$.

(iii): Consider the case where $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$. By Lemma A-6, all the managers in $\mathscr{M}\backslash\mathscr{M}_l$ have the same individual demand, which we denote by z_h. By Lemma A-7, all the managers in $\mathscr{M}\backslash\mathscr{M}_h$ have the same individual demand, which we denote by z_l. Note that, by the definitions of $\mathscr{M}_l$ and $\mathscr{M}_h$, both $\mathscr{M}\backslash\mathscr{M}_l$ and $\mathscr{M}\backslash\mathscr{M}_h$ contain a group of managers with a measure equal to $\theta < 1/2$, and given $\theta < 1/2$, $\mathscr{M}_l \cap \mathscr{M}_h \neq \emptyset$. Thus, for any manager $i \in \mathscr{M}_l \cap \mathscr{M}_h$, it must be that either $z_i = z_h$ or $z_i = z_l$, since otherwise i would always be strictly outperformed by a group of managers with a measure weakly greater than θ no matter whether $\tilde{v} > p$ or $\tilde{v} < p$, in which case i would never win. Thus, there are at most two distinct levels of demand submitted by managers.

Notably, it must *not* be the case that all the managers have the same demand. This is because, if all of them have the same demand, given that $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$, a manager can obtain a probability of winning strictly greater than θ by either demanding more or demanding less. Thus, in equilibrium, there must be exactly two distinct levels of demand.

Let $\mathscr{M}_L$ and $\mathscr{M}_H$ be the groups of managers whose demand equals z_l and z_h, respectively, where $z_l < z_h$. The above analysis implies that $\mathscr{M}_L \cup \mathscr{M}_H = \mathscr{M}$, $\mathscr{M} \backslash \mathscr{M}_l \subset \mathscr{M}_H$, and $\mathscr{M} \backslash \mathscr{M}_h \subset \mathscr{M}_L$. Let μ be the measure corresponding to $\mathscr{M}_L$. Since $\mathscr{M} \backslash \mathscr{M}_h$ has a measure of θ and since $\mathscr{M} \backslash \mathscr{M}_h \subset \mathscr{M}_L$, we must have $\mu \geq \theta$. Similarly, since $\mathscr{M}_H$ has a measure of $1-\mu$, $\mathscr{M} \backslash \mathscr{M}_l$ has a measure of θ, and $\mathscr{M} \backslash \mathscr{M}_l \subset \mathscr{M}_H$, we must have $1-\mu \geq \theta$. These imply that for manager $i \in \mathscr{M}_L$, she wins only if $\tilde{v} < p$, which occurs with probability $F(p)$. Moreover, conditional on $\tilde{v} < p$, all the managers in $\mathscr{M}_L$ have the same chance of winning. Since the measure of $\mathscr{M}_L$ is $\mu \geq \theta$, conditional on $\tilde{v} < p$, prizes must be rationed and each manager in $\mathscr{M}_L$ has a probability of winning equal to θ/μ. Thus, the unconditional probability of winning for manager $i \in \mathscr{M}_L$ is $F(p)\theta/\mu$, which, by Lemma A-2, must equal θ. Hence, $\mu = F(p)$.

Clearly, when $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$, the managers in $\mathscr{M}_L$ must minimize demand and the managers in $\mathscr{M}_H$ must maximize demand, since otherwise, a manager could obtain a probability of winning strictly greater than θ by either maximizing or minimizing demand. Thus, given that $\mathscr{M}_L$ has a measure of $\mu = F(p)$ and $\mathscr{M}_H$ has a measure of $1-\mu = 1-F(p)$, we must have $Z_m = -F(p)S_m + (1-F(p))C_m/p$. This completes the proof of part (iii).

(ii) and (iv): When $p = F^{-1}(\theta)$, the managers in $\mathscr{M}_H$, which has a measure of $1-F(p) = 1-\theta$, must maximize demand (see the proof of part (iii) above), while for each manager in $\mathscr{M}_L$, any feasible demand is optimal, where $\mathscr{M}_H$ and $\mathscr{M}_L$ are defined in the proof of part (iii). When $p = F^{-1}(1-\theta)$, the managers in $\mathscr{M}_L$, which has a measure of $F(p) = 1-\theta$, must minimize demand, while for each manager in $\mathscr{M}_H$, any feasible demand is optimal. It is easy to check that these strategies are mutually optimal and each manager has a probability of winning equal to θ. Thus, when $p = F^{-1}(\theta)$, Z_m can take any value in $[-\theta S_m + \frac{(1-\theta)C_m}{F^{-1}(\theta)}, \frac{C_m}{F^{-1}(\theta)}]$, and when $p = F^{-1}(1-\theta)$, Z_m can take any value in $[-S_m, -(1-\theta)S_m + \frac{\theta C_m}{F^{-1}(1-\theta)}]$. $\square$

Proof of Proposition 1. Lemmas A-1 and A-8 imply that $Z = Z_m + Z_o > 0$ if $p < F^{-1}(\theta)$ and $Z < 0$ if $p > F^{-1}(1-\theta)$. Thus, $p < F^{-1}(\theta)$ or $p > F^{-1}(1-\theta)$ cannot be an equilibrium price. For

