Why the Google IPO might stay exotic
– An experimental analysis of offering mechanisms

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Abstract

Despite their theoretical efficiency in selling shares to the public, auctions are not the preferred mechanisms in Initial Public Offerings (IPOs). Chemmanur and Liu (2006) and Sherman (2005) provide a rational explanation for this "IPO auction puzzle" based on the notion that issuers are not only interested in the offering proceeds, but also the secondary market price, and thus try to induce investors to produce information about the IPO. In this paper, we report the results of an experimental study set up to test the mechanisms underlying this reasoning. Our findings strongly support the theoretical argument. If the issuer has some discretion in setting the offering price (as with bookbuilding or fixed-price offerings), he 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 because, while there is strong demand for information about such firms, the costs of producing this information are high.

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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 transaction (e.g., Dasgupta and Hansen, 2007). Indeed, empirical evidence suggests that the direct costs associated with auctioned IPOs are lower than the costs of IPOs via the typical alternative offering mechanisms, namely, fixed-price and bookbuilding offerings.[1] Further, in countries where auctions and alternative offering 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 the summer of 2004, in which Google raised $1.67 billion of capital. Yet auctions have not become the preferred offering mechanism in IPOs. In contrast, while auction IPOs occurred in many countries in the 1980s and 1990s, they have been abandoned in favor of fixed-price offerings and, more recently, bookbuilding offerings in most countries (Sherman, 2005; Jagannathan and Sherman, 2006; Kutsuna and Smith, 2004, Degeorge et al., 2007). 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; Chen and Wu, 2006).

Chemmanur and Liu (2006) (CL hereafter) provide a rational explanation for the IPO auction puzzle. In their model, issuers not only have a preference for maximizing the offering proceeds (or equivalently, for minimizing underpricing), but also 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

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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 et al. (2006) study the Google IPO as well as the IPOs conducted via the online auction platform of W. R. 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 on the first trading day. Derrien and Womack (2003) find evidence of lower underpricing in auction IPOs in France and Pukthuanthong et al. (2006) find similar for the US IPO market. For evidence on other IPO markets see Ritter (2003).

market. Against this background, CL analyze 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 (multiple-unit second-price sealed bid common value auction). 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 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 an earlier study, Sherman (2005) compares different forms of IPO auctions to the bookbuilding mechanism. With respect to pricing, bookbuilding combines elements of auctions and fixed-price offerings since even though the offering price is ultimately set by the issuer, investor demand is taken into account by collecting bids in the order book. In line with 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.[3]

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[3] While CL and Sherman explicitly take into account the issuer's preference for information production, additional studies compare IPO mechanisms on the basis of offering proceeds in varying information settings (e.g., Biais et al., 2002; Biais and Faugeron-Crouzet, 2002; Maksimovic and Pichler, 2006).

While the models of CL and Sherman provide persuasive explanations for the IPO auction puzzle under the assumption of fully rational risk-neutral agents, the extent to which their sensitive decision mechanisms are able to describe real-life behavior is an open question. 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 thus are remarkably sophisticated decision problems. Sherman, p. 618, notes what this decision problem essentially boils down to:

> 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 a lack of auction IPOs. Without a large sample of IPOs conducted via different offering mechanisms, moreover, it is very hard to distinguish the effects of the offering mechanism and of information costs from the variety of factors influencing investor behavior in IPOs.[4] In this study we aim to shed light on investors' information production and bidding behavior in IPOs by way of a laboratory experiment.

We compare a uniform price auction to the common offering mechanisms with respect to pricing. In uniform price auctions the price is fully determined by demand, whereas in both the bookbuilding and the fixed-price mechanisms the issuer has discretion in setting the offering price.[5] In the following, we focus on fixed-price offerings as bookbuilding would considerably complicate our experiment.[6] Nevertheless, our main results similarly apply to bookbuilding offerings. The fixed-price and

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4 Jagannathan and Sherman (2006) provide a survey of auction IPOs around the world. The anecdotal evidence indicates that the number of bidders fluctuates strongly.

5 Beyond discretion in pricing, bookbuilding also provides discretion in the allocation of shares. As a result, bookbuilding allows the issuer or the investment bank to elicit truthful information from investors by rewarding investors with underpricing and a preferred allocation (e.g., Benveniste and Wilhelm, 1990; Cornelli and Goldreich, 2003). Here we solely model the effect of underpricing on investors' information production behavior, as we focus on discretion in pricing, which is a common feature of fixed-price and bookbuilding offerings.

6 Apart from its simplicity, a comparison of fixed-price offerings to auctions seems reasonable in light of the historic development of offering mechanisms. As Jagannathan and Sherman (2006) show, fixed-price offerings drove out auctions in most countries several years before bookbuilding was introduced.

auction offering games underlying the experimental analysis build on the model by CL. 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.[7] The experiment allows us to observe the effect of the offering mechanism and the level of information costs on investors' information production and bidding behavior. For simplicity, we do not consider a follow-on offering in the experiment, but only look at the IPO event. In order to capture the issuer's preference for information production, we multiply the level of information production by a simple weighting factor. Further, we assume that the costs of producing information are positively related to the issuer's inherent risk. Thereby, the experiment yields insights into the optimal choice of an offering mechanism depending on the issuer's risk characteristics and preference for information production.

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. In auctions, however, high information costs inevitably result in a low propensity to produce information as investors bid too competitively. With respect to the optimal choice of an offering mechanism, our results suggest that an auction is not the preferable offering mechanism if both the costs of information production and the issuer's preference for information production are high. These characteristics often apply to IPO firms, since such firms are typically young, less well-known and engaged in new businesses or technologies.

The relation between students' behavior in experimental IPOs and institutional investors' behavior in real IPOs might appear somewhat tenuous given the considerably higher payments and experience of institutional investors.[8] Indeed, Smith and Walker (1993) find that increased cash payments drive subjects' behavior towards the rational solution in experiments, i.e., they invest more time and effort in the decision process. However, we believe this result rather supports the external validity of

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[7] To be precise, CL model signals that have no information content with very high probability, but fully reveal the shares' true value with very low probability. We model signals that reveal the true value in more than 50% of the cases, but indicate the wrong value in the remaining cases.

[8] See Gillette et al. (2007) for an in-depth discussion of external validity in a lab experiment where the stakes and the decision environment also differ strongly from those in the respective real-life situation.

our experimental design: If even students behave as predicted by the sophisticated theoretical models, institutional investors will be likely to do so too. A growing strand of literature uses both professionals and students in auction experiments in order to measure the impact of experience. These studies indicate that the results obtained by students are qualitatively similar to those obtained by professionals (e.g., Dyer et al., 1989; Gillette et al., 2007, fn. 5).

From a game theory 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 et al. (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 et al. (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 at the aggregate level.

To our knowledge, there are three other experimental studies on IPO mechanisms. Bonini and Voloshyna (2007) focus on investors' information revelation behavior in bookbuilding offerings and in a new mechanism called competitive IPO. Patatoukas (2008) investigates the reasons for underpricing in experimental IPO auctions where the number of bidders is given exogenously. He finds that underpricing increases as the number of bidders decreases due to strategic underbidding. In the case of heterogeneous information among investors, underpricing compensates less informed investors for adverse selection problems. Finally, 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, Zhang bases his experiment on the comparison of offering mechanisms by Biais and Faugeron-Crouzet (2002), which is fundamentally different to our approach. Specifically, unlike CL, Biais and Faugeron-Crouzet rank IPO mechanisms only by their offering proceeds and assume an exogenously given number of investors. This study is thus the first experimental analysis of IPO mechanisms that explicitly considers issuers' preference for accurate secondary market prices and investors' endogenous information production and bidding decisions.[9] This design allows us to test the theoretical solutions to the IPO auction puzzle by CL and Sherman.

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9 Further differences from Zhang (2006) relate to the signal structure and the information processing model.

The paper is organized as follows. Section 2 provides a more detailed discussion of the basic intuition for the issuers' preference for information production in IPOs on the basis of CL and the related literature. Section 3 describes the IPO games that 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 production and bidding behavior in the experimental sessions. Section 6 summarizes and concludes.

2. The Preference for Information Production in IPOs

According to the theoretical models by CL and Sherman, the choice of the IPO offering mechanism affects the overall offering proceeds through a sequence of causal relations. In the following, we discuss the main intuition behind the models. 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.[10] This assumption is plausible in the case of a high quality firm. Here, the secondary market price increases with the amount of information if the pieces of information are aggregated according to Bayes' law.[11] 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), a sensitivity of post-IPO investment to prices (van Bommel, 2002), aftermarket trading activities (Busaba and Chang, 2002), insider selling after the end of the lock-up period (Aggarwal et al., 2002) and management compensation schemes tied to the stock price.[12]

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

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[10] Other papers that point to the importance of buy-side information acquisition include Chemmanur (1993), Sherman (2000), Sherman and Titman (2002) and van Bommel (2002).

[11] A more general rationale for the negative relation between the level of information and the costs of equity capital is provided in Easley and O'Hara (2004).

