Stock Market “Puzzles” Observed in the Experimental Call Auction and Continuous Double Auction Market – a Comparison of the Two Market Institutions

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Abstract: The paper presents an original experimental market design with multiple multi period lived securities where production decisions by human managers are responsible for the cashflows from firms to shareholders. In these conditions of cash-flow uncertainty we investigate with laboratory data patterns of well-documented anomalies of real-world security-markets; the equity risk premium puzzle, the volatility puzzle, the disposition effect, and the excessive trading anomaly. We report on two empirically relevant market-institutions, the once clearing call auction and the continuous double auction, to find worse outcomes in terms of liquidity, leverage and bankruptcy for the call-auction than for the double-auction market.

JEL code: C90; D53; D92; G02; G11; G12
**Introduction**

The paper proposes an experimental design for the controlled laboratory study of stock market behavior. The experimental design incorporates important features that in our view are the essence of real-world equity markets, in fact, subject to tolerable simplifications. Our approach differs from earlier asset market experiments (as e.g., Plott and Sunder 1988, Smith et al 1988) which care about the conditions under which theory can be empirically supported in a simplistic asset market design. Instead we are interested in general questions of the following type: “Given a realistic design, what can we observe in laboratory markets under certain conditions?” More concretely we address the following research question in this paper: “Given that our design cares about essential real-world features, will we be able to observe known behavioral anomalies of real-world stock markets under almost perfect capital market conditions?” In addressing this question, we allude to the equity premium puzzle (Mehra and Prescott 1985), the volatility puzzle (Shiller 1981), the disposition effect (Shefrin and Statman 1985), and the excessive trading anomaly (Odean 1999; Barber and Odean 2000). As reported below in more detail, confirming evidence shows up in our data. That being said, our evidence is not as dramatic as the evidence drawn from real-world data, and thus leaves explanatory room for theories of market imperfections. We do not claim that ours is the simplest design to obtain these anomalies, or that we still would obtain these anomalies in the laboratory if we removed any feature from our design. We have not designed the experiment to test these anomalies, but use the anomalies as a realism test for our design. Given the evidence that puzzles and characteristics of naturally occurring markets are replicated, we believe that our design can be used as a more realistic test bed of policy implications than what is possible with more simplistic designs. Promising extensions and applications are discussed in the concluding section.

In this paper we investigate the behavior of two relevant market institutions used for the exchange of risky securities. Thus we address the following question; do the laboratory market institutions replicate the known features of real world data equally well –or, in other words- which institution would be recommendable for the laboratory study of policy implication or other applications? To this question, equilibrium theory can give little information. In particular, we examine the double auction, and the call auction which differ in the frequency of market clearing. The double-sided call auction market clears only once a period, and the double auction market clears continuously during a period. We study the institutions in the absence of liquidity-needs for consumption, and under conditions of transparent information on the risks and returns of cash flows to equity. Standard theory which assumes frictionless trading would not suggest any systematic differences in the behavior of the markets. Our experimental evidence shows, however, that the market

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1 We have a model of the corporate firm in mind which we outlay in all the details below. Some distinctive features of our design include 1) the macro finance perspective, that is, dependence of the corporative gains on market demand and human manager decisions; 2) human-made uncertainty owed to managerial decisions and their impact on the cash-flows to equity; 3) accounting, that is, regular statements of the company to their investors involving multiples and charts; 4) simultaneous trade of multiple multi-period lived assets; 5) realistic leverage opportunities of investors, and the inherent risk of forced asset sales and bankruptcy; etc.
institutions price risky assets differently. Based on our experimental evidence we conclude that the returns are higher and the risks are lower in the double auction than in the call auction. Relative to the double auction, the call auction market is less liquid, that is, exhibits low trading volumes, leads to excessive pricing, large price variations and excessive debt levels. The risks are evidenced by the higher frequency of individual bankruptcies following forced liquidations of leveraged positions. Overall the data of our laboratory study thus suggest that the behavior of the double auction market is rather in line the call auction market with the known characteristics of real world markets.

The paper is organized as follows. In the following subsection, we point out the differences of the proposed experimental design and relate our study to the existing literature. In section 2 we present the details of the experimental design and derive the testable hypotheses regarding the optimal production decisions for our economy. Section 3 reports experimental results on the aforementioned real-world aggregate market anomalies; we apply the standard tests in the context of the volatility puzzle and the equity premium puzzle. We also investigate levels of market liquidity to find more favorable results for the double auction market than for the call auction market. In section 4 we test for anomalies regarding individual investor behavior. We report evidence for the disposition effect, excessive trading and excessive leveraging. Finally we discuss determinants of risks in our markets. Section 5 alludes to follow up works and potential extensions.

1 Relation to existing literature

1.1 Design differences

Compared to earlier asset-market experimental designs that are rather focused on tests of theory, we make the effort of including important real-world features into our design. Indeed our design is simple and transparent in comparison to the real world. It implements almost perfect capital market conditions as demanded by the theoretical literature (Modigliani and Miller 1958), and we are also able to delineate an objective solution to the decision problem underlying the cash-flows to equity. Owed to the real-world features our design differs in many respects to earlier experimental finance literature (see, for instance, the surveys by Sunder 1995 and Duxbury 1995). The following differences and similarities are emphasized.

1) In our experiment, human subjects in the role of managers make production decisions in public companies which make regular cash distributions to equity shareholders subject to the company’s profits. These profits are dependent on the efficiency of the manager’s decision rather than chance moves of the environment. The inclusion of this fundamental uncertainty inherent to equity investment in our framework is a major departure from the experimental asset-market literature that is concerned with tests of informational efficiency and tests of the rational expectation hypothesis in situations where the set of potential future payoffs is prior knowledge. Important contributions of the experimental literature have revealed, for instance, that experimental markets with repetitions and under conditions of unchanged information are able to disseminate (Plott and Sunder 1982) and
aggregate information (Plott and Sunder 1988), and that asset prices converge to expected payoffs (Smith et al. 1988). In our financial markets likewise the real-world there is no apriori-known objective benchmark. Facts on the cash-flows of the companies are available in form of periodic statements including multiples and charts. Investors can observe the past performance of their companies and as they have guidance on future growth they may be able to predict with confidence the potential range of future cash-flows. Our design introduces human-made uncertainty in real-time that cannot be captured in a theoretical model. In our opinion, the psychology of investors is different when uncertainty depends only on external factors as it would be the case with robot-made chance events or even with selected pre-recorded decisions. Most if not all uncertainty in financial markets is human-made and a significant part of it is related to the skills of the corporate manager. Stakeholders discuss these skills; some managers are considered as bad and some as good or of outstanding abilities. The decisions of managers are a main reason for the success or failure of a company. A change of the management usually has an effect on the stock price. When discussing uncertainty in financial markets and the psychology of people, Soros (2008) has referred to reflexivity. This reflexivity is used to predict the behavior of another person. When you try to put yourself in the position of other persons to predict their behavior, you will feel an uncertainty about this behavior. When persons act, you

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2 If some participants know the true state of the economy, the market disseminates the information so that the price converges towards the rational expectation equilibrium (Plott and Sunder 1982). The introduction of a futures market increases the speed of convergence (e.g., Forsythe et al. 1982, 1984; Friedman et al. 1984). Copeland and Friedman (1991) report enhanced efficiency when information is revealed sequentially. If the information about the true state is not known to any individual, but every individual has a part of the information and the sum of the parts reveals the true state, the market is able to aggregate this information under certain conditions (Plott and Sunder 1988; Sunder 1995; see also Shachat and Srinivasan 2011).

3 Numerous papers have followed up on the research of Smith et al. who found evidence for mispricing in experimental asset markets where a lottery over commonly known outcomes decides on the regular dividend of a long-lived asset. The market features bubbles and crashes in this design although market conditions are perfect in the sense of the theory. Exact repetition of the market leads to a decrease of the mispricing (Smith et al. 1988; Ackert et al. 2001, Dufwenberg et al. 2005, Hussam et al. 2008), but mispricing rekindles if the repetitions involve a different lottery. It has been suggested that confusion may be a driver of mispricing (Lei et al. 2001, Haruvy et al. 2007, Cheung et al. 2010, Kirchler et al. 2012). Insider information seems to decrease mispricing (Sutter et al. 2012) and so seems to do an indefinite horizon with a sudden termination (Camerer and Weigelt 1991). The setting has been criticized based on its special feature of a decreasing fundamental value which has only few real-world equivalents among financial assets (Theissen 1998). The mispricing nevertheless has also been reported when the fundamental value is non-decreasing (Smith et al. 2000, Noussair et al. 2001, Porter and Smith 2003, Oechssler et al. 2007). Palan (2009) offers a recent literature review.

4 In an ongoing study, Jaworski and Kimborough (2011) have included managerial decision making in the asset-market bubble design of Smith et al. (1988). In contrast to our experiment, however, their experiment involves only tape-recorded actions of one manager-subject and not real time and comparable production decisions of several manager-subjects as in our case. Dividend payments in Smith et al. can be interpreted as generated from decisions of a robot manager. It might be hard to prove in our experiment, but we are convinced that there is a real difference in subjects’ psychology when faced with robot decisions or with previously recorded once. However, some experimental studies report on behavioral differences with interactions of subjects facing robots or humans. These studies include experiments on the prisoners' dilemma and auction experiments. Cooperation patterns were reportedly different when being matched with robots than with humans in the repeated prisoners' dilemma (Andreoni and Miller 1993, Kiesler et al 1996, Kirchkamp and Nagel 2007). Bidding strategies were also reportedly different in sequential auction markets when subjects were previously matched with another than when previously matched with equilibrium automata (Neugebauer 2004).
differently predict their actions than when chance moves or robots act. It is not a mechanical process. Uncertainty is risk-induced through human behavior, different from chance-moves according to known probability distributions. Today we do not have a complete descriptive theory about human behavior. Therefore, we regard important the inclusion of human-made uncertainty to the study of decision making in the laboratory asset market. As the data reveal, the ex-post measurable risks of holding shares are substantially increased by the inefficiency of management decisions beyond the risks of demand growth for the company’s products. The managers’ skills at creating value vary largely, spreading from returning very little to shareholders to capturing the potential gains entirely.

2) The demand growth of the company is determined in our setting by an i.i.d. shock in every period. This way, chance moves introduce risk to the managers’ environment. Observing the demand of the past and knowing the expected future growth, managers make decisions over price and production capacity to serve their stochastically growing market. Equity investors receive transparent, realistic information on the risk and returns of the companies but there is uncertainty about future outcomes which are dependent on managerial decisions and demand. The financial statements are simplified compared to the real-world and can easily be compared between companies.

With few exceptions, studies in experimental finance have typically been concerned with stationary settings without cash-flow growth. In the oligopoly literature, already, Becker and Selten (1970) have considered demand growth in the management game SINTO to find that subjects learn to adapt to the changing demand conditions. Even closer to our production-sector approach is the oligopoly game with price variation and investment by Selten (1967), where demand grows in time and production in a given period is the minimum of capacity and demand. Selten (see also Tietz 1967) reports that management decisions are generally inefficient but efficiency increases with subjects’ experience. In our study, we consider monopolies rather than oligopolies to simplify the investors’ problem and the data analysis. Similar approaches have also been developed in the operations literature on capacity investment under uncertainty (see e.g. Swinney et al. 2011).

3) Our design enables subjects to simultaneously trade multiple multi-period lived assets. Although the financial economics literature is generally concerned with portfolio choice, the experimental literature has mostly focused on markets for one security. There are few exceptions. O’Brien and Srivastava (1991) investigate information aggregation in a two-stage state-contingent

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5 Uncertainty of an Ellsberg-urn type was found to have an impact on subjects’ behavior (Bossaerts et al 2012). It is not clear that a similar dramatic effect would be found in our design when lotteries substitute managers. This question will be investigated in our next experimental study.

6 In one experimental study that applies an algorithmic constant growth environment by Bloomfield et al. (2006) it is reported that the choice of financial reporting format (in particular, the inclusion or exclusion of equity-correlated unrealized gains and losses) and investment levels can have an impact on market value and volatility. The experimental design by Levy (1997) has an effect similar to exponential growth, as the book-value which is paid out at the end of the experiment increases through compounding of stochastic returns. Levy’s design involves similar but less complete information than our design to investor subjects. Finally, Kirchler et al. (2012) investigate a setting with a constant growth to report pricing at the risk-neutral value.
setting with three or four assets to find that subjects exploit arbitrage possibilities and that complexity decreases information aggregation. Levy (1997) studies an experimental call auction market that involves one observation with 64 subjects. Subjects trade over ten periods in ten equity securities for which expected returns and risks are known and realizations are drawn from a normal distribution. Levy reports that although subjects’ portfolios are not mean-variance efficient, the mean returns are generally and positively related to risk, thus, qualitatively giving support to the capital asset market model, CAPM. Bossaerts and Plott (2002, 2004) study convergence on the equilibrium in a three-state, three-asset Arrow-Debreu market economy under the assumption of identical covariance-risk pricing. They report that prices in this environment generally have a tendency towards the equilibrium prediction, but fully reflect the theoretical covariance risk only in large markets with at least 19 traders and a judicious choice of trading interface and not in smaller markets. In our multi-period environment we investigate larger markets only for the study of market pricing. Ackert et al. (2006) investigate market-mispricing of two financial assets involving different amounts of risks to find that subjects take more risks if they are allowed to leverage on purchases and sales (see also Fisher and Kelly 2000, and Ackert et al. 2009).