$p \in [F^{-1}(\theta), F^{-1}(1-\theta)]$, Lemmas A-1 and A-8 imply that

a. if $p = F^{-1}(\theta)$, Z can take any value in $[-\theta S_m + \frac{(1-\theta)C_m + C_o}{F^{-1}(\theta)}, \frac{C_m + C_o}{F^{-1}(\theta)}]$;

b. if $p \in (F^{-1}(\theta), v^*)$, $Z = -F(p)S_m + (1-F(p))\frac{C_m}{p} + \frac{C_o}{p}$;

c. if $p = v^*$, Z can take any value in $[-F(p)S_m + (1-F(p))\frac{C_m}{p} - S_o, -F(p)S_m + (1-F(p))\frac{C_m}{p} + \frac{C_o}{p}]$, which interval equals $[-\frac{S_m}{2} + \frac{C_m}{2v^*} - S_o, -\frac{S_m}{2} + \frac{C_m}{2v^*} + \frac{C_o}{v^*}]$ given $p = v^*$;

d. if $p \in (v^*, F^{-1}(1-\theta))$, $Z = -F(p)S_m + (1-F(p))\frac{C_m}{p} - S_o$;

e. if $p = F^{-1}(1-\theta)$, Z can take any value in $[-S_m - S_o, -(1-\theta)S_m + \frac{\theta C_m}{F^{-1}(1-\theta)} - S_o]$.

Note that, given $p \in [F^{-1}(\theta), F^{-1}(1-\theta)]$, increasing p strictly decreases Z (even if Z can take any value in some interval in some special cases). Thus, if there exists an equilibrium, the equilibrium price must be unique. Also note that, in all the cases listed above, fixing p, increasing C_m or decreasing S_m always weakly increases both the lower and the upper bound of the range of values that Z can take on. Thus, given that increasing p strictly decreases Z, it must be that the unique equilibrium price is weakly increasing in C_m and weakly decreasing in S_m.

To show parts (i) to (iii), note that, if $C_m \le C_m^l$, where

$$C_m^l = \frac{\theta F^{-1}(\theta)S_m - C_o}{1-\theta}, \tag{A-1}$$

the set of Z presented in (a) above can take the value of 0, in which case $p = F^{-1}(\theta)$ is the equilibrium price. Thus, part (ii) of Lemma A-8 implies part (i) of Proposition 1. If $C_m \ge C_m^h$, where

$$C_m^h = \frac{F^{-1}(1-\theta)}{\theta}\left((1-\theta)S_m + S_o\right), \tag{A-2}$$

the set of Z presented in (e) above can take the value of 0, in which case $p = F^{-1}(1-\theta)$ is the equilibrium price. Thus, part (iii) of Proposition 1 follows from part (iv) of Lemma A-8. If $C_m \in (C_m^l, C_m^h)$, it must be that $p \in (F^{-1}(\theta), F^{-1}(1-\theta))$. Thus, part (ii) of Proposition 1 follows from part (iii) of Lemma (A-8).

Finally, note that, when C_m satisfies Condition (1), by part (c) presented above, the range of values of Z when $p = v^*$ lies on the strictly positive real line. In this case, given that increasing p strictly decreases Z, Z can take on the value of 0 only when $p > v^*$. Thus, when C_m satisfies

Condition (1), there must exist overpricing. Similarly, when S_m satisfies Condition (2), the range of values of Z when $p = v^*$ lies on the strictly negative real line. In this case, given that increasing p strictly decreases Z, Z can take on the value of 0 only when $p < v^*$. Thus, when S_m satisfies Condition (2), there must exist underpricing. □

Lemma A-9. *When $\theta > 1/2$, if p is an equilibrium price, then in all equilibria associated with p, managers' strategies and their aggregate excess demand, Z_m, are as follows:*

i. if $p < F^{-1}(1-\theta)$, all managers maximize demand, in which case $Z_m = C_m/p$;

ii. if $p = F^{-1}(1-\theta)$, a proportion θ of managers choose the same demand z with $z \in [-S_m, C_m/F^{-1}(1-\theta)]$ and the individual demand of each of the rest of the managers can take any value in $[z, C_m/F^{-1}(1-\theta)]$, in which case Z_m can take any value in $[-S_m, C_m/F^{-1}(1-\theta)]$;

iii. if $p \in (F^{-1}(1-\theta), F^{-1}(\theta))$, all managers demand the same and this demand can take any value in $[-S_m, C_m/p]$ and thus Z_m can take any value in $[-S_m, C_m/p]$;

iv. if $p = F^{-1}(\theta)$, a proportion θ of managers choose the same demand z with $z \in [-S_m, C_m/F^{-1}(\theta)]$ and the individual demand of each of the rest of the managers can take any value in $[-S_m, z]$, in which case Z_m can take any value in $[-S_m, C_m/F^{-1}(\theta)]$;

v. if $p > F^{-1}(\theta)$, all managers minimize demand, in which case $Z_m = -S_m$.