[12] Yung (2005) models both investors' information production and bankers' costly screening of new issues. In his model, price accuracy mitigates the bank's moral hazard problem. Thus, a preference for price accuracy here does not follow from assumptions about post-IPO activities, but arises endogenously in the IPO process.

worthwhile if the shares are sold at a discount to the fair value in the secondary market. Thus, the "money left on the table" associated with 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 that employ famous analysts.[13] 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 prefer to "buy" analyst coverage through underpricing. The point is that issuers care about analyst coverage not only during the IPO but also after the IPO. Consistent with this hypothesis, they find that firms are more likely to switch the underwriter in a seasoned equity offering if they were not satisfied with the 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 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 announces the decision to go public via a certain offering mechanism, an investor has to weigh the costs of purchasing information against the expected profit from informed bidding. CL show that a symmetric risk-neutral Nash equilibrium in mixed strategies exists to this problem. Investors choose the probability of entering the IPO

[13] For example, Dunbar (2000) shows that between 1984 and 1994 an underwriter's market share in the US increased after one of his analysts was highly ranked in the Institutional Investor annual survey. This finding is confirmed by Clarke et al. (2002), who observe the market share of underwriters after losing or acquiring all-star analysts in the US between 1988 and 1999. Krigman et al. (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.

that 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 participation probability by lowering the offering price while this 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 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, but a fixed-price offering in the case of high information costs.

The costs of producing information about an IPO firm are closely related to the amount of publicly available information 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 industry proxy for these information cost factors.[14] 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 and small, operating in a new, innovative industry (e.g., Ljungqvist et al., 2003). Producing information about such a firm is costly. Thus, CL's model predicts that an auction offering should not be the preferred IPO method. This is in line with the empirical observation of a very low proportion of auction offerings in most countries.

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[14] Such measures are commonly used as proxies for IPO uncertainty in empirical studies (e.g., Ljungqvist, 2007).

3. IPO Games

3.1 COMMON CHARACTERISTICS

The IPO games that 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.[15] 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 in 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 bidding in the IPO, an investor considers producing information on 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* that takes either high (S^+) or low (S^-) outcomes. 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 by $p(S^+ | V^+) = p^{++}$ and given the firm is of bad quality by $p(S^+ | V^-) = p^{+-}$. In the 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. The pieces of information gathered by different investors are independently drawn conditional on the pre-determined true value of the shares. Hence, signals are related in the

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[15] While Sherman also assumes that the true value is unknown to the firm, CL assume the value is known. They argue that it is rational for a bad quality firm to mimic the behavior of a good quality firm as there is a chance that this firm will achieve 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, fn. 23 and 32, for a detailed discussion on the bad firms' mimicking behavior. In signaling models of IPO underpricing, however, it is assumed that firms that know about their bad quality cannot mimic the underpricing of good quality firms as they cannot compensate for forgone proceeds through higher proceeds in secondary offerings (e.g., Allen and Faulhaber, 1989). Thus, good firms use underpricing to signal their quality. The empirical evidence for these theories is mixed at best (Spiess and Pettway, 1997).

sense that producing a good signal increases the likelihood that other investors also produce good signals (Kagel et al., 1995). This information setup is common knowledge in the IPO games.

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 to produce information (also referred to as participation decision). In a second step, she decides on bidding for a share in the IPO based on her updated beliefs about firm quality in the case of information production. If an investor chooses not to bid 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 not learn about either other investors' information production decisions or 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 investors' 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 set by the issuer (which is the experimenter in our study) within the range $[V^-, V^+]$ and is communicated to investors prior to their information production and bidding decisions. 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 the number of bidding investors. Further, we maintain the following assumptions regarding the setting of the IPO parameters:

Assumption 1: 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.

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

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 pre-defined 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 of bidding in the IPO is $\Theta p^{++} + (1-\Theta)p^{+-}$. The first term is the probability with which the investor produces the signal S^{+} and the true value of the firm is V^{+}, while the second term is the probability of a signal S^{+} and the true value V^{-}. The expected profit to investor *i* from bidding depends not only 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 by $\beta(m,n,p) = \binom{n}{m} p^{m}(1-p)^{n-m}$. 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 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

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

where

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

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 in the number 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 participation) and chooses 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 participation in such a way as the expected profit exactly offsets the costs of participation. Thus, investor i chooses the q that solves

$$\sum_{n=1}^{N} \beta(N-1, n-1, q) E(G_n) = C^{info} \quad .^{16} \tag{2}$$

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 participation probability is $q = 0.623$.[17] Note that this equilibrium does not constitute a social optimum. In the social optimum, q would be chosen so that the overall expected profit from participating in the fixed-price

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[16] 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 investors choose to stay out.

[17] 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.

game is maximized.[18] If all other exogenous parameters are held constant, lowering the offering price increases the expected profit to investors and in turn the LHS of Equation (2). For Equation (2) to hold, investors react to an offering price decrease by raising the probability of participation, which decreases the probability of allocation and 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 participation unless the expected profits are increased 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 is 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

$$F = \frac{-C^{info} + \sum_{n=1}^{N} \beta(N-1, n-1, q)\left(\Theta p^{++}\pi_n^{++}V^{+} + (1-\Theta)p^{+-}\pi_n^{+-}V^{-} - \left(\Theta p^{++} + (1-\Theta)p^{+-}\right)C^{bid}\right)}{\sum_{n=1}^{N} \beta(N-1, n-1, q)\left(\Theta p^{++}\pi_n^{++} + (1-\Theta)p^{+-}\pi_n^{+-}\right)}. \quad (2')$$

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

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 which case no shares are allocated to investors. Each bidding investor receives one share if $m = K$. In the case of $m > K$, shares are allocated to the K investors that submitted the highest bids.

[18] 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 $E(G) = 3.21$.

All investors who receive an allocation pay the same price for their share. We choose a uniform price mechanism as this is the dominant type used in most countries that allow auction IPOs (e.g., Jagannathan and Sherman, 2006). 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 apply this pricing rule since Vickrey (1961) shows that in such an auction, each bidder's dominant strategy is to bid his own true willingness to pay. This truth-revealing property ensures that in theory, prices in auction offerings reflect the information produced by 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 nontrivial task. Campbell and Levin (2000) derive equilibrium bidding strategies in common value auctions with discrete signals, but they consider first-price, single good auctions with an exogenous number of bidders. Levin and Smith (1994) study common value auctions with endogenous entry in a continuous signal setting.[19] CL and Sherman derive equilibrium bidding strategies for an auction mechanism very close to ours. However, they apply a rather academic signal structure. Specifically, 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 investors would produce uninformative signals in most IPOs.[20] 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 et al. (2001) run a laboratory experiment 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

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

[20] For instance, CL, 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.

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 some intuition for our expectation that the propensity to produce information in the auction IPO game decreases with information costs, mimicing the explicit equilibrium derived in models with the simplified signal structure. We expect that investors will bid competitively in auction offerings irrespective of information and bidding costs. Such costs are sunk at the time of bidding and thus are 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 is unknown to investors who observe neither the number of other informed investors nor the value of their information. We suspect that whenever the number of bidders exceeds the number of shares 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, when 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 $m = K$ decreases with the probability of participation. 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 intuition of the IPO games are able to describe investors' actual behavior. Recall 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 investors' actual 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

Based upon 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 both the offering mechanism and 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 the issuer can keep investors' propensity to participate at a constant level by lowering the offering price as information costs increase comprises our first hypothesis. More formally:

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 it sounds very intuitive that a lower offering price attracts more attention and thus more interest in information production. The theoretical solution to the fixed-price game shows that the expected profit depends not only on the offering price, but also on other investors' unobservable behavior for two reasons. First, the aggregate information constitutes the secondary market price. Second, the allocation probability depends on other investors' bidding decisions.

In contrast, if the issue price is determined by 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 reason is as follows. The fact that the bids determine the allocation of shares should induce investors to bid competitively in auctions. This implies that investors ignore the costs of information production and bidding and that they place bids at the expected share value. In other words, investors do not appropriately lower their bids in the case of high 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 competitively, they have to adjust their probability of participation in order to avoid negative expected profits from participating in the IPOs. This argument results in the following two related hypotheses:

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

H3: In auction offerings, investors bid competitively, i.e., they bid their expected value irrespective of the level of 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 at the time of the study, and had a medium level of experience in financial markets as well as game theory, which is reflected in a median score of three on a scale from one (very low experience) to six (very high experience) in both fields. Descriptive information about the participants is summarized in Table I.

[Insert Table I about here]

4.2 PROCEDURE

The experiment was conducted in seven sessions in a networked computer laboratory at the University of Münster, Germany. Each experimental session lasted about two hours. Each of the 24 students in a session was provided a written copy of the instructions, a ballpoint pen and paper for notes and was seated at a computer terminal.[21] 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 of each session, 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 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 pre-test sessions.

The experiment consisted of 22 rounds. 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.[22] 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 case of an allocation were deducted from the current account. The account balances of one round did not affect the balances of subsequent rounds.[23] After finishing the 22 rounds, one round was randomly selected. Each student

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[21] For an English translation of the instructions including graphical displays of the decision screens see Appendix A.

[22] The random rematching in each round aimed to prevent tacit collusion among the subjects and to avoid learning about the other investors' behavior. Even though the evidence on the effect of random rematching is mixed (Andreoni and Croson, 2008; Schmidt et al., 2003), we believe it is the best compromise for producing a large number of observations with a reasonable number of subjects while mitigating the influence of the history of play. In the analyses we control for history of play effects and for within-session effects by applying panel data models.

[23] Accounts for each round were treated separately in order to avoid any effect of the cumulated balances on participation and bidding behavior. See Ham et al. (2005) for a discussion of (cash) balance effects.

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 shares in eleven IPOs were of bad quality.[24] 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.

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.[25] 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. We defined the fixed-price and the auction offering round with the same information costs as a pair. Within each of the ten pairs of a session, the allocation of the 24 students to the three IPOs per round was identical in order to be able to analyze the difference in information production behavior associated with a mechanism change in a pure within-subject design. 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.