4) Our subjects can use leverage to purchase and short-sell assets under realistic collateral requirements. The initial margin requirements in the experimental markets are adapted from the real world (see for instance, Staley 1997, 277f). Subjects including managers get a fixed return on their cash holdings, and pay a higher interest-rate on borrowed money similar to Selten (1967). Most experimental studies do not enable leverage. If borrowing is allowed, usually a zero interest rate is applied (see Sunder 1995, Duxbury 1995). However, in the setting of Bossaerts and Plott (2002, 2004) a zero-coupon bond is traded (see also Aspharouhova et al. 2011), and in Fischbacher et al. (2011), the interest rate is flexibly adjusted to the bubble-size in the setting of Smith et al. (1988). The experimental design of Smith et al. has been used for studying the effects of short-sale and borrowing (King et al 1993; Ackert 2006; Haruvy and Noussair 2006; Füllbrunn and Neugebauer 2011). The results indicate that borrowing [short-sale] capacities increase [decrease] the mispricing in this setting. Only the latter study involves similar margin requirements as the present study. In the other studies, including Bossaerts and Plott (2002, 2004), margin requirements are unrelated to market values. Bhojraj et al. (2009) investigate margin requirements and report that convergence to equilibrium is weaker when margin requirements are relaxed, that is, when less collateral is required for the assuming of a short position. In the present study, we do not investigate the effects of changed margin requirements, but we do report on the investors’ performance depending on their leverage while fixing initial margin requirements at the empirically relevant level.

7 Kroll et al (1988) study the equilibrium model with three assets in a non-market setting. They find that subjects do not react to changes in correlation risk. Siebenmorgen and Weber (2003) find evidence that investment advisors in private banking do not take account of correlation risk in their decision.
5) Finally, overleveraged investors in our experiment face forced liquidations of asset positions with unfavorable price swings, that is, when debt exceeds equity. Thus, shorts are forced to cover in the bull market, and leveraged long positions must be liquidated in the bear market, as described in Selden (1912). Since in our data the forced liquidations of positions can lead to investors’ bankruptcy, we find that subjects who use leverage to increase their profits do underperform the market. Similarly to Bhojraj et al. (2009) who consider margin calls for short-sales but report no price effect, we find only a limited price impact of margin calls on short positions. However, the forced liquidation of long positions leads to market frictions and bankruptcies.

1.2 Comparison of market institutions

We investigate the market behavior of the two double-sided institutions call auction and continuous double auction. Important stock exchanges around the world, including at New York, London, Tokyo and Frankfurt, employ hybrid versions of these institutions. In our design, the call auction market clears once whereas the double auction clears continuously throughout the period. The behavior of these institutions has been discussed in theoretical and empirical work including experiments. Theissen (1998) provides an excellent survey over this literature. The theoretical comparison has not come to a unanimous result. One problem with the theoretical comparison of the two institutions is that there is no commonly accepted solution to the double auction (see Friedman 1993a; Sadrieh 1998). However, Kyle (1985) models the double auction as an infinitely repeated call auction. Generally, the call auction is suggested to be more informationally efficient than the double auction (Madhavavan 1992), that is, insiders can take less advantage of their information in the call auction. This result has been confirmed by experimental evidence (Schnitzlein 1996, Theissen 1998). However, the assumptions on which these theoretical results are based are restrictive (Theissen 1998, p 164f). Real-world studies have been more concerned with market liquidity. Case studies of a historical switch between trading systems find that trading volume is higher in the double auction market (see, e.g., Amihud et al. 1997). Liquidity seems generally better in the double auction (Lauterbach 2001), but trading costs for small and large transactions may vary between institutions (Kehr et al 2001). Some experimental papers have investigated the related issue price-efficiency of the two institutions with laboratory data. Smith et al. (1982) have shown that the double auction is more efficient than various versions of the call auction in aggregating information (see also Friedman and Rust 1993). Yet hybrid versions of the call and double auction seem to reach a comparable level of efficiency (Cason and Friedman 2008). Schnitzlein (1996), for instance, reports similar price efficiencies for an Arrow-Debreu security market when the call auction clears four times per period. In the present study, the
once-clearing call auction has a lower trading volume than the double auction.\textsuperscript{9} We find for our call auction experiments that risk is increased whereas the expected return is rather reduced; bankruptcy is significantly more frequent in the call auction than in the double auction market.

1.3. Market anomalies

According to the traditional neoclassical paradigm, the market price equals the present value of expected cash flows on an asset and changes occur only randomly in response to changes in fundamentals. The underlying assumptions to this hypothesis are the one of perfect capital markets and investors’ rationality. The behavioral finance literature has pointed out certain regularities of real-world markets that seem to contradict to the neoclassical paradigm. Perhaps the best known anomalies regarding market behavior are the volatility puzzle (Shiller 1981; LeRoy and Porter 1981) and the equity premium puzzle (Mehra and Prescott 1985). The volatility puzzle describes the fact that asset prices move too much to be justified by posterior changes in cash-flows. The equity premium puzzle suggests that the excess of market return over risk free rate has been historically too high for any reasonable level of risk aversion. A significant amount of thought has been advanced in an attempt to solve the puzzle (e.g., Bernartzi and Thaler 1995, Hens and Wohrmann 2006, Fellner and Sutter 2009, Rieger et al. 2012).

Documented evidence from real-world markets has also challenged the standard assumption of investors’ rationality. The disposition effect (Shefrin and Statman 1984), i.e. the asymmetry between selling prior winners and losers,\textsuperscript{10} and excessive trading behavior (Odean 1999) are well-known stylized facts in the literature. We report related evidence also on the excessive leveraging of trades. Debt-spiral effects were pointed out in early literature (Selden 1912) and also recently (Geanakoplos 2009). In face of the risks, one would expect that those who trade more frequently or those who use more leverage do so because they are able to extract value from the market, but, as we report, frequent trading and the usage of leverage are not beneficial to investors. Thus, we confirm with laboratory data real-world studies on the poor performance of private investors’ trading behaviors (Odean 1998; 1999). These results are obviously very good news for experimental finance as they reinforce our belief that one can learn about the behavior of real-world markets by looking at laboratory data.

A third stream of empirical challenge for the standard model focuses on the analysis of cross-section returns. Frequently cited are the overreaction hypothesis (De Bondt and Thaler 1985) and factor models (Fama and French 1992). Due to its considerable scope we have decided to report on cross-sections returns and predictability in a separate paper. In that paper, we report evidence for predictability of returns of value stock. However, we find no evidence for long-term mean reversion

\textsuperscript{9} Theissen (1998, 318) suggests that volume may be higher in the double auction market of one security because it is not possible to buy and sell at the same time. In the market with several securities, like ours, this argument loses grip. However, Cason and Friedman (2008) report that trading volume and efficiency are similar in the double auction and the repeatedly-clearing call auction.

\textsuperscript{10} Weber and Camerer (1998) reported evidence for the existence of the disposition effect in an individual choice experiment with seven assets.
and short-term momentum strategies in the data. This fact may not be surprising since our data lack bankruptcies or turn around stories of companies.

2. Experimental design & theoretical considerations

2.1 General design issues

Our design implements a generic model of the corporate firm. After having issued debt and equity to the market, the management of the firm invests the funds in assets for operations and in financial assets. The manager sets the price at which products are offered for sale. Sales depend on the production capacity, the price, and the consumers’ demand. Cash flows to equity are sales after costs and interests. Corporations pay out their cash flows in form of regular dividends to their shareholders and also retain earnings for future growth. When a corporation ceases to live, the final compensation to their investors depends on its asset values.

Investors trade the corporations’ shares of equity in the stock market. Regular statements are being issued, and investors make use of multiples and of charts to measure and compare the corporations’ past performances. Investors also receive guidance on potential future growth, in particular they are informed on the underlying growth distribution, but no objective benchmark on the underlying fundamental value can be provided as it depends on the efficiency of the manager. Indeed investors are broadly informed about the task of the manager-subjects who were instructed in the adjacent room at the same time. Investors leverage their stock positions to go long and short on margin. Leveraged investors face the risk of forced asset-sales and finally of bankruptcy upon violation of their margin requirements.

The experimental design involves two types of subjects. The first type shortly called manager serves as the manager of a publicly-held monopolistic firm. Similar to the oligopolists in Selten (1967), the manager makes production decisions by choosing the capacity and the price of the product, but for the ease of simplicity in absence of competition. In each period, the firm experiences an independent (demand) growth shock which is uniformly distributed over the interval \([-5\%;9\%]\). Expected growth of cash-flows is 2% per period. However, the manager learns the demand shock only at the end of the period after his decision has been implemented. The compensation of the manager is a fixed share of the long-term cash-flows to equity, that is, the manager receives half the firm’s asset value at the end of the experiment. The manager’s decision task is detailed and the solution to the task is delineated in the appendix. The second type is referred to as investor. Investors own and trade the equity-shares of the companies. Investors realize capital gains when they trade in the market; they receive cash dividends distributed by the companies, and collect interest payments on their cash holdings.

In each experimental session, 23 subjects participate; 3 as managers and 20 as investors. Investors receive all relevant information on the managerial decision task, including the underlying risk and the expected dividend growth. Investors identify the companies by names LEFT, MIDDLE, and RIGHT. The managers and investors make their decisions simultaneously. The period-length is fixed at 150 seconds; after this time the markets close, the managers’ production decisions are
implemented, the companies’ earnings are computed, and dividends are distributed. Managers do not interfere in the stock market and investors do not interfere in production decisions.

All relevant information in an experimental session is transparently presented to subjects in tables and charts. No transaction costs, corporate taxes, income taxes or other fees for trading of shares are levied. Borrowing of money and of shares is permitted, subject to margin requirements. Corporations and investors face identical borrowing conditions, and their interests are perfectly aligned. No agency problem arises since the managers are residual claimants whose claims at liquidation rank pari-passu to the shareholders. In sum, the experimental design comes close to the theoretical assumption of perfect capital market conditions (Modigliani and Miller 1958).

2.2 The investors
The twenty investor-subjects hold and trade the shares of the three companies $i = \text{LEFT, MIDDLE and RIGHT}$. These names refer to the on-screen location of the corresponding trading masks, share-price and general company information. Initially, investors are endowed with a cash-balance of $F_{B0} = 3,000$ currency units and 10 equity-shares of each of the three companies. In total, 200 shares of equity are issued for each company. The regular cash dividend per share paid at the end of the period after market closing, $D_t$, is $1/200$ of a company’s cash distribution which amounts to half of the company’s profit. If the company loses money, the regular dividend is zero in that period. The latter case is neglected in the further analysis because of missing observations. The dividend is declared and immediately paid at the end of the period $t$ to the company’s shareholders. After the regular dividend of the terminal period, the company is liquidated. Unless the firm value is negative, the shareholders receive a liquidation-dividend equal to half the company’s depreciated equity, $1/200$ per share. As the initial cash endowment of each company in experimental currency units ECU is 10,000 and 200 shares represent the equity in the company, the initial price of any share is set to 50 ECU when the market first opens.

2.3 Margin debt
Equivalently to the firms, investor-subjects receive a fixed interest on their cash account, $R_f = 1\%$. They can also borrow on margin at $R_d = 3\%$ as long as the debt-equity ratio is between zero and one. Subjects are also permitted to short-sell shares of each company if this margin requirement is satisfied. The initial margin requirements thus equal those in real-world markets (e.g., Staley 1997). However, two further limitations on short-sales are implemented. First, no subject can short-sell more than 10 shares of any company and, second, the value of the subject’s equity must be in excess of 6,000 ECU. Subjects make dividend payments on the shares held short at the end of a period. The dividend

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11 One outlier exists in the data; one manager-subject made a small loss in the first period.