When $\theta = 1/2$, if p is an equilibrium price, then in all equilibria associated with p, managers' strategies and their aggregate excess demand, Z_m, are as follows:

a. if $p < v^*$, all managers maximize demand, in which case $Z_m = C_m/p$;

b. if $p = v^*$, any demand is optimal for a manager, in which case Z_m can take any value in $[-S_m, C_m/v^*]$;

c. if $p > v^*$, all managers minimize demand, in which case $Z_m = -S_m$.

Proof. (i) and (v): Note that when $\theta > 1/2$, $p < F^{-1}(1-\theta)$ implies that $p < F^{-1}(\theta)$, and $p > F^{-1}(\theta)$ implies that $p > F^{-1}(1-\theta)$. Then the results follow immediately from the argument in the proof of parts (i) and (v) of Lemma A-8.

(iii): Consider the case where $p \in (F^{-1}(1-\theta), F^{-1}(\theta))$. By Lemmas A-4 and A-5, the managers in $\mathscr{M}_l$ have the same asset demand, which we denote by z_l, and the managers in $\mathscr{M}_h$ also have the same asset demand, which we denote by z_h. In this case, it must be that $z_l = z_h$, since otherwise, given that both $\mathscr{M}_l$ and $\mathscr{M}_h$ have a measure of $1-\theta$, by demanding any $z \in (z_l, z_h)$, a manager would never lose, which contradicts Lemma A-2. Given the definitions of $\mathscr{M}_l$ and $\mathscr{M}_h$, $z_l = z_h$ implies that all the managers demand the same. As long as all the managers demand the same, by deviating to a different demand level, a manager will lose either when $\tilde{v} > p$ or when $\tilde{v} < p$. Since $p \in (F^{-1}(1-\theta), F^{-1}(\theta))$, the probability that $\tilde{v} > p$ and the probability that $\tilde{v} < p$ are both strictly greater than $1-\theta$, which is higher than the average probability of losing. Thus, a manager has no incentive to deviate. Hence, Z_m can take any value in $[-S_m, C_m/p]$.

(ii) and (iv): First consider the case where $p = F^{-1}(1-\theta)$. When $\theta > 1/2$, $p = F^{-1}(1-\theta)$ implies that $p < F^{-1}(\theta)$. Thus, by Lemma A-4, all the managers in $\mathscr{M}_l$ have the same demand. By the definition of $\mathscr{M}_l$, the managers in $\mathscr{M}_l$ have weakly lower demand than the rest of the managers, so manager $i \in \mathscr{M}_l$ must have the weakly lowest return if $\tilde{v} > p$, which occurs with probability θ when $p = F^{-1}(1-\theta)$. If μ represents the measure of managers who demand the same as manager i, then conditioned on $\tilde{v} > p$, manager i's probability of losing equals $\min[1, (1-\theta)/\mu]$. Since in equilibrium, manager i's probability of losing equals $1-\theta$ and since the probability of $\tilde{v} > p$ equals θ, we must have $\mu \geq \theta$, i.e., there must exist at least a proportion θ of managers who demand the same as manager $i \in \mathscr{M}_l$. It is easy to see that, as long as a proportion θ of all the managers have the same demand and the rest of the managers have weakly higher demand, given $p = F^{-1}(1-\theta)$, all the managers have a probability of losing equal to $1-\theta$ and no manager has an incentive to deviate. Thus, Z_m can take any value in $[-S_m, C_m/F^{-1}(1-\theta)]$ when $p = F^{-1}(1-\theta)$.

Next, consider the case where $p = F^{-1}(\theta)$. Given that the analysis is similar to above, we shall be brief. By Lemma A-5, all the managers in $\mathscr{M}_h$ have the same demand. Given that the managers in $\mathscr{M}_h$ have weakly higher demand than the rest of the managers, the managers in $\mathscr{M}_h$ must have the weakly lowest return if $\tilde{v} < p$, which occurs with probability θ when $p = F^{-1}(\theta)$. Then for a manager in $\mathscr{M}_h$ to have a probability of losing equal to $1-\theta$, there must exist at least a proportion θ of managers who have the same demand as that manager. Then it is easy to check that, as long as a proportion θ of all the managers have the same demand and the rest of the managers have weakly lower demand, no manager has an incentive to deviate. Thus, Z_m can take any value in

$[-S_m, C_m/F^{-1}(\theta)]$ when $p = F^{-1}(\theta)$.

(a), (b), and (c): When $\theta = 1/2$, $F^{-1}(1-\theta) = F^{-1}(\theta) = v^*$. The proofs of parts (a) and (c) are the same as the proofs of parts (i) and (v). To prove (b), note that if $p = v^*$, then regardless of all the managers' strategies, each manager always has a probability of winning equal to 1/2. Thus, Z_m can take any value in $[-S_m, C_m/v^*]$. $\square$

Proof of Proposition 2. First, consider the case in which $\theta = 1/2$. Lemma A-1 and parts (a), (b), and (c) of Lemma A-9 imply that $Z = Z_m + Z_o > 0$ if $p < v^*$, $Z < 0$ if $p > v^*$, and Z can take any value in $[-S_m - S_o, (C_m + C_o)/v^*]$ if $p = v^*$. Thus, if $\theta = 1/2$, then $p = v^*$ is the unique equilibrium price. Note that, by part (b) of Lemma A-9, when $\theta = 1/2$, managers are indifferent between all feasible demand levels at $p = v^*$. Thus, when $\theta = 1/2$, there exist equilibria in which managers play the same strategy and also there exist equilibria in which managers follow different strategies.

