Trauten, Andreas; Langer, Thomas

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Information production and bidding in IPOs: An experimental analysis of auctions and fixed-price offerings

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ANDREAS TRAUTEN, THOMAS LANGER

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Dr. Jan vom Brocke
brocke@hybride-systeme.de
www.hybride-systeme.de

NR. 50

Andreas Trauten, Thomas Langer

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INSTITUT FÜR WIRTSCHAFTSINFORMATIK DER WESTFÄLISCHEN WILHELMS-UNIVERSITÄT MÜNSTER
LEONARDO-CAMPUS 3, 48149 MÜNSTER, TEL. (0251) 83-38000, FAX. (0251) 83-38009
EMAIL: GROB@UNI-MUENSTER.DE
http://www-wi.uni-muenster.de/aw/

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Content

Abstract

Despite their theoretical efficiency in selling shares to the public, auctions are not the preferred mechanisms of issuers in Initial Public Offerings (IPOs). Chemmanur and Liu (2006) [*WP*] and Sherman (2005) [*JFE 78, 615-649*] provide a rational explanation for this "IPO auction puzzle". They argue that issuers are not only interested in maximizing the offering proceeds, but also care about the secondary market price and thus try to induce many investors to produce information about the IPO. In fixed-price or bookbuilding offerings the issuer might opt to set an offering price that suggests underpricing in order to compensate investors for producing costly information. In auctions, however, competitive bidding impedes underpricing, which in turn lowers the incentive to produce information about the IPO in the first place. In this paper, we report an experimental study that was set up to test the mechanisms underlying this reasoning. Our findings strongly support the theoretical argument. In fixed-price offerings, the issuer can maintain investors' propensity to produce information by appropriately adjusting the offering price even if information costs are high. In auctions, however, high information costs inevitably result in a low propensity to produce information. This is a consequence of investors' competitive bidding behavior which prevents them from recovering the costs of information production. Our results provide experimental support for the theoretical argument that an auction is not the preferable offering mechanism for young and risky IPO firms since the costs of producing information about such firms are high, but there is also a strong need to generate information.

1 Introduction

In an initial public offering (IPO), the issuing firm sells a large number of identical shares to the public where the value of the shares is uncertain. According to economic theory, auctions are a very efficient mean to carry out such a deal (e.g. Dasgupta and Hansen 2006). Indeed, empirical evidence suggests that the direct costs associated with auctioned IPOs are lower than of those IPOs via the typical alternative issuing mechanisms, fixed-price and bookbuilding offerings.[1] Also, in countries where auctions and alternative issuing mechanisms coexist, the indirect costs of IPOs arising from underpricing, i.e. selling the shares at an offering price below the fair value in the secondary market, seem to be lower in auction offerings.[2] A prominent example of a successful IPO auction is the going public of the internet search firm Google in summer 2004, in which Google raised $1.67 billion of capital. However, auctions have not become the preferred offering mechanisms in IPOs. Instead, while auction IPOs occurred in many countries in the 1980s and 1990s, they were abandoned in favour of fixed-price offerings and, more recently, bookbuilding offerings in most countries (Sherman 2005; Jagannathan and Sherman 2006; Degeorge, Derrien and Womack 2006). The crowding out of auctions in IPOs in spite of their theoretical suitability is known as the "IPO auction puzzle" in the literature on IPOs (e.g. Chemmanur and Liu 2006 or Chen and Wu 2006).

Chemmanur and Liu (2006) (CL hereafter) provide a rational explanation for the IPO auction puzzle. In their model, issuers do not only care about maximizing the offering proceeds (or equivalently, about minimizing underpricing), but also have a preference for information production by investors. The rationale is that more information results in higher secondary market prices if the true (but ex ante unknown) value of the firm is high. CL endogenize the preference for precise secondary market prices by assuming that the issuer sells only a part of its shares in the IPO and the remainder in the secondary market. Against this background, CL analyze the IPO proceeds in the primary market and the subsequent proceeds in the secondary market in uniform price auctions and fixed-price offerings. In uniform price auctions of K shares, the K highest bidders receive an allocation at a uniform price, which is usually set equal to the $K+1$-highest bid. In fixed-price offerings, the offering price is set by the issuer and shares are randomly allocated if demand exceeds supply. The central insight of CL's model is that in fixed-price offerings, the issuer can induce investors to produce information by lowering the offering price. In auctions, however, the issuer cannot influence the

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1 Direct costs comprise listing and promotion costs and the underwriter spread. The latter is calculated as a percentage of offering proceeds and is charged by the syndicate of banks conducting the IPO. Pukthuanthong, Varaiya and Walker (2005) study the Google IPO as well as IPO conducted via the online auction platform of WR Hambrecht & Co. They find that the underwriter spreads in auction IPOs are significantly below the spreads in bookbuilding IPOs of matched firms (5.6% versus 7% spread on average).

2 Underpricing is typically defined as the initial return at the first trading day. Derrien and Womack (2003) find evidence for lower underpricing in auction IPOs in France and Pukthuanthong, Varaiya and Walker (2005) for the US IPO market. For evidence on other IPO markets see Ritter (2003).

propensity to produce information. Since investors bid competitively, the compensation for information costs is limited. Thus, fewer investors produce information if the costs of information production are high. In this setting, for a given preference for information production (i.e. a given split of overall shares into those for sale in the primary offering and those for sale in the secondary offering) the ranking of IPO mechanisms depends on the costs associated with producing information. If information costs are low, auctions attract a sufficient number of information producers und generate higher overall proceeds than fixed-price offerings. In contrast, fixed-price offerings generate higher overall proceeds if information costs are high. This is a solution to the IPO auction puzzle since the level of information costs is a proxy for the awareness level and risk associated with the IPO firm. The riskier the firms' business, the more complex it is to evaluate, and hence, the higher are the information costs. As the majority of IPO firms are newly established or operate in new and risky businesses, most IPOs are conducted via mechanisms other than auctions.

In a related study, Sherman (2005) compares different forms of IPO auctions to the bookbuilding mechanism. The bookbuilding mechanism combines elements of auctions and fixed-price offerings since even though the offering price is ultimately set by the issuer, investors' demand is taken into account by collecting bids in the order book. In line with the argument in CL, she finds that the issuer's discretion in pricing and allocating shares in bookbuilding is beneficial in the case of a high preference for information accuracy or high information costs.

While the models of CL and of Sherman provide persuasive explanations for the IPO auction puzzle under the assumption of fully rational, risk-neutral agents, the extent to which their delicate decision mechanisms are able to describe real-life behavior is an open question. Especially, the mixed strategies describing the entry and bidding behavior in IPO auctions assume randomizing over the equilibrium bid functions as well as over the entry decision and hence, are remarkably sophisticated decision problems. Sherman, p. 618, notes to what this decision problem essentially boils down:

> "Ex post, there could be too few entrants and the offering could fail, or there could be too many entrants who bid away all of the potential profits, preventing investors from recovering their information costs (see Levin and Smith, 1994). This risk lowers the entry incentives of all investors, making them less willing to participate."

An empirical test of the models is very difficult due to both a lack of auction IPOs and a lack of data on investors' information production in IPOs. Without a large sample of IPOs conducted via different offering mechanisms, however, it is virtually impossible to distil the effects of the offering mechanism and of information costs from the variety of factors influencing investor behavior in IPOs. Thus, in this study we aim to shed light on investors' information production and bidding behavior in IPOs using a laboratory experiment. We focus on uniform price auctions and fixed-price offerings as these mechanisms represent two extremes with respect to pricing: Either the offering price is fully determined by demand, or it is fully determined by the issuer. Nevertheless, our results also allow us to draw inference on the bookbuilding mechanism which likewise provides discretion in setting the offering price. Our fixed-price and auction offering games underlying the experimental analysis build on the model of CL. However, we alter the information structure towards a more realistic design in order to make an experimental investigation possible, albeit more realism means sacrificing the explicit equilibrium in the auction model.[1] By varying the costs of information production and the offering mechanism, our experiment allows us to draw inference on investors' entry and bidding behavior and consequently, on the relative benefit of an offering mechanism in relation to the risk associated with the issuing firm.

From an experimental economics point of view, we study two coordination games with both outcome and strategic uncertainty. Investors observe neither the true value of the shares in the IPOs nor the strategic behavior of other investors. There are few experimental studies on games that comprise both types of uncertainty. Cox, Dinkin and Swarthout (2001) analyze endogenous entry and exit in a common value auction. Running first-price auctions, they observe fewer entries than predicted by the equilibrium solution. Rapoport, Seale and Ordónez (2002) study the entry in a lottery game where the probabilities of the lottery outcomes are explicitly linked to the number of entrants. They find a good coordination of subjects on the aggregate level. There are also two experimental studies on IPO mechanisms in the literature. Bonini and Voloshyna (2007) tackle a different research question since they study investors' information revelation behavior in bookbuilding offerings and in a new mechanism called competitive IPO in a laboratory experiment. Like us, Zhang (2006) studies uniform price auctions and fixed-price IPOs in laboratory experiments. He finds that IPO auctions generate higher offering proceeds than fixed-price offerings. However, his study fundamentally differs from ours as Zhang bases his experiment on the comparison of offerings mechanisms by Biais and Faugeron-Crouzet (2001). Unlike CL, Biais and Faugeron-Crouzet rank IPO mechanisms only by their offering proceeds and assume an exogenously given number of investors. Hence, this study is the first experimental analysis of IPO mechanisms that explicitly takes into account the issuer's preference for accurate secondary market prices and the investors' endogenous information production and bidding decisions.[2] Thereby, we are able to test the theoretical solutions to the IPO auction puzzle by CL and by Sherman.

