Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

FAKULTÄT
FÜR WIRTSCHAFTS- UND
SOZIALWISSENSCHAFTEN

UNDERPRICING OF INITIAL PUBLIC OFFERINGS IN EXPERIMENTAL ASSET MARKETS

Sascha Füllbrunn
Tibor Neugebauer
Andreas Nicklisch

WiSo-HH Working Paper Series
Working Paper No. 19
December 2014

WiSo-HH Working Paper Series
Working Paper No. 19
December 2014

UNDERPRICING OF INITIAL PUBLIC OFFERINGS IN EXPERIMENTAL ASSET MARKETS

Sascha Füllbrunn, Radboud University Nijmegen
Tibor Neugebauer, University of Luxembourg
Andreas Nicklisch, University of Hamburg

ISSN 2196-8128

Font used: „TheSans UHH“ / LucasFonts

Kontakt:
WiSo-Forschungslabor
Von-Melle-Park 5
20146 Hamburg
E-Mail: experiments@wiso.uni-hamburg.de
Web: http://www.wiso.uni-hamburg.de/forschung/forschungslabor/home/

UNDERPRICING OF INITIAL PUBLIC OFFERINGS IN EXPERIMENTAL ASSET MARKETS

by

Sascha Füllbrunn,[a] Tibor Neugebauer,[b] Andreas Nicklisch [c]

a) Radboud University Nijmegen, Institute for Management Research

b) University of Luxembourg, Luxembourg School of Finance; UJI; UCSB

c) University of Hamburg

Abstract

The underpricing of initial public offerings is a well-documented fact of empirical equity market research. Theories explain this underpricing with market imperfections. We study three empirically relevant IPO mechanisms under almost perfect market conditions in the laboratory: a stylized book building approach, a closed book auction, and an open book auction. We report underpricing in each of these IPO mechanisms. IPO excess returns may partly be accounted for by the uncertainty regarding aftermarket behavior, but underpricing persists even in the repeated setting where uncertainty is largely removed and despite equilibrium adjustment dynamics that we observe in the data. A behavioral bias alike the disposition effect fosters IPO underpricing in our setting; we observe a market-wide impact of investors' reluctance to sell in the aftermarket at a price below the offering price.

Keywords: initial public offerings, underpricing, common value auctions, experimental finance, disposition effect, learning

JEL: C9, D02, D40, D83, G02, G32

The scientific research presented in this publication has been given financial support by the National Research Fund of Luxembourg (PDR 09 044), (F2R-368 LSF-PMA-13SYSB). Part of this paper was written at UJI Castellon and UC, Santa Barbara. We also acknowledge project funding through the University of Luxembourg (F2R-LSF-PUL-09BFAM).

1 Introduction

The underpricing of initial public offerings (IPO) is a well-documented fact of empirical equity market research. Ritter (2003) reports results from stock exchanges in 38 countries, all of which show evidence of first-day abnormal returns. The size of IPO underpricing is cyclical; for example, at the height of the dot-com bubble the average IPO was underpriced by more than 50%, whereas the long-term average of IPO underpricing is 10-20% in the U.S. (see Ljungqvist 2007, Figure 1). The underpricing phenomenon is persistent, even across different IPO mechanisms. The large majority of theories explaining underpricing argue that there are some market imperfections, particularly concerning the *ex-ante uncertainty* of the issuer's intrinsic value (Beatty and Ritter 1986). The present paper challenges the market imperfection account by addressing IPO pricing in a controlled laboratory experiment. Thus, in contrast to "real-world" IPOs (see the literature review in section 2), there is no information asymmetry in the experiment. On the *demand side*, each investor is fully informed about the fundamentals of the issued securities, including their expected risk and return. On the *supply side*, there is no discretion regarding the allocation of shares, as an impartial pro-rata scheme is applied. Under identical ex-ante conditions regarding the number of shares, asset values and market liquidity, we compare three relevant IPO mechanisms: two uniform price auctions and a stylized book building procedure. Hence, our setting puts us in a situation where most of the acknowledged explanations of empirical IPO underpricing are removed. The only uncertainty that remains is about aftermarket behavior. This uncertainty is resolved in a repeated setting. In the first IPO, subjects are perfectly informed about the aftermarket conditions but are inexperienced in trading; in the second IPO, subjects are experienced so that the uncertainty about the aftermarket is largely reduced.

We make several contributions to the literature. First, we report IPO underpricing in each session of each IPO mechanism. This result is striking, as it is obtained in absence of real-world imperfections of demand-side induced information asymmetries or supply-side driven incentives. This evidence suggests that a behavioral bias alike the *disposition effect* (Shefrin and Statman 1985) can play a role in the IPO. In fact, our comparison of bidding and asking prices in the aftermarket shows that IPO investors are reluctant to realize losses in the aftermarket, thus fostering IPO underpricing.[1] The extent of underpricing persists even with repetition. This persistence indicates that despite the largely reduced uncertainty, experienced investors request an equal excess return

[1] Kaustia (2004) also suggests that investors' reluctance to sell may be a likely source of underpricing.

for IPO participation as much as inexperienced investors do. Thereby, successful IPO participation reinforces subsequent IPO participation. Successful first IPO participants are likely to participate again in a second IPO. Our data also reveal adaptive adjustments to foregone payoffs, as net purchasers in the aftermarket of the underpriced IPO increase their participation in the subsequent IPO. Our results on IPO underpricing and aftermarket dynamics represent an important contribution into the investigation of IPO underpricing that other studies have not offered.

Second, in contrast to the advanced literature, our design enables us to distinguish two measures of IPO excess returns: *underpricing* and *expected excess returns*. Underpricing is defined as the IPO return relative to the average market return without an IPO. This approach accounts for market dynamics. Expected excess return is defined as the IPO return relative to the fundamental value, i.e., the constant sum of (discounted) expected future dividends. Underpricing can differ from expected excess return because the latter ignores market dynamics. For the design of our aftermarket we use the standard experimental asset market design of Smith et al. (1988), which has served as a laboratory study of many relevant issues (see Palan 2013 for a survey). Importantly, it has been shown that mispricing persists in markets in the absence of fundamental uncertainty, as beliefs about future market returns need time to move to fundamentals (Haruvy et al. 2007). Our baseline treatment, which involves continuous trading prior to the aftermarket, accounts for potential excess returns in the markets without an IPO. Thus, we measure IPO underpricing relative to our baseline treatment. In contrast to non-experimental studies, we are able to measure deviations from the fundamental value and, thus, measure expected excess returns. Remarkably, our data show that reduced uncertainty about the aftermarket has an effect on expected excess returns but not on IPO underpricing. Comparing experienced and inexperienced IPO participants, we find that excess returns with respect to fundamentals are significantly reduced, as experienced investors request a smaller absolute uncertainty premium. However, underpricing relative to the baseline treatment persists.

Third, we compare three relevant IPO mechanisms: book building, closed-book auction and open-book auction. In the auctions, underpricing is reduced when compared to our book building treatment. The result of larger underpricing with respect to fundamentals in auctions compared to fixed-price offerings seems to be in line with the literature (Derrien and Womack 2003); including experimental studies (Zhang 2009; Trauten and Langer 2012; Bonini and Voloshyna 2013). In contrast to the other experimental designs, our experiment involves an aftermarket in which issued

shares pay dividends and are traded over multiple periods. Our comparison of closed-book and open-book auctions shows that dynamic auctions with price indication may lead to higher revenues for the seller than sealed bid auctions when investors are inexperienced. This effect disappears with repetition. Our approach extends the experimental tests on multiple-unit auctions, which usually involve non-tradable assets in a common-value framework, to tradable claims of cash flow (Kagel and Levin 2002).

The paper is structured as follows. Section 2 briefly surveys the literature on IPO underpricing. Section 3 presents the experimental design and outlines our testable hypotheses (subsection 3.4). In section 4, we report our experimental results in detail. Section 5 concludes the paper.

