Do Option-like Incentives Induce Overvaluation? Evidence from Experimental Asset Markets*

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Abstract

One potential reason for bubbles evolving prior to the financial crisis was excessive risk taking stemming from option-like incentive schemes in financial institutions. By running laboratory asset markets, we investigate the impact of option-like incentives on price formation and trading behavior. We observe (i) that option-like incentives induce significantly higher market prices than linear incentives. We further find that (ii) option-like incentives provoke subjects to behave differently and to take more risk than subjects with linear incentives. We finally show that (iii) trading at inflated prices is rational for subjects with option-like incentives since it increases their expected payout.

JEL classification: C92, D84, G10.

Keywords: Mispricing, incentives, market efficiency, experimental finance.

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1 Introduction

The role of specific compensation structures of financial market participants has become a highly discussed issue since the unfolding of the financial crisis in 2007-2008. It has been argued that bubbles in several markets were caused by excessive risk taking which stemmed from bonus payment systems and option-like compensation structures in financial institutions (Bebchuk and Spamann, 2010; Dewatripont et al., 2010; French et al., 2010; Gennaioli et al., 2012). According to Rajan (2006), one of the main origins of instability in highly developed financial markets are widely used convex incentives structures.[1] He argues that, compared to the 1970s, the reduced downside and the strongly increased upside potentials of investment managers' compensation create stronger incentives to take risks.

From the 1970s onwards, many investors started to delegate their portfolio to financial professionals. In general, this delegation of individuals' investment portfolios to financial professionals results in asymmetric information and creates a moral hazard problem (Allen, 2001). To solve the problems of moral hazard, various mechanisms are used to align the interests of the investment manager (agent) and the investor (principal). The most common mechanisms in the financial industry are bonus payments and option-like incentive contracts (Allen and Gorton, 1993; Kritzman, 1987). However, Rajan (2006) argues that managerial incentives are not always aligned with the investors' interests and these misalignments may result in distortions on financial markets.

Allen and Gorton (1993) model this agency problem theoretically. In their model the investment manager does not share the losses but receives a proportion of the profits.[2] They report "rational bubbles", as the convex incentive structure induces the investment manager to trade at prices far above funda-

[1] We use "option-like" and "convex" synonymously throughout the paper.

[2] Allen and Gorton (1993) and Cuoco and Kaniel (2011) argue that this type of compensation is widely used in the investment industry. Call-option type contracts are widespread in the hedge fund industry as well (Goetzmann et al., 2003). Another strand of literature examines how commonly observed incentive contracts impact portfolio managers' decisions (see e.g. Basak et al. (2008)) and Grinblatt and Titman (1989). These studies mainly examine how incentive contracts may affect the portfolio managers' risk preferences.

mentals. This problem is similar to the risk-shifting problem in Jensen and Meckling (1976) where corporations' shareholders obtain any upside potential but do not bear the full downside risk because of limited liability. Consequently, even risky negative net present value projects may be attractive for the shareholders. Likewise, Allen and Gale (2000) examine how intermediation by the banking sector leads to a similar agency problem which also results in asset bubbles.

Although these financial incentives are nowadays one of the major trading motives of financial professionals, little is known about the consequences of convex incentives on price formation in asset markets.[3] Only James and Isaac (2000) and Isaac and James (2003) investigate price formation in experimental markets under tournament incentive structures. They show that moderate overvaluation emerges under tournament incentives for all traders.

We run laboratory experiments to examine price formation and trading behavior under two different compensation structures. Inspired by Allen and Gorton (1993) and Rajan (2006), we address the following questions:

Research Question 1: Do option-like incentives trigger different price dynamics than linear incentives?

Research question 2: To what extent do option-like incentives change traders' behavior?

To answer the research questions, we implement two different incentive structures. In the first two treatments (Treatment LINEAR and Treatment CONVEX) we either apply a linear or a convex incentive structure for all subjects. In a third treatment (Treatment HYBRID) we endow half of the subjects with linear incentives and half of the subjects with convex incentives. The goal of this treatment is to analyze whether already a lower fraction of subjects with convex incentives induces different price dynamics and whether subjects with different incentives behave differently when competing in the same market.

[3]The impact of many different factors on price formation has been investigated especially in laboratory asset markets. The most prominent drivers of mispricing are lottery assets (Ackert et al., 2006), speculation (Lei et al., 2001), confusion (Kirchler et al., 2012), and positive liquidity shocks (Caginalp et al., 1998, 2001; Haruvy and Noussair, 2006).

We observe (i) significantly higher market prices when subjects are incentivized with option-like incentives than with linear incentives. We further show that (ii) option-like incentives induce subjects to behave differently and to take more risk than subjects with linear incentives. Finally, we report that (iii) trading at inflated prices is rational from an individual perspective since it increases the expected payout of option-like incentivized subjects. However, overvalued prices are harmful for the real economy as prices no longer reflect the assets' future cash flows and therefore prevent the efficient allocation of scarce resources.

2 The Experiment

In each market ten subjects trade assets of a fictive company for experimental currency (Taler) in a sequence of twelve periods of 120 seconds each.[4] At the beginning of each market subjects are endowed with 40 assets and 2000 Taler. Valued at the expected cash-flow, i.e., expected terminal dividend (ED), of 25 each subject's initial wealth is 3000 Taler in each treatment. Taler and asset holdings are carried over from one period to the next. No interest is paid on Taler holdings and there are no transaction costs.

2.1 Experimental Treatments

To achieve comparability it is necessary to set up the treatments in a way that expected earnings are identical across treatments. In particular, the incentive structures in all treatments are modelled such that the expected earnings of a risk-neutral hold strategy are EUR 15. Table 1 presents an overview of the treatment abbreviations and parameters.

Treatment LINEAR endows all subjects with a linear incentive structure.[5]

[4] To avoid end of experiment effects, subjects were told that the experiment will be terminated randomly between periods 8 and 15 with equal probability. In the first market, period 12 was chosen randomly and therefore we sticked to this ending period in all other markets.

[5] In all treatments a cash-flow (i.e., similar to periodic payments of the company) of either 2 or 0 Taler with equal probability is paid out for each unit of the asset after each period. After deducting holding costs of 1 for each unit the expected value of the sum of cash-flows and holding costs equals zero.

Table 1: Treatment parameterization.

	LINEAR	CONVEX	HYBRID[a]
Terminal dividends	15; 65	15; 65	15; 65
Probabilities of the terminal dividends	80%; 20%	80%; 20%	80%; 20%
Expected terminal dividend (ED)	25	25	25
Incentive structure	linear	option-like	linear; option-like
Strike (Taler)	–	3000	– ; 3000
Fixed payment (EUR)	–	8	– ; 8
Bonus payment (Taler/EUR)	100/0.5	100/2.1875[b]	100/0.5; 100/2.1875[b]
Expected payoff of a hold strategy (EUR)	15	15	15
Periods	12	12	12
Assets outstanding	400	400	400
Initial total asset value of the market	10,000	10,000	10,000
Initial cash in the market	20,000	20,000	20,000
Initial Cash/asset-ratio	2	2	2

[a] One half of the subjects is endowed with linear incentives, the other half with convex incentives.
[b] Only for the amount of wealth in Taler which exceeds the strike of 3000 Taler.