This paper is organized as follows. Section 2 provides a more detailed discussion of the basic intuition for issuers' preference for information production in IPOs on the basis of the model of CL and related literature. Section 3 describes the IPO games which underlie the experiment and derives the equilibrium solution for fixed-price offerings. Section 4 provides details on the experimental design and procedures. Section 5 presents the analysis of the information

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1 To be precise, while CL model their signals as having no information content with very high probability, but fully reveal the shares' true value with very low probability, we model signals as revealing the true value with a probability greater than 50%, but revealing the wrong value with the complementary probability.

2 Further differences to Zhang (2006) are related to the signal structure and the information processing model.

production and bidding behavior in the experimental sessions. Section 6 summarizes and concludes.

2 The preference for information production in IPOs

According to CL's model, the choice regarding the offering mechanism in an IPO affects the overall offering proceeds through a sequence of causal relations. In the following, we discuss the main intuitions of the model. A crucial assumption is that the IPO firm has a preference for accurate secondary market prices and thus, has a desire for a high level of information production. This assumption is plausible if the firm's true value is high, the pieces of information are not perfectly correlated and are aggregated according to Bayes' law. In this setting, the secondary market price increases with the amount of information. Easley and O'Hara (2004) provide a more general rationale for the relation between the level of information and the stock price and the equity costs of capital, respectively. They build a multi-asset rational expectations equilibrium model that includes public and private information as well as informed and uninformed investors. They find two effects of information on a stock's risk premium. Firstly, as the stock is less risky for informed investors holding private information than it is for uninformed investors, informed investors hold greater positions in the stock. Thus, the demand for the stock increases with the number of informed investors which results in higher stock prices and lower costs of capital. The second effect works indirectly. By demanding a greater amount of the stock, informed investors reveal their information to the uninformed investors. The more information becomes public through informed investors' trades, the more accurately reflects the equilibrium market price the firm's true value. This, in turn, also lowers the risk of the stock for uninformed investors, which again increases demand and consequently, lowers the costs of capital. Overall, firms have a viable interest in promoting information production. While CL endogenize the issuer's preference for accurate pricing by assuming a follow-on offering, there are several other reasons for this preference, including marketing reasons (Demers and Lewellen 2003) aftermarket trading activities (Busaba and Chang 2002), insider selling after the end of the lock-up period (Aggarwal, Krigman and Womack 2002) and management compensation schemes tied to the stock price.

Irrespective of the benefits of a high level of information about a stock, the question remains why information production has yet to be induced prior to the IPO. CL assume that investors only have an incentive to produce costly information in the primary market. Here, information production is worthwhile if the shares are sold at a discount to the fair value in the secondary market. Thus, the "money left on the table" through underpricing can be regarded as the compensation to investors for producing information (Chemmanur 1993). In an efficient secondary market, however, information is directly reflected in prices and thus, investors have no chance to generate profits from trading in order to compensate the costs of information production. This prevents information production in the secondary market. Indeed, there is empirical evidence that firms do care about information production by investors prior to the

IPO. A major phenomenon pointing to the desire for information production is the IPO firms' request for vast and influential analyst coverage. Enhancing analyst coverage is one reason for committing co-managers in an IPO (Chen and Ritter 2000). Further studies show that issuers prefer underwriters with famous analysts.[1] An economic interpretation for this "analyst lust" (Loughran and Ritter 2004) is that issuers strive to decrease valuation uncertainty and thus the level of underpricing required by investors. However, Cliff and Denis (2004) find that higher analyst coverage increased the underpricing of US IPOs between 1993 and 2000. Apparently, issuers rather "buy" analyst coverage through underpricing. The point is that issuers not only care about analyst coverage of the IPO but in particular about analyst coverage after the IPO. Consistent with this hypothesis, they find that firms are more likely to switch the underwriter in a seasoned offering if they were not satisfied with post-IPO coverage of the IPO underwriter.

Rewarding investors for producing information by underpricing might raise a free-riding problem since investors could forgo information production and would still receive a share at the lower offering price. CL assume in their model that the value of a piece of information exceeds its costs so that informed bidding strictly dominates uninformed bidding. Thus, after a firm announced to go public via a certain offering mechanism, an investor has to weigh the costs of purchasing information against the expected profits from underpricing in case of allocation, whereas the chance to receive an allocation depends on her bid and the other investors' bids in the case of an auction and on the number of other bidders in the case of a fixed-price offering. CL show that a symmetric risk-neutral Nash equilibrium in mixed strategies exists to this problem. Investors choose the probability of entering the IPO which results in zero profits in expectation. As a consequence, the number of bidders is endogenously determined by the offering mechanism and the other IPO parameters. The difference between the offering mechanisms is that in fixed-price offerings, the issuer can induce a higher entry probability by lowering the offering price while the entry probability cannot be influenced in IPO auctions. Here, investors are confronted with the risk that any underpricing is eliminated through competitive bidding. Thus, information production is more risky in auctions, which in turn discourages investors from producing information in the first place. This effect exacerbates with increasing information production costs. Consequently, given a sufficiently high number of shares being sold in the secondary offering (or equivalently, a sufficiently high preference for price accuracy), the optimal offering mechanism is an auction in the case of low information costs and a fixed-price offering in the case of high information costs.

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1 For example, Dunbar (2000) shows that an underwriter's market share in the US in 1984-1994 increased after one of his analysts was highly ranked in the Institutional Investor annual survey. This finding is confirmed by Clarke, Dunbar and Kahle (2002) who observe the market share of underwriters after losing or acquiring all-star analysts in the US between 1988 and 1999. Krigman, Shaw and Womack (2001) survey firms that went public in the US between 1993 and 1995. They present evidence that a major reason to switch the underwriter in a subsequent seasoned offering is to initiate more influential analyst coverage provided by the new underwriter.

The costs of producing information about an IPO firm are closely related to the amount of information publicly available and the firm's risk. The more information about the firm is publicly available, the easier it is to aggregate the pieces of information to a signal of firm quality. The riskier the firm's operations, the harder it is to estimate the future cash flows and the cost of capital. Measures such as firm age, size or the industry the firm is from proxy for these factors of information costs.[1] The older and larger the firm, the more information is publicly available and the greater the probability that the firm operates in an established, well-known industry. Yet, the typical IPO firm is rather young, small and operates in a new, innovative industry. Producing information about such a firm is costly. Thus, CL's model predicts that an auction offering should not be the preferred IPO method which is in line with the empirical observation of a very low proportion of auction offerings in most countries.

3 IPO games

3.1 Common characteristics

The IPO games which underlie the experiment are modeled as follows. A (risk neutral) firm plans to go public by selling K shares to investors. The true value of the shares is unknown to the firm as well as to investors.[2] However, it is common knowledge that the firm is of good quality with probability Θ and of bad quality with probability 1-Θ. If the firm is of good quality, each share is worth V^+. Otherwise, it is worth V^-.

There are N risk neutral investors who get the opportunity to participate in an IPO (enter the IPO game). The alternative to participating in the IPO is to invest into a riskless, interest-free account. If an investor decides to bid for a share, she incurs bidding costs C^{bid} ($C^{bid} > 0$). These costs reflect bank fees and the expenditure of time to submit a bid. Each investor can bid for only one share. The potential demand for shares is assumed to exceed the number of shares offered, thus $N > K$. Prior to participation in the IPO, an investor considers to produce information on the firm quality. If an investor decides to produce information about an IPO firm, she incurs information costs C^{info} ($C^{info} > 0$) which reflect the effort of gathering and evaluating data on the firm. In return, she receives a binary signal S stating either high (S^+) or low (S^-). This signal is correct with probability p. In the following, we denote the probability of receiving a signal S^+ given the firm is of good quality with $p(S^+|V^+) = p^{++}$ and given the

[1] Such measures are commonly used as proxies for IPO uncertainty in empirical studies (e.g. Ljungqvist 2005).

[2] While Sherman also assumes that the true value is unknown to the firm, CL assume that the firms knows its true value. However, note that the results of our model do not change if we assume that the firm knows its true quality. The reason is that it is rational for a firm that knows about its bad quality to mimic the behavior of a good quality firm as there is a chance that this firm still achieves a high offering price due to noise in investors' information. Hence, a firm behaves as if it were a good quality firm irrespective of its knowledge about the quality. See CL, footnotes 23 and 32, for a detailed discussion on the bad firms' mimicking behavior.

firm is of bad quality with $p(S^+|V^-) = p^{+-}$. In case of the signal S^-, the probabilities p^{--} and p^{-+} are defined accordingly. The probability of receiving a correct signal is independent of the firm's true value. Thus, $p^{++} = p^{--}$ and $p^{+-} = p^{-+}$. The pieces of information gathered by different investors are independently drawn conditional on the predetermined true value of the shares. Hence, signals are affiliated in the sense that producing a good signal increases the likelihood that other investors also produced good signals (see Kagel, Levin and Harstad 1995). This information setup is common knowledge in the IPO game.

The investors face a two-stage decision problem. Contingent on K, N, Θ, V^+, V^-, p, C^{bid}, C^{info} and the issue mechanism an investor first decides on whether or not to produce information. In a second step, she decides on bidding for a share in the IPO based on her updated beliefs about the firm quality in case of information production. If an investor forgoes bidding for a share after producing information, the information costs are deducted from the interest-free account. No further gains or losses will be incurred. If the investor bids for a share, bidding costs are deducted irrespective of whether she receives an allocation.

There is no strategic interaction possible between investors in the IPO games. That is to say, investors do learn neither about other investors' information production decision nor about the type of information produced by other investors. Further, other investors' bidding cannot be observed. However, each investor's outcome is affected by the other investor's decisions in the IPO game. If $m < K$ investors decided to bid for a share, the IPO fails as not all shares could be placed with investors. In this case, the IPO is cancelled and no investor receives a share. The IPO takes place if $m \geq K$. Here, the pricing and allocation of shares depends on the offering mechanism.