12 The minimum-equity requirement was implemented to ensure subjects had enough equity to absorb potential losses, and to render short-sales unlikely to occur before subjects had gained some experience. The restriction of short-sales generally limits margin risks.
is the only direct cost to the short-sale. Equity and debt are instantaneously marked to market. The \textit{equity} of investor \( k \) in period \( t \) is the sum of market-valued long positions of equity shares in the company \( i \) and the cash balance, 

\[ \sum_t p_t \max(X_{ikt};0) + F_{Bkt}, \]

where \( p_t \) is the market price-per-share, \( X_{ikt} \) the investor’s number of shares in the company, and \( F_{Bkt} \) the investor’s cash balance. The \textit{debt} is the market-value of shares held short minus the cash balance if it is negative, 

\[ - \sum_t p_t \min(X_{ikt};0) - \min(F_{Bkt};0). \]

If the value of debt exceeds the value of equity at any point in time, a margin-call is triggered. In case of a margin call, the investor-subject’s positions are liquidated automatically and the subject is not allowed to take any action until equity exceeds debt again. Short positions are liquidated first before the long positions are disposed share by share in random order. Positions are offered at the latest market price during a margin call. As soon as the debt-equity ratio is in the admitted unit-interval again, the margin call is terminated. However, if all positions have to be liquidated, the subject may end up bankrupt. Bankrupt subjects have zero positions in equity shares and a negative cash balance. By participating to the experiment, bankrupt subjects earn the show-up fee. Their negative cash balance is covered by the experimenter.

2.4 Asset trading by submitting limit-orders

Subjects can submit limit-orders to trade the equity shares of the three companies. Each limit order indicates a price for one share only. The limit orders are introduced on the investor-subject’s screen in three trading masks. The trading mask and the information regarding the company LEFT are displayed on the left-side of the screen, the trading mask and information regarding the company MIDDLE in the middle of the screen, and for the company RIGHT on the right-side of the screen (see Figure A1 in the appendix). Limit-orders are entered in one of the trading masks and confirmed by the subject as ask or bid. The limit-price can be determined up to the decimal. The bid must exceed the existing ask of the subject; hence, churning –the selling of shares to one self– is disabled. A potential short-sale is forewarned by an automated message, so that accidental short-positions are avoided. Margin requirements are checked for each limit-order too. If the limit-order would lead to an immediate margin-call, it is not accepted. As long as no trade occurs, the own limit-orders are listed as buys and sells in the corresponding segments (left, middle, right) on the subject’s screen.

2.5 Market institution CAM: Call-auction market

In the call-auction market institution, markets clear once at the end of the period. During the period, subjects make buy and sell orders. The orders are ranked on the subject’s screen from best to worst, equivalently to individual demand and supply schedules for each security. At the end of the period, the bids of all subjects are ranked from highest to lowest, their asks are ranked from lowest to highest. If two bids or if two asks are equal they are randomly ranked. Thus market demand and supply schedules are determined, both bids and asks are arranged for each company’s shares from the best to the worst. The market demand and supply curves are undisclosed. In the market-clearing procedure, the best ask
is compared with the best bid, the second-best ask with the second-best bid, the third-best ask and bid, and so on. The number of transactions is maximized, that is, a transaction is made as long as the ranked ask does not exceed the correspondingly ranked bid. The uniform transaction price is, with equal probability, the lowest winning bid or the highest winning ask. This pricing rule was given preference to the bid-ask midpoint for reasons of similarity to the double-auction market, where obviously “transactions occur at either the bid or the ask, not at the average” (Roll 1984, p. 1128). Following the agreed transactions the share counts and cash balances are updated, and, finally, the dividend and interest payments are entered in the subjects’ accounts.

2.6 Market institution DAM: Double-auction market

In the double-auction market institution, markets clear continuously. Upon submission, each bid [ask] is compared to the best outstanding ask [bid]. Unless the ask exceeds the comparable bid the orders match and a transaction occurs. The incoming limit order is treated as a market order, so the best outstanding order determines the transaction price. Upon transaction, the bid and ask are immediately cancelled, the cash balances and share counts of the transaction parties are updated, and the market price is chronologically registered and publicly announced. Subjects are informed if they are buyer or seller in the transaction. If the incoming order does not match with the best outstanding order, the incoming order is placed in the book of open orders. In this order book, better orders rank above worse orders and equal orders are ranked randomly.

2.7 Investor’s information

Accounts are updated upon each transaction. The latest market price, the subject’s average price and the number of shares held are displayed as account record. A short-position is indicated by a negative number of shares. The subject’s own bids and asks for each share are ordered from best to worst and displayed in the corresponding order mask. The information on the current position value in the shares of a company and the unrealized gains in the position can be alternatively switched with the information on open orders. For the call-auction market, the open orders include the best losing bid and ask of the previous period and the volume of these orders. For the double-auction market, these previous period orders are displayed at the beginning of the period, but the numbers are updated with current open orders when they are placed in the order book. Automated orders, in case of margin calls, are not visible as open orders.

Relevant data on current and past periods are organized in different tables between the subject can switch (see Figure AII in the appendix). Subjects receive current information on their purchasing capacity, market value of equity, debt, and short-positions, debt-equity ratio, and the cash balance in the upper left corner. The current period and the remaining time of the period are displayed at the top of the screen. Past period information is presented in tables in the lower half of the screen. The first table located at the top shows the subject’s period income, the total and its components resulting from dividends, interest, and capital gains, as well as the end-of-period cash balance, equity and debt-equity ratio. The display of this table can be switched with the chart of historical closing share-prices of the
three companies. Tables that display company-related data are presented on the left, the center, and the right of the screen, respectively. Subjects switch between these tables by mouse-click which include the historical data chronologically ordered by period. The table that exhibits the report of the company includes the profit per share, the dividend, i.e., half of the profit if it is positive and zero otherwise, the percentage growth in dividends and the liquidation book-value per share receivable by the shareholders. The alternative multiples table includes the price-earnings ratio, price-to-book-value ratio and the debt-to-equity ratio of the company. The third table includes market trading volume, the subject’s number of trades, the value of these trades, and the value of the position at the end of the period. Finally, in the continuous double-auction market treatment, the fourth table presents the opening, high, low and closing prices of the period. All these data are chronologically recorded with the most recent data in the top row.

2.8 Procedures
Each session, including instructions and payment, took about four hours to conclude. When subjects had all arrived at the laboratory, three of them were assigned to the manager-task and instructed in the computer-room. The other subjects stayed in the adjacent instruction-room and were introduced to the investors’ task. Manager-subjects knew that their dividends would flow to their shareholders, but never received any feedback from the market. Investors knew about the endowment, growth perspectives and task description of the manager. They received periodical statements about the performance of the individual companies and were able to compare these on the basis of earnings and book-value multiples, and the above described information. The experiments were computerized using zTree (Fischbacher 2007); ORSEE (Greiner 2004) was used for the recruitment of subjects. The sessions were conducted at the Bonn Economics Laboratory in 2010.

3 Data
In total, 280 (= 20 traders x 7 sessions x 2 treatments) subjects participated as investors in the experiment, each subject in one session. An additional 42 subjects participated as managers. By participating to the experiment, 30 subjects earned only the show-up fee, 24 subjects earned more than 100 Euro, and the maximum payoff was 477 Euro. On average, an investor earned 57 Euro including a show-up fee of 10 Euro. Managers earned an average of 75 Euro, their decisions were quite efficient. Managers’ median quasi-efficiency was 94.9%, the maximum was 100.9%, the minimum 9.3%, and the average 85.8%. The quasi-efficiency level relates the observed liquidation-value of the company to the one in the optimal risk-free solution (equation 10, yielding 100%) and the earnings of a non-producing company (yielding 0%).\footnote{More than 100% quasi-efficiency is hence possible if one is willing to take risk, and minus infinity would be the quasi-efficiency of bankruptcy. We note that the optimum for our data is relatively flat, so that risk preferences different from risk avoidance do not alter the optimum considerably. See the appendix for more details.} The expected growth rate of earnings, $G_i = 2\% \forall i, t$, is the same for the demand and earnings of the three companies.
Investor-subjects were debriefed in questionnaires with free-form comments at the end of the experiment. Very few students stated they had not fully understood everything at the beginning of the experiment (about 7%), but most of these comments referred to the short-sales opportunities (69% of the 7%) which these subjects never used. The comments were equally made in both treatments and did not correlate with subjects’ payoff performance. One subject submitted a comment that sometimes the waiting phases were long during the trading periods. Generally one can say subjects were quite enthusiastic about the experiment. In view of the comments in the debriefings, the level of quasi-efficiency on the side of the managers, as well as the fact that the market size was sufficiently large and incentives high, we have reason to believe that the experiment was generally understood, and that boredom had no impact on our data.  

3.1. Market behavior: price and ex-post rational price

To start our data analysis we report the market price levels and compare them to the rational benchmark. The price level is defined as the average market value per share of companies LEFT, MIDDLE, and RIGHT and is representative of the market portfolio. The indices \( t = \{2, \ldots, 50\} \) and \( i \) denote the period and the company.

\[
P_t = \frac{\sum_{i=1}^{3} P_{it}}{3}
\]

To avoid any confound with the managers’ problem, the notation of market variables uses upper-case letters. Before we turn to the data analysis we note that in our world investors do not consume. They are only interested in the long-term performance of their portfolio. So, in the standard model involving common knowledge of rationality, trading should occur only with regards to the differences in risk aversion. Other than that, the reason for trading may be differences in opinion. Some investors believe that the asset is overvalued others believe the asset is undervaluated. Other investors again may try to outguess the others as in a beauty contest (Keynes 1936). Motives for speculation can be caused by uncertainty in our experiment as the long-term outcome is revealed gradually with the approaching of the terminal period. In the face of these theoretical considerations, nonetheless, we have no reason to expect any systematic differences between treatments CAM and DAM.

The experimental asset market literature has dedicated efforts to the observation of mispricing in the laboratory in the single asset design of Smith et al (1988) under conditions of apriori known risk-neutral value. In Smith et al., the discounted expected-dividend stream of the single asset under

---

14 Some experimentalists seem to have the opinion that experiments should be timely limited, because subjects may feel bored in lengthy experiments. Our markets were opened for 2.5 hours per session, so our experiments’ length seems to be close to the generally proposed limit of 3 hours. Our opinion is that boredom depends on the repetitiveness of the task, and not on the time length. Subjects in our experiments received new information throughout the session, no period equalled the other. It was no repetitive task and, in our opinion, sufficiently exciting. Note that many real-world investors voluntarily spend their day in the trading room to follow the news including every price change tick by tick; and the many teenagers never seem to get tired playing computer games.
consideration is common information to subjects in each period. The distance between the risk-neutral value and the observed prices have been measured in various experiments (Palan 2009; Stöckl et al 2010). In our experiment, similar to the real-world, the rational fundamental value is apriori unknown. To determine the rational benchmark therefore we follow the approach by Shiller (1981) and compute the \textit{ex-post rational price}. Knowing the realizations of all future dividends one can in hindsight compute the ex-post rational price for the given discount rate. In practical terms, the ex-post rational

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Continuous double-auction market - DAM: average price per share. Solid line is average price per share; dashed line is the ex-post rational price.}
\end{figure}
risk neutral price of the market portfolio in period \( t \), \( P_t^* \), is determined by unraveling from the back and discounting by the risk free rate,
\[
P_t^* = \frac{D_t + B_t / 2}{1 + R_f},
\] (2)
and
\[
P_t^* = \frac{D_t + P_{t+1}}{1 + R_f} \quad \forall t = 2, \ldots, T - 1.
\] (3)

Figure I. Call-auction market - CAM: average price per share.
Solid line is average price per share; dashed line is the ex-post rational price.

\[\text{15} \] Other ex-post rational prices could be based on different discount rates than the risk-free rate. So it is important to notice that our conclusions are unaffected by reasonable changes in the discount rate.
The ex-post rational price of the final period $T = 50$ as in (2), is the sum of the realized regular dividend, $D_T$, and the liquidation dividend which is half the final book-value, $B_T / 2$, discounted by the risk free rate of return, $R_f = 1\%$. In every prior period $t = 2, ..., T - 1$, the sum of the ex-post rational price of the next period and the actual dividend of this period must be discounted by the risk free rate. In Figure I the price and ex-post rational price are plotted for each session and period, separately for the treatments DAM and CAM. The solid line in the charts marks the price level and the dashed line is the ex-post rational price per share of the market portfolio.

**Table I. Average price level, risk-neutral value, and ex-post rational price**

The average market price per share of securities $L, M, R$ per period, $P_t$, and the average ex-post rational risk neutral price, $P_t^*$, as defined in the text are computed per period. The table records the arithmetic averages (denoted by the bar) and the relative frequencies where prices exceed the risk neutral price over periods $t = \{2, 3, ..., 50\}$, and where indicated over periods $t = \{36, 37, ..., 50\}$. For each session the independent data and the treatment average are recorded. The bottom row informs on the results of the two-tailed two-sample Mann-Whitney rank-sum test. This non-parametric test examines the null hypothesis of equal outcomes per treatment. The alternative hypothesis rejects the null, thus, a treatment effect is indicated in the realized price levels, and regarding the pricing above the risk-neutral value.