2 Literature review

Recent reviews have summarized the explanations of the financial economics literature on the IPO underpricing phenomenon (Ritter and Welch 2002, Ritter 2003, Ljungqvist 2007, Derrien 2010). Most explanations emphasize different types of institutional imperfections, most importantly concerning the *ex-ante uncertainty* of the issuer's intrinsic value (Beatty and Ritter 1986).

Demand-side explanations assume different degrees of information among investors. Some investors are assumed to be informed about the issuer's value whereas others are uninformed. This asymmetric information leads to oversubscription of attractively priced IPOs as both informed and uninformed investors participate in the offering, whereas unattractively priced IPOs are only subscribed by uninformed investors (Rock 1986). Because uninformed investors' demand is crowded out in attractive IPOs by informed (institutional) investors, while their orders are filled with unattractive offerings, uninformed investors' average returns can be negative. This adverse selection problem is known as the *winner's curse* problem (Thaler 1988, Amihud et al 2003). The winner's curse problem is intensified by the preferential allocation rules applied by investment banks that favor institutional investors (Cornelli and Goldreich 2001; Aggrarwal et al. 2002). Cornelli and Goldreich argue that preferential rules are applied by the underwriter to reward informed investors for revealing information on the issuer's value (Benveniste and Spindt 1989). However, some authors also uncover modes of corruption in relation to the preferential allocation rule (Hao 2007, Liu and Ritter 2010). Finally, Kaustia (2004) also conjectures the existence of a market-wide psychological bias in IPO underpricing; IPO investors are reluctant to realize losses in the aftermarket, therefore, the likelihood of price appreciation is high. Our data support this

conjecture. In contrast to our comparison of bidding and asking data of IPO investors in the immediate aftermarket, Kaustia compares the market transaction volume for prices above and below the IPO price for the mid-term period, i.e., 21 to 508 days after initial public going for the U.S. IPO market during the period 1980-1996.

Supply-side explanations claim that issuers or underwriters willingly underprice IPOs. Ruud (1993) argues that underpricing reduces the underwriter's costs of price stabilization in the aftermarket.[2] Shiller's (1989) *impresario hypothesis* suggests that investment banks underprice IPOs to satisfy their long-term clientele. There are behavioral explanations why the issuer does not get upset with underpricing by the underwriter, including the wealth effect for executives who participate in price increases through stock compensation plans (Loughan and Ritter 2002). In the *signaling theory* to IPO underpricing (Grinblatt and Hwang 1989), however, the issuing company has an interest in a good return for initial investors to attract more interest in subsequent seasoned offerings.[3] A related argument is that the issuer uses the abnormal first-day return as a marketing event to generate greater brand awareness (Demers and Lewellen 2003). Finally, issuers and underwriters underprice the IPO to decrease the risk of litigation by disappointed shareholders (Tinic 1988).

In the literature, the extent of underpricing has been related to the IPO mechanism used; auctions have been associated with lower average first-day returns than the book building mechanism (Derrien and Womack 2003, Kutsuna and Smith 2004). Theory has shown that the uniform price auction is actually an optimal IPO mechanism (Biais et al. 2002). Experimental results show that auctions raise higher IPO revenues than fixed price offerings and thus provide some support for this theory too (Bonini and Voloshyna 2013). The studies involve common value auctions in the presence (Zhang 2009; Bonini and Voloshyna 2013) or absence of (Trauten and Langer 2012) asymmetric information about the underlying value. In contrast to these studies, our design involves aftermarket trading, multi-period cash flows, and a control treatment that provides us with a market benchmark to measure IPO underpricing. Nevertheless, auctions have less than one percent of market share (Ritter 2003). The literature has partly accounted for this observation by

[2] According to evidence presented by Ellis et al. (1998), underwriters always trade actively in the aftermarket. Contrary to the assumption that average stabilization costs are substantial, however, the authors find that underwriters' trading activities are profitable.

[3] Michaely and Shaw (1994) find no support for the signaling theory as the data show rather a negative than positive correlation between the level of underpricing and the reissue decision. Habib and Ljungqvist (2001) note, however, that the smaller the fraction of the firm sold, the lower is the opportunity cost of a big first day run up. They report that many of the 1999–2000 internet IPOs with large first-day price jumps disposed less than 20% of their equity.

the interaction between issuance-size and the contract-choice decision because smaller offers are more likely to use auctions.[4] Supply side explanations that predict larger underpricing intended by the issuer argue in favor of the book building approach. According to DeGeorge et al. (2007), for instance, the search for better analyst coverage may also partly explain the willingness of issuers to choose the book building mechanism over auctions.

3 Experimental design

In initial public offerings, information is distributed among potential investors on the prospective cash flows and on the intended exchange listing of the securities in the aftermarket. Investors are requested to submit a demand schedule that includes price and quantity, which determine the IPO price. The structure of both the IPO mechanism and the aftermarket settings is common information for all participants before the experiment starts, including the number of market participants, financial endowments, and number of issued shares. Following the IPO, the issued shares are traded in a continuous double auction market similar to the stock exchanges around the world.[5] Note that across our experimental IPO institutions the expected values and tradability of assets are constant; only the mechanism varies systematically. Before we explain the mechanisms of our IPO institutions, we describe the aftermarket along with the fundamental value in detail.

3.1 Trading and cash flows of issued securities in the aftermarket

The study involves cash flows to equity and aftermarket settings according to the experimental asset market design of Smith et al. (1988). Accordingly, nine subjects trade 18 asset-shares for 15 periods. A share is an entitlement to receive a regular cash dividend that is declared and instantly paid out to the shareholders at the end of each period. The dividend per share is determined by an independent random draw from the set of payoffs {0, 8, 28, 60}, where one money unit represents 0.01 Euro. The expected cash dividend per share is thus 24 money units per period. For given zero interest rates, the expected asset-value per share is 360 money units in the first period; it depreciates by 24 money units per period. After the dividend payment in the last period, shares are worthless.

[4] As a great exception to this rule, Google used the auction mechanism in its recent public offering (see Trauten and Langer 2012).

[5] The double auction market institution has shown very nice properties in the laboratory. It usually induces relatively liquid trading at a good turnover and is relatively efficient in dissemination and aggregation of information (see for instance Friedman and Rust 1993).

Each period lasts 180 seconds.[6] During this time, subjects trade in an electronic continuous double auction market with an open order book.[7] The bids and asking prices are placed in the order book, which is open and common information to all subjects. An incoming order leads to an immediate transaction if it confirms the best bid or ask on the book, respectively. The transaction price is thus equal to the best outstanding order on the book. Upon transaction the matched order is closed out, that is, it is removed from the order book, and the transaction price is chronologically recorded in the table of historical prices. The cash and shareholdings of buyers and sellers are updated upon the transaction. If an incoming order leads to no transaction, however, it is ranked and registered on the order book; better and older orders rank above worse and newer ones. Orders can be removed from the order book without charge by the traders before they lead to a transaction.

At the end of each period, market participants are given information on the cash dividend per share, their resulting personal dividend income, their updated holdings of cash and shares, and a summary of transaction prices (open, high, low, and close). This past information is recorded in the subject's history table for each past period, which is available onscreen during the 15 trading periods. At the experiment's conclusion, participants are paid in cash the amount of their final cash holdings. All trades in the experiment are equity financed, that is, short sales and margin purchases are not permitted.

3.2 Experimental Treatments: IPO mechanisms

The *treatment variable* is the IPO mechanism. The experiment makes use of between-subjects variation as each subject participates in exactly one treatment, which involves two rounds (i.e., repetitions) of the same IPO mechanism. When we compare inexperienced with once-experienced behavior, however, we also make use of within-subject variation. In each round, which is indicated below by index $\tau = \{1,2\}$, 18 asset shares are issued to market participants. Each subject is endowed with e^{IPO} = 1,305 money units and submits a demand schedule to purchase asset-shares.[8] The IPO purchase price is determined from the aggregate demand schedule and shares are placed at a uniform price with the high bidders.