3.2 Fixed-price offerings

In a fixed-price offering, the offering price F is communicated to investors prior to their information production and bidding decisions. The setting of the offering price is left to the issuer's discretion within the range $[V^-,V^+]$. Given $m \geq K$ investors bid for a share, we define the following allocation rule for the IPO. If $m = K$, each bidding investor receives one share. If $m > K$, the shares are randomly allocated to K investors. Consequently, the probability π of receiving a share decreases with an increasing number of bidding investors. Further, we maintain the following assumptions regarding the setting of the IPO parameters:

Assumption 1: The information quality p is sufficiently high compared to the costs of information C^{info}, and the offering price F is not too low, so that informed bidding strictly dominates uninformed bidding. It follows that investors enter the IPO game by producing information. A strategy where some investors bid informed and others bid uninformed cannot be optimal due to the winner's curse problem of the uninformed bidders.

Assumption 2: The information quality is sufficiently high, the bidding costs C^{bid} are not prohibitively high and the offering price F is not too low so that the equilibrium bidding strategy is bid for one share after producing a high signal is S^+ do not bid after producing a low signal.

Given assumption 1 holds, investors enter the IPO game only by choosing to produce information. Further, assumption 2 ensures that the optimal bidding strategy post information production is predefined depending on the investor's information. If the investor produces the information S^+, bidding is dominant to not bidding. Otherwise, not bidding is dominant to bidding. Under these assumptions, we derive a symmetric risk-neutral Nash equilibrium in mixed strategies for fixed-price offerings.

Suppose that one investor ("investor *i*"), considers producing information about an IPO. Prior to information production, the probability for bidding in the IPO is $\Theta p^{++} + (1-\Theta)p^{+-}$. The first term denotes the probability that the investor produces the signal S^+ and the true value of the firm is V^+, while the second term denotes the probability of a signal S^+ and the true value is V^-. The expected profit to investor *i* from bidding not only depends on the offering price and the bidding costs, but also on the probability π of receiving a share and hence, on the other investors' bidding behavior. Assume that investor *i* produces a high signal and thus, bids for one share. Further, assume that $n-1$ $(K \le n \le N)$ other investors also decide to produce information, and $m-1$ $(K \le m \le n)$ other investors bid for a share. Then, the probability of receiving a share is K/m. In the following, the binomial formula for the probability that m investors out of n information producers bid for a share given the signal quality p is denoted $\beta(m,n,p) = \binom{n}{m} p^m (1-p)^{n-m}$. Thus, for $n \ge K$ investor *i*'s probability of allocation is $\pi_n^{++} = \Sigma_{m=K}^{n} \beta(m-1, n-1, p^{++})(K/m)$ if the firm is of good quality and $\pi_n^{+-} = \Sigma_{m=K}^{n} \beta(m-1, n-1, p^{+-})(K/m)$ if the firm is of bad quality. If $n < K$ investors produce information, the IPO fails and thus, the probability of allocation is $\pi_n^{++} = \pi_n^{+-} = 0$. It follows that the expected profit from bidding is $\pi_n^{++}(V^+ - F) - C^{bid}$ if the firm is of good quality and $\pi_n^{+-}(V^- - F) - C^{bid}$ if the firm is of bad quality. Note that the bidding costs are incurred irrespective of an allocation. Consequently, the expected profit to investor *i* from producing information about the IPO given that $n-1$ other investors also produce information is

$$E(G_n) = \begin{cases} \Theta p^{++}\left(\pi_n^{++}(V^+ - F) - C^{bid}\right) + (1-\Theta)p^{+-}\left(\pi_n^{+-}(V^- - F) - C^{bid}\right) & if\ n \ge K \\ \Theta p^{++}(1-\Theta)p^{+-}\left(-C^{bid}\right) & if\ n < K \end{cases}$$

$$\text{where } \pi_n^{++} = \sum_{m=K}^{n} \beta(m-1, n-1, p^{++})\frac{K}{m} \text{ and } \pi_n^{+-} = \sum_{m=K}^{n} \beta(m-1, n-1, p^{+-})\frac{K}{m} . \quad (1)$$

In order to induce a rational, risk-neutral investor to participate in the IPO by producing information, this expected profit should at least offset the information costs C^{info}. With an increasing number of other information producers, $E(G_n)$ first increases as the probability of IPO failure decreases. A further increase of information producers then lowers $E(G_n)$ since the probability of receiving an allocation decreases.

In the symmetric risk-neutral Nash equilibrium, each investor chooses to produce information with probability q (also called probability of entry) and the certain outcome with probability $1 - q$ where the probability that n out of N potential investors decide to produce information is $\beta(n, N, q)$. In equilibrium, all investors will choose their probability of entry in such a way as the expected profit exactly offsets the costs of entry. Thus, investor i chooses the q that solves

$$\sum_{n=1}^{N} \beta(N-1, n-1, q) E(G_n) = C^{info} \quad .[1] \tag{2}$$

As an example, consider one set of parameters applied in the experiment below: $N = 8$, $K = 2$, $\Theta = 0.5$, $V^+ = 120$, $V^- = 0$, $C^{bid} = 5$, $p^{++} = 0.7$, $C^{info} = 8$ and $F = 42.50$. The equilibrium entry probability is $q = 0.623$.[2] Note that this equilibrium does not constitute a social optimum. In the social optimum, the probability to enter would be chosen so that the overall expected profit from entering the fixed-price game is maximized.[3] If all other exogenous parameters are held constant, lowering the offering price increases the expected profit to investors and thus, the LHS of equation (2). In order that equation (2) holds, investors react to an offering price drop by raising the probability of entry, which in turn decreases the probability of allocation and thus, drives the expected profit back to the information costs. If the RHS of equation (2) increases, i.e. the information costs rise, investors react by lowering the probability of entry unless the expected profits are raised, too. This is the main insight of the fixed-price game: The issuer can maintain a certain level of information production if the downward pressure on information production associated with a rise in information costs are counteracted by cutting the offering price so that equation (2) holds. By substituting equation (1) for $E(G_n)$ and solving for F in the case of $n \geq K$, equation (2) can be rewritten as

$$F = \frac{-C^{info} + \sum_{n=1}^{N} \beta(N-1, n-1, q)\left(\Theta p^{++} \pi_n^{++} V^+ + (1-\Theta) p^{+-} \pi_n^{+-} V^- - \left(\Theta p^{++} + (1-\Theta) p^{+-}\right) C^{bid}\right)}{\sum_{n=1}^{N} \beta(N-1, n-1, q)\left(\Theta p^{++} \pi_n^{++} + (1-\Theta) p^{+-} \pi_n^{+-}\right)} .$$

1 If $K > 1$, the fixed-price game also has a symmetric pure strategy equilibrium where all N investors reject information production and choose the certain outcome instead. Irrespective of K, there are $N! / [n^*! (N - n^*)! + 1$ asymmetric pure strategy equilibria where n^* investors decide to produce information and $N - n^*$ refrain from information production and choose the certain outcome instead. The equilibrium number of investors producing information n^* is the largest integer satisfying the condition that the LHS of equation (2) is greater than C^{info}. However, the pure strategy equilibria do not define which investors choose to enter the game and which stay out.

2 This entry probability in the mixed strategy equilibrium is very close to the proportion of investors choosing to produce information in the pure strategy equilibrium. There, the respective value of n^* is 5 (or 5/8 = 0.625) where $E(G_{n^*}) = 0.51$. Thus, the fixed-price game is profitable in expectation with 5 investors producing information.

3 In the social optimum, the marginal costs of IPO failure equal the marginal costs of entry and bidding in expectation. In the example given previously, the social optimum implies $q = 0.346$ where $E(G) = 3.21$.

This presentation of equation (2) clarifies the relation between C^{info} and F. For a given "target" probability of entry and fixed IPO parameters, both sigma sign terms are constant. Then, the equilibrium offering price decreases linearly with increasing information costs, where the intercept and the slope depend on the IPO parameters and the target probability of entry.

3.3 Auction offerings

If the shares are sold using an auction offering, investors again decide on buying information on the IPO firm first. If investor i decides to bid for a share based on the information, she pays bidding costs C^{bid} and submits a (sealed) bid for a share of the firm. The allocation of the shares is based on investor i's bid and on the $m - 1$ bids submitted by the other bidding investors. Like in fixed-price offerings, the IPO fails if $m < K$. In this case, no shares are allocated to investors. Each bidding investor receives one share if $m = K$. In case of $m > K$, shares are allocated to the K investors that submitted the highest bids.

All investors who receive an allocation pay the same price for their share. We assume such a uniform-price mechanism as this is the common type in most countries that allow auction IPOs (see Jagannathan and Sherman 2006 for details). The price paid by all winning bidders is set equal to the highest losing bid, i.e. the K+1-highest bid. This pricing rule is the multi-unit equivalent to a second-price sealed bid auction. We choose this pricing rule since Vickrey (1961) showed that in such an auction, each bidders' dominant strategy is to bid the own true valuation. This truth-revealing property ensures that in theory, the prices in auction offerings reflect the information produced by the investors.