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24 See Appendix B for details on the information costs and offering mechanism by round and session.

25 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 comprised auction offerings.

In 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 participation 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 and 35.5 MU (rounded to 0.5). Overall, in these parameter settings 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 producing 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 situations 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.[26]

[Insert Figure 1 about here]

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.

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26 For graphical displays of the decision screens, the IPO simulators and the result screen, see Appendix B.

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 the offering price. The true value of the shares was not revealed to any of the students, except for in the round drawn to determine the students' compensation in Euro for participating in the experiment, in which case the true value would be disclosed at the end of the experiment session. Even though 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 practice 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 sessions 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 II exhibits statistics on IPO frequency and failure by offering mechanism and information costs.

[Insert Table II about here]

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 only very few failures 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 in the 21 IPOs by information costs and offering mechanism. The exact figures as well as results of significance tests are presented in Table III.

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 ten populations of 21 fixed-price offerings are equal cannot be rejected. Apparently, the students 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 a 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 et al. (2002) observe that the probability of entering is very close to the equilibrium for equilibrium entry probabilities in the range of 40% to 70%. Cox et al. (2001) analyze entry behavior in a common value auction. They find fewer entries than predicted by the mixed-strategy equilibrium. Possible explanations for over-participation 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).

[Insert Figure 2 about here]

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 III 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 arbitrarily 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 preferred offering mechanisms, but rather mechanisms that allow discretion in setting the offering price. These findings are in line with the theoretical predictions in CL and Sherman.

[Insert Table III about here]

We verify our results for the aggregate level by an analysis of the determinants of investors' individual participation decisions. For this purpose we estimate the influence of information costs and several control variables on the probability of taking 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.[27] We specify the participants as the random effects in

[27] For further examples of the application of panel data econometrics to laboratory experiments and discussions of its benefits see Ham et al. (2005) or Harrison (2007).

order to account for individual heterogeneity in the data.[28] 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 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 IV present the results of the RE logistic regression estimations for both offering mechanisms.

[Insert Table IV about here]

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 auction offerings, however, the information costs odds ratio is highly significant. Since its value is below one, higher information costs lower the probability of participating in the IPO, which is in line with Hypothesis 2. The insignificant odds ratios of Round indicate that the subjects' probability of producing information did not change over the course of the experiment. The remaining control variables reveal that being a female student significantly lowers the probability of participating 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 a better understanding of the difficulty with which costs are recovered 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, respec-

[28] The sessions might be a second source of unobserved heterogeneity as individual decisions 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 are also interested in the effects of several time-invariant control variables that 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). The results indicate that within-session correlation is negligible in our data.

tively, is contributed by the individual heterogeneity. Overall, the regression model significantly explains 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. Therefore, Hypothesis 3 is related to Hypothesis 2: Decreasing the probability of participating 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 of participating 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. Second, 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 their participation probability to their bids, the total profits to investors in the auction offerings are equal to zero on average and are independent of information costs. As a result, investors coordinate their information production and bidding behavior in such a way that they can achieve an equilibrium.

Table V 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 relation with increasing information costs.

[Insert Table V about here]

In order to gain deeper insight into the determinants of the bid levels, we regress the levels of individual bids on information costs, the 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 the sessions as a second random effect in the model. The results of the two-way RE regression estimations (Table VI) 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 that 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 impact on the bid level. It implies that investors raise their bids in later auctions, i.e., they bid more competitively over the course of the experiment. The effect of increasingly competitive bidding also outweighs the moderating effect of increasing information costs on bid levels. The control variables do not significantly affect bid levels.

[Insert Table VI about here]

Even though these results point to competitive bidding, the actual competitiveness of investors' bidding behavior depends on the adjustment of the probability of participating. For example, investors might adjust their probability of participating in such a strong way that they could bid even more competitively to drive the expected profit from participation down to zero. In order to take into account the interrelation with the decision to participate, 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 this fair value. Table VII summarizes the mean offering prices, fair values and total profits of investors by offering mechanism and information costs.

[Insert Table VII about here]

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 the 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.[29] In most cases, the offering prices in high true value auctions are higher and those in low true value auctions are lower than the respective offering prices in fixed-price IPOs.

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 overparticipation. However, in most cases investors realize even larger losses in auction offerings, 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 of participating. A fixed-effects (FE) regression analysis of the determinants of total profits shows that the offering mechanism significantly influences the total profit of investors (Table VIII).

[Insert Table VIII about here]

To be more precise, a change from the auction to the fixed-price mechanism 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 of participating, investors 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.[30]

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 et al. (1995) find evidence that bidders suffer from a winner's curse in second-price common value

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29 A fixed-effects 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 by as much as 8.0 if the true value is 0.

30 Table VIII also reveals that investors do not converge to the equilibrium solution over the course of a session since the coefficient on 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.

auctions with a fixed number of bidders. Cox et al. (2001) observe a winner's curse in a first-price common value auction with endogenous entry.

5.4 IMPLICATIONS FOR THE ISSUER'S CHOICE OF AN OFFERING MECHANISM

In 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.[31] Filled grey areas indicate the combinations of information costs and weighting factor for which fixed-price offerings are superior to auction offerings, whereas shaded grey areas indicate combinations for which auction offerings are superior.

[Insert Figure 3 about here]

Figure 3 shows that for a wide range of medium information costs and medium information weighting, auctions are indeed the superior mechanisms. However, if both information costs and information weighting are low, or if both are high, fixed-price offerings are superior. The first, rather surprising observation follows from the relatively low offering prices in auctions with very low information costs (see Table VII). Here, the higher prices in fixed-price offerings outweigh the superior information production in auctions if information weighting is low. The second observation is in line with our expectation. Issuers who feel that information production is costly but have a high preference for such activity should choose a fixed-price offering. Therefore, our experimental results provide a solution to the IPO auction puzzle. Since the bulk of IPO firms are young, less well-known firms 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.

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[31] The relevant price in auction offerings is the (unweighted) average of the mean price of good quality firms and the mean price of bad quality firms as ex ante the true value is unknown to the issuer.

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 similar 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.

Appendix A: Instructions for the experiment “IPOs in the lab”

(translated from German)

A warm welcome to the experiment “IPOs in the lab”. In this experiment you will have the opportunity to invest in different Initial Public Offerings (IPOs). In the following, we will describe the experiment to you and we will also explain the decision situations you will be facing during the course of the experiment. First of all, we will discuss how the experimental IPOs work. We will then study two examples of IPOs in more detail using screen shots of the experiment software. After we have read through the instructions together, you will have the opportunity to ask any further questions concerning the experiment. From now on until the end of the experiment please do not talk to your neighbours.

1 General issues

In this experiment you can take part in **22 consecutive IPOs**. For every IPO we create an imaginary current account and a deposit account for you. Your deposit account is initially empty in each IPO. In your current account you find a **budget of 150 monetary units (MU)** in each of the IPOs. You can use this budget to take part in the respective IPO. If you choose not to take part in an IPO, this money remains in your current account without interest payment. If you buy a share, this share is deposited in your deposit account. Please note that the balances of your current account and your deposit account in one IPO have no influence on the following IPOs. At the end of the experiment one IPO is randomly drawn. You will be paid the Euro equivalent of your current account balance and your deposit account balance in this particular IPO. The exchange rate is 10 to 1, i.e., 10 MU is 1 Euro.

In each IPO there are **8 investors** involved. However, there are 24 people sitting in this room. This means that there always take place three independent IPOs simultaneously. The allocation of investors to the three IPOs is drawn randomly and will not be announced. Note that prior to each IPO you are again randomly assigned to one of the three groups. Thus, the other investors who take part in an IPO with you change from IPO to IPO.

In each IPO a company offers exactly **2 identical shares**. If you wish to take part in the IPO, you can purchase exactly 1 share. We will explain the rules regarding the purchase of shares to you later on. Firstly, let us have a closer look at these shares. Each share has a true value that was randomly determined prior to the IPO. It may be either 120 MU or 0 MU. However, this true value is unknown to all of you. The only fact you know is that in each IPO there is a **50% probability that both shares have a value of 120 MU and a 50% probability that both shares have a value of 0 MU**. The true value of the shares will not even be announced after the IPO. We will only announce the value of the shares in that IPO which is randomly selected at the end of the experiment in order to determine your payment.

The rules described above, i.e., a budget of 150 MU, 8 investors per IPO, 2 shares per IPO with a 50/50 probability that both are worth either 120 MU or 0 MU, are identical for each of the 22

IPOs. Yet, the rules regarding the pricing of each share and the allocation to the participating investors differ. In this experiment, 11 of the 22 IPOs will take place via a fixed-price mechanism and the other 11 via an auction mechanism. We will now explain to you how both these offering mechanisms work.

2 Offering mechanisms

2.1 Fixed-price offerings

The fixed-price mechanism is characterized by the fact that the shares are offered for sale at a **predetermined price**. You are notified of this price before the start of the IPO. The price is determined without any knowledge of the actual share price. Therefore, this offering price is completely independent of the actual value of the shares. If you decide to participate in a fixed-price offering, you pay the predetermined fixed price, given you receive an allocation. Whether you actually receive an allocation in the case that you bid for a share depends on the decisions of the other 7 investors. If you are **the only** investor who bids for a share, the IPO fails as not all shares can be sold. Therefore you do not purchase a share. If **one other investor, in addition to yourself,** decides to bid for a share, the IPO takes place and both of you purchase one share each at the predetermined offering price. If **more than one other investor, in addition to yourself,** decide to bid for a share, there are more investors than shares. Therefore, a draw takes place in order to determine which investors receive an allocation, i.e., purchase the shares. The more investors bid for a share, the smaller is your chance to receive an allocation. The probability of an allocation is calculated as the total number of shares divided by the number of bidders. Table 1 below summarizes the rules of the fixed-price offerings.