Up to 18 bids submitted by the subject for single asset-shares compose the individual demand

[6] Subjects could unanimously vote for early termination, however.
[7] See Füllbrunn and Neugebauer (2013) for a detailed description.
[8] The amount equals the expected value of endowments implemented in the standard Smith et al. (1988) design (see the description in section 3.3 below).

schedule. The bids are positive integers and the schedules are constrained to non-negative cash balances for any clearing price. Thus, upon submission of each bid, the subject's budget constraint is checked. Let $b_k \geq 1$ denote the k^{th} highest bid of the *subject*, the following *individual budget* constraint must be met for each k.

$$k \times b_k \leq e^{IPO} \qquad (1)$$

If upon bidding, constraint (1) is violated, the subject is alerted and the demand schedule is not updated until the violation is removed. The IPO market closes after 240 seconds. The market demand is computed and the shares are allocated to the bidders of the 18 high bids at a uniform price. Ties are broken randomly. If too few bids are submitted, the IPO fails.[9]

In line with empirical practice the IPO price is chosen at the lower bound between the lowest winning and the highest losing bid. Let B_k denote the k^{th} highest bid in the *market*, the *IPO purchase price* is the first rejected bid,

$$p_0^{IPO} = B_{19}. \qquad (2)$$

Theoretical incentives exist to submit bids in line with and close to the individual preference-revealing amount (Vickrey 1961).[10] We consider three treatments, $IPO = \{CB, BB, OB\}$, that is, *closed book auction*, *book building,* and *open book auction*, respectively.

3.2.1 Closed book auction (*CB*)

The *CB* treatment involves a uniform price auction in line with the *OpenIPO* implemented by WR Hambrecht & Co (DeGeorge et al. 2010). Subjects submit sealed bids, each of which for the purchase of a single asset share. Their own bids are recorded onscreen in view of constraint (1). No information is given on the bids of other subjects or the likelihood of winning during the auction. After all subjects submit their demand schedules, the IPO purchase price is determined given the

[9] There were sufficient bids submitted in each IPO, so all IPOs succeeded in our experimental sessions.

[10] As pointed out in Noussair (1995), there are incentives to understate demand for multiple units in auctions with "first rejected bid" pricing (see also Kagel and Levin 2001). These incentives decrease with increased competition, however. Due to high demand elasticity that results in our setting from the large number of bids/shares-ratio and the relatively large number of bidders, expected deviations from the preference revealing amount should be negligible (Ausubel and Crampton 2004; Engelbrecht-Wiggans et al. 2006). Note that the results of our statistical analysis do not change if the price is fixed at the upper bound between the lowest winning and the highest losing bid. Hence, with unchanged conclusions any point in this interval could be used to determine the price.

aggregate demand. Asset-shares are placed with the submitters of the winning bids, $B_k : k \leq 18$, respecting equation (2).

3.2.2 Open book auction (*OB*)

The *OB* treatment involves similar rules to the *CB* regarding bidding, price determination and the allocation of shares to the winning bidders. During the auction, however, subjects receive updated real-time information on the purchase price, B_{19}, and rejected bids $B_k < B_{19}$. *OB* is a dynamic auction in which bidders can react to the submitted bids of the others.[11] In theory, such dynamics must not necessarily affect the bidding and the expected IPO purchase price (Vickrey 1961). Nevertheless, if bids are indications of prices in the asset market, such a revelation of the bids can help decrease uncertainty about future prices and thus aid price discovery in the IPO. The difference between the IPO price and the aftermarket price might be reduced relative to the other treatments.

One potential adverse effect of the *OB* is an encouragement of early signaling and late bidding. A late-bidding effect has been documented for single-unit dynamic auctions with a fixed deadline (Roth and Ockenfels 2002; Füllbrunn and Sadrieh 2012). However, in multi-unit discriminative auctions such an effect has not been confirmed (Chiang and Kung 2005).

3.2.3 Book building-BB treatment

The *book building-BB* treatment represents a stylized book building approach involving a *two-stage* procedure. The first stage involves the closed-book IPO price determination rule equivalently to the *CB* treatment. Every subject submits a sealed demand-schedule involving up to 18 bids for multiple assets in agreement with equation (1). The IPO purchase price is fixed according to equation (2) in the first stage and is publicly announced in the second stage. Upon the announcement, investors state the number of shares they are willing to acquire at that fixed price. Shares are allocated according to a probabilistic pro-rata rule; each share request is equally considered and the winning bids are randomly drawn. The quantity demand of the second stage is

[11] Direct revelation of such price information is rather exceptional in real world public offerings. During the IPO auction of Health Communications Network and Charos Music, the IPO underwriter, Ord Minnetts's eCapital auction, repeatedly revealed additional bidding information, including average bid price (Jagannathen and Sherman, 2006). Some information regarding the other bidders, however, may be leaked in closed book IPOs through internet forums or private conversation. In related real-world auctions for bond issues WR Hambrecht & Co. typically offers real-time information on the development of the market demand curve.

individually limited to the number of bids submitted in the first stage. Thus, submission is encouraged of a maximal number of bids in the first stage. As bids in *CB* have no direct allocation implication, on the other side, incentives exist to low ball on bidding in the first stage to induce a lower offering price (as suggested by Ljunqvist 2007). The IPO price in the *BB* treatment must therefore be expected to be lower than in the *CB* treatment.

3.3 The baseline-BL treatment

As IPO-underpricing is empirically measured relative to the regular market return, our *baseline-BL* treatment involves no IPO mechanism. The *BL* is, in fact, a variant of the design by Smith et al. (1988), including three non-dividend paying periods prior to the start of the 15 dividend paying periods. Subjects are randomly assigned to one of three income classes; the first three subjects are endowed with e^{BL} = 225 money units and three shares of assets, the second three subjects are endowed with e^{BL} = 585 money units and two shares of assets, and the last three subjects with e^{BL} = 945 money units and one shares of assets. Hence, including cash and the expected sum of dividends, the value of each trader's endowment is 1,305 money units, which equals the individual cash endowment in the IPO treatments. Finally, it should be noted that in the first dividend paying period – the aftermarket in the IPO treatments - the fundamental value is 360 money units in each of our treatments.

3.4 Return measures

To measure underpricing, in line with the literature, we focus on the aftermarket excessive return of the IPO. For this purpose we start by measuring the return in round $\tau = \{1,2\}$ of *treatment {BL, BB, OB, OC}* by the capital gains yield:

$$R_{\tau} = \frac{p_{1,\tau} - p_{0,\tau}}{p_{0,\tau}} \qquad (3)$$

where $p_{0,\tau}$ denotes the IPO price and the closing price of the last pre-period in *BL*, respectively. For the aftermarket price $p_{1,\tau}$ we investigate the average, median, and closing price of period 1. *IPO underpricing* in each cohort is then defined by the difference between IPO return and average baseline return:

$$\textit{Underpricing:} \qquad X_{\tau}^{IPO} = R_{\tau}^{IPO} - \overline{R_{\tau}^{BL}}, \qquad (4)$$

where the superindex *IPO* represents each considered treatment but *BL*.

In contrast to real-world markets, our experimental setting enables us to measure *expected excess returns* by the price deviations from the fundamental value. The *a priori* asset value per share in terms of (discounted) sum of expected dividend payments is 360 money units in each treatment prior to the first dividend payment because the risk-free interest rate is zero in our experiment. Hence, we define the *expected excess return* of the IPO, x_τ, by the deviation of IPO price from the risk neutral fundamental value.

$$\textit{Expected Excess Return:} \quad x_\tau = \frac{360 - p_{0,\tau}}{p_{0,\tau}} \tag{5}$$

3.5 Testable hypotheses

In our experiment, investors have common information about the entire procedure of the IPO and the aftermarket. They are symmetrically and transparently informed about the dividend distribution and the expected cash flows to equity. The market imperfections emphasized in the above surveyed demand side and supply side explanations of underpricing are absent. It is a justifiable theoretical benchmark if we propose that the price should equal the discounted sum of expected dividends.