Given these features, our auction mechanism can be described as a multiple-unit, second-price sealed-bid common value auction with endogenous entry and discrete signals. Deriving explicit equilibrium bid functions in the presence of endogenous entry and discrete signals is a non-trivial task. Campbell and Levin (2000) derive equilibrium bidding strategies in the case of a common value auction with discrete signals, but they consider a first-price mechanism for a single good and an exogenous number of bidders. Levin and Smith (1994) study common value auctions with endogenous entry in a continuous signal setting.[1] CL as well as Sherman derive equilibrium bidding strategies for an auction mechanism very close to ours. However, they apply a rather academic signal structure. They use signals that fully reveal the true value of the IPO firm with very low probability, but are uninformative with high probability. Such a design is unsuitable for an experimental study where the number of potential investors is relatively low since in most IPOs, investors would only produce uninformative signals.[2]

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1 Other studies investigating auctions with endogenous entry and continuous signals include Menezes and Monteiro (2000), Landsberger and Tsirelson (2003) and Ye (2004).

2 For instance, Chemmanur and Liu (2006), pp. 25-31, use signal qualities of 2% and of 0.5% to demonstrate the information trade-off between fixed-price offerings and auctions. This requires very large subject groups in order to obtain a sufficient number of informative signals in an experimental IPO.

Further, the noisy signals applied in our study are more realistic since both the production of a perfect signal and the production of a completely uninformative signal are very unlikely in real-life IPOs. Cox, Dinkin and Swarthout (2001) run a laboratory experiments to study the bidding behavior in common value, sealed-bid auctions with endogenous entry. In contrast to our treatment, they use a first-price mechanism where signals are drawn from a continuous distribution. Also, the number of participants in the auction is announced prior to the subjects' bidding decisions. This allows them to resort to the equilibrium bid functions provided in Kagel and Levin (1986) for common value auctions with exogenous entry.

While we leave the derivation of explicit equilibrium bidding strategies in our auction model to auction theorists, we give an intuition for our expectation that the propensity to produce information in the auction IPO game decreases with increasing information costs and thus mimics the explicit equilibrium derived in the models with the simplified signal structure. We expect that investors will bid competitively in the auction offerings irrespective of information and bidding costs. Such costs are sunk at the time of bidding and thus, not relevant for the decision to bid (e.g. Menezes and Monteiro 2000). Yet, bids will vary as the true expected value of the shares taking all information into account is unknown to investors who neither observe the number of information producers nor the value of their information. We suspect that whenever the number of bidders exceeds the number of share for sale ($m > K$) so that the offering price equals the K+1-highest bid, underpricing will be low due to investors' competitive bidding behavior. However, in the case the number of bidders equals the number of shares ($m = K$), the shares are maximally underpriced as the offering price equals V^-. This case generates large expected profits to investors. The probability of $m = K$ increases with a decreasing probability of entry. Consequently, the higher the information costs, the lower should be the probability of participation in order to increase the chance of $m = K$. This effect induces a declining probability of information production with increasing information costs.

The focus of this study is not on the derivation of explicit bidding strategies in theoretical models, but on the extent to which the basic intuitions of the IPO games are able to describe actual investors' behavior. Remind that the models of CL and of Sherman build on the assumption that rational investors fully grasp the sophisticated decision problems and behave according to the delicate mixed equilibrium strategies. It is an open question whether these theoretical models allow drawing inference on actual investors' behavior. Our laboratory experiment allows us to investigate the effect of the offering mechanism and the level of information costs on investors' information production and bidding decisions by controlling for all other IPO variables.

3.4 Experimentally testable hypotheses

In support of the preceding discussions we expect investor behavior in IPOs to differ with the offering mechanism. If investors participate in the IPO, they first incur information costs and, if they bid for a share, bidding costs. The latter arise irrespective of the particular IPO or the particular offering mechanism. The focus of this study is on information costs. There are several reasons why the costs of producing information differ from firm to firm. Some firms may engage in projects that are more complex to evaluate than others, or the amount of publicly available information about the offering firms may differ. The aim of this study is to investigate the effect of the offering mechanism and of the information costs on the propensity to participate and the bidding decision.

In fixed-price offerings, the discretion in setting the offering price supposedly allows the issuer to compensate investors for costs incurred in the offering process by adjusting the offering price according to equation (2). In other words, by lowering the offering price the issuer can virtually induce any desired level of information production up to full participation of investors. In the following, we assume that issuers aim to achieve a certain "target" level of information production irrespective of the information costs. The notion that with increasing information costs the issuer can keep investors' propensity to participate at a constant level by lowering the offering price constitutes our first hypothesis.

> **H1**: In fixed-price offerings, the propensity to participate can be held constant if investors are compensated for higher information costs by a lower offering price according to the theoretical prediction in the fixed-price game.

Note that hypothesis 1 is by no means trivial even though is sounds very intuitive that a lower price raises expected profits which again compensate for higher costs. The model of the fixed-price game shows that the offering price is only one factor determining the expected profit. An investor also has to take into account that her signal as well as other investors' behavior affect the expected profit.

In contrast, if the issue price is determined by the investors, we suspect that investors do not react to a certain level of information costs by appropriately adjusting their bids, but by adjusting their propensity to participate. The fact that the bids in the auction game do not only determine the offering price, but also the allocation of shares should induce investors to bid competitively. This implies that investors ignore the sunk costs of information production and bidding and place bids at their expected value for the shares. Consequently, they drive the offering price to levels that allow, if at all, a partial compensation for the costs incurred. If rational investors anticipate this effect, their propensity to participate decreases with increasing information costs. This constitutes the hypotheses 2 and 3.

> **H2**: In auction offerings, the propensity to participate decreases with increasing information costs.

> **H3**: In auction offerings, investors bid competitively, i.e. they bid their expected value irrespective of the level of information costs.

Given these hypotheses, we expect the propensity to participate in IPO auctions to fall below that in fixed-price offerings if information costs are high. This may sound somewhat arbitrary to a critical reader as a high propensity to participate in fixed-price offerings can easily be achieved by very low offering prices. However, for offering prices that theoretically imply a constant level of information production, the propensity to participate in IPO auctions should be higher than in fixed-price offering for low information costs and lower for high information costs.

4 Experimental design and procedure

4.1 Participants

Overall, 168 students from the University of Münster volunteered to participate in the experiment. About 18 % of the students were female, and more than 90 % were majoring in Business or Economics. The median participant was 23 years old, had been studying for six semesters so far, and has a medium experience in financial markets as well as in game theory, which is reflected in a median score of three on a scale from 1 (very low experience) to 6 (very high experience) in both fields. The information on the participants is summarized in Table 1.

Table 1: Descriptive statistics on the participants

Experience in financial markets and experience in game theory are measured on a scale from 1 (very low experience) to 6 (very high experience).

	Mean	Median	St. Dev.
Age	23.55	23	2.28
Experience in financial markets	3.23	3	1.22
Experience in game theory	2.93	3	1.19
Number of semesters studied so far	6.03	6	2.57
Number (ratio) of female students		30 (17.9%)	
Number (ratio) of students with majors other than economics or business		15 (8.9%)	

4.2 Procedure

The experiment was conducted in seven sessions in a networked computer laboratory at the University of Muenster, Germany. Each experimental session lasted for about two hours. Each of the 24 students in a session was provided with a written copy of the instructions[1], a ball pen and paper for notes and was seated at a computer terminal. The computer terminals were furnished with blinds in order to ensure that participants could not look at other screens. Communication between the participants was prohibited. At the beginning, the instructions were read out loud to the students by the instructor. Afterwards, the instructor answered remaining questions to ensure that each participant completely grasped the decision situations

1 Complete instructions can be obtained from the authors upon request.

in the experiment. Prior to the experimental sessions, we extensively tested the computer systems as well as the understandability of the instructions by running three pretest sessions.

The experiment consisted of 22 rounds. Without telling the students, the first two rounds were taken as practice rounds and were not included in the analysis. In each round, each of the 24 students was randomly assigned to one of three groups of equal size.[1] Then, the eight students in each group got the opportunity to participate in an IPO as investors. The IPOs in a round were identical for the three groups of investors. The participants were not made aware of the identity of the other investors in their groups.

Each student was given an endowment of 150 monetary units (MU) in a fictitious, interest-free account in each round. This endowment could be used to participate in this round's IPO. The part of the endowment not used for participating in the IPO remained in the account until the end of the round. If the student participated in the IPO and received an allocation, the share was entered into a fictitious security account. Costs incurred in a round as well as the share price in the case of an allocation were deducted from the current account. The account balances of one round did not affect the balances of subsequent rounds.[2] After finishing the 22 rounds, one round was randomly selected. Each student received the Euro-equivalent of the balance of the respective current and security account for the selected round. Monetary units were converted into Euros at a rate of 10 MU = 1 Euro.

In each round, the students were presented the offering characteristics of an IPO, i.e. N, K, V^+, V^-, Θ, p, C^{bid}, C^{info}, the offering mechanism and, in the case of a fixed-price offering, the offering price F. Most of the IPO parameters were identical in all IPOs: In each IPO, $N = 8$ investors got the opportunity to submit a bid for one share of an IPO firm. Overall, $K = 2$ shares with the same true value were sold in each IPO. The true value of the shares of the IPO firm was $V^+ = 120$ MU or $V^{--} = 0$ MU with equal a priori probability ($\Theta = 0.5$). The share quality was supposed to be randomly drawn for each IPO. However, unbeknownst to students, in each session shares in eleven IPOs were of good quality and eleven of bad quality.[3] This was done to simplify data analysis and aggregation. The information quality was p = 70%. The bidding costs were set to 5 MU in all IPOs.

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1 The random rematching in each round aimed to prevent tacit collusion among the subjects and to avoid learning about other investor's behavior. Andreoni and Croson (2002) study the relevance of random rematching in public good experiments. They conclude that random rematching is the appropriate methodology.

2 Accounts for each round were treated separately in order to avoid any effect of the cumulated balances on participation and bidding behavior. See Ham, Kagel and Lehrer (2005) for a discussion of (cash) balance effects.