Next, consider the case in which $\theta > 1/2$. By Lemma A-1 and parts (i) and (v) of Lemma A-9, when $\theta > 1/2$, $Z = Z_m + Z_o > 0$ if $p < F^{-1}(1-\theta)$ and $Z < 0$ if $p > F^{-1}(\theta)$. Thus, $p < F^{-1}(1-\theta)$ and $p > F^{-1}(\theta)$ cannot sustain an equilibrium. For $p \in [F^{-1}(1-\theta), F^{-1}(\theta)]$, Lemma A-1 and parts (ii), (iii), and (iv) of Lemma A-9 imply that (a) if $p \in [F^{-1}(1-\theta), v^*)$, Z can take any value in $[-S_m + \frac{C_o}{p}, \frac{C_m+C_o}{p}]$, (b) if $p = v^*$, Z can take any value in $[-S_m - S_o, \frac{C_m+C_o}{v^*}]$, and (c) if $p \in (v^*, F^{-1}(\theta)]$, Z can take any value in $[-S_m - S_o, \frac{C_m}{p} - S_o]$. The price p is an equilibrium price if Z can take the value of 0. Thus, when $\theta > 1/2$, p is an equilibrium price if p satisfies one of the following conditions:

i. $p \in [F^{-1}(1-\theta), v^*)$ and $p \geq \frac{C_o}{S_m}$;

ii. $p = v^*$;

iii. $p \in (v^*, F^{-1}(\theta)]$ and $p \leq \frac{C_m}{S_o}$.

Among the above set of p, only $p = v^*$ is consistent with the security principle (the argument is provided right before Proposition 2 in the main text). The result that managers demand the same at $p = v^*$ when $\theta > 1/2$ follows from part (iii) of Lemma A-9. $\square$