Terminal dividends of the tradable asset are either 15 or 65 with probabilities of 80% and 20%, respectively. The payoffs given a hold strategy are either EUR 13 (Wealth is calculated as the sum of 40 assets multiplied by 15 and 2000 Taler in cash. To arrive at the payout in Euro wealth is divided by the exchange rate of 200.) or EUR 23 under the two different terminal dividends. By multiplying both payouts with the probabilities for each state of nature, we arrive at the expected earnings of EUR 15.

Treatment CONVEX endows all subjects with a convex incentive structure. In particular, the option-like payment kicks in at a wealth level of 3000 Taler (similar to an "at-the-money" Call option).[6] The fixed payment is EUR 8 and the bonus payment (slope of the payoff function in Figure 1) is set to EUR 2.1875 for every 100 Taler in wealth exceeding 3000 Taler. If a subject holds the

[6]Typically, the compensation structures in the investment industry include two main components (Cuoco and Kaniel, 2011). One component is linearly or non-linearly related to the performance of the portfolio. The other component is linearly related to the absolute value of the managed portfolio. However, net investment flows are less sensitive to past returns when these are bad and much more sensitive when performance is good (see e.g. Brown et al. (1996), Chevalier and Ellsion (1997), and Sirri and Tufano (1998)). Thus, the second compensation component is implicitly convex in performance as well. Therefore, our simple convex incentive structure mimics the compensation structure of investment managers on real markets. Of course, traders on real markets face other social, legal and moral consequences that we cannot model in our experiment. However, the isolation from a specific real-world context is typical for all kinds of laboratory work. It might even be less relevant in market experiments as social preferences are less important and therefore do not influence results (see the discussions in Levitt and List (2007) and Al-Ubaydli and List (2012)).

initial portfolio and a terminal dividend of 15 is realized, she receives EUR 8, as final wealth of 2600 Taler does not exceed the strike of 3000 Taler. Instead, if a terminal dividend of 65 is drawn final wealth equals 4600 Taler which results in a payoff of EUR 43 ((4600–3000)*2.1875/100 + EUR 8).

Treatment HYBRID endows five subjects with the linear incentives of Treatment LINEAR and five subjects with the convex incentives of Treatment CONVEX in each market. Subjects knew that other subjects in the market were incentivized differently, but they were not aware of the precise incentive structure of the others and the number of subjects being incentivized differently. Figure 1 displays the two incentive structures used in the various treatments.

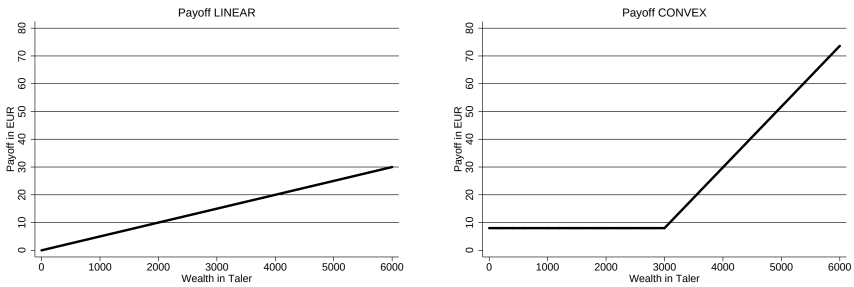

Figure 1: Incentive structures of subjects either being endowed with linear incentives (left) or with convex incentives (right).

2.2 Market Architecture

Subjects trade in a continuous double auction with open order books (see the Appendix for a screenshot and a detailed explanation of the trading screen). Firstly, all orders are executed according to price and secondly, time priority. Market orders have priority over limit orders and are always executed instantaneously. Any order size, the partial execution of limit orders, and deleting of already posted limit orders are possible. Shorting assets and borrowing money is not allowed.

2.3 Experimental Implementation

Six markets were run for each treatment. All 18 markets were conducted at the Universities of Gothenburg and Innsbruck with a total of 180 students (bachelor and master students in business administration and economics). Three markets of each treatment were run at each University.[7] Each subject participated in only one market and we made sure that subjects did not participate in earlier asset market experiments of comparable design. The markets were programmed and conducted with z-Tree 3.2.8. by Fischbacher (2007). Subjects were recruited using ORSEE by Greiner (2004). In total, each experimental session lasted approximately 75 minutes, including 20 minutes to study the written instructions, three trial periods and the main experiment. Average earnings of the experimental subjects were EUR 15.6.

3 Results

3.1 Descriptives

Figure 2 shows volume-weighted period prices of individual markets (grey lines) and mean treatment prices (bold line with circles) over time. Table 2 outlines mean market prices and asset overvaluation (OV) as a percentage of the expected terminal dividend (ED).[8] With a median OV of -0.2% Treatment LINEAR exhibits efficient prices which are almost identical with the ED. Instead, when a convex incentive structure is applied, we observe strong median overvaluation of 50.9%. With a value of 25.5%, median overvaluation in Treatment HYBRID is located between Treatment LINEAR and Treatment CONVEX.

[7]We find no differences in results between Universities for the market variables investigated below.

[8]We define overvaluation (OV) as the percentage deviation of prices from the expected terminal dividend (ED).

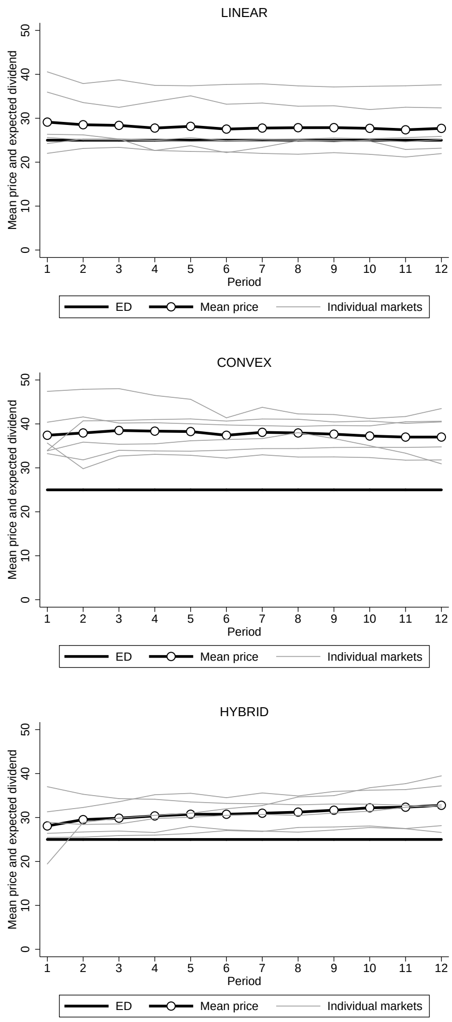

Figure 2: Expected terminal dividend (ED, bold line), mean treatment prices (bold line with circles) and volume-weighted mean prices of individual markets (grey lines) as a function of period. Upper panel: Treatment LINEAR – all traders are incentivized with a linear incentive structure. Middle panel: Treatment CONVEX – all traders are endowed with a convex incentive structure. Bottom panel: Treatment HYBRID – half of the traders is incentivized linearly while the other half is given convex incentives.