Hypothesis 0. Initial public issues yield no excess returns and IPO price equals fundamental value, $x_\tau, X_\tau^{IPO} = 0 \forall \tau$.

However, at least two alternative explanations could justify underpricing even in our setting where symmetric and transparent information on the fundamental asset value is given: (i) uncertainty of aftermarket behavior and (ii) a market-wide impact of IPO investors' reluctance to sell at a loss.

(i) Traders face strategic uncertainty about the behavior of the others, about asset pricing and their opportunities to buy and sell in the aftermarket. Therefore, it is reasonable for investors to request an uncertainty premium on an IPO investment. This uncertainty premium is similar to the adverse selection problem resulting in the winner's curse referred to above, despite the fact that information in our setting is symmetric. When subjects are inexperienced, the strategic uncertainty about the aftermarket behavior looms larger than when once experienced.

(ii) Underpricing may be influenced by a psychological bias alike the disposition effect (Shefrin and Statman 1985) according to which investors are reluctant to sell below their purchase price.

Because in the IPO, every investor pays the same asset price, the IPO price thus could be a psychological anchor of the market. Allowing for a market-wide impact of the reluctance to sell below the purchase price, there is more upside than downside to share appreciation. Hence, we formulate the first alternative hypothesis.

Hypothesis 1. Underpricing in each IPO mechanism and each round, $X_{\tau}^{IPO} > 0 \; \forall \; IPO, \tau$.

In view of (i), one may expect that learning by experience has a decreasing effect on underpricing in a repeated IPO. As subjects' uncertainty about aftermarket behavior is reduced in the second IPO once subjects are experienced, the level of underpricing should be affected if the driver of underpricing is uncertainty. Earlier experimental evidence suggests that a learning effect may show up in our data (as most illustratively presented by Haruvy et al., 2007) so that pricing is closer to fundamentals once experienced. Based on evidence from asset market experiments, we anticipate a repetition effect on expected excess returns of the IPO with respect to fundamentals (2a). This effect may be reinforced by the decreased uncertainty about aftermarket trading behavior, which again may result in a decreased uncertainty premium required by the market and thus reduced underpricing (2b).

Hypothesis 2. (a) IPO investors' expected excess returns decrease with repetition, $x_2 < x_1$, and (b) the level of underpricing decreases with repetition $X_2^{IPO} < X_1^{IPO}$.

The alternative explanation (ii) does not preclude but does not require a reduction of underpricing. So 2b) or not 2b), a market-wide impact of the reluctance to sell below the purchase price implies some degree of persistence of underpricing. To examine whether IPO investors are reluctant to sell below their purchase price (Odean 1998) we check the asking prices of sellers in the aftermarket. In view of (ii) we state the following hypothesis.

Hypothesis 3. Aftermarket asking prices equal or exceed the IPO price.

Anticipating the result that the alternative explanation (i) is only weakly supported by our data (see Observation 2a), and given the recent literature of learning in markets, we investigate if learning plays a role in our data at all. The question is how personal experiences in IPO participation feed into future participation in the IPO. It has been conjectured that past experience is an important driver of individual IPO participation (Kaustia and Knüpfer 2008). An investor who has a positive

experience in an IPO will likely participate in the next IPO. As Kaustia and Knüpfer (2008) note, reinforcement learning would be a theory that predicts such behavior. Because participants in the first IPO of our experiment achieve excess returns in each session (Observation 1), we simply predict that participants in the first IPO will also participate in the second IPO. A well-known alternative learning theory that captures much of the round-to-round behavior in auctions is learning direction theory (see, e.g., Selten and Buchta 1999, Neugebauer and Selten 2006). According to this theory, changes in behavior would be expected in the direction of the ex-post best response. Hence, if such learning plays a role in our data we expect that net purchasers in the aftermarket following the first IPO would increase their participation in the next IPO.

Hypothesis 4. (a) (Reinforcement Learning:) The number of shares an individual purchases in the second IPO is positively correlated with the number of shares purchased in the first IPO. (b) (Direction Learning:) The change in the number of shares purchased in the second IPO is positively correlated with the number of shares purchased in the aftermarket following the first IPO.

DeGeorge et al. (2010) report a smaller extent of underpricing in the IPO auction mechanism than in the book building mechanism with a fixed-price offering (see also Zhang 2009; Trauten and Langer 2012; Bonini and Voloshyna 2013). A lack of incentive compatibility (Ljunqvist 2007) could be the reason for this difference, as low price indications are not necessarily punished. In related literature, Levin and Kagel (2001) reported evidence that bidding in dynamic multi-unit auctions with feedback is closer to the risk neutral equilibrium than bidding without feedback.[12] So, demand reduction may play a bigger role in the closed book format than in the open book format. Generally, the used mechanism can play a role for the pricing of offerings. Based on the referenced evidence we state the next hypothesis.

Hypothesis 5. Owing to price feedback, underpricing may be smaller in *OB* than in *CB*, and owing to incentive compatibility in *CB* smaller than in *BB* treatments, $X_{\tau}^{OB} < X_{\tau}^{CB} < X_{\tau}^{BB}$.

An enhanced price discovery in the OB treatment would not be surprising as IPO investors receive feedback on market demand. In the dynamic *hard-close* auction, however, late bidding is an important issue. Such behavior has been observed in single-commodity auctions (Ariely et al 2005).

[12] With the laboratory approach to pricing of initial public issues, we also contribute to the experimental common value auctions literature (Kagel and Levin 2002). Our approach is different in the way the common value is generated, i.e., by a stream of cash flows and the potential capital gains from trade in the aftermarket.

Therefore, we investigate the following hypothesis.

Hypothesis 6. Subjects of the *OB* treatment submit bids later than in the other treatments.

3.6 General experimental procedures

At the beginning of each treatment, subjects are randomly placed at their computer terminals. Instructions, including a detailed explanation of the dividend stream, are read aloud and questions that arise are answered. Thereafter, participants practice trading and learn the interface of the aftermarket trading-platform in a trial period without payoff consequences. Next, one dividend stream involving 15 random draws is auctioned off in a pen-and-paper second-price sealed-bid auction to remind subjects of the fundamental asset value process.[13] The results of this second-price auction and the realization of the auctioned dividend stream are revealed and privately paid out to the winner only at the end of the experimental session. In the instruction session, we prepare subjects for trading and the pricing of dividend streams.

The first round starts after the remaining instructions are read aloud for the treatments with the IPO and in the BL treatment with the pre-dividend market, respectively. In the IPO, the subject's endowment, including share and cash allocation for the aftermarket, is determined; the asset-shares are allocated according to the described mechanisms and the IPO price of these assets is subtracted from the subject's initial cash endowment. After the end of the first round, subjects are asked to repeat the experiment. The second round does not include a repetition of the instructions, and no cash is carried over from the first to the second round.

We used an experimental currency unit equivalent to 0.01 Euro. At the end of the session, the payoff to subjects is the sum of their final cash balances in both rounds and the show-up fee of 5 Euro.

4 Data and results

4.1 Experimental Setup

Subjects were undergraduate students of the universities at Magdeburg and Bonn. Each subject participated in exactly one market involving nine investors. The data consist of seven independent

[13] Along with the instructions, we provided a sheet with 48 dividend streams showing that the average of the sum of dividend streams is indeed about 24 per period and 360 in total.

observations in each treatment.[14] In total 252 participants (= 7 independent markets × 9 participants × 4 treatments) were recruited via ORSEE (Greiner, 2004) from the pool of economics students who had no prior experience with asset market experiments. The experimental software was programmed using z-Tree (Fischbacher, 2007). The experimental sessions were completed within three hours and the participants' average earnings including the show-up fee was 32.30 Euros,[15] the maximum being 105.60 Euro and the minimum 10.74 Euro.