Table 1: Rules of the fixed-price offerings

	1 bidder	2 bidders	More than 2 bidders
Offering price	Known, predetermined	Known, predetermined	Known, predetermined
Allocation	No allocation (IPO fails)	Both bidders receive 1 share	**Lottery** (Probability of receiving a share = Number of shares/ Number of bidders)

2.2 Auction offerings

If you decide to participate in an auction offering, you need to place a limit bid for one share, i.e., you need to indicate the limit price you are willing to pay at the most. You may freely choose a limit price **between 0 MU and 120 MU**. Whether you receive an allocation and if so, the offering price you have to pay for that share, not only depends on your bid but also on the other investors' bids. If you are **the only** investor who bids in the auction, the IPO fails as not all shares can be sold. Therefore, you do not purchase a share. If **one other investor, in addition to yourself,** decides to bid for a share, the IPO takes place and both of you receive an allocation. If **more than one other investor, in addition to yourself,** bid in the IPO, the two investors who bid the highest price will receive one share each. If more than two investors bid the same price, so that no single highest or second highest bid can be determined, the equal bids enter into a draw.

The **offering price** depends on the bids placed by the investors. The type of auction applied here is known as a uniform-price auction. This means that the two highest bidders pay the same offering price. The offering price paid by the two highest bidders equals the limit price of the **third highest bid**. It may surprise you that not the bids of the two highest bidders, but the bid of the third highest bidder, the one who just does not receive an allocation any more, determines the offering price. However, we carefully chose this auction mechanism since auction theorists have shown that in this mechanism, all bidders have the incentive to bid the limit price that they are really willing to pay for the share. Due to time restrictions here we cannot explain this reasoning in detail. Yet, you should keep in mind that it is not worth your while to bid a price that does not reflect your true willingness to pay. You may now wonder what happens if only two investors bid for a share, i.e., there is no third highest bid to determine the offering price. In this case, we assume that the third highest bid is 0 MU, so the offering price is 0 MU for the two bidders. Table 2 below summarizes the rules for the auction offerings.

Table 2: Rules for the auction offerings

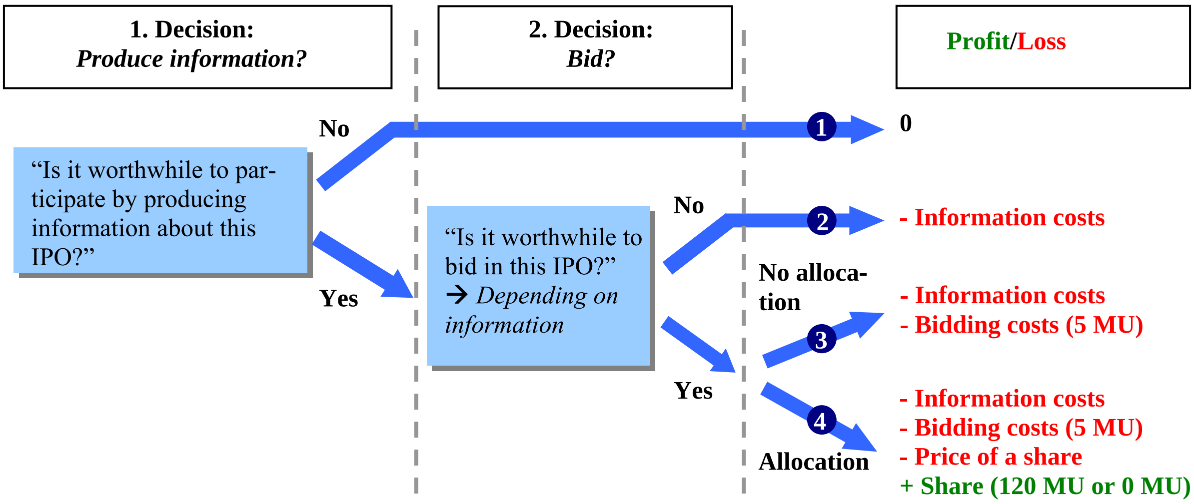
	1 bidder	**2 bidders**	**More than 2 bidders**
Offering price	Not available	Set to 0 MU	Third highest bid
Allocation	No allocation (IPO fails)	Every bidder receives one share	The bidders with the two highest bids purchase one share each

After we have explained the theory of the experiment to you, we would now like to continue and discuss the decision situations and the choices that you face during the experiment.

3 Decision situations and your choices

In each IPO you may face up to two decisions. Figure 1 provides a sketch of the decision tree in the experiment. We will discuss the different decisions in more detail below.

Figure 1: Sketch of the decision tree in the experiment



First of all you decide whether you would like to buy information about the IPO. In each IPO you can only purchase one piece of information. Information helps you to estimate the true value of a share more accurately. The piece of information tells you either **"120 MU" or "0 MU"**. Unfortunately, this information has only **a 70% probability of being correct**. Let us look at the following example in order to completely grasp this idea. Imagine you have an urn in front of you that contains 10 balls. On 7 of these balls the correct value of the share is written and on the other 3 the wrong value is written. Buying the information is equivalent to reaching into the urn and pulling one ball out. In 70% of the time you will pull out a ball which shows the correct value of the share (i.e., the correct information) and in 30% of the time you will pull out a ball which shows the wrong value of the share (i.e., the wrong information). Each investor has such an urn in front of him in each IPO. Since each of you draws one ball out of his own urn, the information that each investor receives varies, although the true value of the shares (and hence, the composition of the urns) is the same for everyone. The only difference is that some people receive the correct and some the false information.

If you receive the information "120 MU", you know that there is a 70% chance that the shares have a value of 120 MU. Obviously, if you receive the information "0 MU", the shares have a 70% chance of having a value of 0 MU. In reality, the purchase of information about the true value of a share is expensive and therefore, is also associated with costs in this experiment. These information costs vary from IPO to IPO.

If you do not purchase information in an IPO, you do not consider this IPO further and cannot place a bid for the shares. You neither make a profit nor a loss in this IPO (**situation ❶ in Figure 1**).

If you purchase information, your second decision is whether you would like to bid for a share in the IPO. Please note that you can only bid for a share if you have bought the information in this IPO. Initially this may surprise you, but the reasoning is that in this experiment you do not take the role of a private investor, but the role of a large, institutional investor (for example a pension fund or an insurance company). These investors thoroughly analyze the value of an IPO before deciding whether or not to bid for a share. If you decide it is not worth investing in the IPO after receiving the information, your loss equals the information costs (**situation ❷ in Figure 1**).

If you decide to bid in an IPO, you pay the **bidding costs of 5 MU** (in addition to the previously mentioned information costs). These costs are constant throughout the experiment. They represent various fixed costs that investors incur in reality, including bank charges. If you have placed a bid, but you do not receive an allocation, your loss is equal to the information and bidding costs (**situation ❸ in Figure 1**). In case you receive an allocation, you make a profit if the share is worth 120 MU and a loss if the share is worth 0 MU (**situation ❹ in Figure 1**).

We will now briefly summarize the decision situations shown in Figure 1. In your first decision situation you have to weigh up the costs from purchasing information regarding the IPO against the chance of a profit from this information. This profit is uncertain as you do not know the actual value of the share and your allocation of the share depends on the other investors' decisions. With the fixed-price method, the uncertainty of the profit depends on the decisions of the other investors as the probability of receiving a share decreases with an increasing number of bidders. With the auction method, the uncertainty of the profit depends on the decisions of the other investors as the level of the profits and the allocation of the shares is directly related to the other investors' bidding decisions.

After purchasing the information, you need to decide whether to bid for a share. If the information states "120 MU" bidding is more attractive as there is a 70% probability of making a profit (**situation ❹ in Figure 1**). If the information states "0 MU", bidding is less attractive as the chance of making a loss is 70%.

In each case, your chance of receiving a share depends on the decisions of the other 7 investors. However, you cannot observe the other investors' decisions. That is, at the time you make your decisions you know neither how many other investors purchase information nor how many wish to bid in the IPO.