3 See Appendix A for details on the information costs and offering mechanism by round and session.

While the IPO parameters given above were identical irrespective of round and session, the offering mechanism as well as the information costs varied from round to round.[1] In the first two practice rounds, information costs were set to 5.5 MU in each session. The information costs in the following rounds were integers between 1 MU and 10 MU. They were assigned so that each combination of offering method and information costs (2 * 10) appeared only once. Thus, each session consisted of ten pairs where the fixed-price and auction offering rounds with the same level of information production constitute a pair. In order to be able to analyze the difference in information production behavior associated with a mechanism change in a pure within subject design, the allocation of the 24 students to the three IPOs per round was identical within each pair. Except for the two practice rounds, each combination of round and information costs (10 * 10) appeared at most once in the seven sessions. This design aimed to eliminate potential order effects.

In the case of the fixed-price IPOs, variations in information costs were accounted for by choosing an offering price that was supposed to keep the participation ratio at a constant level according to the theoretical prediction in equation (2). The target probability of entry maintained in all fixed-price offerings was five out of eight investors, or 62.5%. The offering prices corresponding to the information costs $C^{info} \in \{1,...,10\}$ were 67.5, 64.0, 60.5, 57.0, 53.5, 49.5, 46.0, 42.5, 39.0, 35.5 MU (rounded to 0.5). Overall, in these settings of IPO parameters informed bidding is strictly dominant to uninformed bidding and not bidding is dominant after producing a low signal in fixed-price offerings, i.e. assumptions 1 and 2 hold.

Having learned about the offering characteristics of an IPO, the subjects principally faced the multi-stage decision problem described in the previous section. Figure 1 presents a sketch of the decision tree that is taken from the instructions. Initially, students decided whether it is worth to produce information about the IPO. If a student decided to produce information, the decision of whether to bid for a share depended on the information. Next, if a student decided to bid, the total gain or loss depended on whether she received an allocation and ultimately, on the quality of the share. In both decision situation students were assisted by an IPO simulator. In fixed-price offerings the simulator could be used to calculate the probability of receiving an allocation depending on the number of other bidders in the IPO and the gains or losses from participating contingent on allocation and share quality. In auction offerings, the simulator could be used to calculate the gain or loss from participating contingent on the number of bidders, the third bid and the own bid being below or at least equal to the third highest bid.[2]

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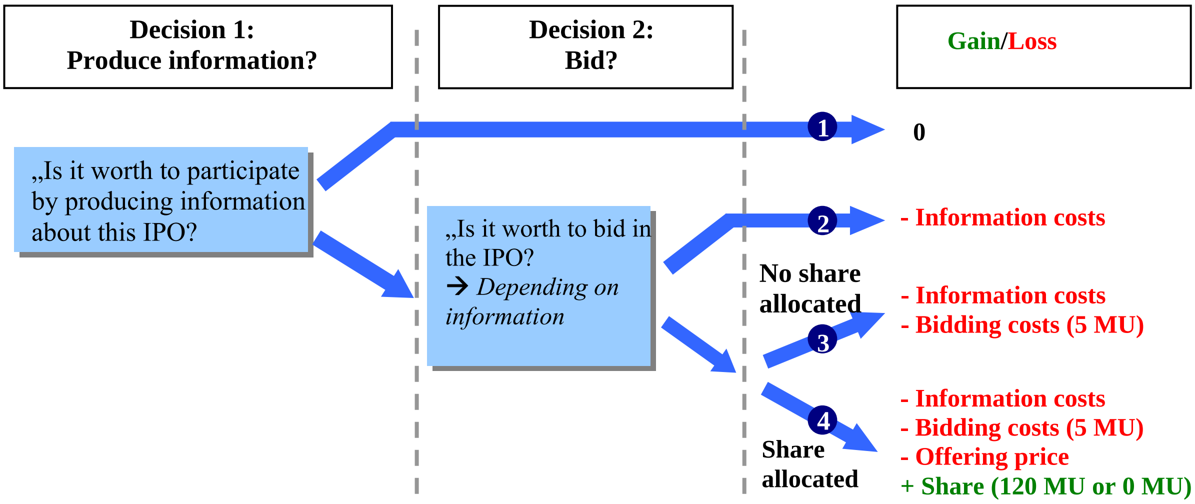
[1] Regarding the offering mechanism, fixed-price offerings and auction offerings alternated from round to round and the starting mechanism was counterbalanced. Of the 22 rounds of each session, eleven rounds comprised fixed-price offerings and eleven auction offerings.

[2] For screen shots of the decision screens, the IPO simulators and the results screen see Appendix B.

Figure 1: Sketch of the decision tree in the experiment



Note that a student who decided to forgo producing information was not allowed to bid for a share. This abstracted from reality where investors can also choose to bid in an IPO without buying information. We rationalize our simplification by the fact that uninformed bidding is dominated by informed bidding. As we do not want to test the extent to which investors are capable of understanding the dominance relation between uninformed and informed bidding, we ease the decision problem by tying participation in the IPO to information production.

If the IPO took place, the two shares were priced and allocated according to the rules described in the previous section. Each student was told about the overall status of this round's IPO and about her individual outcome within this round. The former includes information about whether the IPO took place, the number of investors who bid for a share and, if applicable, the offering price. The latter includes information about whether the student received an allocation and detailed statements of her current and security accounts. If the student received an allocation, the share was entered into the security account at initial costs, i.e. the offering price. The true value of the shares was not revealed to any of the students. Only if this round was drawn to determine the students' compensation in Euro for participating in the experiment, the true value would have been disclosed at the end of the experiment session. Even though it is irrelevant with fully rational subjects, in the case of bounded rationality this approach prevents subjects from falling prey to the gambler's fallacy. However, students were informed about their gains or losses depending on share quality. By running seven sessions comprising 20 rounds (without practicing rounds) and 3 IPOs per round, we yield 21 IPOs for each combination of offering mechanism and information costs.

5 Results

5.1 Summary statistics on IPO success

Overall, we observe 420 IPOs by running seven session with 60 (ten rounds per offering mechanism times three IPOs per round) IPOs each. The propensity to participate in the IPOs by producing information is rather high as reflected in an average number of participants of 6.5 out of eight. Some IPOs failed because investors decided to forgo the investment opportunity after producing information. Table 2 exhibits statistics on IPO frequency and failure by offering mechanism and information costs.

Table 2: IPO frequencies and failures by offering mechanism, true value and information costs

Freq. denotes the frequency of occurrence. Failed denotes the frequency of IPO failures due to an insufficient number of bidders out of the number of IPO that occurred. In the cases of information costs of two and nine, no fixed-price offerings with a true value of zero occurred.

	Fixed-price				Auction					
Inform.	**True value = 0**		**True value = 120**		**True value = 0**		**True value = 120**		**Sum**	
costs	**Freq.**	**Failed**	**Freq.**	**Failed**	**Freq.**	**Failed**	**Freq.**	**Failed**	**Freq.**	**Failed**
1	12	2	9	0	9	0	12	0	42	2
2	-	-	21	2	3	0	18	0	42	2
3	12	5	9	0	12	0	9	0	42	5
4	18	3	3	1	15	0	6	0	42	4
5	9	3	12	0	15	0	6	0	42	3
6	18	2	3	1	15	0	6	0	42	3
7	9	2	12	0	9	0	12	0	42	2
8	15	3	6	0	9	0	12	0	42	3
9	-	-	21	0	3	0	18	0	42	0
10	12	0	9	0	15	2	6	0	42	2
Sum	105	20	105	4	105	2	105	0	420	26

The vast majority of IPO failures occur within fixed-price offerings with bad share quality. This is in line with the theoretical prediction as investors cannot react to adverse information by adjusting their bid level but only by forgoing the investment. Accordingly, we observe very few failures only in the case of auction offerings. The sum of failed IPOs is negatively, albeit not significantly correlated with information costs, which is reflected in a Spearman’s rank correlation coefficient of -0.31 (p-value = 0.383).

5.2 The propensity to participate in the IPOs

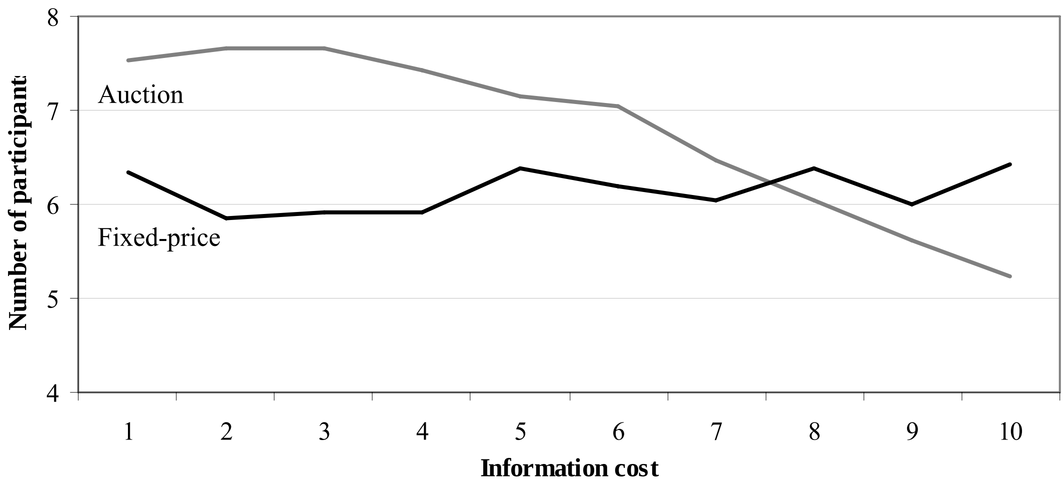
The average number of participants compared to the total number of potential investors measures the propensity to participate in the IPOs by producing costly information and thus allows us to test our hypotheses 1 and 2. Figure 2 shows the average number of participants of the 21 IPOs by information costs and offering mechanism. The exact figures as well as results of significance tests are presented in Table 3.