4.2 IPO excess returns

Observation 1: Each IPO treatment shows significant underpricing in both rounds.

Support. In Table 1, the first column records the short-term returns in the *BL* treatment. Following DeGeorge et al. (2010), we calculate excess returns vis-à-vis the following reference prices: closing price, median price, average price, and the bid-ask-midpoint at the closing of the aftermarket. Returns are reported for the first and second repetition of the experiment, when subjects are inexperienced and once-experienced, respectively. We use the one-sample Wilcoxon signed ranks test on the sample of seven independent *BL* observations to check whether the returns are significantly different from zero. Returns are positive and significantly different from zero for inexperienced subjects. For experienced subjects, average returns in *BL* are not significantly different from zero. Note the return differences between first and second repetition of *BL* point to differences between underpricing and expected excess return (see observation 2). *U*nderpricing is significantly different from zero whether subjects are inexperienced or experienced as seen in columns (II)-(IV) of the table, jointly with the z-scores of the two-sample test and asterisks indicating significant differences. The results of the Mann-Whitney two-sample test as reported in columns (II)-(IV) are based on seven observations, the test results in column (V) are based on 21 independent markets. It is remarkable that underpricing is positive in each *IPO*, in each repetition and with respect to each reference price.

Observation 2a): Underpricing is not significantly reduced once experienced.

Support. The one-tailed Wilcoxon signed ranks test of the null hypothesis $X_1^{IPO} \leq X_2^{IPO}$ cannot be

[14] Sessions were conducted at the Magdeburg Experimental Laboratory (MaXLab) and the Laboratory for Experimental Economics at University of Bonn (BonnEconLab). At the MaXLab we ran one session with three groups simultaneously playing and at the BonnEconLab we ran two sessions with two groups simultaneously playing in each session.

[15] Being approximately US$ 43.07 at that time.

rejected in favor of the alternative (Hypothesis 2b) of lower underpricing once experienced at any commonly used significance level when no distinction is made between treatments, i.e., based on 21 markets. Overall, as suggested by the measures recorded in Table 1 (column V), underpricing increases rather than decreases from the first to the second IPO. On the treatment level, however, we find differences in *CB* at the 5% significance level; once experienced, underpricing is significantly reduced in *CB* ($z \leq -1.690$, depending on the reference price). This reduction, we must caution, could be a market reaction to the abnormally high level of underpricing in the first IPO of the *CB* treatment. In *OB* and *BB*, in contrast, there are more independent observations for which the level of underpricing increases rather than decreases between rounds. Therefore, our data suggest persistence of underpricing between repetitions.

Table 1: IPO underpricing

First-period average returns of the Baseline treatment, R_τ^{BL}, are recorded in column (I). Realized excess returns of IPO treatments, as defined in equation (4), are reported in columns (II)-(IV).Column (V) reports the average of excess returns from all IPO treatments taken into account. Round index τ = {1; 2} indicates subjects when inexperienced and once experienced, respectively. Significant results of the Mann-Whitney test and Wilcoxon signed ranks test are recorded in columns (II)-(V) and (I), respectively. Standard normal z-scores are recorded in parenthesis. Two-tailed significance levels are indicated by asterisks $^{***}\alpha$ = 1%; $^{**}\alpha$ = 5%; $^{*}\alpha$ = 10%.

	Round τ	(I) R_τ^{BL}	(II) X_τ^{OB}	(III) X_τ^{CB}	(IV) X_τ^{BB}	(V) X_τ^{IPO}
Reference to Closing Price	1	6.5%**	14.2%**	82.1%***	47.5%*	42.0%***
		(2.197)	(2.364)	(3.130)	(1.725)	(3.806)
	2	-0.8%	33.9%***	36.5%***	59.4%***	42.4%***
		(-.572)	(3.165)	(3.165)	(3.165)	(4.015)
Reference to Median Price	1	5.5%**	19.6%***	53.5%***	44.5%***	36.0%***
		(2.197)	(3.134)	(3.134)	(2.875)	(2.875)
	2	-0.8%	33.2%***	31.0%***	55.6%***	39.1%***
		(-1.463)	(3.134)	(3.134)	(3.134)	(3.134)
Reference to Average Price	1	5.5%**	14.2%***	50.1%***	53.6%***	35.9%***
		(2.197)	(2.747)	(2.875)	(2.747)	(2.747)
	2	-1.0%**	33.9%***	32.3%***	57.1%***	40.7%***
		(-2.156)	(3.137)	(3.137)	(3.137)	(3.137)
Reference to Bid-Ask-Midpoint	1	9.1%**	14.5%***	74.2%***	54.0%***	36.0%***
		(2.366)	(2.364)	(3.130)	(2.364)	(2.364)
	2	0.5%	32.0%***	32.8%***	60.4%***	39.1%***
		(.338)	(3.003)	(3.130)	(3.130)	(3.130)

<u>Observation 2b):</u> IPO investors' expected excess returns are significantly positive in both repetitions but decrease once experienced.

Support. Table 2 records the average expected excess returns as defined in equation (5). As shown in column (VI), the excess return on the pre-market price in *BL* is significant with inexperienced subjects, but close to zero once experienced. In other words, closing prices in period zero are almost at fundamental value. The expected excess returns on the *IPO* price are significantly positive in each *IPO* treatment and repetition (see columns (VII)-(X)). Thus, IPO prices are significantly below fundamental value. The overall average expected excess return on the IPO price, however, declines significantly from 64.9% to 39.7% between rounds (column X). The decline in expected excess returns on IPO prices are significant based on the reported results of the Wilcoxon signed ranks test with 21 observations. The results support the testable Hypothesis 2a. On the treatment level, however, the decline in expected excess return on the IPO prices between periods is significant only for the *CB* treatment, but not for the *OB* and *BB* treatments. In sum, the general support of Hypothesis 2 is weak, and Hypothesis 0 must be clearly rejected, although the second round return in *BL* is close to zero.

Table 2: Expected excess return on IPO price

The average expected excess return x_τ is the difference of price and fundamental value, as defined in equation (5). Round index τ = {1; 2} indicates subjects when inexperienced and once experienced, respectively. Wilcoxon signed ranks test results are recorded. Standard normal z-scores are in parentheses, two-tailed significance levels are indicated by asterisks $^{***}\alpha$ = 1%; $^{**}\alpha$ = 5%; $^{*}\alpha$ = 10%.

	(VI)	(VII)	(VIII)	(IX)	(X)
Round τ	x_τ^{BL}	x_τ^{OB}	x_τ^{CB}	x_τ^{BB}	x_τ^{IPO}
1	33%**	31%**	135%**	112%**	85%***
	(2.371)	(2.371)	(2.371)	(2.366)	(4.015)
2	-0.8%	37%**	40%**	63%**	46%***
	(-.677)	(2.366)	(2.366)	(2.371)	(4.016)
Difference	-34%**	5.5%	-96%**	-49%	-39%**
between rounds	(-2.366)	(0.000)	(-2.366)	(-1.183)	(-2.450)

4.3 Asks and bids in the aftermarket

Having observed that the underpricing in our markets does not vanish (Observation 2a) we must pose the question why? The literature reports that a psychological bias alike the disposition effect plays a crucial role in the decisions of investors (e.g., Odean 1999). In particular, investors are reluctant to realize their losses. This behavioral trait is a good candidate theory in support of the

underpricing anomaly. If investors collectively refrain from selling their shares below the IPO price, prices can only have an upward direction. Towards this quest, we investigate the asking pattern of investors in the aftermarket.