Table 2: Descriptive statistics for mean market prices and overvaluation (OV).

Treatment	Market	Mean Price	OV(%)
LINEAR	1	33.33	33.3%
	2	24.51	−1.9%
	3	25.25	1.0%
	4	22.24	−11.1%
	5	37.86	51.5%
	6	24.66	−1.4%
Median		24.96	−0.2%
CONVEX	1	40.18	60.7%
	2	35.32	41.3%
	3	34.02	36.1%
	4	40.14	60.5%
	5	32.51	30.1%
	6	44.29	77.1%
Median		37.73	50.9%
HYBRID	1	26.86	7.4%
	2	34.88	39.5%
	3	33.73	34.9%
	4	30.41	21.6%
	5	32.32	29.3%
	6	27.02	8.1%
Median		31.37	25.5%

3.2 Research Question 1

To answer the first research question whether option-like incentives lead to different price levels than linear incentives, we run pairwise Mann-Whitney U-tests.

Table 3: Pairwise Mann-Whitney U-tests for overvaluation (OV) between the different treatments. Absolute differences in OV in percentage points (pp) and p-values in parenthesis are provided. Sample size N of each test equals 12.

Treatments	CONVEX	HYBRID
LINEAR	51.1**	25.7
	(0.0250)	(0.2001)
CONVEX		25.4**
		(0.0163)

*, ** and *** represent the 10%, 5%, and 1% significance levels of a double-sided test.

One can see from Table 3 that there is a significant difference in OV between Treatment LINEAR and Treatment CONVEX. However, due to the high variance of individual market results for OV, HYBRID is statistically indifferent from LINEAR, but shows a significantly lower value of OV compared to CONVEX. Thus, convex incentives generate price dynamics that lead to significantly higher prices. Furthermore, a fraction of 50% of subjects with convex incentives is already sufficient to drive prices considerably away from the expected terminal dividend. Hence, research question 1 can be answered positively.[9]

3.3 Research Question 2

To answer the second research question whether subjects' behavior changes when incentivized differently, Treatment HYBRID is most suitable since subjects with both incentive structures trade in the same market environment.

We find that subjects who are incentivized with convex incentives show a markedly different trading behavior and take on more risk compared to subjects with linear incentives.[10] We derive our results from a LS-regression with clustered standard errors on a market level:

$$y_j \quad = \alpha + \beta_1 CONVEX_j + \epsilon_j. \tag{1}$$

The binary dummy $CONVEX_j$ is 1 if subject j is endowed with a convex incentive structure, zero otherwise. y_j is a generic placeholder for the dependent variables *STOCK*, *MONEY*, *PFRISK*, and *ACCRATIO*. For the variables *STOCK* and *MONEY* we take the median in asset and cash holdings from period 8 to 12 of subject j, respectively. This serves as reliable proxy for subjects' final endowments, as the experiment can be terminated beginning in period 8. We apply the same approach for variable *PFRISK* which measures the absolute difference in portfolio wealth between the high state and the low state of the

[9]The Appendix provides details on other descriptive market variables. Share turnover (*ST*) is applied as a measure of trading volume, the average bid-ask-spread as a percentage of the ED in the market (*SPREAD*), and the standard deviation of log-returns (*SD_RET*) as a proxy volatility in the various markets. However, we detect no significant differences in any of the investigated variables.

[10]We ran a risk aversion test before the experiment and we found no significant difference between the two subgroups. Therefore, all observe differences are due to the incentive structure.

buyback price. With this variable we measure the riskiness of each subject's portfolio. In particular, a low number hints at a low-risk portfolio while a high number points at a risky portfolio with major investments in the risky asset. Finally, $ACCRATIO$ serves as a proxy for the cautiousness of subjects and is defined as the number of all posted market orders of subject j divided by the total number of her posted limit orders (Kirchler et al., 2011). For instance, a high value of acceptance ratio indicates a more immediate and risky trading behavior. Table 4 outlines the results.

Table 4: LS-regression for differences in behavior between subjects with either convex or linear incentives in Treatment HYBRID.

	$STOCK$	$MONEY$	$PFRISK$	$ACCRATIO$
α	27.93***	2375.13***	1396.67***	0.52***
	(4.51)	(11.47)	(4.51)	(4.43)
$CONVEX$	22.86*	−718.42*	1143.33*	1.31*
	(1.76)	(−1.66)	(1.76)	(1.75)
N	60	60	60	60

Dependent variables: $STOCK$: median stock holdings of subject j from period 8 to 12. $MONEY$: absolute median money holdings of subject j from period 8 to 12. $PFRISK$: median difference of the portfolio value in case of a high buyback price and in case of a low buyback price of subject j from period 8 to 12. $ACCRATIO$: acceptance ratio of subject j (market orders divided by limit orders). z-values are given in parentheses. $CONVEX$: binary dummy showing 1, if subject j is incentivized with a convex incentive structure, zero otherwise.
*, ** and *** represent the 10%, 5% and the 1% significance levels of a double-sided test.

First, one can see from column $STOCK$ that subjects with convex incentives hold significantly more stocks in their portfolio. While subjects with linear incentives only hold 28 stocks, those endowed with convex incentives hold 51 towards the end of the experiment.[11]

Second, we find the opposite effect for endowments in cash as outlined in column $MONEY$. Subjects with linear incentives hold on average 2375 units of cash, while subjects with convex incentives show significantly lower money holdings by 30% towards the end of the experiment.

Third, we report that subjects with convex incentives have a significantly

[11]Note that with endowments being calculated as the median of each subject, numbers do not necessarily sum up to on average 40 stocks and 2000 in cash.

riskier portfolio composition than subjects with linear incentives (see column *PFRISK*). The differences are strong in magnitude as portfolio risk of option-like incentivized subjects is more than 80% higher compared to the one of linearly incentivized subjects.

Fourth, subjects show differences in their cautiousness to trade (see column *ACCRATIO*). In particular, the acceptance ratio of subjects with a convex incentive structure is more than 2.5 times higher compared to subjects with a linear incentive structure. This indicates that subjects with convex incentives actively seek to maximize their expected payout by a rather impatient and risk seeking trading behavior.

To sum up, subjects directly respond to the applied incentives and show significantly different trading patterns, which answers research question 2 affirmatively.

3.4 Discussion

The goal of this section is to analyze whether the observed prices are a rational response to the different incentives. Therefore, we detecte the trading price at which individual subjects are indifferent between buying and selling assets, i.e. the subjects' reservation price (RP), under different incentives. We assume that the representative agent j maximizes his expected profit. We further assume, for the sake of simplicity, that the representative agent does not make net capital gains from trading and therefore the volume-weighted average price of all purchases equals the volume-weighted average price of all sales. So, $\overline{p_j}$ is the average trading price of agent j.