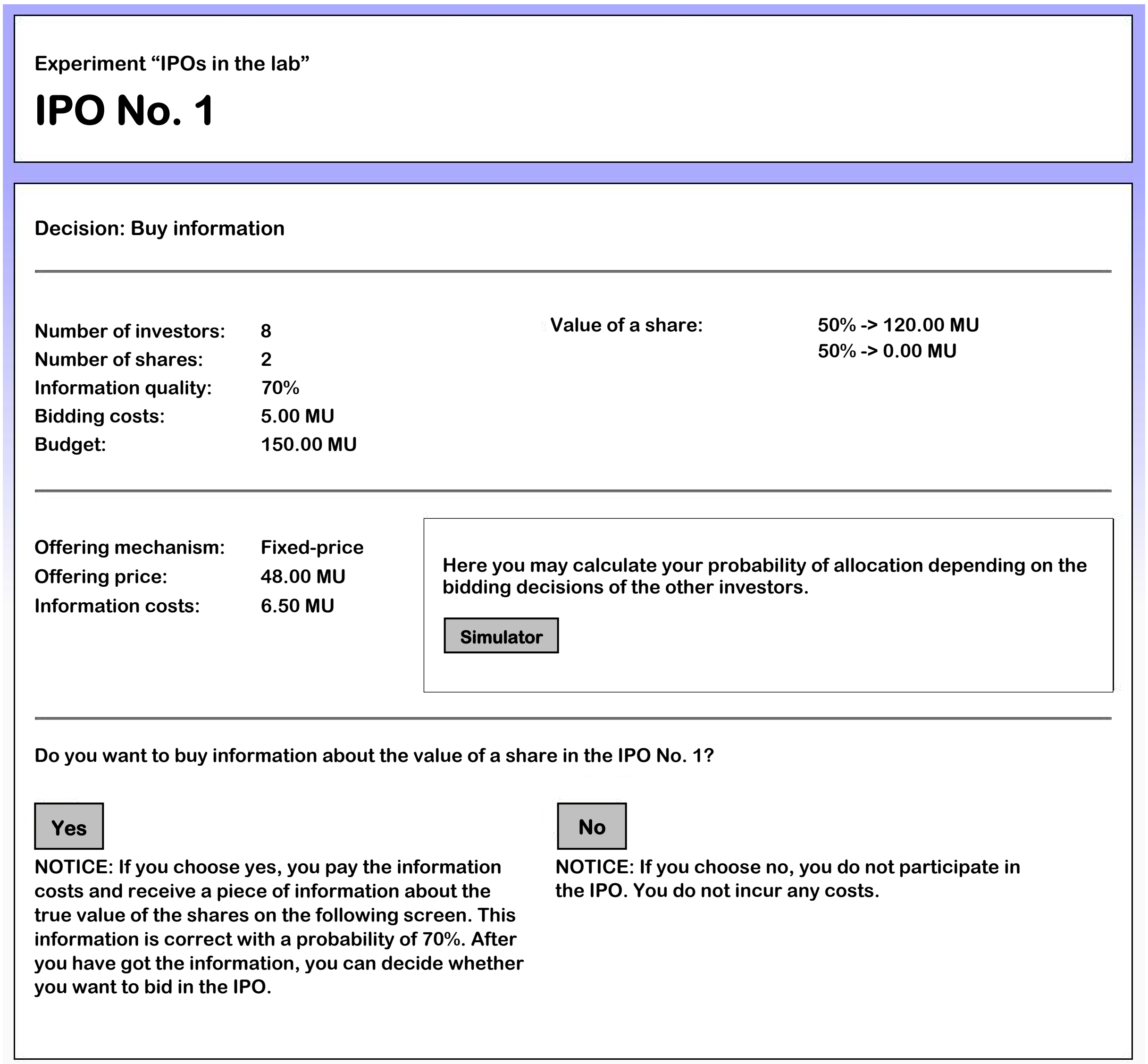
4 Examples

4.1 A fixed-price IPO

In the following section we will look at an example of an IPO using the fixed-price method. Figure 2 displays the first screen that you will see in a fixed-price IPO. In the title you see the name of the experiment and the number of the IPO. The window below the header contains all the necessary information about this IPO, so that you can think about your first decision (whether to buy information).

The section under the window header "Decision: Buy information" contains all the information which is identical for every IPO; 8 investors, 2 shares, an information quality of 70%, bidding costs of 5 MU, your budget of 150 MU and that both shares have a 50% probability of being worth either 120 MU or 0 MU.

Figure 2: First decision in a fixed-price offering



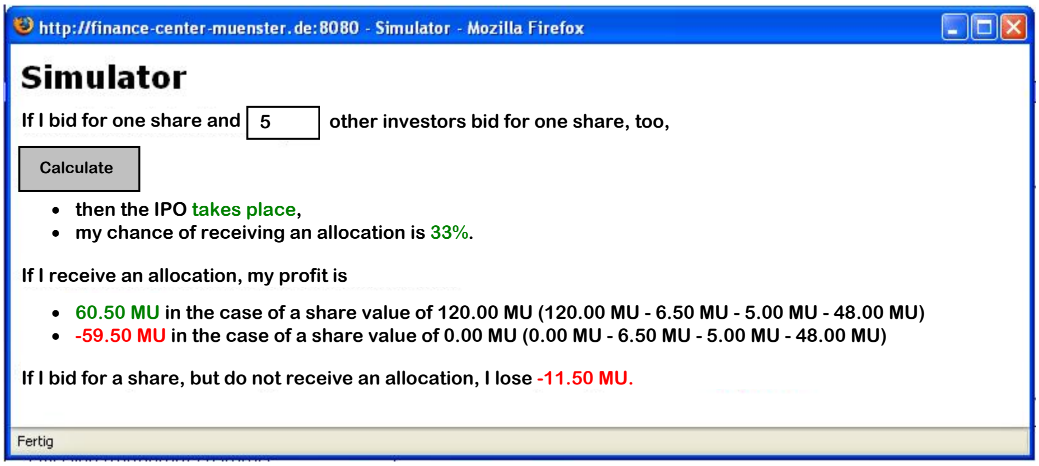
Below the section with the general data you find the specific data for this IPO: The offering mechanism is fixed-price, the offering price is 48.00 MU and the information costs are 6.50 MU. In the bottom section of the screen you make your decision by pressing either the "Yes" or the "No" button. Below both buttons there are brief reminders stating the consequences of pressing the buttons.

You now face a complex decision problem. If you pay 6.50 MU, you receive information which has a 70% probability of giving you the true value of the shares.

- Let us assume that you receive the information "120 MU", decide to bid for a share in IPO No. 1 on the basis of this information, incur the bidding costs of 5 MU and then, receive an allocation. [*Please note: This is only an assumption regarding your choice and does by no means imply that this would be the "correct" decision.*]
  - If the actual value is 120 MU indeed, which is the case in 70% of the times given that you received the information "120 MU", you make a total profit of 60.50 MU: (*120 MU - 48.00 MU offering price - 6.50 MU inform. costs - 5 MU bidding costs*).
  - If the actual value is 0 MU, which is the case in 30% of the times given that you received the information "120 MU", you make a loss of 59.50 MU: (*0 MU - 48.00 MU offering price - 6.50 MU information costs - 5 MU bidding costs*).
  - If you have bid in the IPO, but you do not receive a share, either because the IPO failed or because you did not receive an allocation in the draw, your loss amounts to -11.50 MU: (- *6.50 MU information costs - 5 MU participation costs*).
- Alternatively, let us assume that you receive the information "0 MU" and due to this decide against bidding in the IPO No. 1. In this case your total loss would be -6.50 MU. [*Please note once again that this does not have to be the recommendable decision in this situation.]*

For help regarding this difficult decision you can use the simulator. If you press the "Simulator" button on the decision screen, the window presented in Figure 3 will show up in a fixed-price offering.

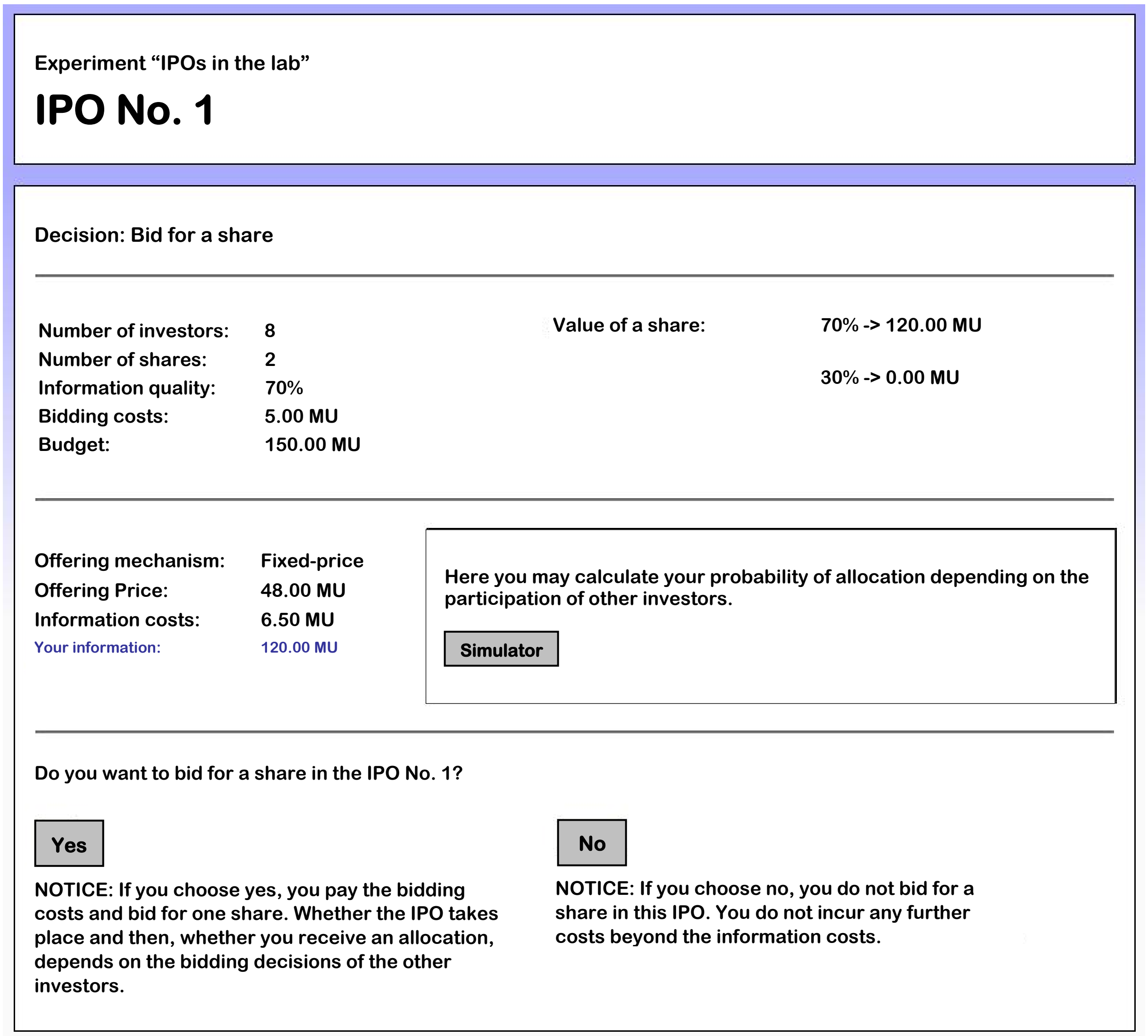
Figure 3: Simulator in a fixed-price offering



Using the simulator in fixed-price offerings you can compute your probability of receiving an allocation depending on the bidding decisions of the other investors. The simulator also shows your profit or loss in the case that you bid and receive an allocation and in the case that you bid, but you do not receive an allocation.