> *Observation 3:* *Investors exhibit a reluctance to sell shares in the aftermarket below the IPO price (disposition effect). Investors' average asking prices suggest a high required return on the IPO price in each repetition.*

Support. In Table 3, we report the total number of asking and bidding prices that we observe in the aftermarket of our IPO treatments including market orders; 15% and 12% of total orders were market orders (leading to transactions confirming outstanding limit orders) in the first and second round, respectively. We observe only a minority of asks below the IPO price, and thus a systematic imbalance of bids and asks on the supply side of the market. The table shows that the frequency of bids and asks is similar above the IPO price (bids slightly outnumbering asks), but apparently different below the IPO price.[16] We observe a total of 27 (2.21%, see Table 4) and 2 (0.22%) of asking prices below the IPO price in 21 sessions in the first and second round respectively. We check the significance of the investors' reluctance to sell at a loss with a simulation of the observed IPO prices over the 21 IPO sessions. The 21 observed IPO prices are exchanged between sessions (by random draw without replacement), while the observed aftermarket asking prices are kept with their sessions. For each such pairing of random-sample IPO prices with actual aftermarket asking prices we count and total over our 21 sessions the number of asks that are below the randomly assigned IPO prices. Only 2 of 100,000 (0.002%) such simulations produce more (or equally) extreme outcomes than the reported 2.21% observed for the first repetition. For the second repetition, we find that 0.04907 (0.08303) outcomes are more (or equally) extreme than the reported outcome of 0.22%.[17] As an outcome as extreme or more extreme than the observed one thus is unlikely to have occurred by chance, we conclude that sellers anchor on the IPO prices when they submit their asking prices or when they accept an outstanding bid. In support of Hypothesis 3, hence, we conclude that IPO investors are unwilling to sell their shares at a loss in the aftermarket.

[16] Counting bids and asks, we find they are both equally frequent above the IPO price ($p = .6764$ and $p = .2169$). At ($p = .0032$ and $p = .0048$) and below ($p = .0001$ and $p = .0001$) the IPO price, yet, bids are significantly more frequent than asks (p-value of two-tailed Wilcoxon signed ranks test of first and second IPO on the sample of 21 markets).

[17] The observed data involves only two asking prices below the IPO price (0.22% see Table 4), including one submitted ask and one accepted bid below the realized IPO price. Both the accepted bid (market order) and the submitted ask (limit order) were submitted within seconds by the same seller in the same session.

Table 3: Aftermarket asks and bids relative to IPO price

Recorded numbers of asking prices and bids (%) include limit and market orders. Total number of valid bids and asks are in the bottom line.

	Round 1	Round 2
Asks above IPO price	37.04	41.50
Asks at IPO price	.41	.00
Asks below IPO price	2.21	.22
Bids above IPO price	39.74	46.64
Bids at IPO price	2.29	1.12
Bids below IPO price	18.32	10.51
Total # bids and asks	1,223	894

We also compare the outcomes to the baseline treatment by testing the share of asks that are submitted below the IPO price (3.00% on average) against the share of asks that are submitted below the latest pre-period price in the baseline treatment (16.10% on average). The difference between these numbers is significant; the p-value of the two-tailed Mann-Whitney test is .047. This evidence reinforces our observation.

The ratio of average aftermarket asking price to IPO price is 1.76. This number indicates an average required return on the IPO of 76 percent, thus supporting Observation 3. The changes between rounds are not significant in the sample of 21 independent markets; 0.2586 is the p-value of the two-tailed Wilcoxon signed ranks test on the null hypothesis of equal ratios between rounds. The result reinforces observation 2a) suggesting a persistence of underpricing in the repetition.

4.4 Within-subject comparison: IPO participation

The rather weak support of Hypothesis 2 indicates that reduction of uncertainty between repetitions has only a minor effect on the market outcome. We check next which type of behavior is reinforced by repetition on the individual level. In a recent paper, Kaustia and Knüpfer (2008) reported a positive link between past IPO returns and future IPO participation for the Finnish stock market. The authors suggest that experimentation in an IPO – especially if the outcome is positive – makes participation in future IPOs more likely. To test this pattern with our data, we regress the individual stock purchases of the second round IPO on the purchases in the first IPO, given that positive excess returns were available in each first IPO (see Observation 1).

> *Observation 4a):* *The individual asset purchases in the second IPO are positively correlated with the asset purchases in the first IPO.*

Support. We conduct a random effects regression of individual shareholdings following the second *IPO* on the individual shareholdings following the first *IPO*. We stratify by session to obtain the following result, where S_{ij}^{τ} denotes the shareholdings of individual i of group j in the *IPO* of round τ (standard normal z-scores are reported in parentheses) and asterisks indicate significance at the 1% level.

$$S_{ij0}^{2} = \underset{(8.80)}{1.32}^{***} + \underset{(6.12)}{0.34} S_{ij0}^{1}{}^{***}, \text{ Wald } \chi^2 = 37.42^{***} \qquad (6)$$

The estimated coefficient for S_{ij0}^{2} indicates a significant positive influence between successful participation in the first IPO and participation in the second IPO. We conclude that a successful past experience increases the willingness to participate in another IPO.

In several auction papers, Selten and collaborators (e.g., Selten and Buchta 1999, Neugebauer and Selten 2006) have provided evidence that the round-to-round changes in behavior can be reasonably well predicted by learning direction theory. The theory suggests that subjects act with ex-post rationality adjusting their actions in the *direction* of best response. As purchasers in the aftermarket usually paid a higher price than in the IPO in our experiment, the purchasers obviously experienced an opportunity cost, as they had made a better purchase of more units in the IPO. Applying the reasoning of learning direction theory, we state the following observation.

> <u>*Observation 4b):*</u> *The changes in individual asset purchases in the second IPO are positively correlated with the net purchases in the aftermarket following the first IPO.*

Support. We conduct a random effects regression of changes in individual shareholdings following the second IPO relative to the first IPO on the individual net purchases in the aftermarket following the first IPO. We stratify by session to obtain the following result;

$$S_{ij0}^{2} - S_{ij0}^{1} = \underset{(0.00)}{.00} + \underset{(6.16)}{0.50}(S_{ij1}^{1} - S_{ij0}^{1})^{***}, \text{ Wald } \chi^2 = 37.90^{***} \qquad (7)$$

where S_{ij1}^{τ} denotes the individual's shareholdings at the end of period 1 in round τ, the asterisks indicate significance at the 1% level (and standard normal z-scores are reported in parentheses). The significant positive coefficient for the difference in purchases between the IPO and the first aftermarket implies a systematic impulse of increased participation in the second IPO. Thus,

Hypothesis 4 is broadly supported by our data.

4.5 Differences in underpricing between IPO treatments

Observation 5: Underpricing in IPO is largest in BB and lowest in OB. Once experienced, the difference gradually disappears.

Support. The Jonckheere test of ordered alternatives yields significant results for each return measure in the first repetition at the 10 percent level with regard to Hypothesis 5.[18] Once experienced, the result is significant for the closing price and bid-ask-midpoint.[19] Once experienced, one-tailed Mann-Whitney tests show significant differences in underpricing with respect to the bid-ask-midpoint between *BB* and the *CB* and *OB* ($p \leq .071$), and between *BB* and *OB* based on the closing price ($p = .090$). The differences between *CB* and *OB* are no longer significant once experienced amid an economically large but statistically non-significant increase of underpricing in the latter treatment. Therefore, our data support Hypothesis 5, but not strongly; it seems that the dynamic exchange of information in *OB* reduces underpricing during the first IPO. In turn, one may want to ask why this IPO format is rarely used in reality. Our next observation suggests an answer to this question.

4.6 Timing of bids

Observation 6: The majority of winning bids in OB are submitted relatively late.

Support. Figure 1 shows the share of submitted winning bids in *CB* and *OB* (high bids in *BB*) per time interval aggregated over both rounds. These bids are submitted rather early in *BB* and *CB*, and rather late in *OB*. The differences of *BB* and *CB* to *OB* are overall highly significant in this respect ($p < .01$), and similar results are confirmed for each repetition by the results of the two-tailed Mann-Whitney test (N_1, N_2 = 7). The fact that the tendency to submit winning bids late in *OB* intensifies once experienced while at the same time the tendency of bidding early increases in the other IPO treatments we interpret as an indication of strategic late bidding. Amid late bidding, we observe some indications of demand reduction. First, average underpricing increases in *OB* from

[18] The one-tailed test yields the following p-values: closing price ($p = .083$), median ($p = .057$), average ($p = .057$), bid-ask-midpoint ($p = .038$).

the first to second IPO (see Table 1 and Table 2); second, we find that upon decline in IPO price between repetitions the aftermarket transaction volume tends to increase.[20] This challenges a successful IPO and may explain why *OB* is rarely used in real-world IPOs.