In Treatment LINEAR, the Taler value of the cash position of agent j at the end of the market is equal to $2000 + (40 - n) \cdot \overline{p_j}$ where n is the number of assets held at the end. The Taler value of her asset position is $n_j \cdot d_i$ where d_i is the terminal dividend in state i (either low or high). The expected Euro payoff $E(\text{Payoff})_j$ of agent j can be written as,

$$E(\text{Payoff})_j = \frac{1}{\text{FX}} \sum_{i=1}^{2} \pi_i (2000 + (40 - n_j)\overline{p_j} + n_j \cdot d_i), \tag{2}$$

where FX is the exchange rate Taler to Euro and π_i stands for the probability of the terminal dividend d_i in state i. If the average trading price is above (below) 25, the expected payoff to a net seller increases (decreases) and the expected payoff to a net buyer decreases (increases). Thus, the representative agent has no incentives to acquire (sell) assets at prices above (below) 25 since this would reduce his profits. Thus, 25 will be his reservation price with linear incentives.

In contrast, Equation (3) shows the expected Euro payoff $E(\text{Payoff})_j$ for the representative agent under a convex incentive structure (Treatment CONVEX):

$$E(\text{Payoff})_j = 8 + \frac{1}{\text{FX}} \sum_{i=1}^{2} \pi_i (max[0, 2000 + (40 - n_j)\overline{p_j} + n_j \cdot d_i - 3000]). \tag{3}$$

It is evident from equation (3) that option-like incentives trigger different price dynamics of the reservation price compared to linear incentives. Figure 3 plots the expected payoff ($E(\text{Payoff})_j$) as a function of the average trading price $\overline{p_j}$ for asset end holdings n_j (in steps of five) from zero (dashed line) to 120 (bold line) of agent j in Treatment CONVEX. At low (high) average trading prices, large (low) end holdings of the asset dominate low (high) end holdings. For instance, if the market price equals the ED of 25, the agent has incentives to acquire as many assets as possible (end holdings of 120 dominate all lower end holdings at a price of 25). In particular, the average trading price at which agent j is indifferent between being a net-purchaser and a net-seller is 39.40. Consequently, 39.40 is the reservation price (RP) which results in OV of 57.6%.[12]

[12]Note, that a benchmark for Treatment HYBRID would be within the boundaries of 25.00 and 39.40. However, finding a clear-cut benchmark would be problematic as any values within the boundaries would be arbitrary and solely rely on the modelling assumptions of both

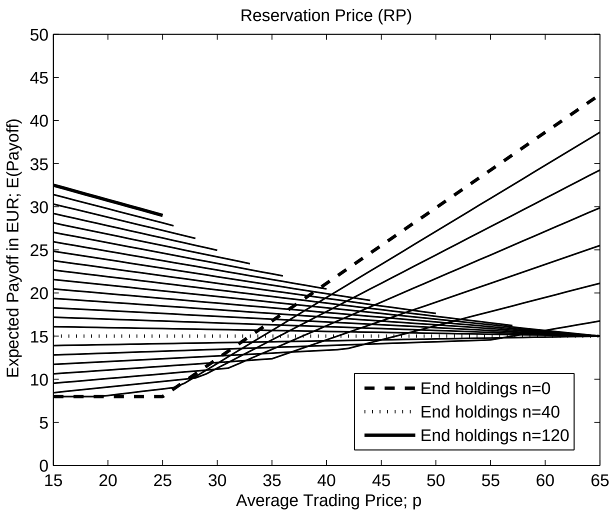

Figure 3: Expected payoff in EUR of agent j ($E(\text{Payoff})_j$) as a function of agent j's average trading price under various end holdings (n_j) of the asset in Treatment CONVEX.

Importantly, the reservation prices (RP) of 25.00 (OV of 0.0%) in Treatment LINEAR and 39.40 (OV of 57.6%) in Treatment CONVEX are not statistically different from the experimentally observed price levels (one sample median test – Wilcoxon signed-rank test: z=0.314, p=0.7532, N=6 for Treatment LINEAR and z=0.734, p=0.4631, N=6 for Treatment CONVEX). Thus, the observed prices are a rational response to the applied incentives. It is remarkable that under convex incentives, subjects quickly recognize the shift of the optimal trading price and bid up prices to their reservation level.

4 Conclusion

In this paper we used laboratory asset markets to examine whether option-like incentives lead to different price dynamics and trading behavior. We observed (i) overvalued prices when subjects were endowed with option-like incentives. Furthermore, we found (ii) that subjects, when incentivized option-like, showed

subgroups. Therefore, we refrain from providing a clear benchmark for Treatment HYBRID.

a different trading behavior and took on significantly more risk than subjects with linear incentives. We concluded that (iii) trading at overvalued prices and taking on excessive risks were rational for traders with convex incentives. Due to the convexity of option-like incentives trading at these prices increases traders' expected payouts. Although rational from a trader perspective, overvalued assets are harmful for other "market participants": (1) Investors frequently delegate their portfolio to investment managers with convex incentives. These investors, however, face a linear incentive structure and therefore carry the losses of buying overvalued assets. Furthermore, (2) the real economy and society as a whole suffer losses as asset prices do no longer reflect discounted future cash flows and therefore efficient allocation of scarce resources is harmed. For instance, these inflated prices might especially be problematic when a sufficient number of option-like incentivized traders inflate prices of commodities, leading to distortions in several industrial sectors.

We further extend existing literature along three dimensions. First, we contribute to the literature on whether option-like incentives lead to a risk-shifting problem and asset overvaluation as argued by Allen and Gorton (1993). Our experimental results suggest that when subjects have convex incentives, they quickly recognize the risk-shifting problem and bid up prices close to their individual reservation price. Thus, we arrive experimentally at similar results as Allen and Gorton (1993).

Second, earlier experimental studies on asset overvaluation mainly discuss irrational explanations such as capital-gains trading (Smith et al., 1988), speculation (Lei et al., 2001) or confusion (Kirchler et al., 2012). Except the studies of James and Isaac (2000) and Isaac and James (2003) little is known about the role of incentives on price formation in experimental asset markets. We contribute to this line of literature by documenting rational overvaluation.

Third, our research is in line with the claim of Rajan (2006) that one of the main origins of instability in highly developed financial markets are convex incentives of market participants. Compared to the 1970s the reduced downside and strongly increased upside potentials of investment managers' compensation create stronger incentives to take risks. Consequently, this increases the likelihood that managerial incentives are not always aligned with the investors' interests and these misalignments may result in distortions such as mispricing of assets.

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Appendix

Appendix A: Additional Analysis

Table A1 provides other descriptive market variables. Share turnover (ST) is applied as a measure of trading volume, the average bid-ask-spread as a percentage of the ED in the market ($SPREAD$), and the standard deviation of log-returns (SD_RET) as a proxy volatility in the various markets. Table A2 shows the results. In particular, treatments show moderate differences in these variables. However, we detect no significant differences between any of the investigated variables.

Table A1: Additional market variables: Share turnover (ST), bid-ask-spread (SPREAD), and standard deviation of log-returns (SD_RET).