If you decide against buying information (**situation ❶**), you will see a result screen after the other participants have made their decisions. We will discuss this screen later. Firstly, we assume that you decide to purchase information. Then, you will view the screen shown in Figure 4.

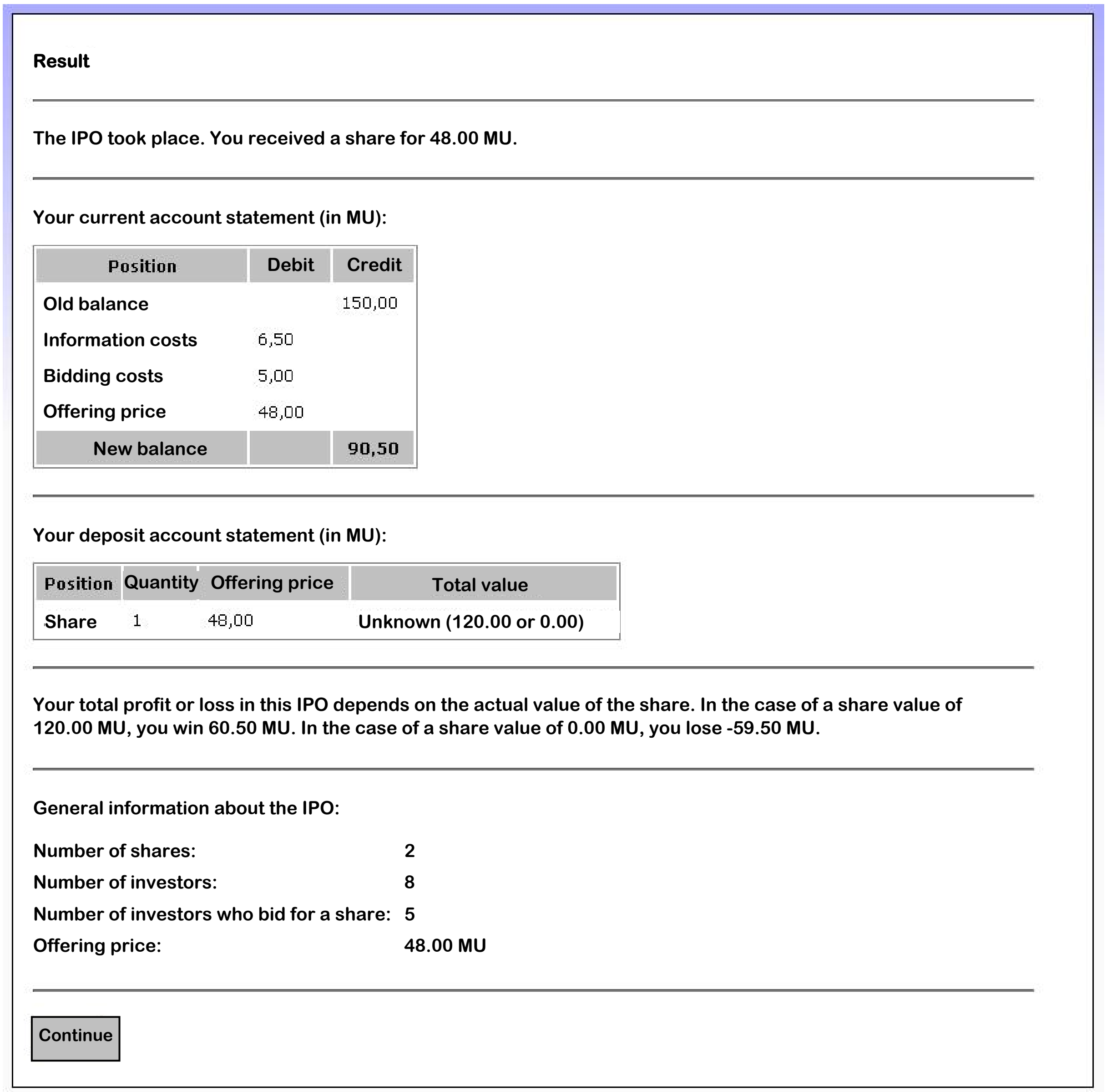
Figure 4: Second decision in a fixed-price offering



You will notice that this screen is similar to the previous one. In the top left section you find the information which is identical for all IPOs. In the middle section you find all the information which is specific to IPO No. 1. Your information is highlighted in blue. Due to the fact that you received the information "120 MU", the probabilities of the actual share values have changed as you can see in the top right section of the screen. Now, there is a 70% chance that the true value is 120 MU and a 30% chance that it is 0 MU. Based on this information, you can now decide whether you would like to bid for a share in this IPO. Below the buttons you are once again reminded of the consequences of each decision.

We now assume that you bid for a share in IPO No. 1. After you and the other 7 investors have made their decisions regarding this IPO, you see the result screen shown in Figure 5. Here, you are notified of whether the IPO took place and if so, whether you received a share. In our example, the IPO took place and also, you received a share.

Figure 5: Result screen of a fixed-price IPO



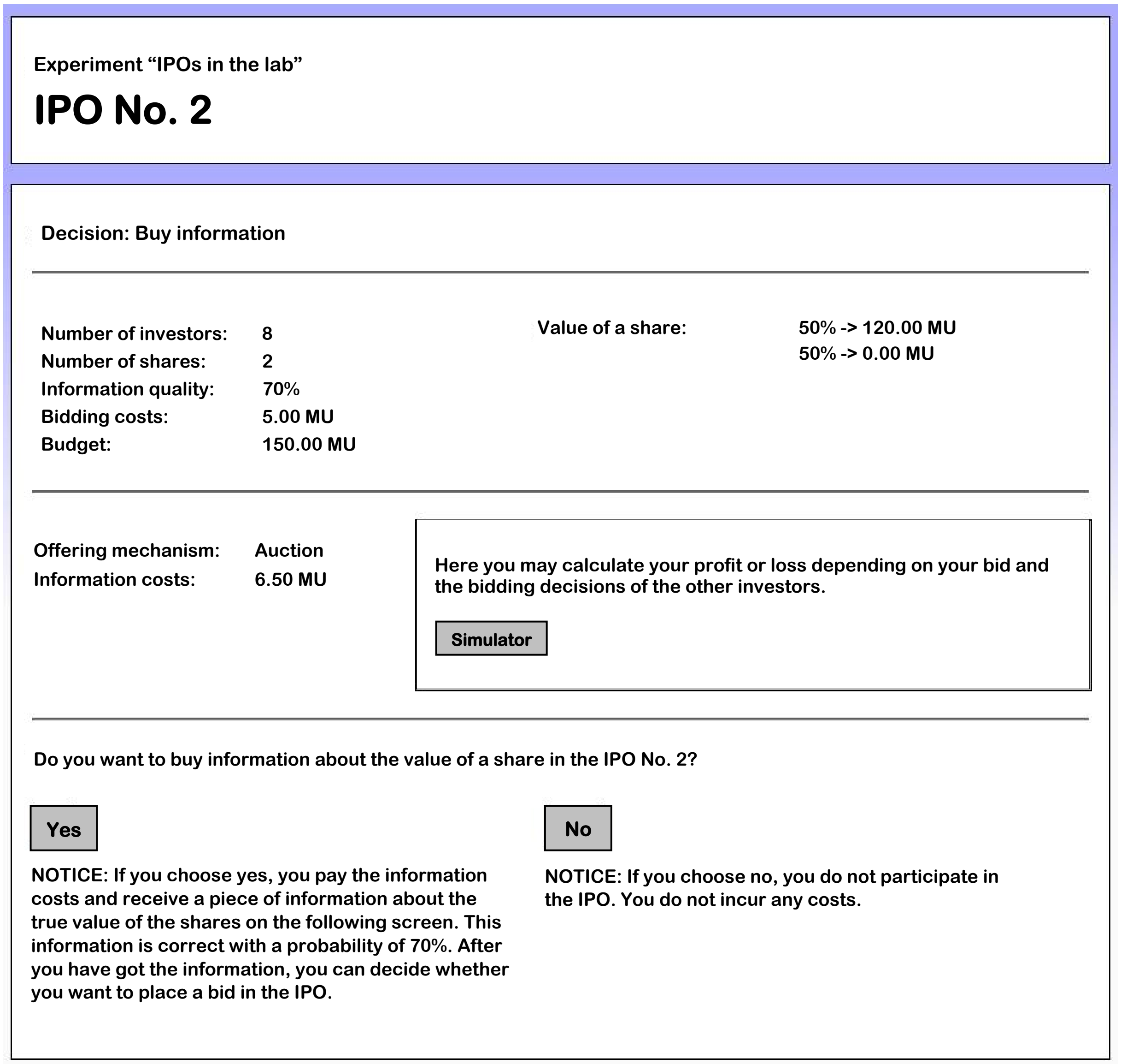
In the following section you find your current account statement for this IPO. From your initial budget of 150 MU the information costs, bidding costs and the offering price have been deducted, leaving you with a new balance of 90.50 MU. You will notice that the share has been entered into your deposit account at the offering price of 48.00 MU. The total value of the deposit account is unknown as you do not know the true value of the share.