<table>
<thead>
<tr>
<th>Session</th>
<th>$\bar{P}_t$</th>
<th>$\bar{P}_t^*(R_f)$</th>
<th>$\bar{P}_t - \bar{P}_t^*(R_f)$</th>
<th>Rel. freq. % $P_t &gt; P_t^*(R_f)$ $t \in [46, 50]$</th>
<th>Rel. freq. % $P_t &gt; P_t^*(R_f)$ $t \in [46, 50]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>199</td>
<td>145</td>
<td>55</td>
<td>76</td>
<td>14</td>
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<tr>
<td>2</td>
<td>170</td>
<td>127</td>
<td>42</td>
<td>37</td>
<td>-17</td>
</tr>
<tr>
<td>3</td>
<td>301</td>
<td>162</td>
<td>139</td>
<td>63</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>442</td>
<td>169</td>
<td>273</td>
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<td>21</td>
</tr>
<tr>
<td>5</td>
<td>227</td>
<td>121</td>
<td>106</td>
<td>61</td>
<td>5</td>
</tr>
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<td>6</td>
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<tr>
<td>7</td>
<td>298</td>
<td>120</td>
<td>177</td>
<td>82</td>
<td>7</td>
</tr>
<tr>
<td>Average</td>
<td>CAM</td>
<td>272</td>
<td>143</td>
<td>129</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>115</td>
<td>109</td>
<td>6</td>
<td>33</td>
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<tr>
<td></td>
<td>9</td>
<td>140</td>
<td>128</td>
<td>12</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>189</td>
<td>177</td>
<td>12</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>124</td>
<td>157</td>
<td>-32</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>165</td>
<td>184</td>
<td>-18</td>
<td>16</td>
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<tr>
<td></td>
<td>13</td>
<td>134</td>
<td>174</td>
<td>-39</td>
<td>16</td>
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<td></td>
<td>14</td>
<td>163</td>
<td>156</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Average</td>
<td>DAM</td>
<td>147</td>
<td>155</td>
<td>-8</td>
<td>29</td>
</tr>
<tr>
<td>MW-test</td>
<td>p-value</td>
<td>0.0027</td>
<td>0.2248</td>
<td>0.0017</td>
<td>0.0039</td>
</tr>
</tbody>
</table>
We make a couple of observations regarding the price-level differences in CAM and DAM. Note that the observed price levels are usually for some periods above and for some periods below the ex-post rational price. Generally as the figures suggest, the DAM tracks well the fundamental whereas prices in the CAM seem frequently unrelated to fundamentals. Applying a count heuristic, as recorded in Table I, the relative frequency when price levels exceed the rational benchmark in DAM and CAM are 29% and 66%. The average price levels in the two treatments are 147 and 272 as recorded in Table II, too. These differences between treatments are significant at the 5% level; the p-value of the exact two-tailed between-sample test is reported in the bottom-row of the table. The price effect between the CAM and the DAM is institutional as it cannot be justified on grounds of the cash-flows to equity. The fundamental values are, by chance, larger in the DAM as the average demand growth is lower in the CAM. The average difference of the observed one from the ex-post rational price in the CAM is at 129 significantly larger than the DAM at -8 as also shown in Table I. Price efficiency of the continuous double auction market is remarkable in our data. There is no significant difference of the price and the ex-post rational price for the DAM. The deviation from the fundamentals, however, is significant for the CAM. In comparison to experimental evidence from standard asset market experiments with known declining fundamental value (Smith et al 1988, van Boening et al. 1993, Baghestanian et al. 2013), hence, we find average pricing at the rational benchmark for the DAM and pricing above the rational benchmark in the CAM. In Smith et al (1988) subjects’ behavior converges on the risk neutral benchmark only in the third repetition of 15 periods. To investigate the repetition effect in our data, hence, we report data on the last 15 periods in Table I. We do find a similar repetition effect for our CAM experiment. The deviations from the rational benchmark are much smaller for these periods than over all periods, and moreover, prices are observed as likely above as below the benchmark. So we observe that the CAM prices converge on the rational benchmark with time. Nonetheless, the deviation from the benchmark is still positive in the CAM and therefore larger than in the DAM where it is rather negative. The dynamics in the DAM, on the other hand, seem rather stable over time and prices track fundamentals obviously much better than in the CAM.

3.2 Excessive volatility

The volatility puzzle describes the fact that real-world stock returns move too much to be rationalized by movements of underlying cash-flows. One simple test of the excessive volatility hypothesis has been proposed by Shiller (1981, p. 423). The test is constructed on the fundamental principle that the price is the present value of expected future dividends. As pointed out by Shiller (1981), the observed price forecasts the ex-post rational price and should deviate from it, therefore, by an uncorrelated error term only. Application of basic principles in mathematical statistics yields that the variance of the

---

16 The long-term dividend payments are larger in the DAM than in the CAM. The average liquidation dividend per share is 93.72 ECU in the CAM and 100.76 ECU in the DAM. As recorded in Table II, the ex post rational price is also larger for the DAM. Both differences are not significant between treatments.

17 The p-value of the one sample two-tailed Wilcoxon signed ranks test is 0.0180. The p-value of the same test on the DAM data is 0.4982, indicating no significant difference between the price and its rational benchmark.
price is equal to the sum of the variances of ex post rational price and error term. Taking standard deviations, thus, Shiller proposed the following variance bounds test,

$$\sigma(P) \leq \sigma(P^*)$$ \hspace{1cm} (4)

Rejecting inequality (4), Shiller reported that the standard deviation of price in the S&P500 over the period 1871 – 1979 was about five times the standard deviation of the ex-post rational price, and more than ten times for the Dow Jones over the period 1928 – 1979. In line with Shiller’s observation, we report in Table II a similar violation of inequality (4) for our data; the standard deviation of price is 11 times and 3.5 times the standard deviation of the ex-post rational price in CAM and DAM. According to the one-way one-sample Wilcoxon signed ranks test we reject inequality (4) at the 5% level of significance in favor of the alternative excessive volatility hypothesis; the p-values are 0.0090 and 0.0213, respectively.

Instead of inequation (4), LeRoy and Parke (1990) proposed an alternative variance bounds test based on the price-to-dividend ratio. Using again standard deviations, the resulting inequality can be written as follows.

$$\sigma(P/D) \leq \sigma(P^*/D)$$ \hspace{1cm} (5)

Based on American stock market data for the period 1871 – 1988, LeRoy and Parke estimated the variance of the ex-post rational price-to-dividend ratio as 19.6 and the variance of the price-to-dividend ratio as 26.4. The standard deviations of both ratios are exhibited in Table III for our experimental data. In line with the reported real-world violation of inequality (5), we report for both market institutions a significantly smaller volatility of the ex-post rational price than of the observed price. The null-hypothesis of inequality (5) is thus rejected in favor of the excessive volatility hypothesis.

According to yet another variance bounds test suggested by LeRoy and Parke (1990, p. 987), and based on the present value model (West 1988), the standard deviation of logarithmic returns should only be as high as the standard deviation of dividend growth,

$$\sigma(\ln(1 + R)) \leq \sigma(\Delta D)$$ \hspace{1cm} (6)

where

$$1 + R_t = \frac{P_t + D_{t-1}}{P_{t-1}}$$ \hspace{1cm} (7)

is the return on the market portfolio per period including capital gain and dividend yield, and

$$\Delta D_t = \ln \frac{D_t}{D_{t-1}}.$$ \hspace{1cm} (8)

denotes the logarithmic dividend growth. LeRoy and Parke (1990) report that the variance of logarithmic returns and the variance of dividend growth were 3.05% (= 17.46%²) and

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18 The p-values of the one-tailed one-sample Wilcoxon signed ranks test are 0.0175 and 0.0315 for CAM and DAM.
Table II. Standard deviations of price and returns

The standard deviation of the price, the ex-post rational price, the price-dividend ratio, the ex post rational price-to-dividend ratio, the logarithmic gross return, the logarithmic dividend growth, and the consumption growth as defined in the text are determined over the periods \( t=\{2, \ldots, 50\} \). For each session, the independent data and the treatment averages are recorded. The bottom row informs on the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal outcomes per treatment. The alternative hypothesis contradicts the null. Thus, a treatment effect is indicated in price variation and price-to-dividend variation.

<table>
<thead>
<tr>
<th>Session</th>
<th>( \sigma(P) )</th>
<th>( \sigma(P^*) )</th>
<th>( \sigma\left(\frac{P}{D_{t-1}}\right) )</th>
<th>( \sigma\left(\frac{P^*}{D_{t-1}}\right) )</th>
<th>( \sigma(\ln(1 + R)) )</th>
<th>( \sigma(\Delta D) )</th>
<th>( \sigma(\gamma_t) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73</td>
<td>13</td>
<td>46</td>
<td>29</td>
<td>14.2</td>
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<td>18</td>
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<td>18.7</td>
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<td>4.0</td>
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<tr>
<td>Average CAM</td>
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<td>91</td>
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<td>18.90</td>
<td>7.18</td>
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<td>20.0</td>
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<td>85</td>
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<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Average DAM</td>
<td>70</td>
<td>20</td>
<td>45</td>
<td>29</td>
<td>15.93</td>
<td>7.10</td>
<td>4.12</td>
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<tr>
<td>MW-test p-value</td>
<td>0.0126</td>
<td>0.5596</td>
<td>0.0476</td>
<td>0.4413</td>
<td>0.6547</td>
<td>0.9491</td>
<td>0.6547</td>
</tr>
</tbody>
</table>

For our laboratory data, we find evidence that the standard deviation of logarithmic returns significantly exceeds the standard deviation of logarithmic dividend growth for both laboratory market institutions.\(^{19}\) The average dividend growth volatility is 7\% in both treatments, and the average historical return volatilities are 19\% and 16\%, respectively. Thus, we confirm an excessive volatility for our laboratory data based on the three depicted variance bounds tests. From the between-treatment tests reported in the bottom-row

\(^{19}\) For the real world, indeed, one cannot exclude that the result may be driven by expectations about changes in risk-free rates or dividend growth, or by the intuition that managers are inclined to smooth dividends over periods. These arguments do not apply to our controlled laboratory setting, since dividends are a function of earnings, and the risk-free rate and the expected dividend growth-rate are constant.

\(^{20}\) The one-sample Wilcoxon signed-ranks test returns a p-value of 0.0180 for the CAM and 0.0425 for the DAM. The same test on the overall sample yields a p-value of 0.0019.
of Table II we find that the standard deviations of prices are different between treatments CAM and
DAM but the return volatilities are not. The excessive volatility is hence more pronounced in the
CAM than in the DAM. Note that the return volatilities are usually used to measure market risk.

3.3 Equity risk premium
The equity risk premium is the excess return on the market over the risk free rate. In Figure I, the
difference between the risk-neutral value and the market price indicates the investors’ required equity
premium. In the finance literature, the equity risk premium is most frequently estimated from
historical data. One of the most recent studies to report on equity risk premiums has been by
Damodaran (2012). Generally, the equity premium varies largely over time and between equity
markets. According to the data Damodaran reports, the annual geometric and arithmetic equity
premiums were 2.3% and 3.4% in the S&P500 over 10-year US-government bonds for the period
1961-2011. The arithmetic and the geometric equity premiums are defined by the difference of
average return on the market and average return on the risk free rate. Over the most recent 50 years
period, the annual equity risk premium was negative in 39% of the years. Our data documents smaller
though still similar numbers; the geometrical average is 1.3% and 1.6%, the arithmetic average is
3.1% and 3.1%, and the risk premium is negative in 36% and 38% of periods in CAM and DAM (see
Table III).

Note that the historical equity risk premium in real world markets has been argued to be
excessive (Mehra and Prescott 1985). So, it is noteworthy that we find a similar size in the laboratory.
The standard procedure for testing the excessiveness of the equity premium is the consumption-based
capital asset pricing model. The model incorporated constant relative risk aversion parameter, \( \alpha \), is
estimated by the ratio of equity risk premium and standard deviation of consumption growth (see e.g.
Mehra 2012).

\[
\alpha = \frac{E[\ln(1 + R_t)] - \ln(1 + R_f)}{\sigma^2(\gamma)}
\]

Using our data of geometric returns and observed standard deviation of consumption growth,\(^{21}\)
\( \sigma(\gamma) = 4\% \), we obtain parameter values of constant relative risk aversion of 8 and 10 for our
treatments CAM and DAM. These numbers are smaller than the ones reported in Mehra and Prescott
(1985), but still larger than the frequently presumed values of constant relative risk aversion,
\( 1 \leq \alpha \leq 2 \). Indeed, the model seems generally misplaced in the context of our experiment because our
investors have no impact on consumption growth. Nonetheless, we note that our reported numbers
would lead to an excessive equity risk premium in the standard consumption based asset pricing model
owed to the implied excessive level of constant relative risk aversion. Between treatments we find no
significant differences.