The black line in Figure 2 shows that investors' participation in fixed-price offerings is virtually unrelated to information costs. The result of a Kruskal-Wallis rank test confirms this observation: Given a p-value of 0.8516, the null hypothesis that the 10 populations of 21 fixed-price offering are equal cannot be rejected. Apparently, the students fully understand the trade-off between information costs and underpricing. Thus, we cannot reject hypothesis 1: Indeed, the propensity to participate in the IPOs is unaffected by information costs if investors are compensated for higher information costs by an appropriately lower offering price.

The overall participation in fixed-price offerings is higher than predicted by the mixed-strategy equilibrium solution. While the predicted number of entries is five, we observe an average participation between 5.9 and 6.4. A Wilcoxon signed rank test reveals that these differences are highly significant (p-values between 0.0105 and 0.0001). This result contrasts to other experimental studies of market entry with strategic and outcome uncertainty. Rapoport, Seale and Ordónez (2002) observe that the probability to enter is very close to the equilibrium for equilibrium entry probabilities in the range of 40% to 70%. Cox, Dinkin and Swarthout (2001) analyze entry behavior in a common value auction. They find fewer entries than predicted by the mixed-strategy equilibrium. Possible explanations for over-entry are risk-seeking behavior, overinvestment in information production due to overconfidence (Ko and Huang 2007; Camerer and Lovallo 1999) or simply that students might attach some utility to gambling in this experimental setting (Conlisk 1993).

Figure 2: Number of participants by information costs and offering mechanism

The number of participants is calculated as the mean number of information producers in the 21 IPOs observed for each combination of information costs and offering mechanism.



Regarding the auction offerings, Figure 2 shows that for information costs greater than 2 MU, the number of participants monotonically decreases from 7.7 to 5.2 participants on average in the case of information costs of 10 MU. In line with this observation, the Kruskal-Wallis test strongly rejects the hypothesis of equality of populations (p-value = 0.0001). Thus, we cannot reject hypothesis 2: In auction offerings, the propensity to participate decreases with increasing information costs. We conjecture that the marginal increase at very low information costs can be ascribed to the very high overall participation rate.

A comparison of offering mechanisms shows that the number of participants is higher in auction IPOs up to information costs of 7 MU. For information costs exceeding that level, more investors participate in the fixed-price offerings. The last column of Table 3 reveals that based on a Wilcoxon signed rank test, the difference in participation is highly significant for information costs up to 6 MU and for information costs of 10 MU. A critical reader might object that even though the level of information production is endogenous in the auction offerings, it is set arbitrary in the fixed-price offerings. Nevertheless, this result strongly supports the notion that if information costs as well as the preference for information production are high, auctions are not the preferable offering mechanisms but mechanisms that allow discretion in setting the offering price. These findings are in line with the theoretical predictions in CL and in Sherman.

Table 3: Information production contingent on information costs

The p-value of difference is based on a Wilcoxon signed rank test. For each level of information costs, the p-value is calculated for a pairwise comparison of auction and fixed-price offerings. KW-test refers to a Kruskal-Wallis test of equality of populations.

	Fixed-price		Auction		
Information costs	**Mean**	**Median**	**Mean**	**Median**	***p-value of difference***
1	6.33	6	7.52	8	*0.0001*
2	5.86	6	7.67	8	*0.0001*
3	5.90	6	7.67	8	*0.0001*
4	5.90	6	7.43	8	*0.0006*
5	6.38	6	7.14	7	*0.0240*
6	6.19	6	7.05	7	*0.0146*
7	6.05	6	6.48	7	*0.1793*
8	6.38	7	6.05	6	*0.2623*
9	6.00	6	5.62	6	*0.3097*
10	6.43	6	5.24	6	*0.0046*
KW-test P(χ2)	*0.8516*		*0.0001*		

We verify our results for the aggregate level by an analysis of the determinants of the investors' individual participation decisions. For this purpose we estimate the influence of information costs and several control variables on the probability to take part in an IPO using random-effects (RE) logistic regressions. Due to the fact that we observe 168 subjects and 20 participation decisions per subject, the use of panel data models is most appropriate.[1] We specify the participants as the random effects in order to account for individual heterogeneity

1 For another example of the application of panel data econometrics to laboratory experiments and a discussion of its benefits see Ham, Kagel and Lehrer (2005).

in the data.[1] In order to account for a potentially better understanding of the decision situations over the course of a session, the variable round is included in the regression. The other explanatory variables are supposed to control for participants' personal characteristics. We include age, the number of semesters being enrolled, a dummy variable for gender (where female equals 1), and the participants' experience in financial markets as well as in game theory. Note that the offering price is not included in the regression for fixed-price offerings since in our design (i.e. with a constant q) the offering price is a linear transformation of information costs. Table 4 present the results of the RE logistic regression estimations for both offering mechanisms.

Table 4: RE logistic regression of individual participation decisions

Random-effects logistic regression where the individual decision to participate is the dependent variable and the subjects are the random effects. Odds ratios denote the ratio of the probability to participate and the complementary probability to forego the IPO. An increase in the independent variable increases [decreases] the probability to participate if the odds ratio is greater [smaller] than one. N denotes the number of observations. Wald-test (p-value) denotes the probability that the model is insignificant (i.e. all coefficients are equal to zero according to a Wald test). ρ denotes the fraction of variance that is contributed by individual heterogeneity and LR-test (p-value) denotes the probability that ρ is greater than zero according to a Likelihood-ratio test.

Explanatory variables	**Fixed-price**		**Auction**	
	Odds ratio	***p-value***	**Odds ratio**	***p-value***
Information costs	1.027	0.269	0.6444	0.000
Round	1.001	0.959	0.9786	0.165
Age	0.962	0.503	1.0488	0.486
Semester	1.082	0.172	1.0534	0.470
Gender (female=1)	0.921	0.835	0.3656	0.032
Exp. in Fin. Markets	0.870	0.288	0.9132	0.576
Exp. In Game Theory	1.234	0.120	1.0312	0.858
N	1680		1680	
Wald-test(p-value)	*0.4901*		*0.0000*	
P	0.4227		0.5225	
LR-test (p-value)	*0.0000*		*0.0000*	

The odds ratios for information costs and the associated p-values strongly support our findings for the aggregate level. The odds ratio is close to one and insignificant for fixed-price offerings which confirms that hypothesis 1 cannot be rejected, i.e. participation is independent of information costs if the offering prices are appropriately adjusted. For auctions offerings, however, the information costs odds ratio is highly significant. Since its value is below one, higher information costs lower the probability to participate in the IPO which is in line with

[1] The sessions might be a second source of unobserved heterogeneity as individual decision within a session might be correlated although we randomly rematch the subjects in each round. A fixed-effects model would allow for within session correlation, but is not appropriate for our data as we also interested in the effects of several time-invariant control variables which would be dropped in fixed-effects models. In an analysis not reported here we account for within session correlation by including session dummy variables (e.g. Wooldridge 2002, p. 288). Results indicate that there is no within session correlation in our data.

hypothesis 2. The insignificant odds ratios of Round indicate that the subjects' probability to produce information did not change over the course of the experiment. A view on the remaining control variables reveals that being a female student significantly lowers the probability to participate in auction offerings in a statistical as well as an economic sense. The aversion of female students to auction offerings might be explained by a generally higher risk aversion, less overconfidence or simply by a better understanding of the difficulty to recover costs in auction offerings. While the latter is just a conjecture, the two former points have been observed by several experimental researchers (e.g. Croson and Gneezy 2004). The values of ρ reveal that more than 40% and 50% of the total variance in the fixed-price offerings and the auction offerings, respectively, is contributed by the individual heterogeneity. Overall, the explanatory variables significantly explain the participation in auctions, but not in fixed-price offerings.

5.3 Investors' bidding behavior in auction offerings

Hypothesis 3 states that investors bid competitively in auction offerings. Competitive bidding means that investors' do not appropriately lower their bids in the case of higher information costs. As a consequence, the level of underpricing in the auction offering is too low to compensate investors for the costs of information production. If investors bid as described above, they have to adjust their probability to participate in order to avoid negative expected profits from participating in the IPOs. Thereby, hypothesis 3 is related to hypothesis 2: Decreasing the probability to participate with increasing information costs is the rational response to competitive bidding and vice versa. As we already found strong evidence for a negative relation between information costs and the probability to participate in the previous section, we also expect investors to bid competitively.

We proceed in two steps in order to investigate investors' bidding behavior. First, we analyze the levels of investors' individual bids. Secondly, we study the extent to which the individual bid levels and the resulting offering prices yield positive or negative profits from participation on average. If investors correctly adjust the participation probability to their bidding behavior, the total profits to investors in the auction offerings are equal to zero on average and irrespective of information costs. Then, investors' information production and bidding behavior constitutes an equilibrium solution to the auction game.

Table 5 provides information about the distribution of bids in auction offerings by type of information and information costs. Indeed, investors seem to bid competitively since the mean bid levels do not show a clear tendency with increasing information costs.