In the next section of the result screen you are reminded of your total profit or loss from this IPO depending on the true value of the share. In this example your profit would be 60.50 MU in case of a share value of 120 MU and your loss would be -59.50 MU in case of a share value of 0 MU. Finally, you receive some general information about this IPO: In this example 5 investors bid for a share and the offering price was 48.00 MU.

4.2 An auction IPO

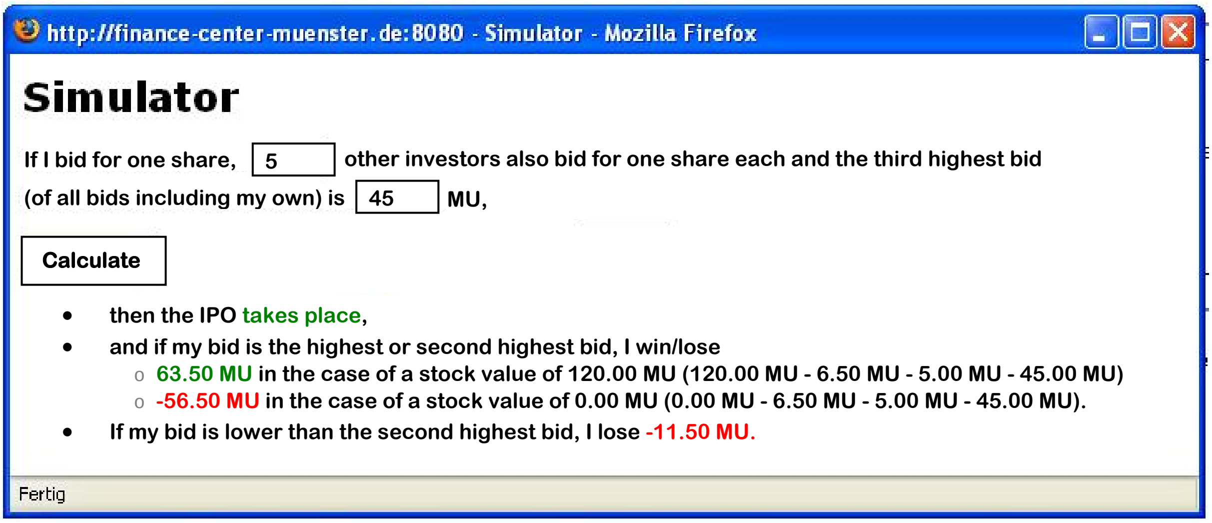
An auction offering is very similar to a fixed-price offering. Hence, we would like to save time and abstain from a detailed description of an auction IPO but concentrate on explaining how auction offerings differ from fixed-price offerings. Figure 6 shows the first decision screen in auction offerings. Only the middle section of this screen is different from the respective screen in fixed-price offerings. Here, the offering mechanism is an auction. Since the offering price is not determined until all investors have made their bidding decisions, no predetermined price is given to you.

Figure 6: First decision screen in an auction offering



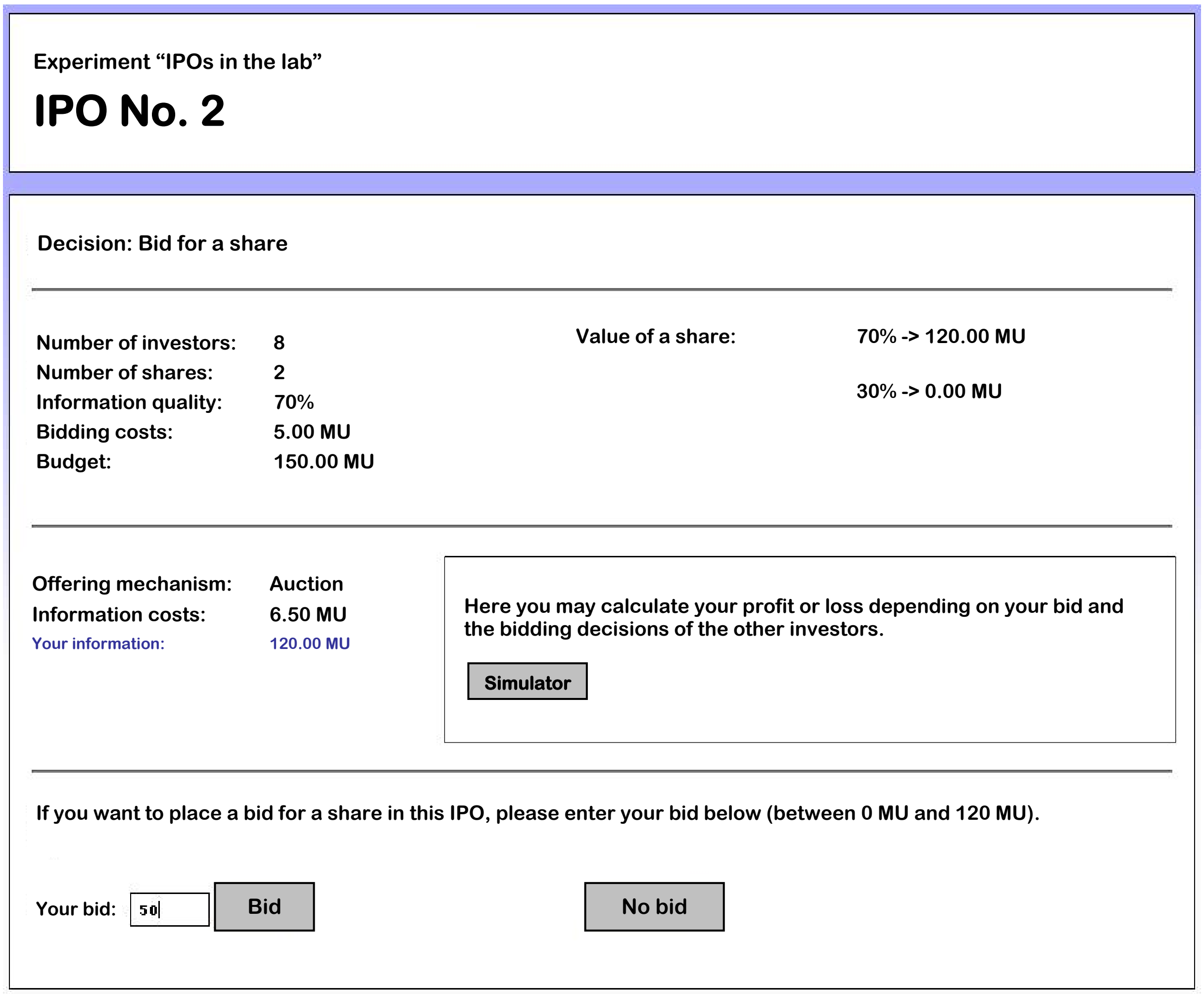
By using the simulator during an auction offering, you can calculate your profit or loss depending on your bid and the bids of the other investors. The example in Figure 7 shows the profit or loss calculated by the simulator in the case that you and 5 other investors place a bid and the third highest bid is 45 MU. You will see that the IPO takes place. If you had bid the highest or second highest price, you would receive a share. Your profit would then be 63.50 MU, if the share had an actual value of 120 MU, or you would incur a loss of -56.50 MU, if the share's value was actually 0 MU. If you did not place the highest or second highest bid for the share, you would not receive a share, so your total loss would be -11.50 MU.

Figure 7: Simulator during an IPO auction



If you initially decided against buying information (**situation ❶ in Figure 1**), you will see a result screen after all other investors have made their decisions. Here, we assume that you purchase information, so you will now view the screen shown in Figure 8. As in a fixed-price IPO, your piece of information is shown in the middle of the screen. In this case it is “120 MU”. In the bottom section you can then decide if you would like to bid in this IPO. You bid by entering the price that you are willing to pay and then pressing “Bid”. Your limit price must be between 0 MU and 120 MU. Let us now assume that you decide to place a bid of 50 MU. [*Again, please note that this is only an assumption about your decision and does by no means imply that this is the recommendable decision.*]

Figure 8: Second decision in an auction offering



After you and the other investors have decided to bid or not, you will see a result screen like the one shown in Figure 9. This is basically the same screen as at the end of a fixed-price IPO. As Figure 9 shows, your offer of 50 MU was either the highest or the second highest bid, so that you received a share (so situation ❹ occurred). The third highest bid was 45 MU. Therefore, the offering price is 45 MU. Like in fixed-price offerings, your current and deposit account statements, the calculation of the total profit or loss, and the general information about the IPO are presented on the result screen.

Figure 9: Result screen of an auction offering

Result

The IPO took place. You received a share for 45.00 MU.