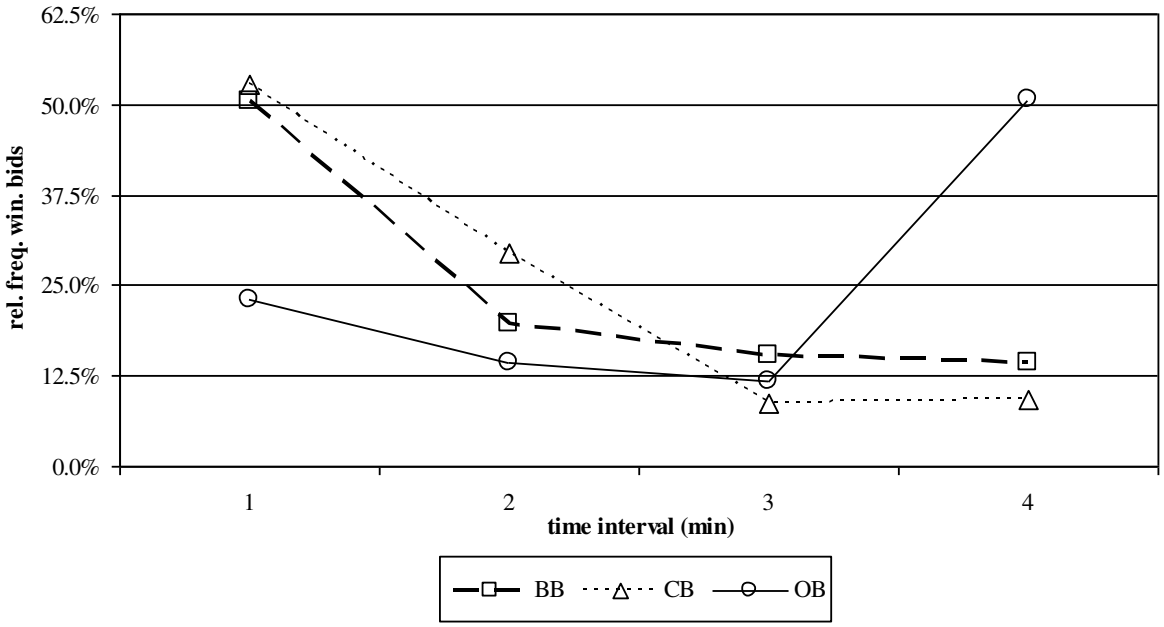

Figure 1. Share of "winning" bids per minute interval

5 Summary

In our laboratory study, we have investigated the behavior of initial public offerings and the aftermarket. In contrast to other empirical studies, we measure both *underpricing* relative to the market in absence of an IPO and *expected excess returns* relative to fundamental asset value. In our design most, if not all, of the commonly specified reasons for underpricing are eliminated (Ritter and Welch 2002; Ritter 2003; Ljungqvist 2007: Derrien 2010). Despite our controlled, transparent

[19] The one-tailed test yields the following p-values: closing price ($p = .074$), median ($p = .129$), average ($p = .129$), bid-ask-midpoint ($p = .065$).

[20] The increasing IPO price implies a drop in the aftermarket transaction volume. The IPO price decreases between IPOs, yet aftermarket transaction volume is higher indicating demand reduction. The IPO price decreases in three sessions of *OB* and in two sessions of *BB*. Additionally we report for *BB* that the smaller the increase in IPO price the larger the increase in oversubscriptions of the IPO. The Spearman rank correlation coefficient is .727 (p-value = .064, two-tailed test $N = 7$).

and symmetric laboratory conditions, we observe underpricing in each IPO session and each repetition. Underpricing persists even as we resolve subjects' uncertainty in the repeated setting, where we expected a decline in underpricing. Comparing aftermarket asking prices with IPO prices, we find that the average IPO excess returns required by investors do not decline significantly between repetitions. The decrease in expected excess returns that we observe at the same time, however, implies that subjects' uncertainty about aftermarket behavior does impact absolute IPO pricing. Therefore, we conclude that uncertainty impacts expected excess returns, but the impact of uncertainty on IPO underpricing is much less important than we thought before we turned to the data.

Our data suggest that IPO investors are reluctant to realize losses in the aftermarket. We suggest that the IPO underpricing anomaly may partly be explained by a market-wide impact of this psychological bias. As all IPO investors have the same purchase price, the reluctance to sell at a loss implies that the IPO price serves as a psychological support level of the aftermarket price. A similar impact was conjectured in the work of Kaustia (2004) who examined, starting from day 21, stock turnover in US markets over two years following the IPO. Kaustia's observation that turnover is significantly lower for negative initial return IPOs when the stock trades below the offer price, and increases significantly on the day the price surpasses the offer price for the first time, seems to be related to our observation for positive initial return IPOs that asking prices in the aftermarket usually exceed the IPO price.

IPO underpricing is a very robust result in our data, which we observe across our three IPO mechanisms. Our relative result of auctions and fixed price offering is in line with the literature (Zhang 2009, DeGeorge et al. 2010, Trauten and Langer 2012, Bonini and Voloshyna 2013); the underpricing of the uniform price auctions is less pronounced than of the fixed-price offering, where the offering price in our setting is determined by book building. When we distinguish between an open book auction and a closed book auction, we find a larger underpricing in the latter one for inexperienced subjects. Once experienced, the difference between the auction approaches disappears. One reason for the convergence of underpricing levels is that subjects in the open book auction tend to submit their bids strategically late, eventually reinforcing underpricing and demand reduction.

We also report on IPO dynamics. First, we find that successful IPO participation reinforces future IPO participation. Second, we report that aftermarket participants increase their IPO participation,

probably because they regret the opportunity costs they incur by purchasing the higher priced shares in the aftermarket of the IPO. The former effect is in line with Kaustia and Knüpfer (2008) and the latter with learning direction theory (Selten and Buchta 1999). Both effects affect a lower average expected excess return. Because the required return by IPO investors does not decrease, however, underpricing persists.

We conclude that investor behavior may partly explain the underpricing anomaly, as we observe underpricing under almost perfect market conditions. Other demand-side and supply-side effects that are absent in our design but are present in the real world (see section 2) may well explain further partial impacts of empirically observed underpricing. These additional impacts deserve further investigation in the laboratory.[21] Our approach can be extended in many different directions.

[21] For instance, asymmetric information may significantly affect IPO underpricing. In the asset market design of Smith et al (1988), Sutter et al (2012) recently showed that varying the information setting can impact the price.

References

Aggarwal, R., N.R. Prabhala, and M. Puri, 2002, Institutional Allocation in Initial Public Offerings: Empirical Evidence, *Journal of Finance* 57, 1421-1442.

Amihud, Y., S. Hauser, and A. Kirsh, 2003, Allocations, Adverse Selection and Cascades in IPOs: Evidence from the Tel Aviv Stock Exchange, *Journal of Financial Economics* 68, 137-158.

Ariely, D., A. Ockenfels, and A.R. Roth, 2005, An Experimental Analysis of Ending Rules in Internet Auctions, *The RAND Journal of Economics* 36, 890-907.

Ausubel, L.M., and P. Cramton, 2004, Auctioning many divisible goods, *Journal of the European Economic Association* 2, 480-493.

Beatty, R.P., and J.R. Ritter, 1986, Investment banking, reputation, and the underpricing of initial public offerings, *Journal of Financial Economics* 15, 213-232.