\(^{21}\) Consumption in our experiment is the minimum of the monopolist’s capacity and demand.
### Table III. Historical equity risk premium

The geometric and arithmetic risk premiums are computed. The bottom row displays the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal risk premiums across treatments. The alternative hypothesis contradicts the null and indicates a treatment effect. We do not observe significant differences in risk premiums between treatments.

<table>
<thead>
<tr>
<th>Session</th>
<th>Geom. average (%)</th>
<th>Arithm. Average (%)</th>
<th>Relative frequency of realized neg. risk premium (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.06</td>
<td>2.3</td>
<td>39</td>
</tr>
<tr>
<td>2</td>
<td>1.90</td>
<td>3.1</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>1.64</td>
<td>1.3</td>
<td>33</td>
</tr>
<tr>
<td>4</td>
<td>1.70</td>
<td>4.1</td>
<td>41</td>
</tr>
<tr>
<td>5</td>
<td>1.28</td>
<td>5.3</td>
<td>39</td>
</tr>
<tr>
<td>6</td>
<td>1.52</td>
<td>3.7</td>
<td>31</td>
</tr>
<tr>
<td>7</td>
<td>0.08</td>
<td>1.8</td>
<td>43</td>
</tr>
<tr>
<td>Average CAM</td>
<td>1.31</td>
<td>3.07</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>2.29</td>
<td>4.3</td>
<td>37</td>
</tr>
<tr>
<td>9</td>
<td>2.03</td>
<td>3.5</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>0.79</td>
<td>2.4</td>
<td>61</td>
</tr>
<tr>
<td>11</td>
<td>1.03</td>
<td>1.3</td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>0.12</td>
<td>0.4</td>
<td>49</td>
</tr>
<tr>
<td>13</td>
<td>3.66</td>
<td>6.8</td>
<td>24</td>
</tr>
<tr>
<td>14</td>
<td>1.63</td>
<td>3.1</td>
<td>37</td>
</tr>
<tr>
<td>Average DAM</td>
<td>1.61</td>
<td>3.12</td>
<td>38</td>
</tr>
<tr>
<td>MW-test p-value</td>
<td>.6547</td>
<td>.9491</td>
<td>.8470</td>
</tr>
</tbody>
</table>

#### 3.4 Liquidity and leverage in the market

As pointed out above, some papers have reported differences in volume between the call auction market and the double auction market institutions (see e.g., Theissen 1998). We confirm the findings of the literature on this liquidity measure for our data (Amihud et al 1997; Kehr et al 2001); trading volume is significantly enhanced in the DAM relative to the CAM treatment. Table IV displays the relevant per-session data including the test results in the bottom row. Average trading-volume per period is 4.2% and 7.6% of float in CAM and DAM, respectively. The differences between treatments are significant. Illiquidity is considered a major risk in financial markets. We note based on the

---

Kehr et al. suggest that spreads are smaller for large positions but larger for small positions in continuous trading markets. We look only on the aggregate level and compare the spreads after market closing.
correlations reported in Table VIII that liquidity is positively correlated with short-interest and negatively correlated with price variation.

Table IV also informs on the volume of forced asset sales, the debt-to-equity ratio, and the short-interest at the end of the period. The observed average short interest is about 2%, forced asset sales are above 0.5% of float. We find no evidence of significant differences between treatments. The debt-to-equity ratio looks higher in the CAM than in the DAM, but the difference is not statistically significant.

Table IV. Liquidity and leverage

The trading volume is the average number of transactions per period relative to the number of shares outstanding. The volume of forced asset sales is the average number of involuntary transactions per period relative to the number of outstanding shares. The average number of assets sold short is recorded relative to the number of outstanding shares. Finally, the average of negative cash-balances relative to the market value of equity is recorded. All computations are based on the end-of-period data. The bottom row displays the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal results across treatments. The test indicates a treatment effect in volume.

<table>
<thead>
<tr>
<th>Session</th>
<th>Trading volume: Average turnover of float (%)</th>
<th>Volume of forced asset sales: turnover of float (%)</th>
<th>Average short interest relative to float (%)</th>
<th>Average Debt/Equity ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.6</td>
<td>0.97</td>
<td>6.7</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>4.2</td>
<td>0.88</td>
<td>1.5</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>0.20</td>
<td>0.5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3.9</td>
<td>0.90</td>
<td>2.0</td>
<td>53</td>
</tr>
<tr>
<td>5</td>
<td>3.6</td>
<td>0.42</td>
<td>0.6</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>4.7</td>
<td>0.74</td>
<td>2.0</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>4.3</td>
<td>1.12</td>
<td>0.2</td>
<td>31</td>
</tr>
<tr>
<td>Average CAM</td>
<td>4.20</td>
<td>0.75</td>
<td>1.91</td>
<td>18.21</td>
</tr>
<tr>
<td>8</td>
<td>6.6</td>
<td>0.99</td>
<td>3.1</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>6.2</td>
<td>0.74</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>8.5</td>
<td>0.77</td>
<td>1.0</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>11.6</td>
<td>0.00</td>
<td>8.6</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>6.6</td>
<td>0.00</td>
<td>3.1</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>5.7</td>
<td>0.49</td>
<td>1.2</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>8.1</td>
<td>0.59</td>
<td>0.9</td>
<td>4</td>
</tr>
<tr>
<td>Average DAM</td>
<td>7.60</td>
<td>0.51</td>
<td>2.56</td>
<td>6.05</td>
</tr>
<tr>
<td>MW-test p-value</td>
<td>0.0006</td>
<td>0.2491</td>
<td>.7100</td>
<td>.1797</td>
</tr>
</tbody>
</table>
4 Data analysis: Individual behavior

Individual rationality requires that trading in absence of liquidity needs increases the investor’s expected return. Empirical evidence is therefore puzzling as it documents that investors’ returns are adversely affected by trading volume (Barber and Odean 2000). The excessive trading anomaly describes the observation that individual investors perform worse the more they trade. Another prominent behavioral anomaly that seemingly disagrees with the assumption of individual rationality is the observation that investors treat past gains and past losses differently.

4.1 Disposition effect

The effect that investors are inclined to hold on too long to their losing positions and to sell their winning positions too early has been referred to as the disposition effect (Shefrin and Statman 1985). Odean (1998) has measured the disposition effect by the comparison of the following two ratios:

\[
\frac{\text{Realized Gains}}{\text{Realized Gains + Paper Gains}} = \text{Proportion of Gains Realized (PGR)} \quad (10)
\]

\[
\frac{\text{Realized Losses}}{\text{Realized Losses + Paper Losses}} = \text{Proportion of Losses Realized (PLR)} \quad (11)
\]

Paper gains and losses are non-disposed long positions. We apply these measures to the periods of our experiments following the method detailed in Odean (1998). We count the number of shares in long positions that trade at a gain or a loss at the end of the period, and the number of long positions sold at a gain or a loss.\(^{23}\) The number of shares sold, the proportions of realized gains and losses, and the ratio of both are recorded for each session in Table V. In session #1, for instance, PGR is 3.1%; there were 20,825 shares classified as paper gains and 677 shares were sold at a gain. PLR in that session is 1.8% with 189 shares sold at a loss and 10,161 shares classified as paper losses. The PGR-to-PLR ratio is thus 1.7. The average PGR-to-PLR ratio is 2.7 for the CAM and 1.6 for the DAM treatments.\(^{24}\) The one sample test reveals that the PGR-to-PLR ratio is significantly different from unity in both treatments, thus, confirming the disposition effect.\(^{25}\) The between sample test shows that the reported frequency of realized gains and losses in the CAM and the DAM are significantly different. The result reflects the reported difference on trading volumes (Table VI). The PGR-to-PLR ratio, however, is not significantly different between treatments.

\(^{23}\) We exclude periods in which the investor faces forced asset sales and we do not consider short positions. In contrast to us, Odean counts winners and losers at the time of a sale not at the end of the period.

\(^{24}\) Odean reported the PGR/PLR ratio between 1.5 and 2 per calendar year. Many realized losses were related to tax benefits as losses are capital-gains tax deductible in the US. His sample included 10,000 individual accounts at a large brokerage house. In a sample of similar size, Ben-David and Hirshleifer (2012) reported that the disposition to sell losing stock may depend on the size of the loss.

\(^{25}\) The one-tailed Wilcoxon signed ranks test yields p-values 0.0089 and 0.0375 for CAM and DAM, and 0.0018 overall.
Table V. Disposition effect

The realized gains, the realized losses, the ratios PGR and PLR (as defined in the text) and the ratio of both are reported. The PGR/PLR ratio is different at the 5% level of significance from 1 in CAM and DAM. The bottom row displays the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal results across treatments. The alternative hypothesis contradicts the null and indicates a treatment effect. The test indicates a significant treatment effect in realized gains and losses, but not in the PGR/PLR ratio.

<table>
<thead>
<tr>
<th>Session</th>
<th>#Realized Gains</th>
<th>#Realized losses</th>
<th>PGR (%)</th>
<th>PLR (%)</th>
<th>PGR/PLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>932</td>
<td>266</td>
<td>4.3</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>2</td>
<td>613</td>
<td>272</td>
<td>4.5</td>
<td>1.6</td>
<td>2.8</td>
</tr>
<tr>
<td>3</td>
<td>679</td>
<td>179</td>
<td>3.1</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td>4</td>
<td>762</td>
<td>63</td>
<td>4.0</td>
<td>0.5</td>
<td>7.4</td>
</tr>
<tr>
<td>5</td>
<td>661</td>
<td>222</td>
<td>3.2</td>
<td>2.4</td>
<td>1.3</td>
</tr>
<tr>
<td>6</td>
<td>936</td>
<td>174</td>
<td>3.8</td>
<td>3.0</td>
<td>1.3</td>
</tr>
<tr>
<td>7</td>
<td>755</td>
<td>163</td>
<td>4.0</td>
<td>1.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Average CAM</td>
<td>762</td>
<td>191</td>
<td>3.84</td>
<td>1.96</td>
<td>2.68</td>
</tr>
<tr>
<td>8</td>
<td>826</td>
<td>559</td>
<td>6.4</td>
<td>3.2</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>992</td>
<td>398</td>
<td>6.9</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>10</td>
<td>943</td>
<td>686</td>
<td>7.4</td>
<td>3.9</td>
<td>1.9</td>
</tr>
<tr>
<td>11</td>
<td>1803</td>
<td>583</td>
<td>6.7</td>
<td>10.4</td>
<td>0.6</td>
</tr>
<tr>
<td>12</td>
<td>868</td>
<td>620</td>
<td>5.6</td>
<td>4.1</td>
<td>1.4</td>
</tr>
<tr>
<td>13</td>
<td>867</td>
<td>265</td>
<td>3.5</td>
<td>4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>14</td>
<td>1150</td>
<td>703</td>
<td>8.5</td>
<td>4.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Average DAM</td>
<td>1064</td>
<td>545</td>
<td>6.44</td>
<td>4.70</td>
<td>1.63</td>
</tr>
<tr>
<td>MW-test p-value</td>
<td>0.0060</td>
<td>0.0017</td>
<td>0.0059</td>
<td>0.0027</td>
<td>0.4418</td>
</tr>
</tbody>
</table>

4.2 Excessive trading and excessive leveraging

The literature suggests that investors trade too much, so that transaction costs eat up much of their gains from trade (Odean 1999; Barber and Odean 2000). From their sample of retail investors, Odean and Barber find that investors' returns are negatively correlated to the frequency of trading. In our setting, there are no transaction costs, so one could find arguments favoring more trade. If there are opportunities to buy low and sell high, subjects who trade more would perform well. On the other hand, since subjects are long-term investors by construction, the standard no-arbitrage argument suggests that no trading would occur. However, we know that trading occurs in our markets (e.g., Table IV). In Table VI we record rank-correlations between subjects' trading frequency and payoff. In most sessions the correlation coefficients are negative, thus, supporting the excessive trading hypothesis. We present the average data of the 14 sessions in Figure II by quintiles; within sessions,

---

26 The result of the one-tailed one-sample Wilcoxon signed ranks test suggests that the correlation coefficient is rather negative than positive. The evidence is significant; the p-values of the test on the overall sample are .0022
payoffs of investor-subjects are ranked from lowest to highest and their average number of voluntary trades per period is ranked from highest to lowest. Periods that include automated trades are treated as missing observations. Figure II shows the average payoff level of subjects who rank among the 20% of low frequency traders to those who rank among the 20% of high frequency traders. The average payoff level across quintiles is 10.5, ranging from 2.5 to 18.5. One easily recognizes from the chart that overall the payoff decreases with increased trading frequency. Nonetheless, the negative correlation is not perfect. The highest average payoff level is achieved in the second quintile. 