Appendix B Additional figures

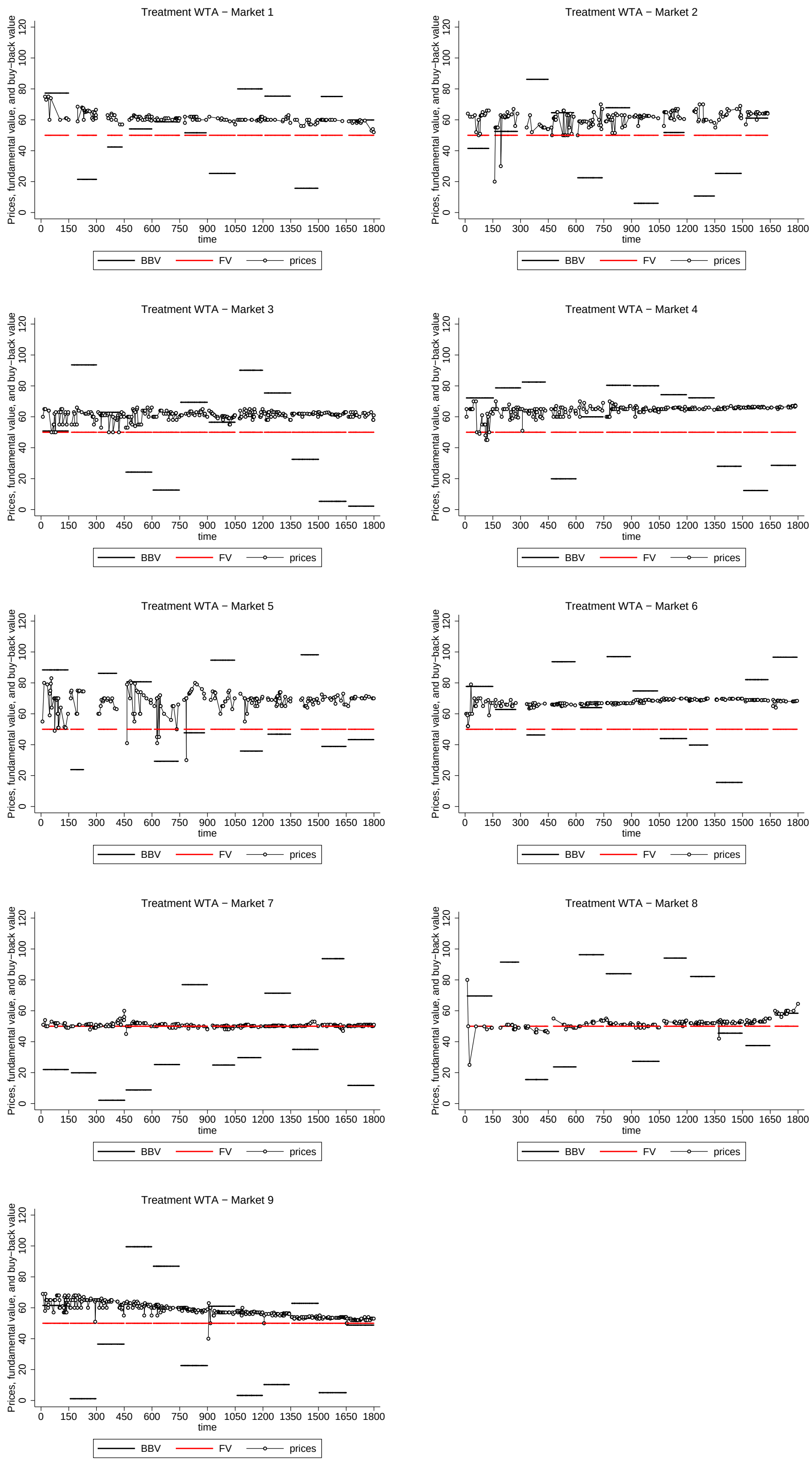

Figure B1: Individual transaction prices, fundamental value (FV) and buy-back value (BBV) of the asset in Treatment WTA as a function of time.

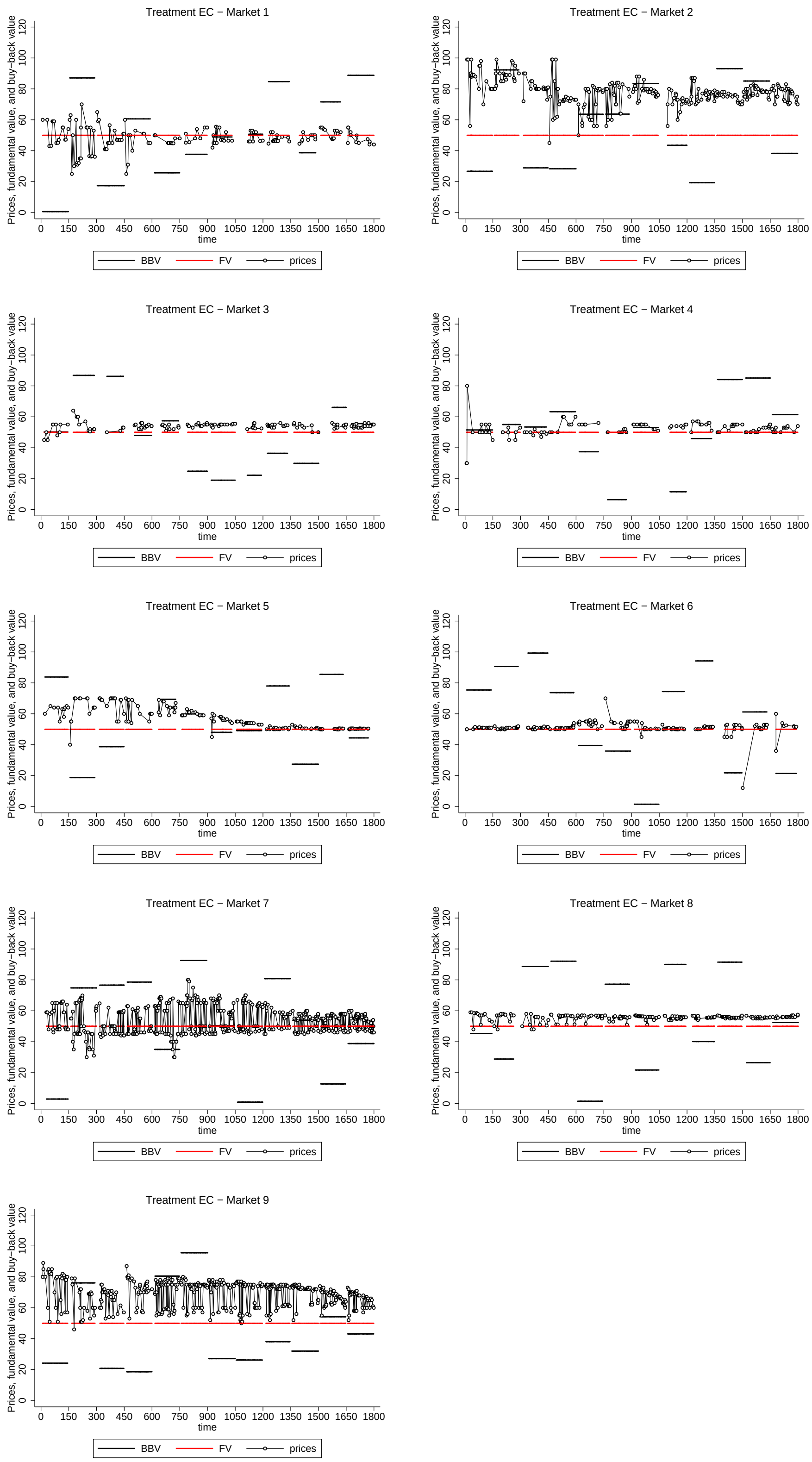

Figure B2: Individual transaction prices, fundamental value (FV) and buy-back value (BBV) of the asset in Treatment EC as a function of time.