Measure	**calculation**
Share turnover	$ST \quad = \sum_{p=1}^{N} VOL_p/TSO$
Relative spread	$SPREAD = \frac{1}{N} \sum_{p=1}^{N} \overline{SPREAD_p}/ED_p$
Standard deviation of log-returns	$SD\_RET = \sqrt{\frac{1}{T} \sum_{t=1}^{T} (R_t - \overline{R})^2}$

Notes: ED = expected terminal dividend. VOL_p = trading volume in period p; TSO = total shares outstanding; $\overline{SPREAD_p}$ = (volume-weighted) mean difference between best bid and best ask at every trade t in period p; N = total number of periods; $R_t = ln(P_t/(P_{t-1}))$; T = total number of trades; $\overline{R}$ = average log return.

Table A2: Top panel: Treatment averages of *ST*, *SPREAD*, and *SD_RET*. Other panels: Pairwise Mann-Whitney U-tests for *ST*, *SPREAD*, and *SD_RET* (z-values and p-values in parenthesis are provided). Sample size N of each test equals 12.

Treatment	*ST*	*SPREAD*	*SD_RET*
LINEAR	2.761	0.091	0.043
CONVEX	2.467	0.129	0.046
HYBRID	2.311	0.0849	0.035

ST	CONVEX	HYBRID
LINEAR	0.160	0.961
	(0.8728)	(0.3367)
CONVEX		0.961
		(0.3367)

SPREAD	CONVEX	HYBRID
LINEAR	1.441	0.320
	(0.1495)	(0.7488)
CONVEX		1.601
		(0.1093)

SD_RET	CONVEX	HYBRID
LINEAR	0.160	0.641
	(0.8728)	(0.5218)
CONVEX		0.801
		(0.4233)

*, ** and *** represent the 10%, 5%, and 1% significance levels of a double-sided test.

Appendix B: Individual Market Data

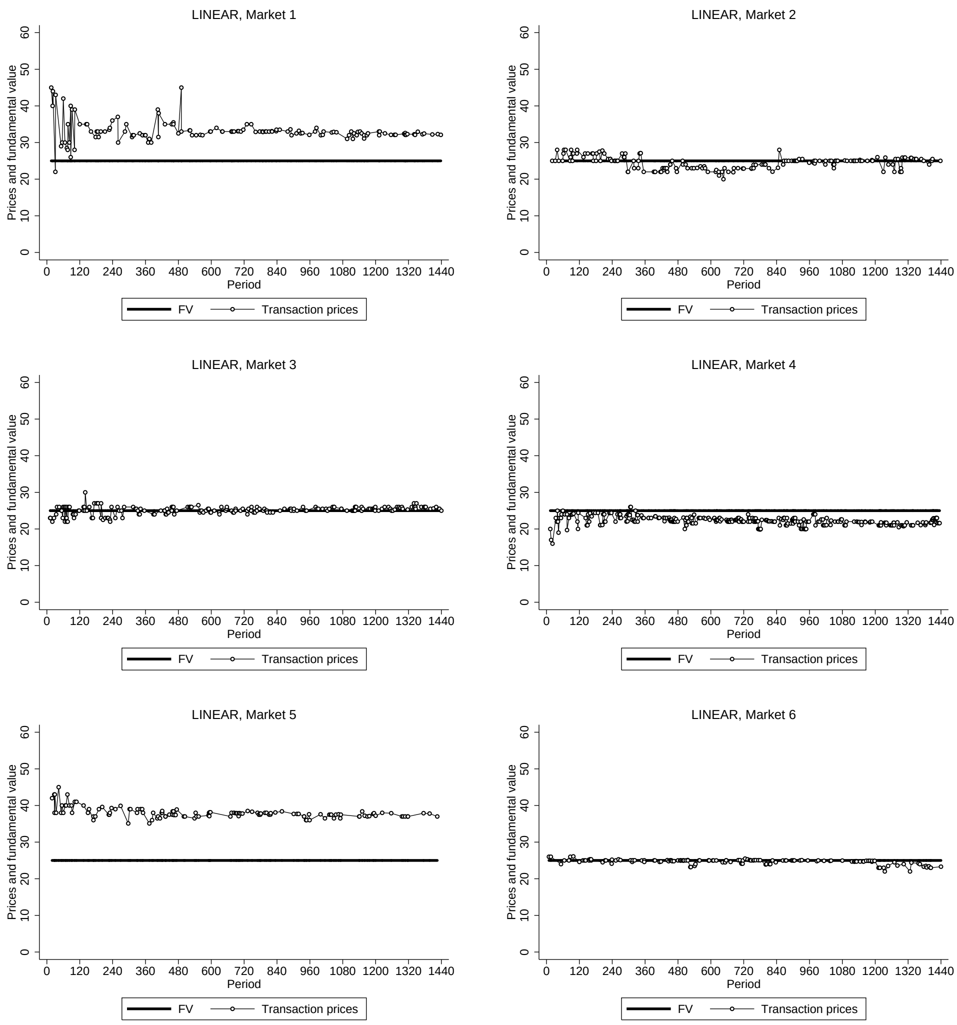


Figure A1: Expected terminal dividend (ED, bold line) and individual transaction prices in all markets of Treatment LINEAR.