Our data thus suggest that some subjects manage to buy low and sell high and perform better than those who trade less. This suggestion can however not obscure the fact that the majority of subjects trade too much. The subjects who rank within the three high frequency trading quintiles realize a payoff level below the 10.5 average (the third quintile is at 10.4), and hence, would have performed better by trading less. Figure II indicates also how the frequency of voluntary transactions behaves to the investors’ level of leverage in our sample. From the chart it is clear that investors who trade more also use more leverage to finance their purchases. Given the high required return on margin loans, investors who debt finance their purchases signal confidence with their decision (Odean 1999). Therefore one must ask if investors earn excess returns if they take advantage of the possibility of using leverage such as margin-buying and short-selling. The answer to this question can be anticipated after having seen the chart. Subjects use excessive leverage for their investments in both treatments. We observe a negative correlation in each session between the level of leverage and their payoff. The overall average correlation coefficient is -0.465, and -0.584 for CAM and -0.345 and DAM. Even without accounting for bankrupt investor-subjects, who evidently use excessive leverage, we find that leverage does not lead to a higher payoff. The average correlation of leverage and payoff is still rather negative than positive (see Table VI).

The excessive trading effect does not show up if we neglect subjects who leveraged their positions during some period of the experiment. These data involve only 41 percent of subjects and are therefore not representative of behavior. In the experiment excessive trading cannot be separated from leveraging. In contrast, Odean (1998) suggested that the excessive trading effect may arise from poor timing skills of portfolio-rebalancing.

---

27 We observe a broad range of behavior including investor-subjects who sell their shares at the beginning of the experiment at a low price and abstain from trading throughout the experiment. The existence of such risk-avoiding behavior explains that the first quintile is not the mode of the chart.

28 According to the two-tailed Wilcoxon signed ranks test, the probability of an outcome at least as extreme as the observed one has a probability of 0.0596 under the null hypothesis that negative and positive signs are equally likely.
Figure II. Subject quintiles of trading frequency (both treatments)
High payoff levels correspond to high payoff ranks; the investor subject with the highest payoff in a session is ranked 20; the investor with the lowest payoff is ranked 1. The average payoff level per quintile is 10.5. Subjects are ranked by average debt/equity ratio per period. Individual leverage levels positively correlates with trading frequency. Periods of involuntary trading are treated as missing observations.

4.3 Margin trading and bankruptcy
Out of the 140 investor-subjects per treatment, 66 (47%) and 56 (40%) subjects used at least in one period margin-debt to finance their security purchases in CAM and DAM. Margin calls lead to forced liquidation of positions, and a substantial number of bankruptcies occurred; 23 (16%) and 7 (5%) subjects went bankrupt in CAM and DAM. This number looks quite alarming when one takes into account the fact that only subjects with leverage were able to go bankrupt. One out of every three subjects who used leverage to finance their long positions went bankrupt in CAM. The number is significantly larger than in DAM, where it is only one in eight subjects. That being said, bankruptcy is also possible through margin calls on short sales. We observe that the majority of investor subjects had a short position at some point of the experiment (see Table VII). Some margin calls actually occurred but in our sample never led to bankruptcy. Overall, there were 37 margin calls on short positions in CAM; and one such margin call in DAM. This margin call did not last until the end of a period; six shares were automatically purchased and the price briefly spiked. We believe that the institutional regulations of the experimental design were an important reason for why margin calls on short-positions were infrequent and did not lead to bankruptcy. As described above, the experimental design

29 We count margin calls by investor-periods. In each session there are $20 \times 50$ investor periods.
Table VI. Individual payoffs related to trading frequency and level of speculation

The final payoff of investor subjects is correlated to their number of transactions, their average leverage, and their observed number of short-sales (bankrupt investors are included or excluded). The trading frequency of non-leveraged investors is also correlated with the final payoff. The Spearman rank correlation which is the non-parametric pendant to Pearson’s correlation is used in all computations. For each session the independent data are recorded, and summarized by the average per treatment. The bottom row displays the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal results across treatments. The test indicates a significant treatment effect on payoff in relation to margin debt when bankrupt subjects are included in the test.

<table>
<thead>
<tr>
<th>Session</th>
<th>Trading frequency</th>
<th>Leverage</th>
<th>amount of margin debt</th>
<th>#shares held short</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#shares traded</td>
<td>#shares traded</td>
<td>amount of</td>
<td>No BK</td>
</tr>
<tr>
<td></td>
<td>No BK</td>
<td>no leverage</td>
<td>margin debt</td>
<td>No BK</td>
</tr>
<tr>
<td>1</td>
<td>-0.077</td>
<td>-0.446</td>
<td>-0.100</td>
<td>-0.399</td>
</tr>
<tr>
<td>2</td>
<td>-0.435</td>
<td>-0.270</td>
<td>0.400</td>
<td>-0.822</td>
</tr>
<tr>
<td>3</td>
<td>0.062</td>
<td>-0.191</td>
<td>0.333</td>
<td>-0.627</td>
</tr>
<tr>
<td>4</td>
<td>-0.408</td>
<td>-0.312</td>
<td>-0.107</td>
<td>-0.612</td>
</tr>
<tr>
<td>5</td>
<td>-0.216</td>
<td>0.146</td>
<td>0.146</td>
<td>-0.378</td>
</tr>
<tr>
<td>6</td>
<td>-0.274</td>
<td>-0.311</td>
<td>0.098</td>
<td>-0.557</td>
</tr>
<tr>
<td>7</td>
<td>-0.566</td>
<td>-0.035</td>
<td>0.747</td>
<td>-0.693</td>
</tr>
<tr>
<td>Average CAM</td>
<td>-0.273</td>
<td>-0.203</td>
<td>0.217</td>
<td>-0.584</td>
</tr>
<tr>
<td>8</td>
<td>-0.230</td>
<td>-0.032</td>
<td>-0.357</td>
<td>-0.260</td>
</tr>
<tr>
<td>9</td>
<td>-0.323</td>
<td>0.044</td>
<td>-0.900</td>
<td>-0.556</td>
</tr>
<tr>
<td>10</td>
<td>-0.317</td>
<td>0.114</td>
<td>0.261</td>
<td>-0.223</td>
</tr>
<tr>
<td>11</td>
<td>0.087</td>
<td>-0.246</td>
<td>0.033</td>
<td>-0.185</td>
</tr>
<tr>
<td>12</td>
<td>-0.044</td>
<td>-0.125</td>
<td>0.391</td>
<td>-0.087</td>
</tr>
<tr>
<td>13</td>
<td>-0.069</td>
<td>-0.028</td>
<td>0.287</td>
<td>-0.522</td>
</tr>
<tr>
<td>14</td>
<td>-0.163</td>
<td>-0.172</td>
<td>-0.024</td>
<td>-0.585</td>
</tr>
<tr>
<td>Average DAM</td>
<td>-0.151</td>
<td>-0.064</td>
<td>-0.044</td>
<td>-0.345</td>
</tr>
<tr>
<td>MW-test p-value</td>
<td>.2248</td>
<td>.0845</td>
<td>.3379</td>
<td>.0253</td>
</tr>
</tbody>
</table>

implemented an equity requirement and a cap on short-sales. Margin calls on long positions increased market frictions in the CAM treatment where margin calls were more frequently triggered and longer lasting. On average we observe that the clearing of the forced asset sales in the CAM took about three times as long as in the DAM, despite the reported similar turnover rate (Table IV). The difference is significant as reported in the bottom row of Table VII.

4.4 Risk determinants

The largest risk for participants is arguably to lose their entire equity stake in the experiment. Based on the bankruptcy frequency, we can conclude that the CAM treatment is more risky than the DAM. In a search for patterns we look at correlations between the recorded results and the frequency of investors’ bankruptcy. There are few significant correlations to report which have been recorded in Table VIII.
Subjects can leverage their purchases and sales of assets. The number of short sellers and margin purchasers records those subjects who were leveraged at least in one period. The margin purchasers are almost a subset of the short-sellers, with one exception in session 6 where one subject was margin purchaser without being a short seller at another occasion. The number of periods is recorded in which any subject received a margin call on a leveraged long or short position. Finally, the relative frequency of bankrupt subjects is recorded. For each session the independent data are recorded, and summarized by the average per treatment. The bottom row displays the results of the two-tailed two-sample Mann-Whitney rank sum test. This non-parametric test examines the null hypothesis of equal results across treatments. The test indicates a significant treatment effect in relation to the number of short sellers, the number of margin calls on long and short positions, and the number of bankruptcies.

<table>
<thead>
<tr>
<th>Session</th>
<th>Short sellers (%)</th>
<th>Margin purchasers (%)</th>
<th># Margin call periods on long positions</th>
<th># Margin call periods on short positions</th>
<th>Bankruptcies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>50</td>
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<td>Average CAM</td>
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<td>14</td>
<td>60</td>
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<td>Average DAM</td>
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<td>40.00</td>
<td>25.1</td>
<td>0.1</td>
<td>6.67</td>
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<td>MW-test p-value</td>
<td>.0070</td>
<td>.4758</td>
<td>.0252</td>
<td>.0196</td>
<td>.0379</td>
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The table records high correlation coefficients for the overall sample only if the correlation levels in the treatments CAM and DAM are also relatively high and point into the same direction. According to the correlation results in the table, the bankruptcy frequency in a session is correlated with the debt-to-equity ratio and the standard deviation of price. In line with the reported correlations, high levels of debt correspond with a higher frequency of forced asset sales and margin calls. Trading volume and short interest amend price variation, whereas margin calls, excessive price levels with regards to the risk neutral value lead to higher price variation. Both effects are obviously in line with the reported evidence on the excessive trading hypothesis. In sum, higher levels of margin debt in CAM than in DAM lead to higher price levels, more frequent margin calls and finally more bankruptcies. Investing is consequently more risky and expected returns are smaller in CAM than in DAM.
Table VIII. Spearman rank correlations

The Spearman rank correlation test is performed on the results of Tables II – VIII (exclusive VI, VII), within treatments CAM and DAM, and for the overall sample of $n = 14$ sessions. The correlation for the overall sample is recorded if signs of the correlations coincide with the ones of the subsamples, the size of their sum is larger than 0.459, and the size of the correlation of the overall sample is at least 0.363. Other correlations are not recorded. The (one-tailed) quantiles of the Spearman correlation test are (.363; .459; .534; .622; .675) for $p$-values (.900; .950; .975; .990; .995).

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<th></th>
<th>$\bar{P}^*$</th>
<th>$V(R_F)$</th>
<th>$\bar{P}'(R_F)$</th>
<th>$\bar{P}_i - \bar{V}(R_F)$</th>
<th>$#P_i &gt; V(R_F)$</th>
<th>$\sigma(P)$</th>
<th>$\sigma(P')$</th>
<th>$\sigma(P/D_{e+1})$</th>
<th>$\sigma(P'/D_{e+1})$</th>
<th>$\sigma(\ln + R)$</th>
<th>Geom ERP</th>
<th>Arithm ERP</th>
<th>trade vol.</th>
<th>forced sales</th>
<th>debt/equity ratio</th>
<th># short sellers</th>
<th># margin purchasers</th>
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<td>$\bar{P}^*$</td>
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<tr>
<td>$V(R_F)$</td>
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<td>0.836</td>
<td>0.606</td>
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<td>$\bar{P}'(R_F)$</td>
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<td>$\bar{P}_i - \bar{V}(R_F)$</td>
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<td>0.896</td>
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<tr>
<td>$#P_i &gt; V(R_F)$</td>
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<td>$\sigma(P)$</td>
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<td>$\sigma(P')$</td>
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<td>$\sigma(P/D_{e+1})$</td>
<td>0.582</td>
<td>0.473</td>
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<tr>
<td>$\sigma(P'/D_{e+1})$</td>
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<td>0.757</td>
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<td>$\sigma(\ln + R)$</td>
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<td>$\sigma(\Delta D)$</td>
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<tr>
<td>Geom ERP</td>
<td>0.665</td>
<td>0.639</td>
<td>-0.778</td>
<td>0.508</td>
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<td>Arithm ERP</td>
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<td># Negative ERP</td>
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<td>trade volume</td>
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<td>Debt/equity ratio</td>
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<td># short sellers</td>
<td>-0.446</td>
<td>-0.516</td>
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<td># margin purchasers</td>
<td>-0.390</td>
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<td># Marg calls long</td>
<td>-0.550</td>
<td>-0.601</td>
<td>0.678</td>
<td>0.593</td>
<td>0.584</td>
<td>0.841</td>
<td>0.841</td>
<td>0.431</td>
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<td>0.774</td>
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<td># Marg call short</td>
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<td>0.645</td>
<td>0.553</td>
<td>0.477</td>
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<td># bankruptcies</td>
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</table>
5 Conclusions

Our security market experiments have been designed to capture crucial features of real world asset markets including human-manager induced cash-flow uncertainty,\textsuperscript{30} margin requirements, and risks of forced liquidations of leveraged positions. With our approach we have addressed a recent demand for a more realistic experimental financial market design that enables simultaneous trading of multiple long-term lived assets (see Duxbury 1995, p. 353).