Your current account statement (in MU):

Position	Debit	Credits
Old balance		150,00
Information costs	6,50	
Bidding costs	5,00	
Offering price	45,00	
New balance		93,50

Your deposit account statement (in MU):

Position	Quantity	Offering price	Total value
Share	1	45,00	Unknown (120.00 or 0.00)

Your total profit or loss in this IPO depends on the actual value of the share. In the case of a share value of 120.00 MU, you win 63.50 MU. In the case of a share value of 0.00 MU, you lose -56.50 MU.

General information about the IPO:

Number of shares:	2
Number of investors:	8
Number of investors who bid for a share:	5
Offering price:	45.00 MU

Continue

After you have completed all 22 IPOs, one IPO is randomly drawn. The actual value of the shares in this IPO is revealed and your payment is calculated. Your payment is determined as the value of your current and deposit accounts for this IPO converted into Euros. The exchange rate is 10:1, i.e., 10 MU equal 1 Euro. After the calculation of your payment we will ask you for some personal information. At this point we also welcome any views, criticism or comments that you have regarding the experiment.

Finally, before you start the experiment we have a couple of concluding hints and tips for you:

- We would like to stress once again that any decisions assumed in the examples that we have just run through do by no means have to be the only correct or optimal decisions and must not be interpreted as recommendations for your decisions.
- In every IPO you face a trade off between certain costs (information and bidding costs) and an uncertain profit. The profit is uncertain because you do not know the actual value of the shares and you may or may not receive a share depending on the decisions of the other investors.
- The uncertainty about the profit in the fixed-price offerings depends on the decisions of the other investors as the chance of you being allocated a share decreases with an increasing number of bidders.
- The uncertainty about the profit in the auction offerings depends on the decisions of the other investors as the offering price and the chance of you being allocated a share is determined by the other investors' bidding decisions.
- Please keep in mind that due to the auction mechanism that determines the offering price according to the third highest bid, it is rational to place a bid that reflects your true willingness to pay. It is not worthwhile to bid a price above or below the price you are actually willing to pay.
- Please take your time to make decisions. Particularly in the first IPOs, please test the consequences of different decisions using the simulator. As the experiment progresses and the decision situations become even more familiar to you, you can make your decisions quicker.

If you now have any questions regarding the experiment please ask, if not good luck!

Appendix B: Ordering of IPOs in the Experiment Sessions

Table BI. Information costs and offering mechanism by round and session

The columns display the information costs in monetary units and the offering mechanisms 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 and 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)

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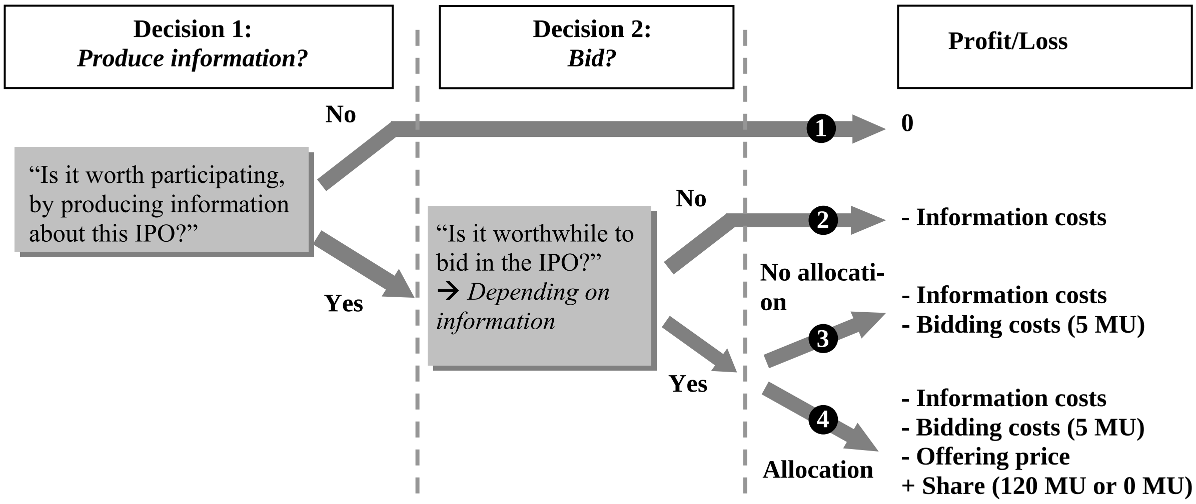

Figure 1. Sketch of the decision tree in the experiment. The level of information costs varies from IPO to IPO. The offering price is pre-determined in fixed-price offerings and determined endogenously by investors' bids in auction offerings. Ex ante, the probability of a share being worth 120 MU is 50%.

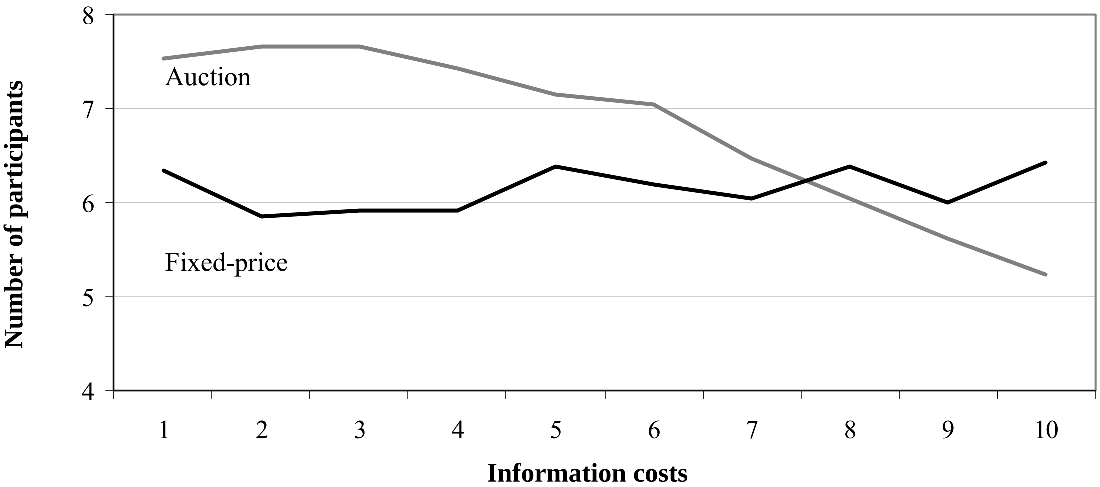

Figure 2. Number of participants by information costs and offering mechanism. The number of participants is calculated as the mean number of information producers in the 21 IPOs observed for each combination of information costs and offering mechanism.

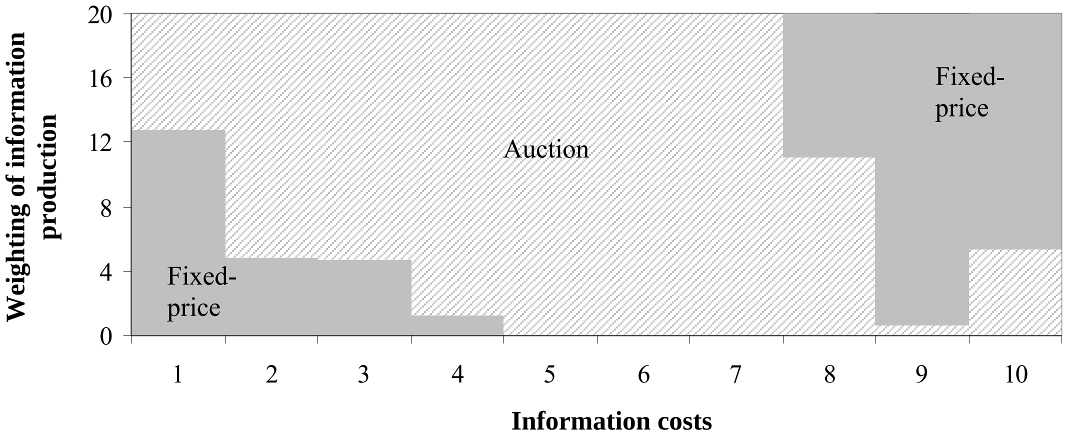

Figure 3. Superior offering mechanism by information costs and weighting of information production. Areas filled in grey [shaded in grey] indicate that fixed-price offerings [auction offerings] are superior. The offering mechanisms are ranked by the following measure: (Mean offering price) + (Mean number 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 VII).

Table I. Descriptive statistics about the participants

Experience in financial markets and experience in game theory are measured on a scale from one (very low experience) to six (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%)	

Table II. 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 IPOs 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

Table III. 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 the 21 auction and the 21 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*		

Table IV. 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 forgo the IPO. An increase in the independent variable increases [decreases] the probability of participating 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	**Fixed-price**		**Auction**	
variables	**Odds ratio**	***p-value***	**Odds ratio**	***p-value***
Information costs	1.027	*0.269*	0.644	*0.000*
Round	1.001	*0.959*	0.979	*0.165*
Age	0.962	*0.503*	1.049	*0.486*
Semester	1.082	*0.172*	1.053	*0.470*
Gender (female=1)	0.921	*0.835*	0.366	*0.032*
Exp. in Fin. Markets	0.870	*0.288*	0.913	*0.576*
Exp. In Game Theory	1.234	*0.120*	1.031	*0.858*
N	1680		1680	
Wald-test(p-value)	*0.4901*		*0.0000*	
ρ	0.4227		0.5225	
LR-test (p-value)	*0.0000*		*0.0000*	

Table V. 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

Table VI. 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	**Information = 120**		**Information = 0**	
variables	**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*	

Table VII. Mean offering prices, fair values and total profits to investors by information costs

The fair values are calculated according to Bayes' law by taking into account all information produced in an IPO. 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

Table VIII. 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*	