Benveniste, L.M., and P.A. Spindt, 1989, How investment bankers determine the offer price and allocation of new issues, *Journal of Financial Economics* 24, 343-361.

Biais, B., P. Bossaerts and J.-C. Rochet, 2002, An optimal IPO mechanism, *Review of Economic Studies* 69, 117-146.

Bonini, S., and O. Voloshyna, 2013, A, b, or c? Experimental test of IPO mechanisms, *European Financial Management* 19, 304-344.

Chemmanur, T.J. and M.H. Liu, 2006, How should a firm go public? A dynamic model of the choice between fixed-price offerings and auctions in IPOs and privatizations, *Carroll School of Management Working Paper*.

Chiang, K.C.H., and A.W.P. Kung, 2005, Bidding dynamics in multi-unit auctions: empirical evidence from online auctions of certificates of deposit, *Journal of Financial Intermediation* 14, 239–252.

Cornelli, F., and D. Goldreich, 2001, Bookbuilding and strategic allocation, *Journal of Finance* 56, 2337-2369.

DeGeorge, F., F. Derrien, and K.L. Womack, 2010, Auctioned IPOs: the U.S. evidence, *Journal of Financial Economics* 98, 177–194.

DeGeorge, F., F. Derrien, and K.L. Womack, 2007, Analyst hype in IPOs: explaining the popularity of book-building, *Review of Financial Studies* 20, 1021-1058.

Demers, E., and K. Lewellen, 2003, The marketing role of IPOs: evidence from internet stocks, *Journal of Financial Economics* 68, 413-437.

Derrien, F., and K.L. Womack, 2003, Auctions vs. bookbuilding and the control of underpricing in hot IPO markets, *Review of Financial Studies* 16, 31-61.

Derrien, F., 2010, Initial public offerings. In: H.K. Baker, and J.R. Nofsinger (eds.), *Behavioral Finance, Investors, Corporations, and Markets.* NJ: John Wiley and Sons, 475-490.

Engelbrecht-Wiggans, R., J.A. List and D.H. Reiley, 2006, Demand reduction in multi-unit auctions with varying numbers of bidders: theory and evidence from a field experiment, *International Economic Review* 47, 203-31.

Ellis, K., R. Michaely and M. O'Hara, 2000, When the underwriter is the market maker: an examination of trading in the IPO aftermarket, *Journal of Finance* 55, 1039-1074.

Friedman, D. and J. Rust, 1993, *The Double Auction Market. Institutions, Theories and Evidence.* Proceedings of the Workshop on Double Auction Markets, held June, 1991 in Santa Fe, New Mexico. Addison-Wesley.

Füllbrunn, S., and T. Neugebauer, 2013, *Deflating Bubbles in Experimental Asset Markets: Comparative Statics of Margin Regulations*, LSF Research Working Paper Series No. 13-14.

Füllbrunn, S. and A. Sadrieh, 2012, Sudden termination auction – An experimental study, *Journal of Economics and Management Strategy* 21, 519-540.

Grinblatt, M., and C.-Y. Hwang, 1989, Signalling and the pricing of new issues, *Journal of Finance* 44, 393-420.

Hao, Q., 2007, Laddering in initial public offerings, *Journal of Financial Economics* 85, 102-122.

Haruvy, E., Y. Lahav, Y., and C.N. Noussair, 2007, Traders' expectations in asset markets: experimental evidence, *American Economic Review* 97, 1901-1920.

Ibbotson, R.G., 1975, Price performance of common stock new issues, *Journal of Financial Economics* 2, 235-272.

Kagel, J.H. and D. Levin, 2001, Behavior in multi-unit demand auctions: experiments with uniform-price and dynamic Vickrey auctions, *Econometrica* 69, 413-454.

Kagel, J.H. and D. Levin, 2002, *Common Value Auctions and the Winner's Curse*. Princeton University Press.

Kaustia, M., 2004, Market-wide impact of the disposition effect: evidence from IPO trading volume, *Journal of Financial Markets* 7, 207-235.

Kaustia, M. and S. Knüpfer, 2008, Do investors overweight personal experience? Evidence from IPO subscriptions, *Journal of Finance* 63, 2679-2702.

Kutsuna, K., and R. Smith, 2004, Why does book-building drive out auction methods of IPO issuance? Evidence from Japan", *Review of Financial Studies* 17, 1129-1166.

Liu, X., and J.R. Ritter, 2010, The economic consequences of IPO spinning, *Review of Financial Studies* 23, 2024-2059.

Loughran, T., and J.R. Ritter, 2002, Why don't issuers get upset about leaving money on the table in IPOs? *Review of Financial Studies* 15, 413-443.

Ljungqvist, A., 2007, IPO underpricing. In: B.E. Eckbo (ed.), *Handbook in Corporate Finance 1: Empirical Corporate Finance*, North-Holland, 375-306.

Neugebauer, T. and R. Selten, 2006, Individual behaviour of first-price auctions: the importance of feedback information in experimental markets, *Games and Economic Behavior* 54, 183-204.

Michaely, R., and W.H. Shaw, 1994, The pricing of initial public offerings: Tests of adverse-selection and signaling theories, *Review of Financial Studies* 7, 279-319.

Odean, T., 1998, Are investors reluctant to realize their losses? *Journal of Finance* 53, 1775-1798.

Palan, S., 2013, A review of bubbles and crashes in experimental asset markets, *Journal of Economic Surveys* 27, 570-588.

Ritter, J.R., 2003, Investment banking and securities issuance. In: G.M. Constantinides, M. Harris, and R. Stulz (eds.), *Handbook of the Economics of Finance 1A: Corporate Finance*, North-Holland, 255-306.

Ritter, J.R., and I. Welch, 2002, A review of IPO activity, pricing, and allocations, *Journal of Finance* 57, 1795-1828.

Rock, K., 1986, Why new issues are underpriced, *Journal of Financial Economics* 15, 187-212.

Roth, A.E. and A. Ockenfels, 2002, Last-minute bidding and the rules for ending second-price auctions: evidence from eBay and Amazon auctions on the internet, *American Economic Review* 92, 1093-1103.

Ruud, J.S., 1993, Underwriter price support and the IPO underpricing puzzle, *Journal of Financial Economics* 34, 135-151.

Selten, R., and J. Buchta, 1999, Experimental sealed bid first price auctions with directly observed bid functions. In: A. Rapoport, D.V. Budescu, I. Erev, and R. Zwick (eds.), *Games and Human Behavior: Essays in Honor of Amnon Rapoport*, 101-116.

Shefrin, H., and M. Statman, 1985, The disposition to sell winners too early and ride losers too long: Theory and evidence, *Journal of Finance* 40, 777-790.

Sherman, A.E., 2005, Global trends in IPO methods: book building versus auctions with endogenous entry, *Journal of Financial Economics* 78, 615-649.

Shiller, R., 1988, Initial public offerings: investor behavior and underpricing, *NBER working paper 2806*, unpublished.

Smith, V., G. Suchanek, and A. Williams, 1988, Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets, Econometrica 56, 1119-1151.

Sutter, M., J. Huber, and M. Kirchler, 2012, Bubbles and Information: An Experiment *Management Science* 58, 384-393.

Thaler, R., 1988, Anomalies: the winner's curse, *The Journal of Economic Perspectives* 2, 191-202.

Tinic, S.H., 1988, Anatomy of initial public offerings of common stock, *Journal of Finance* 43, 789-822.

Trauten, A. and T. Langer, 2012, Information production and bidding in IPOs – An experimental analysis of auctions and fixed-price offerings, *Zeitschrift für Betriebswirtschaft* 82, 361-388.

Vickrey, W., 1961, Counterspeculation, auctions, and competitive sealed tenders, *Journal of Finance* 16, 8 -37.

Zhang, P., 2009, Uniform price auctions and fixed price offerings in IPOs: an experimental comparison, *Experimental Economics* 12, 202-219.