The experiment has not been designed to test for real-world anomalies. Nonetheless, the patterns in our data are in line with the reported anomalies of real-world markets. We have reported excessive levels of risk premium, volatility, trading, leverage, and the selling of winning stocks. These observations have been confirmed for both considered market institutions. Thus one of our main contributions is to observe in the laboratory similar evidence as has been reported from the field. The logical next step would be to experimentally investigate the sources of the anomalies in our data.

Our experimental design can generally be useful for the controlled laboratory study of market organization. In this paper, we have compared the performance of two market institutions, the once-clearing call-auction and the continous double auction. Earlier experimental studies have suggested that even in thin asset markets informational efficiency may be preferable in the once clearing call auction market (Friedman 1993b). We cannot dispute informational efficiency in the call auction market since in our design information is transparently provided to all subjects. Our data, however, suggest that the call auction actually makes markets thinner in terms of liquidity. There are fewer transactions in the call auction market than in the double auction market. Liquidity has an impact on price variation. Price variation and debt ratios are the main drivers of bankruptcy risk in the experiment. The continuous double auction appears thus less exposed to leverage and distress, and seems generally less risky than the once clearing call auction market.\textsuperscript{31} As our data reveal, convergence on and thus learning of the rational benchmark takes far longer in the call auction than in the double auction market where price convergence is almost instantaneous. Prices in the double auction are relatively stable over the course of the experiment and track the ex-post rational price relatively well. So our study provides fresh evidence of the efficiency and rapid convergence of prices in the double auction (Friedman 1993a) even with multiple multi period lived assets and realistic leverage opportunities. In fact, the world leading stock exchanges employ a hybrid market institution where a call auction is used for the rush hours in opening and closing trading. In view of the experimental

\textsuperscript{30} In fact, the underlying value is subject to the uncertainty created by the decisions of the manager in the company, which again may be affected by the risky environment. It could be interesting to investigate the effect of both uncertainties by making growth a degenerate variable and by substituting the manager decision by the optimal strategy. Relative to the optimal risk-free strategy of the manager, we remind the reader, that the average quasi-efficiency of managers has been 0.858, and the median 0.949. So, decisions were good but leave potential for improvement.

\textsuperscript{31} This observation brings to mind experimental results in simpler settings where price-efficiency has been shown to depend on the frequency of market clearing (Cason and Friedman 2008). It would be interesting to see how a repeated call auction performs in our design.
evidence, thus, a tentative interpretation of the real-world fact is that these exchanges weight both, price efficiency and informational efficiency. Price efficiency is overweighted when liquidity is at or below average and informational efficiency when liquidity is above average (e.g., in rush hours).

Considering our results it seems obvious that promising future research should take account of the properties of the market institution. Since the price patterns in the double auction market are more stable over the course of the experiment, experimental asset pricing studies applying valuation and forecasting models should apply the double auction institution. Given the fact that the data gathered in the double auction look closer to the real world counterparts, experimental studies on alternative institutions with policy implications like for instance alternative tax regimes or margin regulations seem also well placed within this market institution. Issues of managerial incentive pay and insider trading can also easily be implemented in future research. On the other hand, as learning seems to take longer in the call auction market, this institution seems to be a natural starting point with regards to the study of learning dynamics in experimental markets with multiple multi period lived assets. In conclusion, we believe that laboratory design can provide important tools to investigate and disentangle the institutional and behavioral peculiarities of empirical asset markets and that a realistic market design as ours is necessary in the process of knowledge accumulation.

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Appendix

A.1 Description of the publicly-held monopoly and the managerial decision problem

The objective of the subject acting as a company’s manager is to maximize the long-term cash flows to equity. After $T$ periods, the manager’s payoff is half the company’s equity. The managerial decision problem in period $t = \{1, 2, ..., T\}$ is described by the equation system in Table A1 and the parameter values according to Table AII. The manager chooses in every period a capacity-price tuple $(c_t, p_t)$. The company’s demand, defined in equation (A1), is a function of the chosen price and the growth-factor of the current period, $\gamma_t$. The growth-factor is a priori uncertain, but the past growth path of the company is known to the manager prior to his decision, $m_{t-1} = m_0 \prod_{\tau=1}^{t-1} \gamma_{\tau}$. Normalization of the dynamic multi-period decision problem by accounting for the realized past-growth, $m_{t-1}$, allows a stationary representation of the manager’s decision problem. In the described stationary representation, the solution to the manager’s dynamic multi-period decision problem can be described by a normalized capacity-price choice.

Sales $x_t$ as described in equation (A2) are equal to the minimum of the chosen production-capacity, $c_t$, and the realized demand, $n_t$. Companies hold no inventories. The operating profit $u_t$ depends on sales and the capacity-price choice. When the investment decision is made, the monopolist must take into account the direct costs of capacity allocation. Capacity is subject to real depreciation at rate $\delta$ at the end of the period. Besides these production costs, there are financing costs since the allocation of capacity binds cash at a unit-price $q$ for the period. The company’s opportunity cost on cash-use is the risk-free interest-rate $r$ which is paid on the company’s bank deposit, $f_{B_t}$. If the bank deposit is completely invested in capacity, additional investment can be debt-financed. As shown in equation (A6), debt $f_t > 0$ is the difference between the company’s capital investment $c_t q$ and its initial equity in the period, $b_{t-1} = \frac{b_{t-1}}{\gamma_{t-1}}$. Note that the period’s initial equity is equivalent to the period’s initial cash since capacity can always be purchased and sold at the unit price. Debt is subject to the interest rate $r_B$ and to the requirement

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32 At the end of the experiment, the company is liquidated. By design, the terminal capacity is disposed at the unit price. Generally, at that price, capacity-units can be acquired and disposed in every period. The manager of the firm receives half the liquidation-proceeds while the other half is distributed among the shareholders according to shareholdings. The incentives perfectly align the interests of the manager with those of the shareholders.

33 To implement the normalized capacity-price choice in the experimental environment, the capacity choice must be multiplied by the past growth multiplier, and both capacity and price are hundredfold. The growth distribution implemented in the experiment has support on the interval .95 to 1.09, so that the expected growth rate is two percent. This information is also communicated to the investor-subjects in the instructions.
Table AI. Monopoly model’s normalized variables

Information at the beginning of the period: At the beginning of the period $b_{t-1}$ is known. The variable $f_B$, $f_t$, and $z_t$ are uniquely determined by the information available at the beginning of the period. However the value of $\gamma_t$ is not known until the end of period $t$. Since $x_t$ depends on $\gamma_t$ in view of (2), the same is true for $u_t$, $\pi_t$, and $b_t$.

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<th>Capacity and price</th>
<th>$c_t$, $p_t$</th>
<th>instruments</th>
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<tr>
<td>Demand growth factor</td>
<td>$\gamma_t \sim U[.95,1.09]$</td>
<td>random variable</td>
</tr>
<tr>
<td>Constants</td>
<td>$\delta$, $q$, $r$, $r_D &gt; 0$</td>
<td>(A1)</td>
</tr>
<tr>
<td>Demand</td>
<td>$n_t = (1 - p_t)\gamma_t$</td>
<td>(A2)</td>
</tr>
<tr>
<td>Sales</td>
<td>$x_t = \min[n_t, c_t]$</td>
<td>(A3)</td>
</tr>
<tr>
<td>Operating profit</td>
<td>$u_t = x_t p_t - q\delta x_t$</td>
<td>(A4)</td>
</tr>
<tr>
<td>Bank deposit</td>
<td>$f_{B_t} = \max[0, b_{t-1} \gamma_{t-1} - c_t q]$</td>
<td>(A5)</td>
</tr>
<tr>
<td>Debt</td>
<td>$f_t = \max[0, c_t q - b_{t-1} \gamma_{t-1}]$</td>
<td>(A6)</td>
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<tr>
<td>Interest payment</td>
<td>$z_t = r f_{B_t} - r_D f_t$</td>
<td>(A7)</td>
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<tr>
<td>Retained earnings</td>
<td>$\pi_t = u_t + z_t - \max[0, u_t + z_t / 2]$</td>
<td>(A8)</td>
</tr>
<tr>
<td>Equity</td>
<td>$b_t = b_{t-1} \gamma_{t-1} + \pi_t$</td>
<td>(A9)</td>
</tr>
</tbody>
</table>

that it must not exceed initial equity. The sum of received interest payment $z_t$ and operating income is the net earnings of the company. Half of the net earnings are distributed among the equity shareholders as a regular dividend at the end of the period, and the other half is retained in the company, $\pi_t$. Retained earnings and dividends are tax-free. In periods of corporate losses, the dividend is zero (see equation A8). The equity at the end of the period $b_t$ is defined in equation (A9). Its maximization is the long-term objective of the manager. The company’s initial endowment in the first period is the initial shareholder’s equity, $b_0 / \gamma_0$.

For the derivation of the analytical solution in the appendix we assume that the monopolist has a planned growth, $\gamma$, which is constant across all periods and, thus, determines his strategy. The considered strategies are case-wise constant combinations of prices and growth-adjusted capacities. A solution to the optimization task of the manager is provided under the assumption that the manager is risk avoiding, that is, the planned growth factor is $\gamma = .95$ and the decision is risk-free. Applying the parametrization used in the experiment (Table AII), the optimal management decision can be described through the three-case capacity-price choice described in equation (A10). Note the first two cases refer to an interior solution with leverage and without leverage, respectively. The third case
describes the corner-solution in which the monopolist invests all equity but no debt in capacity and optimally adjusts the price.

\[
(c^*_t, p^*_t) = \begin{cases} 
(.14725, .845) & \text{if } .14725 \geq \frac{b_{t-1}}{3\gamma_{t-1}} \\
(.17575, .815) & \text{if } .17575 < \frac{b_{t-1}}{3\gamma_{t-1}} \\
\left(\frac{b_{t-1}}{3\gamma_{t-1}}, 1 - \frac{b_{t-1}}{2.85\gamma_{t-1}}\right) & \text{otherwise}
\end{cases}
\]  

(A10)

**Proof of equation (A10):**

Interested in a stationary solution, we assume that the monopolist has a planned growth, \( \gamma \), which is constant across all periods and, thus, determines the strategy. Considered strategies are therefore case-wise constant combinations of prices and growth-adjusted capacities. The marginal costs of production differ, depending if the capacity-price choice requires financing with debt or equity only. Towards the monopolistic objective function, we start at the equation for the net earnings before dividend distribution, neglecting losses as they play no role in the data.

\[
2\pi_t = u_t + z_t = x_t p - cq\delta + rf_{k_t} - r_d f_t 
\]  

(A11)

where

\[
x_t = \begin{cases} 
(1-p)\gamma & \text{if } \gamma_t \leq \gamma \\
c & \text{if } \gamma_t \geq \gamma
\end{cases}
\]  

(A12)

Now, we shall look at policies by which \( c_t \) and \( p_t \) are kept constant.

\( c_t = c \) for \( t = 1,2,\ldots \) with \( .95 \leq \gamma \leq 1.09 \)

\( p_t = p \) for \( t = 1,2,\ldots \) with \( 0 \leq p \leq a \)

Let \( \gamma \) be the value of \( \gamma_t \) with

\( (1-p)\gamma = c \)

\[
\gamma = \frac{c}{1-p}
\]  

(A13)

This value is the location of the “leverage kink” of \( x_t \).