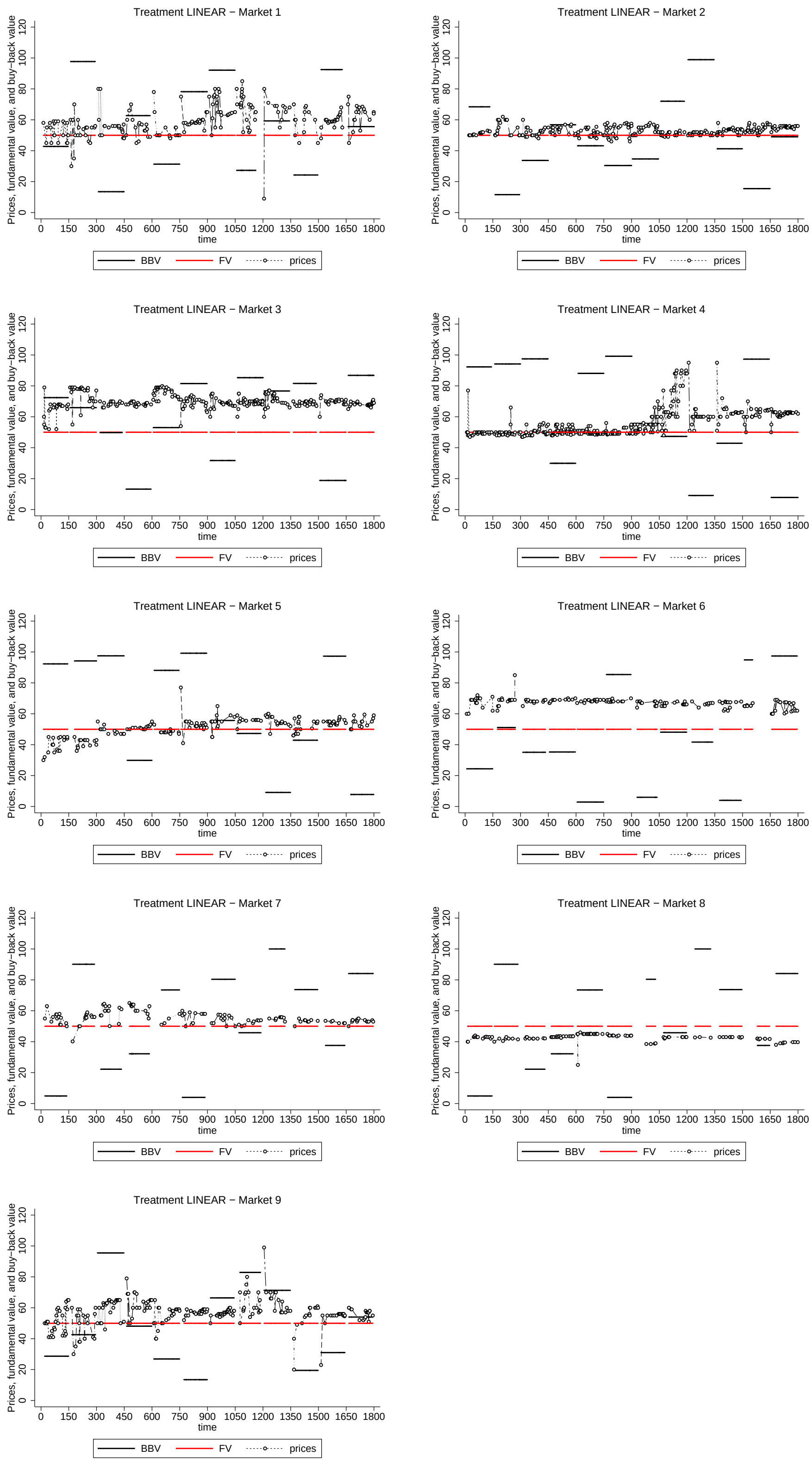

Figure B3: Individual transaction prices, fundamental value (FV) and buy-back value (BBV) of the asset in Treatment LINEAR as a function of time.

Appendix C Instructions of the experiment

General Information

The experiment replicates an asset market, which is populated by 8 traders. The experiment consists of 12 independent periods where you can buy and sell assets. Each trading period lasts for 150 seconds. In each of the 12 independent periods you are earning money. At the end of the experiment, one period is randomly drawn to determine your payout. *There are two types of traders in the market: ordinary traders and fund managers (4 of each type). Note that your payment depends on your trader type, which will be explained in more detail below.*

Your role in the experiment:[18] **Ordinary Trader or Fund Manager** [19]

Your task within a period

At the beginning of each period, each trader receives 4000 Taler (the virtual currency) and 20 assets of a fictive company. The asset and Taler inventories are NOT transferred from one period to the next. The trading mechanism is a double auction, i.e., each trader can appear as buyer and seller at the same time. Note that your Taler and asset holdings cannot drop below zero.

Terminal asset value

The terminal value of the asset is the Taler amount that you get for each asset you hold at the end of a period. The terminal asset value is randomly drawn from a uniform distribution between 0 and 100 (with one decimal place), i.e., each value within this range is equally likely to be the terminal asset value.