Table 5: Bids in auction offerings by type of information and information costs

	Information = 120 (S^+)			Information = 0 (S^-)		
Information costs	**Mean**	**St. Dev.**	**Frequency**	**Mean**	**St. Dev.**	**Frequency**
1	64.4	12.6	84	32.5	21.0	74
2	65.3	15.0	100	31.8	13.4	61
3	63.1	16.8	74	28.6	14.0	87
4	66.4	13.6	63	28.8	16.6	93
5	63.0	11.4	64	31.4	16.3	86
6	64.9	15.6	59	29.3	18.2	89
7	60.8	18.2	75	26.4	15.7	61
8	59.8	16.2	61	31.9	16.1	66
9	67.0	16.9	72	31.3	21.0	46
10	62.6	16.3	45	29.3	21.2	65

In order to gain a deeper insight into the determinants of the bid levels, we regress the levels of individual bids on information costs, round and the control variables described previously. Here, the use of a linear regression model allows us to directly control for individual heterogeneity as well as for session heterogeneity by including session as a second random-effect into the model. The results of the two-way RE regression estimations (Table 6) confirm our conjecture of independence between information costs and bid levels after low signals, but reject this conjecture after high signals. In the latter case, investors significantly lower their bids with increasing information costs after high signals. However, the adjustment of -0.43 for a one unit increase in information costs is very small compared to the adjustment of -3.6 on average which is necessary to keep participation at a constant level in fixed-price offerings. Hence, this finding suggests that investors insufficiently adjust their bid levels. Irrespective of the kind of information, the variable Round has a positive and highly significant influence on the bid level. It implies that investors raised their bids in later auctions, i.e. they bid more competitively over the course of the experiment. The increasingly competitive bidding effect also outweighs the moderating effect of increasing information costs on bid levels. The control variables do not significantly affect bid levels.

Even though these results point to competitive bidding, the actual competitiveness of investors' bidding behavior depends on the adjustment of the probability to participate. For example, investors might adjust their probability to participate so strongly that they could bid even more competitively to drive the expected profit from participation down to zero. In order to take the interrelation with the decision to participate into account, we analyze the resulting offering prices in the auction offerings and the total profits of investors from participating in auction offerings. We calculate the total profit of investors for each IPO by adding up the fair values of the shares and deducting the offering prices and the sum of information costs and bidding costs. The fair value equals the expected value of the shares when taking into account all information in this IPO and thus, is calculated using Bayes' law. In an efficient secondary market where prices reflect all available information, the shares should trade at the fair value.

Table 7 summarizes the mean offering prices, fair values and total profits of investors by offering mechanism and information costs.

Table 6: Two-way RE regression of bid levels in auction offerings by information

Two-way RE regression where the individual bid level is the dependent variable. The subjects and the sessions are defined as the random effects. N denotes the number of observations. Wald-test (p-value) denotes the probability that the model is insignificant (i.e. all coefficients are zero according to a Wald test). Est. St. Dev. [St. Err.] denotes the estimated standard deviation [the standard error of this estimation] of the RE parameters. LR-Test (p-value) denotes the probability that all RE parameters are simultaneously zero according to a likelihood-ratio test.

Explanatory variables	Information = 120		Information = 0	
	Coefficient	*p-value*	Coefficient	*p-value*
Information cost	-0.426	0.001	0.090	0.657
Round	1.089	0.000	0.650	0.001
Age	-0.314	0.487	-0.471	0.344
Semester	0.239	0.594	0.018	0.974
Gender (female=1)	-1.489	0.619	3.360	0.416
Experience in Financial Markets	-1.476	0.135	1.208	0.265
Experience in Game Theory	-0.088	0.931	1.219	0.138
Constant	71.127	0.000	36.054	0.001
N	692		431	
Wald-test (p-value)	*0.0000*		*0.0236*	
Est. St. Dev. [St. Err.] of session	0.465 [5.479]		1.870 [2.455]	
Est. St. Dev. [St. Err.] of subject	12.917 [0.843]		13.752 [1.083]	
LR-Test (p-value)	*0.0000*		*0.0000*	

At first sight, the fact that the offering prices in auction IPOs decrease with increasing information costs seems to be at odds with the competitive bids observed on individual bidding level. However, this phenomenon can be explained by the decreasing number of bidders. The lower the number of bidders in the auction, the greater is the probability that the K+1-highest bid (i.e. the offering price) is below the mean bid.[1] Compared to the offering prices in the fixed price IPOs, in most cases the offering prices in high true value auctions are above and those in low true value auctions are below.

The analysis of total profits in the IPOs shows that investors lose money in fixed-price offerings on average which reflects the previous observation of over-entry. However, investors realize even larger losses in auction offerings in most cases which indicates that investors' participation and bidding behavior in the auction offerings does not constitute an equilibrium either. In other words, investors either bid too competitively or insufficiently adjust their probability to participate to their bidding behavior.

[1] A fixed-effects (FE) regression of the offering price on information costs, round and the number of bidders confirms this conjecture. On average, the existence of one more bidder in an auction offering increased the offering price by 4.8 if the true value is 120 and even by 8.0 if the true value is 0.

A fixed-effects (FE) regression analysis of the determinants of total profits shows that the offering mechanism significantly influences the total profit of investors indeed (Table 8). To be precise, a change from auction to fixed-price increases the total profit by about 14.5. In the light of these results, hypothesis 3 cannot be rejected. Given the observed adjustment of the probability to participate, investors indeed bid too competitively to generate zero or positive expected profits on average. This effect becomes even more severe with increasing information costs since an increase in information costs by one unit decreases the total profit by 2.7 on average in auction offerings.[1]

Table 7: Mean offering prices, fair values and total profits to investors by information costs

The fair values are calculated according to Bayes' law by taking all information produced in an IPO into account. Mean total profits are calculated as the equally weighted mean of the respective total profits of high true value and low true value IPOs. The total profit to investors in each IPO is calculated by adding up the fair values of the shares and deducting the offering prices and the sum of information costs and bidding costs.

	Fixed-price offerings				Auction offerings				
Inform.	**Offering**	**Fair value**		**Total**	**Offering price**		**Fair value**		**Total**
cost	**price**	**120**	**0**	**profit**	**120**	**0**	**120**	**0**	**profit**
1	67.5	100.3	17.4	-27.9	63.0	41.4	109.2	20.1	-11.5
2	64.0	98.2	-	-	66.9	43.7	102.8	7.6	-46.7
3	60.5	108.1	11.6	-10.4	59.9	44.3	100.1	22.6	-35.8
4	57.0	109.6	20.6	-31.9	67.7	42.7	101.1	18.8	-48.3
5	53.5	106.1	11.4	-21.0	64.0	44.3	106.2	18.8	-47.4
6	49.5	115.5	16.5	-39.6	64.2	37.4	107.3	12.7	-50.9
7	46.0	95.7	22.2	-26.9	52.4	40.3	100.4	17.7	-45.2
8	42.5	109.6	19.1	-22.7	59.6	32.8	95.8	9.3	-60.2
9	39.0	100.5	-	-	56.8	21.7	102.1	2.4	-47.3
10	35.5	102.7	11.7	-43.5	50.9	32.7	105.0	19.6	-37.2

The overly competitive bidding indicates that investors fall prey to the winner's curse, a phenomenon commonly observed in experimental studies on common value auctions. For instance, Kagel, Levin and Harstad (1995) find evidence that bidders suffer from a winner's curse in second-price common value auctions with a fixed number of bidders. Cox, Dinkin and Swarthout (2001) observe a winner's curse in a first-price common value auction with endogenous entry.

[1] Table 8 also reveals that investors do not converge to the equilibrium solution over the course of a session since the coefficient of Round is small and insignificant. We conjecture that given the complexity of the decision situations, the sessions with 22 rounds were too short to observe a gradual convergence to the equilibrium solution through an improved understanding of the decision situation.

Table 8: FE regression of total profits on IPO parameters

Fixed-effects regression where total profits is the dependent variable and the sessions constitute the fixed effects. N denotes the number of observations. F-Test (p-value) denotes the probability that the model is insignificant and R^2 denotes the overall explanatory power. ρ denotes the fraction of variance that is contributed by the fixed effects and F-test (p-value) of FE denotes the probability that the fixed effects are equal to zero.

Explanatory	All offerings		Fixed-price offerings		Auction offerings	
Variables	**Coefficient**	***p-value***	**Coefficient**	***p-value***	**Coefficient**	***p-value***
Mechanism (auction=0)	14.465	0.000				
True value (dummy)	134.226	0.000	141.032	0.000	127.394	0.000
Information costs	-1.827	0.008	-1.013	0.279	-2.669	0.007
Round	0.021	0.952	0.231	0.620	-0.186	0.707
Constant	-100.140	0.000	-95.781	0.000	-89.940	0.000
N	420		210		210	
F-test (p-value)	*0.0000*		*0.0000*		*0.0000*	
R^2 (overall)	0.7429		0.7641		0.7210	
ρ	0.0163		0.0826		0.0213	
F-test (p-value) of FE	*0.4299*		*0.0153*		*0.6889*	

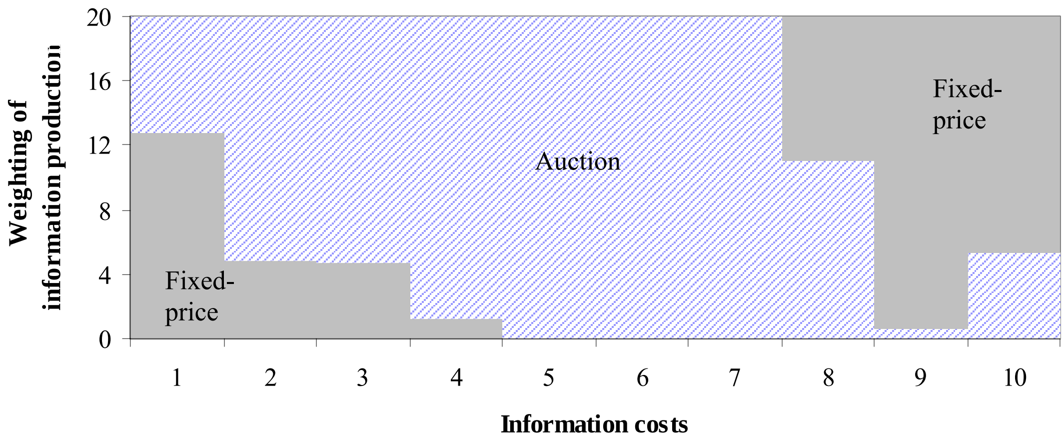
5.4 Implications for the issuer's choice of an offering mechanism

In the light of these findings regarding investors' information production and bidding behavior in IPOs, the issuer should choose the optimal offering mechanism given his preferences for offering proceeds and information production. Based on our experimental data, Figure 3 exhibits the superiority of the offering mechanism in our laboratory experiment by information costs and the weighting of information production. Superiority is determined by comparing the offering mechanisms with respect to the sum of the mean offering price per share plus the mean number of information producers times a weighting factor. Grey areas indicate the combinations of information costs and weighting factor for which fixed-price offerings are superior to auction offerings, whereas in shaded areas auction offerings are superior.