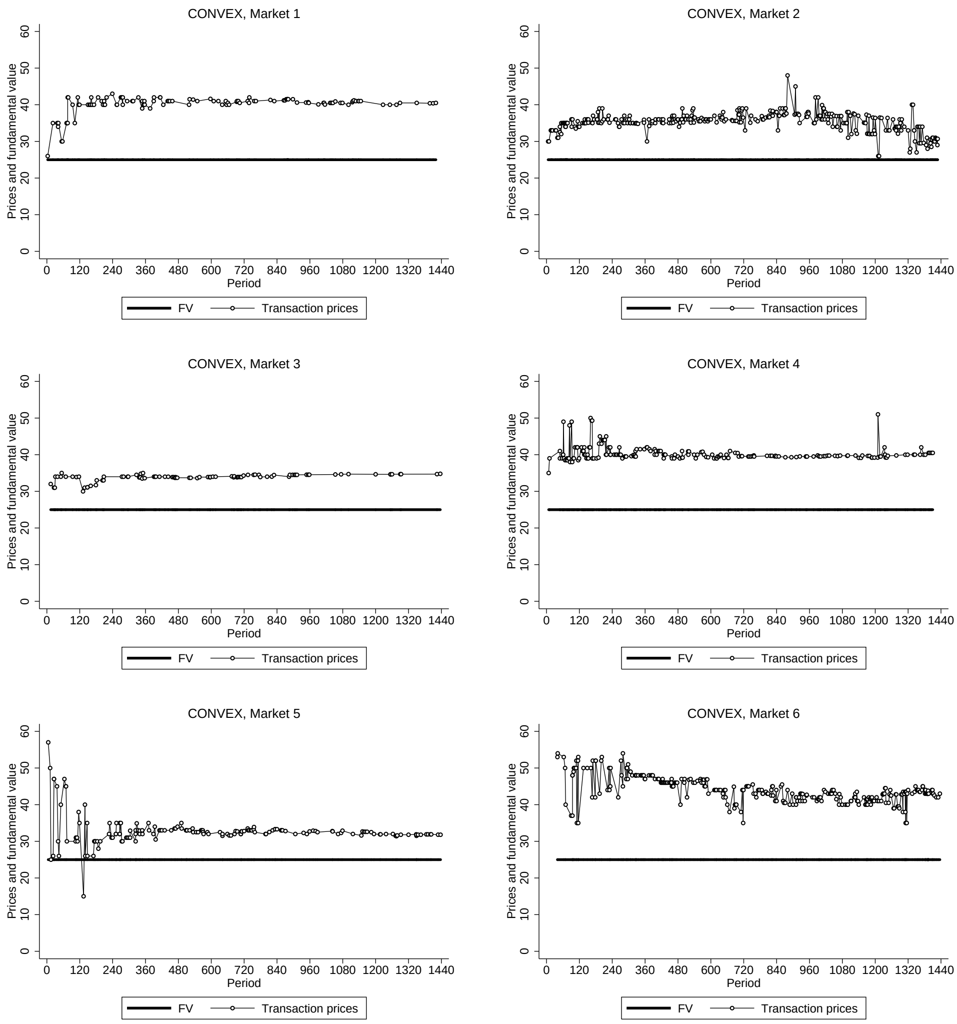


Figure A2: Expected terminal dividend (ED, bold line) and individual transaction prices in all markets of Treatment CONVEX.

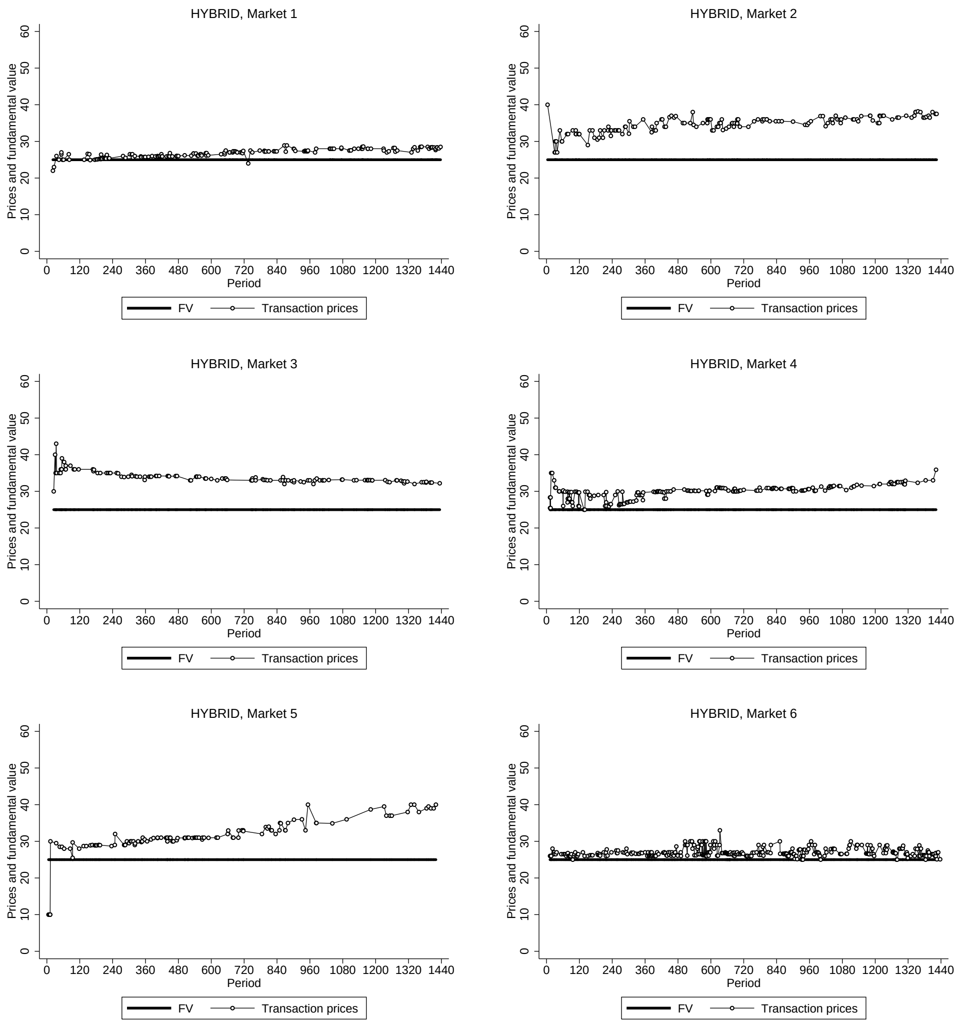


Figure A3: Expected terminal dividend (ED, bold line) and individual transaction prices in all markets of Treatment HYBRID.

Appendix C: Experimental Instructions

Instructions for Treatment LINEAR and Treatment HYBRID[13]

General Information

This experiment is concerned with replicating an asset market where traders can trade assets of a fictive company for 8-15 consecutive periods - with equal probability of termination for each period.

Market Description

The market consists of ten traders. Each trader gets an initial endowment of 40 assets (to be precise: 40 units of ONE asset) and a working capital of 2000 Taler (experimental currency). In every period you can sell and/or buy assets, and your asset and Taler holdings are transferred to the next trading period, respectively. Each trading period automatically terminates after two minutes.

Dividends, Holding Costs, and Buyback of the Assets

At the end of each period you have to pay 1 Taler of holding costs for each asset you hold. Additionally, at the end of each trading period, you get a dividend for each asset you hold. The dividend is drawn randomly and can take on the following values.

Dividend for each asset in Taler	Probability of the dividend
0	50%
2	50%

Your dividend earnings and holding costs during the course of the experiment are directly transferred to a savings account. Thus, the sum of holding costs and dividends for each asset is -1 or 1 with equal probability. All traders in the market get the information in the table mentioned above.

[13] Instructions and screenshots are for Treatment LINEAR. In Treatment HYBRID the subjects with linear incentives received the same instruction as for Treatment LINEAR except one sentence mentioned below in **bold**.

At the end of the experiment (after 8-15 periods) the assets you own are bought back by the experimenter. The buyback price is determined randomly and can take on the following values (all traders in the market get the information in the table mentioned below).

Probability of the buyback prices:

Buyback price for each asset in Taler	Probability of the buyback price
15	80%
65	20%

Savings Account

Your dividend earnings received and your holding costs paid during the experiment are directly transferred to a savings account. At the end of the experiment the value of your savings account is added to your payoff (see below).

Trading

Trade is accomplished in form of a double auction, i.e., each trader can appear as buyer and seller at the same time. You can submit any quote of assets with prices ranging from 0 to a maximum of 999 Taler (with at most two decimal places). For every quote you make, you have to enter the number of assets you intend to trade as well. Note that your Taler and asset holdings cannot drop below zero. If you buy assets, your Taler holdings will be diminished by the respective expenditures (price x quantity) and the number of assets will be increased by the quantity of newly bought assets. Inversely, if you sell assets, your Taler holdings will be increased by the respective revenues (price x quantity) and the number of assets will be decreased by the quantity of newly sold assets.