[Begin Payout Ordinary Trader]

Your period earnings

[18] This section was removed in Treatment LINEAR. Everything else was the same as in the instructions for ordinary traders in WTA and EC.

[19] Here, the subjects were informed about their role (either ordinary trader or fund manager) during the experiment.

Your period earnings depend on your terminal wealth in that period.

Your terminal wealth = Number of assets held in the end * terminal asset value + Taler holdings

Your period earnings in Euro = Your wealth * exchange rate of 0.002 Euro

Example 1: At the end of the period you own 12 assets and 4600 Taler. The terminal asset value is 81.2 Taler. Your terminal wealth equals 12 * 81.2 + 4600 = 5574.4 Taler. The exchange rate is 0.002. Your earnings in Euro for that period are 5574.4 * 0.002 = 11.15 Euro.

Example 2: At the end of the period you own 35 assets and 3260 Taler. The terminal asset value is 36.1 Taler. Your terminal wealth equals 35 * 36.1 + 3260 = 4523.5 Taler. The exchange rate is 0.002. Your earnings in Euro for that period are 4523.5 * 0.002 = 9.05 Euro.

[End Payout Ordinary Trader]

[Begin Payout Fund Manager in WTA]

Your period earnings

Your period earnings depend on your trading performance in relation to the other 3 fund managers' trading performance. Specifically, you receive a prize of 40 Euro if your fund's terminal wealth is ranked the first among the 4 fund managers. (Note: Your fund performance is only compared to the other 3 fund managers' fund performance, but not to ordinary traders' performance.) In case you are not ranked the first, you earn nothing.

The calculation of your fund's terminal wealth is as follows:

Your fund's terminal wealth = Number of asset holdings * terminal asset value + Taler holdings

Note that in each period with fund managers participating in the market, only 1 prize will be offered. In the case that there is more than 1 winner, tied winners will split the prize equally.

Example 1: At the end of the period you own 25 assets and 3800 Taler. The terminal asset value is 60.5 Taler. Your fund wealth equals 25 * 60.5 + 3800 = 5312.5 Taler. Your earnings in that period depend on the comparison of your fund wealth with the other 3 fund managers' fund wealth. Suppose Fund Managers A and B both own 15 assets and 4200 Taler at the end of the period, in which case their fund terminal wealth both equals 15 * 60.5 + 4200 = 5107.5 Taler. Suppose Manager C owns 30 assets and 3400 Taler, in which case his fund terminal wealth equals 30 * 60.5 + 3400 = 5215 Taler. Among the 4 managers, you are ranked the first, so your period earnings are 40 Euro while Managers A, B, and C earn nothing for this period.

Example 2: At the end of the period you own 30 assets and 3450 Taler. The terminal asset value is 27.6 Taler. Your fund wealth equals 30 * 27.6 + 3450 = 4278 Taler. Suppose Fund Managers A and B both own 15 assets and 4250 Taler at the end of the period, in which case their fund terminal wealth both equals 15 * 27.6 + 4250 = 4664 Taler. Suppose Manager C owns 10 assets and 4550 Taler, in which case his fund terminal wealth equals 10 * 27.6 + 4550 = 4826 Taler. Among the 4 managers, Manager C is ranked the first, Managers A and B both are ranked # 2 and you are ranked # 4, so Manager C's period earnings are 40 Euro, while Manager A, Manager B, and you earn nothing.

[End Payout Fund Manager in WTA]

[Begin Payout Fund Manager in EC]

Your period earnings

Your period earnings depend on your trading performance in relation to the other 3 fund managers' trading performance. Specifically, you receive a prize of 13.33 Euro if your fund's terminal wealth is ranked either # 1, 2, or 3 among the 4 fund managers. (Note: Your fund performance is only compared to the other 3 fund managers' fund performance, but not to ordinary traders' performance.) In case you are not ranked # 1, 2, or 3, you earn nothing.

The calculation of your fund's terminal wealth is as follows:

Your fund's terminal wealth = Number of asset holdings * terminal asset value + Taler holdings

Note that in each period with fund managers participating in the market, only 3 prizes will be offered. In the case that there is a tie, tied winners split the prize(s) equally. (So do not be confused if your earning is different from 13.33 and 0 Euro; that simply implies the occurrence of a tie.)

Example 1: At the end of the period you own 25 assets and 3800 Taler. The terminal asset value is 60.5 Taler. Your fund wealth equals 25 * 60.5 + 3800 = 5312.5 Taler. Your earnings in that period depend on the comparison of your fund wealth with the other 3 fund managers' fund wealth. Suppose Fund Managers A and B both own 15 assets and 4200 Taler at the end of the period, in which case their fund terminal wealth both equals 15 * 60.5 + 4200 = 5107.5 Taler. Suppose Manager C owns 30 assets and 3400 Taler, in which case his fund terminal wealth equals 30 * 60.5 + 3400 = 5215 Taler. Among the 4 managers, you are ranked # 1, Manager C is ranked # 2, Managers A and B are both ranked # 3. Therefore, you and Manager C receive 13.33 Euro and Managers A and B split the prize and receive 6.67 Euro each.