The output

\[ x_t = \min[(1-p)\gamma, c] \]  

(A14)

can be written as a function of the planned growth \( \gamma \) in the following way:

\[
x_t = \begin{cases} 
(1-p)\gamma & \text{for } \gamma_t \leq \gamma \\
c & \text{for } \gamma_t \geq \gamma
\end{cases}
\]  

(A15)
We now delineate the consequences of the constancy of \( c_t \) and \( p_t \). The equations for \( f_t \) and \( f_{B_t} \) yield

\[
\begin{align*}
f_{B_t} &= \max[0, \frac{b_{t-1}}{\gamma_{t-1}} - cq] \\
f_t &= \max[0, cq - \frac{b_{t-1}}{\gamma_{t-1}}]
\end{align*}
\]  

(A16)

First, we compute the expected operating profit for the planned growth factor.

\[
E(u_t) = \int_{t}^{\gamma} (1 - p) p_{\gamma} \frac{d\gamma_t}{1.09 - .95} + \int_{t}^{\gamma} p_c \frac{d\gamma_t}{1.09 - .95} - c q \delta
\]

(A17)

\[
E(u_t) = \left[ (1 - p) p_{\gamma} \frac{\gamma_t}{1.09 - .95} \right]_{t}^{\gamma} + \left[ p_c \frac{\gamma - t}{1.09 - .95} \right]_{t}^{\gamma} - c q \delta
\]

(A18)

\[
E(u_t) = (1 - p) p' \frac{\gamma - .95^2}{2(1.09 - .95)} + p_c \frac{(1.09 - \gamma)}{(1.09 - .95)} - c q \delta
\]

\[
E(u_t) = c((1 - \frac{c}{\gamma}) \frac{1.09 - .95^2 - \gamma}{2\gamma - \frac{2}{1.09 - .95} - q \delta})
\]

(A19)

By inserting this result in equation (A3) we can compute the expected net earnings including operating profits and interest payments for every planned \( \gamma \).

\[
E(u_t + z_t) = c(1 - \frac{c}{\gamma}) \frac{1.09 - .95^2 - \gamma}{2\gamma - \frac{2}{1.09 - .95} - q \delta} + r f_{B_t} - r_d f_t
\]

(A20)

At zero bank deposit there is a kink in the function. We compute the expected net earnings on both sides of the kink; first, for the case of all-equity financing, \( f_t = 0 \); and second, for the case of debt and equity financing, \( f_t > 0 \).

Given the planned \( \gamma \), we have the following expected net earnings if debt is zero.

\[
E(u_t + z_t) \bigg|_{f_t=0} = c(1 - \frac{c}{\gamma}) \frac{1.09 - .95^2 - \gamma}{2\gamma - \frac{2}{1.09 - .95} - q \delta} + r \frac{b_{t-1}}{\gamma_{t-1}} - c q
\]

(A21)

We compute the optimal capacity from the following first order condition.

\[
\frac{dE(u_t + z_t)}{dc} \bigg|_{f_t=0} = (1 - \frac{2c}{\gamma}) \frac{1.09 - .95^2 - \gamma}{2\gamma - \frac{2}{1.09 - .95}} - (r + \delta)q = 0
\]

With no debt-financing the optimal solution is given by
The second case involves cash and debt financing the capacity investment, \( f_t > 0 \) and \( f_{t+1} = 0 \). Given the planned \( \gamma \), we have the following expected net earnings.

\[
E(u_t + z_t)|_{f_{t+1}=0} = c(1 - \frac{c}{\gamma}) \frac{1.09 - \frac{0.95^2}{\gamma}}{2} \frac{2}{1.09 - 0.95} - q c \delta + r_d \frac{b_{t-1}}{\gamma_{t-1}} - c q
\] (A23)

Hence, the first order condition yields the optimal capacity choice.

\[
\frac{dE(u_t + z_t)}{dc}|_{f_{t+1}=0} = (1 - \frac{2c}{\gamma}) \frac{1.09 - \frac{0.95^2}{\gamma}}{2} \frac{2}{1.09 - 0.95} - (r_d + \delta)q = 0
\]

\[
c_t^*|_{f_{t+1}=0} = a \frac{1.09 - \frac{0.95^2}{\gamma}}{2} \frac{2}{1.09 - 0.95} - (r_d + \delta)q(1.09 - 0.95)\frac{b_{t-1}}{\gamma_{t-1}} - c q
\] (A24)

Both solutions differ with respect to the financing cost only. Normalized equity is \( \frac{b_{t-1}}{q \gamma_{t-1}} \). If the first solution is optimal, \( c_t^*|_{f_{t+1}=0} \leq \frac{b_{t-1}}{q \gamma_{t-1}} \) must be true given the planned \( \gamma \), and capacity can be financed with equity only. If the second solution is optimal, \( c_t^*|_{f_{t+1}>0} > \frac{b_{t-1}}{q \gamma_{t-1}} \) must be true given the planned \( \gamma \), and the optimal capacity must be financed by debt and equity. If both conditions are violated, we have the corner solution, that is, equity but no debt is completely invested \( c_t|_{f_{t+1}=f_{t+2}=0} = \frac{b_{t-1}}{q \gamma_{t-1}} \). The amount of capacity in the corner-solution is likely to change in every period. In the same way the price must be adjusted, since the capacity-price relationship remains the same.

\[
p_t^* = (1 - \frac{c_t^*}{\gamma})
\] (A25)

The optimal solution for the company also depends on the risk attitudes of the monopolist. If we assume that the manager wants to avoid risk, he will plan the most pessimistic demand scenario, that is \( \gamma_t = 0.95 \), and thus choose the riskless solution. This strategy seems plausible, because it ranks high in terms of risk-adjusted returns. The net earnings maximum is rather flat in our parameterization so that
taking on additional risk is not worthwhile.\textsuperscript{34} (For instance, if the planned growth factor equals the expected growth factor, $\gamma = 1.02$ (as used in equations 31, 33, 34), the simulated quasi-efficiency based on the realizations in the experiment is 99.0% on average, with 102.1% as a maximum, 95.6% as a minimum and 99.2% as a median). So, assume the planned $\gamma$ is set at the lower bound of the demand-growth-factor distribution, $\gamma = .95$, and use the experimental parameters of Table AII. Equation (A10) defines the optimal capacity-choice:

$$c^*_t = \begin{cases} 
\frac{.95}{2} - \frac{.95}{2} + (.01 + .02) \cdot 3 = .185 & \text{if } f_t = 0; f_{B_t} > 0 \\
\frac{.95}{2} - \frac{.95}{2} + (.03 + .2) \cdot 3 = .155 & \text{if } f_t > 0 \\
\frac{b_{t-1}}{3\gamma_{t-1}} & \text{otherwise}
\end{cases}$$

(A26)

Table AII. Overview of parameter-values in normalized monopoly model

In line with the equation system presented in Table AI, this table presents the normalized values in the experimental task. *The exhibited values are fractions of the numbers presented to the monopolistic subjects. In the experiment subjects chose capacities between 0 and 1,000 and prices between 0 and 100.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lower and upper borders for $\gamma$</td>
<td>.95, 1.09</td>
</tr>
<tr>
<td>Initial growth shock</td>
<td>$\gamma_0 = 1$</td>
</tr>
<tr>
<td>Initial demand multiplier</td>
<td>$m_0 = 2$</td>
</tr>
<tr>
<td>Number of periods</td>
<td>$T = 50$</td>
</tr>
<tr>
<td>Interest rate for bank deposit</td>
<td>$r = .01$</td>
</tr>
<tr>
<td>Interest rate for debt</td>
<td>$r_D = .03$</td>
</tr>
<tr>
<td>Depreciation rate of capacity</td>
<td>$\delta = .2$</td>
</tr>
<tr>
<td>Price of a capital unit*</td>
<td>$q = 3$</td>
</tr>
<tr>
<td>Price $p_t$ with $n_t = 0$ *</td>
<td>1</td>
</tr>
<tr>
<td>Slope of the price factor $1 - p_t$ of $n_t$</td>
<td>$-1$</td>
</tr>
<tr>
<td>Initial cash balance*</td>
<td>$b_0 = 1$</td>
</tr>
</tbody>
</table>

\textsuperscript{34} More general solutions involve tedious computations of complicated polynomials. Given the flat maximum and the generally subordinate importance of the monopolists’ maximization problem in view of the paper’s focus, we skip these computations.
A.2 The experimental decision-tools of the manager

The manager-subject’s task of choosing two variables in a stochastically growing economy is aided by an onscreen search-tool (“flight-simulator”). For each combination of price and capacity inserted by the subject, the conditional profit-distribution over the given interval of growth-rates is graphically displayed (see Figure AI). Given any managerial choice, the conditional profit-distribution is piece-wise linear over the interval of possible growth-rates. It is either a non-decreasing line, or is linearly increasing up to a kink which is determined by the capacity choice and thereafter flat. The conditional profit-distribution is thus perfectly described by the potential profits at minimum and maximum growth rates, and at the kink. These three potential profits are recorded in a table together with the potential profit to be achieved at the expected demand growth, $E[y] = 1.02$. The chart displays the conditional profit-distribution for the latest production choice only, but the table makes comparable all the entered conditional profit-distributions. The table represents, thus, a menu of lotteries researched by the subject through the period. From this menu the preferred capacity-price choice must be selected at any time before the end of the period. Once selected, however, the choice can still be altered. Each period takes 150 seconds, the remaining time being displayed on the subject’s screen. When time is up, the latest selected choice and the realization of the randomly drawn growth-factor determine the profit. If no choice is being made in time, the default choice is the capacity after depreciation carried over from and the selected price of the previous period.

For each entered feasible and selected capacity-price choice, the manager-subject receives updated forward-looking information about the equity, the cash-balance, the debt, the debt-equity ratio, the capacity, the turnover, and the demand multiplier of the previous period. Thus, managers can compare several potential choices and adjust them before making their individual decision. After each period, subjects are informed about the revenue, production costs, operating income, dividends, interest-income, and net-earnings. These numbers are recorded on the screen in a table for all past periods. In a second table, subjects also have a record of the current cash-balance, the debt, the chosen capacity and the capacity after depreciation at the end of the period. The monopoly’s equity is the sum of price-weighted capacity and cash balance.

An important limitation to managerial decision-making is the debt-equity ratio must not exceed unity. If it does, capacity can only be liquidated but not increased anymore. No information is given to managers regarding the decisions and outcomes of the other companies, and no stock-market prices are revealed to them. Insolvency of the company is possible. However, automatic messages on the screen forewarn losing decisions to the subject, so that insolvency seems possible only if intended. After having distributed the regular dividend of the last period, $T = 50$, the company’s capacity after depreciation is changed in cash. Half the company’s liquidation value, i.e., $b_Tm_T/2y_T$ is the payoff to

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35 If no such choice is made throughout, the price and the depreciated capacity of the previous period are chosen by default. Subjects were not given this information in the instructions, however, to encourage an active decision-making. The search-protocol of the monopolistic subjects will be discussed in another paper.
the manager-subject. Updated private payoff-information is received by the manager at the end of each period revealing the manager’s payoff that would result in immediate company-liquidation.\(^{36}\)

**Figure A1. Profit-Growth diagram**

\(c\) is the profit at a growth-rate of -5\%; \(a\) is the profit at a growth-rate of +9\%; \(x\) is the minimum-required growth-rate to achieve the maximum profit given capacity 2\% is the expected growth-rate; the profit at that point is displayed in the table, too.

---

\(^{36}\) The corresponding amount of \(b_i \cdot m_i / 2 \gamma_i\) is the normalized payoff per experimental currency unit. In the experiment, monopolists were endowed with 10,000 currency units.
Subjects can submit limit-orders to trade the equity shares of the three companies LEFT, MIDDLE and RIGHT. Each limit order indicates a price for one share only. The limit orders are introduced on the investor-subject’s screen in three trading masks. The trading mask and the information regarding the company LEFT are displayed on the left-side of the screen, etc. Limit-orders are entered in one of the trading masks and confirmed by the subject as ask or bid through a press on the button. The limit-price can be determined up to the decimal. The bid must exceed the existing ask of the subject. Company related information is displayed in the corresponding sections on the screen. Tables that display company-related data are presented on the left, the center, and the right of the screen, respectively. Subjects can switch between these tables which include the historical data chronologically ordered by period. The table that exhibits the report of the company includes the profit per share, the dividend, which is half of the profit if it is positive and zero otherwise, the percentage growth in dividends and the liquidation book value per share receivable by the shareholders. The alternative multiples table includes the price-earnings ratio, price-to-book-value ratio and the debt-equity ratio of the company. The third table includes market volume, subject’s number of trades, the value of these trades, and the value of the position at the end of the period. Finally, in the double auction market treatment, the fourth table presents the opening, high, low and closing prices of the period. Subjects receive current information on their purchasing capacity, market value of equity, debt, and short-positions, debt-equity ratio, and the cash balance in the upper left corner. The current period and the remaining time of the period are displayed above. Past period information is presented in tables between the subject is able to switch the display in the lower half of the screen. The table located at the top shows the subject’s period income, the total and its components resulting from dividends, interest, and capital gains, as well as the end of period cash balance, equity and debt-equity ratio. The display of this table can be switched with the chart of historical closing share-prices of the three companies. All historical data are chronologically recorded with the most recent data in the top row.