Calculation of your Earnings (payoff) in EUR

Your payoff at the end of the experiment (after 8-15 periods) is calculated as follows:

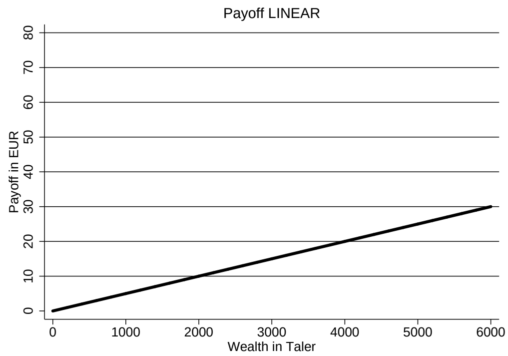
PAYOFF in EUR = WEALTH IN TALER / EXCHANGE RATE

Your wealth in Taler is the number of assets you hold multiplied by the buyback price plus your Taler holdings plus your inventory on the savings account.

WEALTH IN TALER = ASSETS * BUYBACK PRICE + TALER + SAVINGS ACCOUNT

Your wealth in Taler will be exchanged into EUR at an exchange rate of 100 Taler = 0.5 EUR at the end of the experiment. So, you will get 5 EUR for every 1000 Taler in wealth.

Payoff structure:



Example 1: At the end of the experiment you have 45 assets, 1700 in Taler and 100 Taler on your savings account. The randomly drawn buyback price is 65. Wealth in EUR: 45*65+1700+100=4725; 4725/200=23.6 (see above in the graph) Payoff in EUR: 23.6

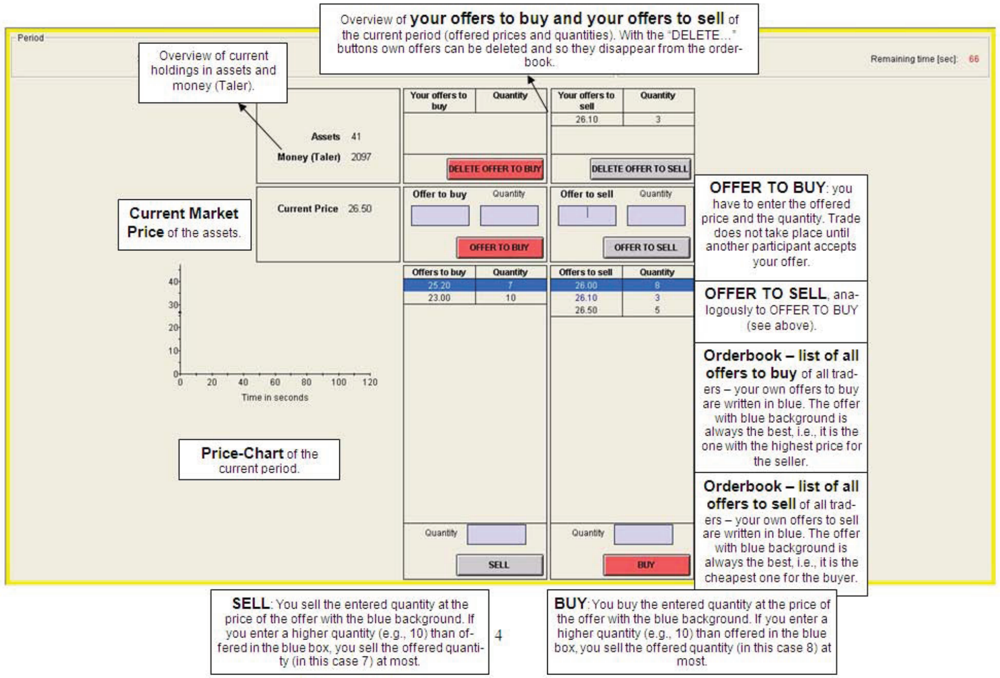
Example 2: At the end of the experiment you have 45 assets, 1700 in Taler and 100 Taler on your savings account. The randomly drawn buyback price is 15. Wealth in EUR: 45*15+1700+100=2475; 2475/200=12.4 (see above in the graph) Payoff in EUR: 12.4

Important Information

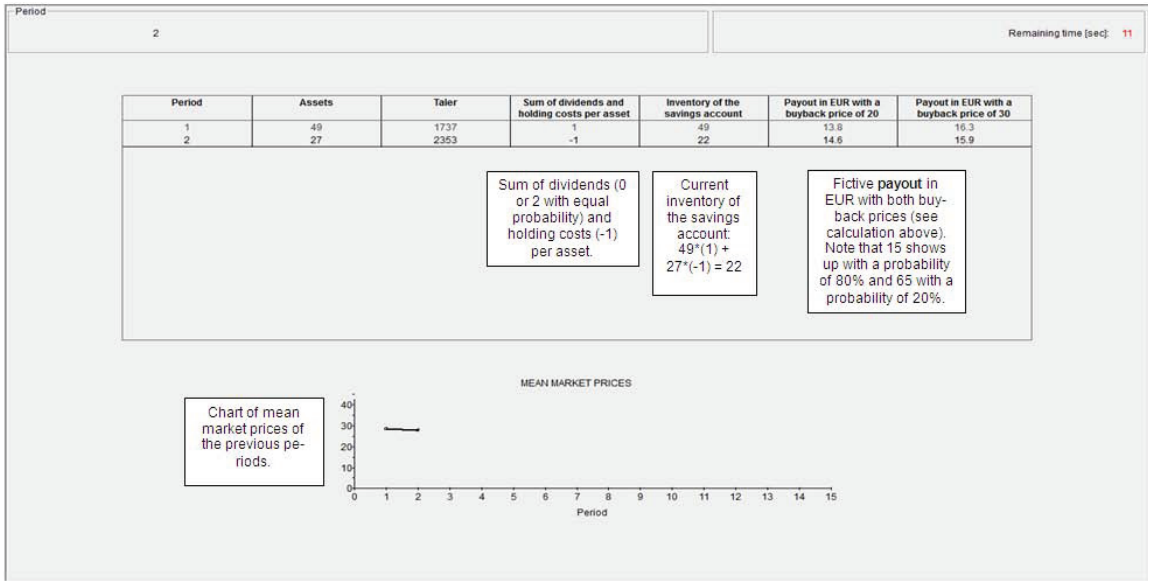
- **Please note that some traders have a different payoff function.**
- Your current fictive payoffs in EUR under both buyback prices are listed in the history screen (see below)

- Each trading period lasts for 120 seconds.
- Use the full stop (.) as decimal place.

Trading Screen: In the following graph trading will be explained in detail. Note, that the offers in the orderbooks are drawn randomly and thus have nothing to go with this experiment!