Figure 3 shows that when information costs are low, those who attach some importance to information production should choose an IPO auction, thereby forgo offering proceeds but maximize information production. However, for issuers who feel that information production is costly but have a high preference for such activity, a fixed-price offering is the method of choice. Thereby, our experimental results provide a solution to the IPO auction puzzle. Since the bulk of IPO firms are young, less well-known and operating in new and risky businesses, they can be located in the upper right corner of Figure 3. Consequently, such firms should care for a sufficient level of information production by choosing an offering mechanism other than auctions. Nevertheless, an auction is the preferable offering mechanism of large, established or well-known firms that decide to go public, e.g. in the course of a privatization.

Figure 3: Superior offering mechanism by information costs and weighting of information production

Areas filled grey [shaded grey] indicate that fixed-price offerings [auction offerings] are superior. The offering mechanisms are ranked by the following measure: (Mean offering price) + (Mean number of information producers) * (weighting factor). This is repeated for each combination of information costs and weighting factor. The weighting factor serves as a simple measure for the preference for information production. The mean offering prices of the auction offerings are calculated as the equally weighted mean of the high true value and the low true value offering prices (see Table 7).



6 Conclusion

This study contributes to the literature on IPO mechanisms by analyzing investors' behavior in fixed-price and auction offerings via a laboratory experiment. Our experimental design is based on the theoretical model by CL. The central argument is that issuers not only care about offering proceeds, but also about the level of information production by investors in IPOs. However, the incentives for producing costly information differ with the offering mechanism. Our experimental findings strongly support the theoretical argument. In fixed-price offerings, the issuer can maintain investors' propensity to produce information by appropriately adjusting the offering price even if information costs are high. This result also applies to the bookbuilding mechanism where the issuer has likewise discretion in setting the offering price. In auctions, however, high information costs inevitably result in a low propensity to produce information. This is a consequence of investors' competitive bidding, i.e. their insufficient adjustment of bid levels to increasing information costs. Given their bidding behavior, investors also insufficiently adjust their information production to increasing information costs. Our results suggest that an auction is not the preferable offering mechanism for young and risky IPO firms since the costs of producing information about such firms are high, but there is also a strong need to generate information. Since these are the characteristics of the bulk of IPO firms, our findings explain the worldwide predominance of fixed-price and bookbuilding offerings.

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Appendix A: Ordering of IPOs in the experiment sessions

Table B1: Information costs and offering mechanism by round and session

The columns display the information costs in monetary units and the offering mechanism where (A) denotes a uniform-price auction and (F) denotes a fixed-price offering. Information costs were set to 5.5 MU in the practice rounds (first two rounds) and to integers between 1 MU and 10 MU in the subsequent rounds. Each combination of round, information costs occurred only once in the seven sessions.

	Session						
Round	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	5.5 (A)	5.5 (F)	5.50 (A)	5.50 (F)	5.50 (A)	5.50 (F)	5.50 (A)
2	5.5 (F)	5.5 (A)	5.50 (F)	5.50 (A)	5.50 (F)	5.50 (A)	5.50 (F)
3	3 (A)	5 (F)	1 (A)	4 (F)	8 (A)	2 (F)	4 (A)
4	6 (F)	6 (A)	7 (F)	7 (A)	3 (F)	5 (A)	1 (F)
5	6 (A)	8 (F)	7 (A)	1 (F)	2 (A)	6 (F)	5 (A)
6	2 (F)	3 (A)	5 (F)	1 (A)	7 (F)	8 (A)	9 (F)
7	2 (A)	6 (F)	3 (A)	7 (F)	6 (A)	3 (F)	8 (A)
8	9 (F)	7 (A)	10 (F)	9 (A)	8 (F)	1 (A)	4 (F)
9	10 (A)	9 (F)	5 (A)	6 (F)	9 (A)	10 (F)	1 (A)
10	1 (F)	4 (A)	8 (F)	3 (A)	4 (F)	6 (A)	7 (F)
11	5 (A)	2 (F)	8 (A)	10 (F)	7 (A)	4 (F)	3 (A)
12	5 (F)	10 (A)	6 (F)	6 (A)	1 (F)	2 (A)	3 (F)
13	8 (A)	1 (F)	4 (A)	2 (F)	1 (A)	7 (F)	10 (A)
14	8 (F)	2 (A)	9 (F)	5 (A)	5 (F)	9 (A)	2 (F)
15	7 (A)	4 (F)	2 (A)	3 (F)	5 (A)	1 (F)	9 (A)
16	10 (F)	8 (A)	2 (F)	10 (A)	9 (F)	4 (A)	6 (F)
17	1 (A)	10 (F)	10 (A)	5 (F)	3 (A)	9 (F)	2 (A)
18	4 (F)	9 (A)	3 (F)	4 (A)	2 (F)	7 (A)	8 (F)
19	9 (A)	3 (F)	6 (A)	9 (F)	4 (A)	8 (F)	7 (A)
20	7 (F)	1 (A)	1 (F)	2 (A)	10 (F)	10 (A)	5 (F)
21	4 (A)	7 (F)	9 (A)	8 (F)	10 (A)	5 (F)	6 (A)
22	3 (F)	5 (A)	4 (F)	8 (A)	6 (F)	3 (A)	10 (F)

Appendix B: Screen shots (in German)

Figure B1: Decision screen 1 – Information production decision (example for fixed-price offering)

Figure B2: IPO simulator for fixed-price offerings

Figure B3: Decision screen 2 – Bidding decision (example for auction offering)

Figure B4: IPO simulator for auction offerings

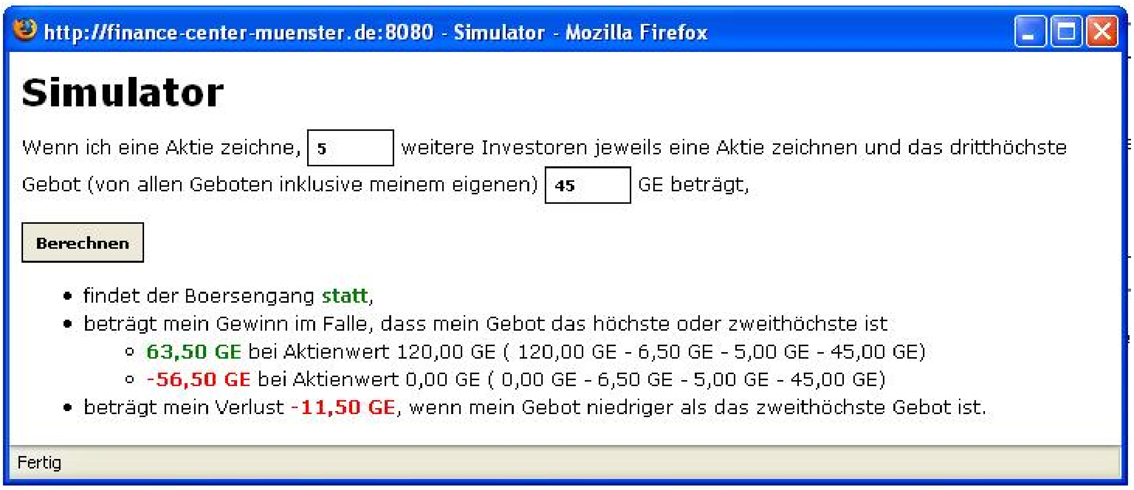

Figure B5: Results screen

Ergebnis

Börsengang hat stattgefunden. Ihnen wurde eine Aktie zum Preis von 48,00 GE zugeteilt.

Ihr Kontoauszug (in GE):

Position	Soll	Haben
Alter Saldo		150,00
Informationskosten	6,50	
Teilnahmekosten	5,00	
Bezug einer Aktie	48,00	
Neuer Saldo		**90,50**

Ihr Depotauszug (in GE):

Position	Anzahl	Einstands-Preis	Gesamtwert
Aktie	1	48,00	Unbekannt (120,00 oder 0,00)

Ihr Gesamtgewinn/-verlust bei diesem Börsengang hängt vom tatsächlichen Wert der Aktie ab. Bei einem Aktienwert von 120,00 GE beträgt Ihr Gewinn 60,50 GE, bei einem Aktienwert von 0,00 beträgt Ihr Verlust -59,50 GE.

Allgemeine Informationen zum Börsengang:

Anzahl angebotener Aktien:	2
Anzahl der Investoren	8
Anzahl der Investoren, die teilgenommen haben:	5
Emissionspreis:	48,00 GE

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