Example 2: At the end of the period you own 30 assets and 3450 Taler. The terminal asset value is 27.6 Taler. Your fund wealth equals 30 * 27.6 + 3450 = 4278 Taler. Suppose Fund Managers A and B both own 15 assets and 4250 Taler at the end of the period, in which case their fund terminal wealth both equals 15 * 27.6 + 4250 = 4664 Taler. Suppose Manager C owns 10 assets and 4550 Taler, in which case his fund terminal wealth equals 10 * 27.6 + 4550 = 4826 Taler. Among the 4 managers, Manager C is ranked # 1, Managers A and B both are ranked # 2 and you are ranked # 4, thus Managers A, B, and C receive 13.33 Euro each and you earn nothing.

[End Payout Fund Manager in EC]

Earnings from the Experiment

After the 12 trading periods, one period earning is randomly drawn and determines your payout. Note that each period is equally likely to be the payout-relevant period. In the end of the experiment one subject will be assigned to draw a card from a deck of twelve cards to determine the period relevant for payout.

Important information and some reminders

- There are 4 ordinary traders and 4 fund managers in the market, with the same initial Taler and asset holdings.
- Your earnings depend on your own terminal wealth.[20]
- Depending on your ranking relative to the other 3 fund managers, you either win a prize of 40 Euro, split the prize with someone else, or win nothing.[21]
- Depending on your ranking relative to the other 3 fund managers, you either win a prize of 13.33 Euro, split the prize with someone else, or win nothing.[22]
- In each trading period you have 150 seconds time to trade.
- This experiment ends after 12 independent periods.
- Use the full stop (.) as decimal place.
- Your final payment from the market experiment equals your earnings in one randomly drawn period.

[20]Only for ordinary traders in all treatments.
[21]Only for fund managers in Treatment WTA.
[22]Only for fund managers in Treatment EC.

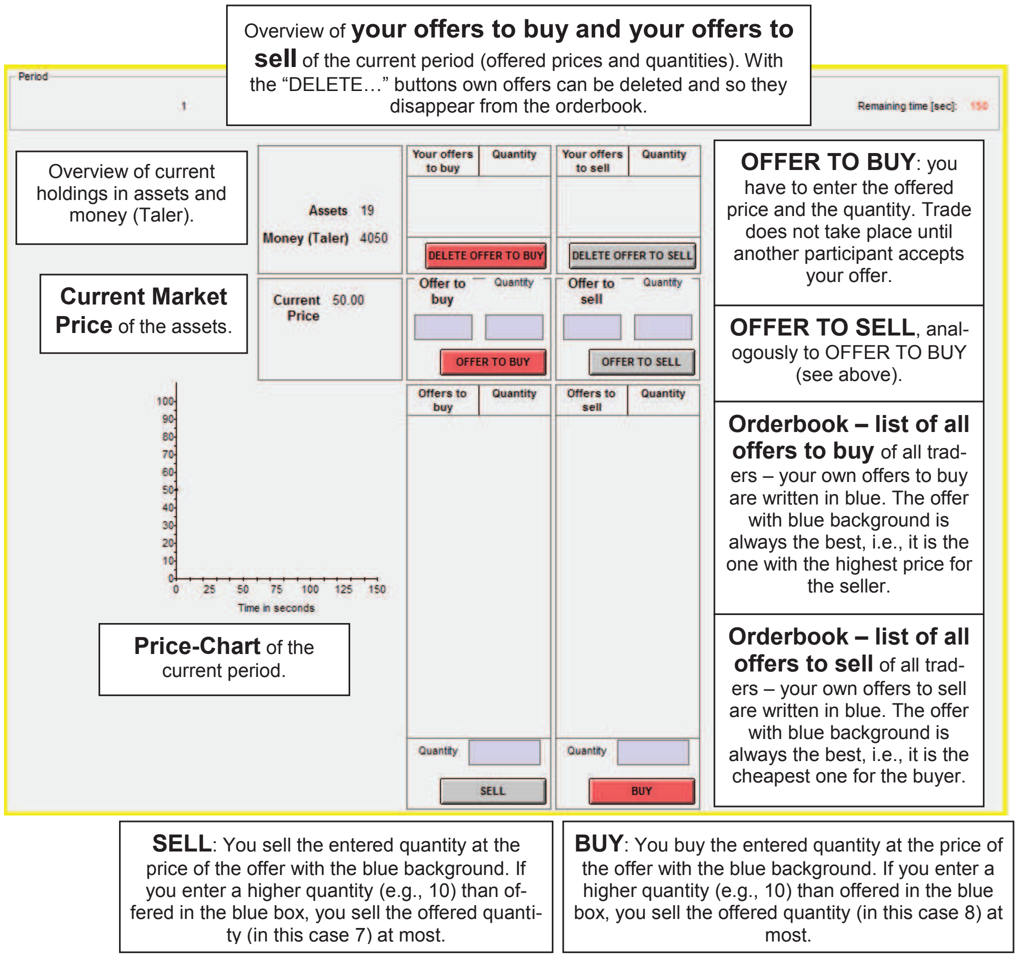

Figure C1: Trading screen