History Screen: Provides you with a summary of the past trading periods and shows up for 15 seconds after each period:



Instructions for Treatment CONVEX and Treatment HYBRID[14]

General Information

This experiment is concerned with replicating an asset market where traders can trade assets of a fictive company for 8-15 consecutive periods - with equal probability of termination for each period.

Market Description

The market consists of ten traders. Each trader gets an initial endowment of 40 assets (to be precise: 40 units of ONE asset) and a working capital of 2000 Taler (experimental currency). In every period you can sell and/or buy assets, and your asset and Taler holdings are transferred to the next trading period, respectively. Each trading period automatically terminates after two minutes.

Dividends, Holding Costs, and Buyback of the Assets

At the end of each period you have to pay 1 Taler of holding costs for each asset you hold. Additionally, at the end of each trading period, you get a dividend for each asset you hold. The dividend is drawn randomly and can take on the following values.

Dividend for each asset in Taler	Probability of the dividend
0	50%
2	50%

Your dividend earnings and holding costs during the course of the experiment are directly transferred to a savings account. Thus, the sum of holding costs and dividends for each asset is -1 or 1 with equal probability. All traders in the market get the information in the table mentioned above.

At the end of the experiment (after 8-15 periods) the assets you own are bought back by the experimenter. The buyback price is determined randomly and can

[14]Instructions and screenshots are for Treatment CONVEX. In Treatment HYBRID the subjects with convex incentives received the same instruction as for Treatment CONVEX except one sentence mentioned below in **bold**.

take on the following values (all traders in the market get the information in the table mentioned below).

Probability of the buyback prices:

Buyback price for each asset in Taler	Probability of the buyback price
15	80%
65	20%

Savings Account

Your dividend earnings received and your holding costs paid during the experiment are directly transferred to a savings account. At the end of the experiment the value of your savings account is added to your payoff (see below).

Trading

Trade is accomplished in form of a double auction, i.e., each trader can appear as buyer and seller at the same time. You can submit any quote of assets with prices ranging from 0 to a maximum of 999 Taler (with at most two decimal places). For every quote you make, you have to enter the number of assets you intend to trade as well. Note that your Taler and asset holdings cannot drop below zero. If you buy assets, your Taler holdings will be diminished by the respective expenditures (price x quantity) and the number of assets will be increased by the quantity of newly bought assets. Inversely, if you sell assets, your Taler holdings will be increased by the respective revenues (price x quantity) and the number of assets will be decreased by the quantity of newly sold assets.

Calculation of your Earnings (payoff) in EUR

Your payoff at the end of the experiment (after 8-15 periods) is calculated as follows:

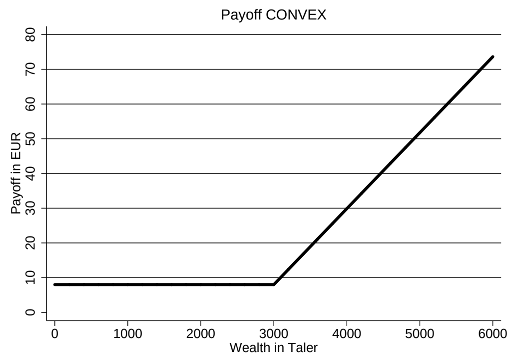
PAYOFF in EUR = WEALTH IN TALER + FIXED PAYMENT

Your wealth in Taler is the number of assets you hold multiplied by the buyback price plus your Taler holdings plus your inventory on the savings account.

WEALTH IN TALER = ASSETS * BUYBACK PRICE + TALER + SAVINGS ACCOUNT

If your wealth in Taler is above 3000 Taler you will get 7 (*2.1875*) EUR for every 100 Taler exceeding 3000 Taler. In addition you will get a fixed payment of 8 EUR as well. If your wealth is below 3000 Taler, you will only get the fixed payment of 8 EUR.

Payoff structure:



Example 1: At the end of the experiment you have 45 assets, 1700 in Taler and 100 Taler on your savings account. The randomly drawn buyback price is 65. Wealth in EUR: 45*65+1700+100=4725; (4725-3000)*0.021875=37.7 (see above in the graph) Fixed payment in EUR: 8 Payoff in EUR: 37.7+8=45.7

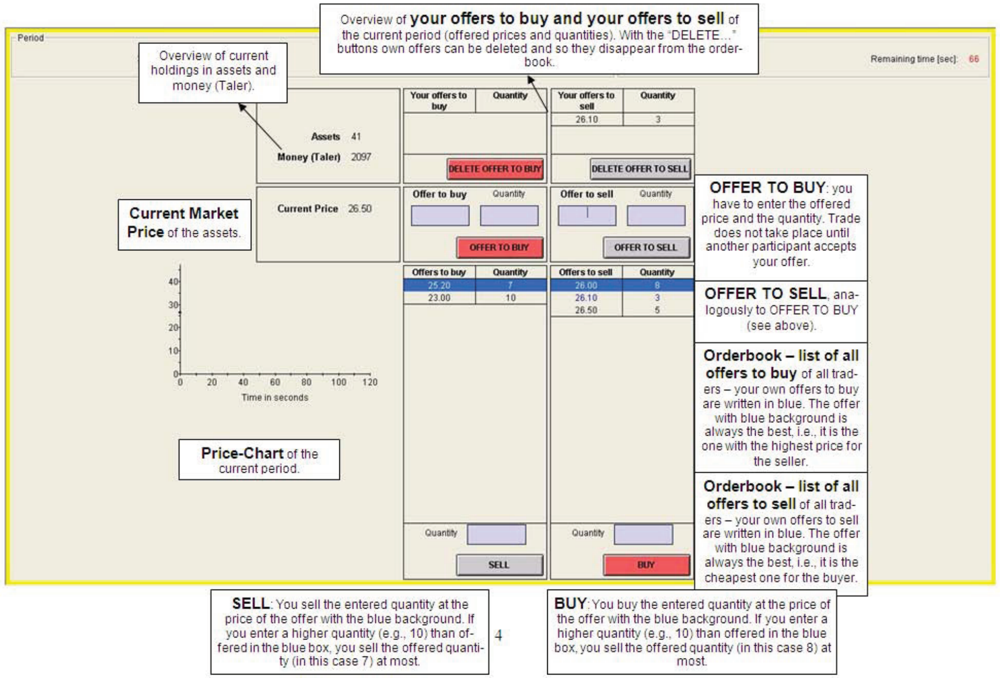
Example 2: At the end of the experiment you have 45 assets, 1700 in Taler and 100 Taler on your savings account. The randomly drawn buyback price is 15. Wealth in EUR: 0 (your wealth (45*15+1700+100=2475) is lower than 3000) Fixed payment in EUR: 8 Payoff in EUR: 0+8=8

Important Information

- **Please note that some traders have a different payoff function.**
- Your current fictive payoffs in EUR under both buyback prices are listed in the history screen (see below)

- Each trading period lasts for 120 seconds.
- Use the full stop (.) as decimal place.

Trading Screen: In the following graph trading will be explained in detail. Note, that the offers in the orderbooks are drawn randomly and thus have nothing to go with this experiment!



History Screen: Provides you with a summary of the past trading periods and shows up for 15 seconds after each period: