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ATUALIZAÇÃO BAYESIANA DE OFERTAS DE COMPRA EM
MÉTODOS EXPERIMENTAIS DE APREÇAMENTO DE OFERTAS
PÚBLICAS INICIAIS DE AÇÕES

BAYESIAN BID UPDATING IN EXPERIMENTAL IPO PRICING
METHODS

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BAYESIAN BID UPDATING IN EXPERIMENTAL IPO PRICING METHODS

OBJECTIVE

The purpose of this article was to verify whether the update of bids and investor learning differ according to three experimental versions of initial public offers (IPO) methods. Investors learn about their performance and can improve their pricing decisions in successive experimental rounds.

METHODOLOGY

A simulated trading and stock pricing environment was built with support from the Zurich Toolbox for Readymade Economic Experiments. We simulate the methods of Dutch auction, book building and competitive IPO. The participants are undergraduate and graduate students from a large public university in Brazil and professionals affiliated with a large Brazilian retail bank.

RESULTS AND CONCLUSIONS

Investors are more likely to bid in the next round if they have a gain in the previous round under the Dutch auction and book building. Participants were more likely to positively update their bids with regard to their ideal bid after they were allocated in an offer under book building, but not so much under the Dutch auction and the competitive IPO. Book building was the method where learning led to gains more often.

PRACTICAL IMPLICATIONS

The evidence in the bids update analysis suggests that learning occurs according to the Bayesian update and not according to the naive update in the book building. This is consistent with the fact that book building is the most widely used IPO method in the largest world markets, which supports its widespread application, despite criticism of the method.

KEYWORDS

IPO pricing methods, Bayesian updating, book building, competitive IPO, auction

ATUALIZAÇÃO BAYESIANA DE OFERTAS DE COMPRA EM MÉTODOS EXPERIMENTAIS DE APREÇAMENTO DE OFERTAS PÚBLICAS INICIAIS DE AÇÕES

OBJETIVO

O objetivo deste artigo foi verificar se a atualização de ofertas de compras (bids) e a aprendizagem dos investidores diferem de acordo com três versões experimentais de métodos de ofertas públicas iniciais de ações ou initial public offers (IPOs). Os investidores aprendem sobre seu desempenho e podem melhorar suas decisões de preços em sucessivas rodadas experimentais.

METODOLOGIA

Foi construído um ambiente simulado de negociação e apreçamento de ações com apoio do Zurich Toolbox for Readymade Economic Experiments. Simulamos os métodos de leilão holandês, book building e IPO competitivo. Os participantes são alunos de graduação e pós-graduação de uma grande universidade pública do Brasil e profissionais afiliados a uma grande instituição bancária de varejo brasileira.

RESULTADOS E CONCLUSÕES

Os investidores são mais propensos a fazer um bid na rodada seguinte se tiverem um ganho na rodada anterior sob o leilão holandês e book building. Os participantes foram mais propensos a atualizar positivamente seus bids no que diz respeito ao seu bid ideal depois de terem sido alocados em uma oferta sob book building, mas não tanto sob o leilão holandês e o IPO competitivo. Book building foi o método onde a aprendizagem levou a ganhos com mais frequência.

IMPLICAÇÕES PRÁTICAS

A evidência na análise de atualização de bids sugere que a aprendizagem ocorre de acordo com a atualização Bayesiana e não de acordo com a atualização ingênua no book building. Isto é consistente com o fato do book building ser o método IPO mais utilizado nos maiores mercados do mundo, o que sustenta sua aplicação generalizada, apesar das críticas ao método.

PALAVRAS-CHAVE

apreçamento em IPO, atualização Bayesiana, book building, IPO competitivo, leilão

INTRODUCTION

There are various methods to set the offer price in an Initial Public Offer (IPOs) of stocks but book building is the preferred method worldwide (JAGANNATHAN, SHERMAN, 2005; JAGANNATHAN, JIRNYI, SHERMAN, 2009). The underwriting market can be very competitive and underwriters usually keep the information they obtained during the pricing process private if local regulations permit. Thus, experiments are a way to infer what happens during a pricing process. Experimental IPO pricing includes the design of a pricing method simulation. Observers will be able to study subject behavior through the outcomes from repeated rounds of the process. Outcomes in the IPO experiments case will include bids, prices, returns and the reaction to new information, for example. Observers may also study bid updating and subject learning through repetition. The recent literature on experimental IPO methods brought about alternatives to deal with the possible shortcomings of book building, theoretically as well as empirically (BIAIS, BOSSAERTS, ROCHET, 2002; ZHANG, 2006, 2009; TRAUTEN, LANGER, 2012; BONINI, VOLOSHYNA, 2013).

The objective of this article is to ascertain if bid updating and subject learning differs according to three experimental versions of IPO methods. Subjects learn about their performance and may improve their pricing decisions in successive experimental rounds. Chiang, Hirshleifer, Qian, and Sherman (2011) conjecture that rational (Bayesian) updating is present when there is improvement in investor bidding and better performance. Naive reinforcement leads to a deterioration of performance because investors participate in future rounds solely based on past successes and not on their analysis of future events. Bayesian and naive bid updating are the two forms of learning addressed here.

This study uses the data from the experiment performed in Almeida and Leal (2015) to investigate bid updating. These authors examined three experimental auction variations that they called "Dutch auction", "book building", and "competitive IPO". The first two emulated traditional methods that have been widely used in IPOs. The third method is a two-stage book building innovation used in some European IPOs designed to reduce potential conflicts of interest between issuers and underwriters. Their article was concerned with the joint comparison of pricing and welfare allocation efficiency among the three experimental methods in the same environmental setting, and did not address bid updating and learning.

This article is motivated by gaps in the IPO methods experimental literature. Bonini and Voloshyna (2013) did not compare emulations of the three methods addressed herein jointly in

the same experimental design. Besides, this study also offers a general experimental analysis of bid updating and learning considering the competitive IPO while Chiang et al (2011) used actual data from Taiwanese IPO auctions and Trauten and Langer (2012) compared different types of auctions to fixed price offers. Thus, the contribution to the experimental IPO methods literature is a more detailed study of the nature of investor learning and bid updating as participants receive information in each experimental round. In particular, the article probes bid updating in the three different IPO methods mentioned jointly, under the same experimental environment, including emulations of book building and the competitive IPO.

Smith (1976) asserts that economic experiments are laboratory simplifications designed to capture the selected aspects of a real process. They are important to the theoretical testing and empirical comprehension of economic phenomena. Kagel (1995) declares that comparing experimental evidence is a challenge because of variations in experiment design and focus. This article uses three experimental auction variations to represent the Dutch auction, book building, and the competitive IPO emulated under the same design. It does not contrast its results with those in the vast auctions literature, which by and large does not address IPO methods, focusing only on experiments about IPO methods. Subjects experience recurrent interactions and inform price and quantity to a non-discretionary underwriter in the latter two simulated IPO pricing methods. The experiments encompass solely pricing and allocate shares to winning bids on a pro rata basis. Naturally, real-world underwriters may be discretionary when they select investors for their repeated interactions and allocation after book building. This article also does not address allocation outcomes. These are limitations of the experimental design that hopefully will not affect the essential conclusions about bid updating.

The results herein evince Bayesian, but not naive updating, with “book building”. The kind of updating with the “Dutch auction” is not clear. The bids were on average greater than optimal bids with the competitive IPO. Higher bids benefit issuers. The competitive IPO maintains the discretionary character of book building, which is apparently appreciated by underwriters, and could be advantageous if underwriters aspire to greater seller welfare. On the other hand, Almeida and Leal (2015) pointed out that “book building” was price efficient where as “competitive IPO” was not. This combined evidence supports the notion that the experimental “book building” is a better IPO pricing method relative to the other two laboratory versions analyzed. It is also consistent with the preference of the global underwriting community for book building. Section 2 presents a brief review of the related literature on IPO pricing methods. The

design and procedure of the experiments is detailed in section 3. Section 4 discusses bid updating and learning and section 5 concludes.

LITERATURE REVIEW

Lowry and Schwert (2004) and Almeida and Leal (2015) state that there is price efficiency when initial IPO market returns are close to zero. They concluded that book building is as price efficient as the Dutch auction. The competitive IPO is seller welfare efficient because it maximizes the offer proceeds but is not price efficient. The Dutch auction is the method that maximized buyer welfare. Almeida and Leal (2015) also infer that underwriters probably seek pricing efficiency because of their widespread preference for book building to price IPOs.

Specific Brazilian literature on IPO methods is scarce. Leal and Bocater (1992) review the international literature on the topic with a policy discussion about the replacement of the fixed price method used in Brazil with auctions but, since then, book building became the IPO method of choice in the country. Maurer and Barroso (2011) review the recent experience with electricity auctions and Rego and Parente (2013) study different auction methods applied in Brazilian energy auctions.

Bonini and Voloshyna (2013) is a closely related work because they also study the competitive IPO. However, they compare their experimental versions of book building to the competitive IPO, but not to an auction. They compare auctions separately, including the new Ausubel (2004) method. This article compares bid updating in auction emulations of the Dutch auction, book building, and the competitive IPO jointly, in the same experimental environment. Chiang et al (2011) investigated learning and is another closely related study that employed actual IPO auction data from Taiwan. The evidence in these two articles will be discussed in the section that describes the bid updating results. This section proceeds with a brief literature review of three IPO methods.

Auctions

Kagel (1995) presents many types of auctions. Two common types in the IPO methods literature are the clock and the sealed-bid uniform price auctions. Clock auctions are also known as open-outcry descending price or Dutch auction. The version used herein handles the

sale of several identical units of an asset, as in an IPO. The auctioneer starts with the highest asked price and lowers it until someone bids for a certain quantity of the offered asset. The auctioneer asks new lower prices and bidding continues until she allocates the entire offer or reaches a minimum price. The "Dutch auction" in this article is an open-outcry descending price clock auction.

The sealed-bid uniform price auction is quite common too. Bidders present their price and quantity bids in a secret (sealed) manner and not as an open outcry. The auctioneer ranks bids from highest to lowest in terms of price. Assets are allocated to the highest bidder first, then on to the next highest bidder until the total quantity offered is placed. The uniform clearing price for all bidders is the one offered by the lowest winning bid. Sherstyuk (2009) claims that the price and allocation efficiency of clock auctions are better than in the sealed-bid version whereas Zhang (2009) maintains that the uniform price auction is better than the fixed price auction. A variation of a sealed-bid uniform price auction will represent "book building" in this article.

There is some evidence favorable to IPO auctions in France, especially when they are similar to book building (BIAIS, FAUGERON-CROUZET, 2002; DERRIEN, WOMACK, 2003; DERRIEN, 2005) and some authors prefer them due to the shortcomings of book building, especially its lack of transparency and discretionary nature (SPATT, SRIVASTAVA, 1991; LOWRY, OFFICER, SCHWERT, 2010). Yet, book building became the dominant IPO method (JAGANNATHAN, SHERMAN, 2005; JAGANNATHAN ET AL, 2009). A key problem is that the single allocation criterion of auctions is price and they may not necessarily achieve greater price efficiency than book building, which may contemplate other discretionary allocation principles. Jagannathan et al. (2009) argue that a large fluctuation in the number of bidders may discourage participation and is another problem of auctions. Cason (2000) contends that collusion may also be a problem if bidders can communicate privately. Bidders may collude tacitly as well when they observe the information other bidders convey. Markets, however, may achieve efficiency when bidders cannot communicate, even when they are very few.

Book building

Underwriters may simply play the role of public information aggregators in auctions. They will not be able to allocate discretionarily and thus investors will not have stimulus to reveal private information. Sherman (2005) sustains that book building, on the other hand, allows

for discretionary allocations and encourages the revelation of private information that helps underwriters to set the price of the offer. Underwriters plan a series of visits to selected investors and provide them with company and offer information (the road show). The number and types of investors visited and the information provided is subjected to local regulation. Investors, on the other hand, have privileged access to company representatives and underwriters and offer them information about their willingness to buy during the visits. The more information investors offer the greater their allocation (BENVENISTE, WILHELM, 1997; LJUNGQVIST, WILHELM, 2002; SHERMAN, 2000, 2005). Book building possibly became the most widely used IPO method in the world due to this private information and allocation bargaining.

Price discovery is a key task in an IPO. Book building may be a better IPO method because its price discovery is more effective. Effectiveness possibly stems from superior information disclosure and allocation as book building may be regarded as a dynamic kind of auction (BIAIS, FAUGERON-CROUZET, 2002; CORNELLI, GOLDREICH, 2003; SHERMAN, 2005; WILHELM, 2005; LJUNGQVIST, 2007). Wilhelm (2005) claims that book building overcame technological difficulties of consolidating bid information around the world while keeping the ability of underwriting discretion in an increasingly globalized capital market. Nevertheless, Jenkinson and Jones (2009b) point out to a few downsides. Institutional investors doubt that book building produces useful information. Aftermarket IPO trading behavior, the level of underwriter compensation, and potential agency problems between issuers and underwriters may constitute deleterious side effects of book building (BUSABA, CHANG, 2010; BARTLING, PARK, 2010). Yet, book building advocates contend that underwriters avert from abuse to protect their reputation (WILHELM, 2005; CARTER, DARK, SAPP, 2010).

Competitive IPO

A "bait and switch" scheme is one in which customers are initially lured by some teaser price, which they cannot really get, and then directed to lower quality or higher priced merchandise. Underwriters may use this stratagem to attract issuers with an enticing initial offer price range when bidding for the book building job. It is costly to replace an underwriter once hired. The appointed underwriter may gain material clout over the issuer and argue successfully in favor of a lower initial price range at the time of the actual sale to ease distribution and benefit the buyers they lined up during the book building process. The competitive IPO addresses "bait and switch".

In book building, the lead underwriter conducts the IPO process, advising the issuer, making all the legal filings, and taking care of a myriad of required and managerial activities that must take place before the offer, including the road show, in the advising phase. It is also the lead underwriter that takes care of pricing and distributing the offer through an underwriting syndicate it puts together in the selling phase. There is a potential conflict of interest if the same institution is entrusted to carry out these two phases, as in book building. An underwriter encumbered solely with the advising phase (the advising institution) would charge for these services but would not be responsible to set the offer price. Underwriters entrusted to execute only the sale task (the selling institution) would have an incentive to set the offer price range higher if they compete for the job. The competitive IPO is the splitting of these two underwriting phases, which are bundled in book building, between the advising and selling underwriters selected according to a competitive process. The issuer naturally selects the one it believes will conduct each task better, according to whatever criteria it establishes, including setting a higher offer price range. The selling underwriters would have to set an offer price range in their bid for the selling task in a competitive selection that occurs towards the end of the advising phase. The selling underwriter compensation may be a function of the price range. Jenkinson and Jones (2009a) describe the competitive IPO employed in some European offers and claim that it preserves the best qualities of book building.

METHODOLOGY

This article uses the results obtained in the Almeida and Leal (2015) experiments. This section will present their experiment design. Almeida and Leal (2015) used the Zurich Toolbox for Readymade Economic Experiments described in Fischbacher (2007). Subjects are undergraduate and graduate students from a large public university in Brazil and professionals affiliated to a large Brazilian retail banking institution, experienced in portfolio management and company and industry research.

Table 1 presents session details. A session is a collection of twenty-four experimental executions (rounds) of the emulation of one of the three IPO methods, each standing for an IPO. There were nine sessions in total, three dedicated to each IPO method. There were five sessions with professional subjects and four with student subjects. Students and professionals did not mix. The number of subjects in each session ranged from 9 to 11. Compensation was

paid to participants according to their performance and it could range from 5 to 25 US dollars. Table 1 shows that the average compensation in each round ranges from 9.50 to 10.50 US dollars.

Table 1

Sessions details

Session	IPO Method	No. of Subjects	Type of Subject	Average subject compensation (US dollars)
1	Dutch auction	10	Students	10.00
2	Book building	11	Professionals	9.50
3	Dutch auction	11	Professionals	9.50
4	Competitive IPO	9	Professionals	10.50
5	Book building	9	Students	10.50
6	Dutch auction	9	Professionals	10.50
7	Book building	9	Students	10.50
8	Competitive IPO	10	Students	10.00
9	Competitive IPO	9	Professionals	10.50

Note. "Dutch auction" is an open outcry descending price or clock auction. "Book building" refers to a sealed-bid uniform price auction and "competitive IPO" to a two-stage version of it. Students may be undergraduate or graduate and professionals work for a large financial institution. The compensation offered to subjects varied between 5 and 25 US dollars.

Table 1 also shows that there were 38 students and 49 professionals. Almeida and Leal (2015, p. 18) provide subject qualitative details. In summary, professional subjects are older (36) on average than students (26). Professionals had an average of ten years of experience. There were 73 males and 14 females, and only 3 female professionals. Seventy-three subjects had some stock market experience, all but two of the professionals. However, the results in Almeida and Leal (2015) were essentially the same for students and professionals and so these two types of subjects will not be compared in this article.

Table 2 shows the definitions of the variables. The virtual auctioneer draws the true share value V before each round but does not reveal it to subjects. Subjects also receive the lower (LPR) and upper (UPR) prices in the price range of the IPO, which are a function of V , disguised according to an adjustment factor, as depicted in Table 2. The price range is public information. Each subject privately receives a different price signal (S_i), a function of V as portrayed in Table 2. It represents their inaccurate private IPO valuation. Kagel and Levin (1986, 1999) devised this informational structure, adopted here and in Almeida and Leal (2015).

Table 2

Variable definitions in order of appearance in the text

Variable	Conceptual definition	Form to obtain
V	True share value and closing market value on the first trading day	Drawn randomly from the uniform distribution range [10, 110]
S_i	Private signal about the value of V received by each subject	Drawn randomly from the uniform distribution [0.8 V , 1.2 V] for each subject
UPR	Upper limit of the offer price range	Drawn randomly from [0.95 \times mid , 1.3 \times mid]
LPR	Lower limit of the offer price range	Drawn randomly from [0.70 \times mid , 0.95 \times mid]
mid	A price reference to obtain the price range	$mid = V \times a$, whereas a is an adjustment factor drawn randomly from [0.8, 1.2]
$Gain_i$	The gain or loss of each subject in each round in a session, as a function of the offer price (P) and the quantity allocated to the subject (q_i)	$Gain_i = (V - P) \times q_i$
P	The offer price	The price asked by the virtual auctioneer that clears the offer in the "Dutch auction" and derived from the bids in the other methods
PS	The public signal	$PS = (LPR + UPR)/2$
B_i	The optimal bid for a subject in a round	$B_i = (S_i + PS)/2$

Thirty shares are offered in each IPO (round). The IPO is cancelled if demand is not sufficient to allocate all shares. Table 2 shows the definition of gain for each subject in each IPO (round). The total gain of each subject at the end of a session is the sum of the gains in its 24 rounds. Subjects received detailed instructions before each section that are available with the authors.

In the "Dutch auction" simulation, the auctioneer draws V and S_i and determines the public price range. Subjects receive their private IPO valuation S_i . The virtual auctioneer sets prices and subjects present their quantity bids. The virtual auctioneer announces a new and lower price if the offer quantity is not cleared, otherwise the round ends. Offer price drops are a percentage of V and are not too small to avoid protracted rounds. All bidders are allocated, fractionally in some cases. Subjects do not know the allocations of other participants but are, obviously aware of their gain or loss.

Like in the "Dutch auction", the auctioneer draws V and S_i and determines the public price range in "book building". Subjects receive their private IPO valuation S_i and present their price and quantity bids. The auctioneer builds the book in descending order of bid price. The offer price to all bidders is the bid price that clears the offer, i.e., the lowest priced winning bid.

Allocations are proportional to the bid quantity. Subjects do not know the bids and the allocations of other participants but see their gain or loss.

"Competitive IPO" consists of the advisory and the selling phases and there is a different underwriter appointed to each one. Underwriters bid to secure the selling institution appointment. Clients of the winning bank may benefit. Subjects are randomly divided into groups of at least three participants. Each group is the clientele of a bidding institution. Groups do not change throughout the session. Subjects are not aware of their fellow group members and cannot communicate during the experiment to avoid collusion.

The auctioneer draws V and S_i but not the price range. Subjects then bid for price and quantity. The auctioneer computes the average price bid per group and the one with the highest average wins the selling appointment. The auctioneer then computes the price range with the winning price bid average in lieu of V as in the other methods. Subjects learn about their bank success or failure and the offer price range. There is probably an upward tendency in the range but subjects may not realize it and believe that V lies within the range, which will not necessarily be the case. The session proceeds as in "book building". As before, subjects see their gain or loss but are not aware of the bids and the allocations of other participants.

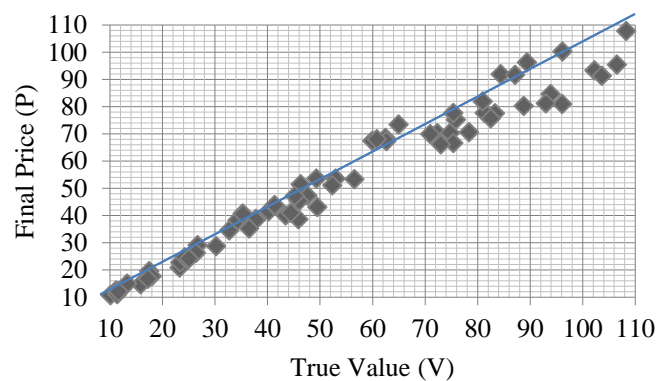
Subjects belonging to the winning group (clients of the appointed underwriter) enjoy allocation benefits. Their allocation increase by a factor f drawn randomly from the $(1, 2)$ open range if the bids from clients of the winning underwriter are among the winning bids of a round. Allocations decrease by a factor of $2 - f$ for clients (subjects) of other banks with winning bids. Almeida and Leal (2015) claim that their procedure randomized parameters more than other studies to hamper the ability of subjects to realize any misspecifications.

BID UPDATING

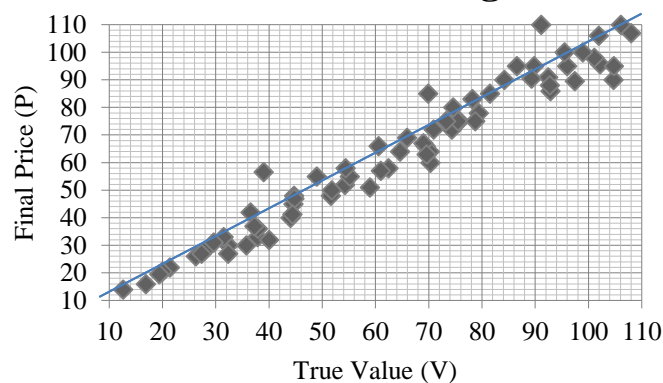
Figure 1 depicts three scatter plots of the final prices resulting from the offer (P) according to each one of the three methods and of the true value (V) that corresponds to the market value of the stock at the end of the first trading day, randomly picked at the beginning of each round. A visual inspection of the charts in Figure 1 suggests that "book building" may result in higher initial returns (underpricing). Figure 2 seems to confirm this observation and shows the round by round evolution of initial returns per method. There are three observations for the first round, for example, because there were three sessions for each IPO method, each one with

twenty-four rounds, with a first round in each session. The same happened with the other twenty-three rounds, which show three initial returns each. The greater concentration of positive initial returns with “book building” and of negative initial returns with the “competitive IPO” is clearly visible. There are more positive initial returns in the early rounds of “book building” while negative initial returns were more concentrated in the middle rounds of “competitive IPO”. There was no discernable pattern under the Dutch auction.

"Dutch Auction"



"Book building"



"Competitive IPO"

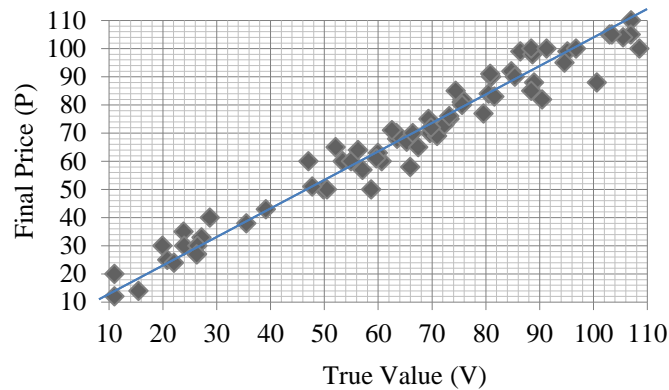
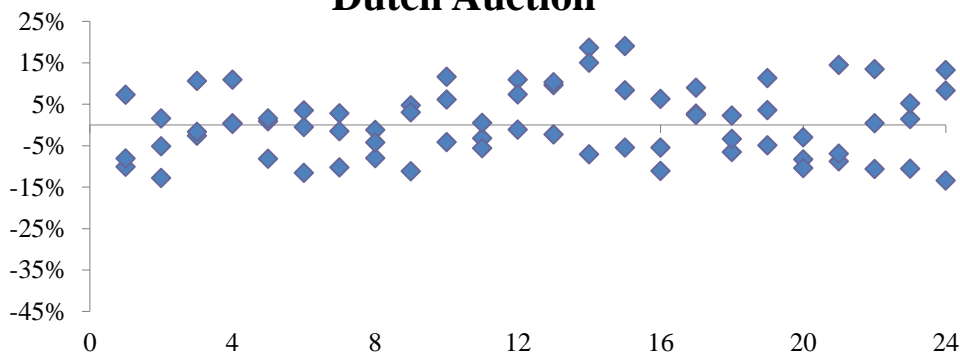


Figure 1

Scatter plot with final prices and true values

Figure 3 portrays private signals (S_i) relative to bids. There was a maximum bid set at 150 for all pricing methods because it might have been necessary to limit subjects whose bids deviate significantly from their signals in the “competitive IPO”. Participants were aware of such limit. Bonini and Voloshyna (2013) did not control for this possibility and did not impose restrictions on this behavior with their “competitive IPO”. The dispersion of bids is greater under the “competitive IPO”. Perhaps its more complex rules led to a greater differentiation in the strategies followed by subjects. Looking over the distribution of the adjustments between the fundamental values (private signals, S_i) and bids, 6.7% of the bids were under -50% and 0.6% were above 50% with “book building”. “Competitive IPO” displayed 5.1% of the bids under -50% and 7% above 50%. There were more negative extreme bids under “book building” and more positive extreme bids under “competitive IPO”.

"Dutch Auction"



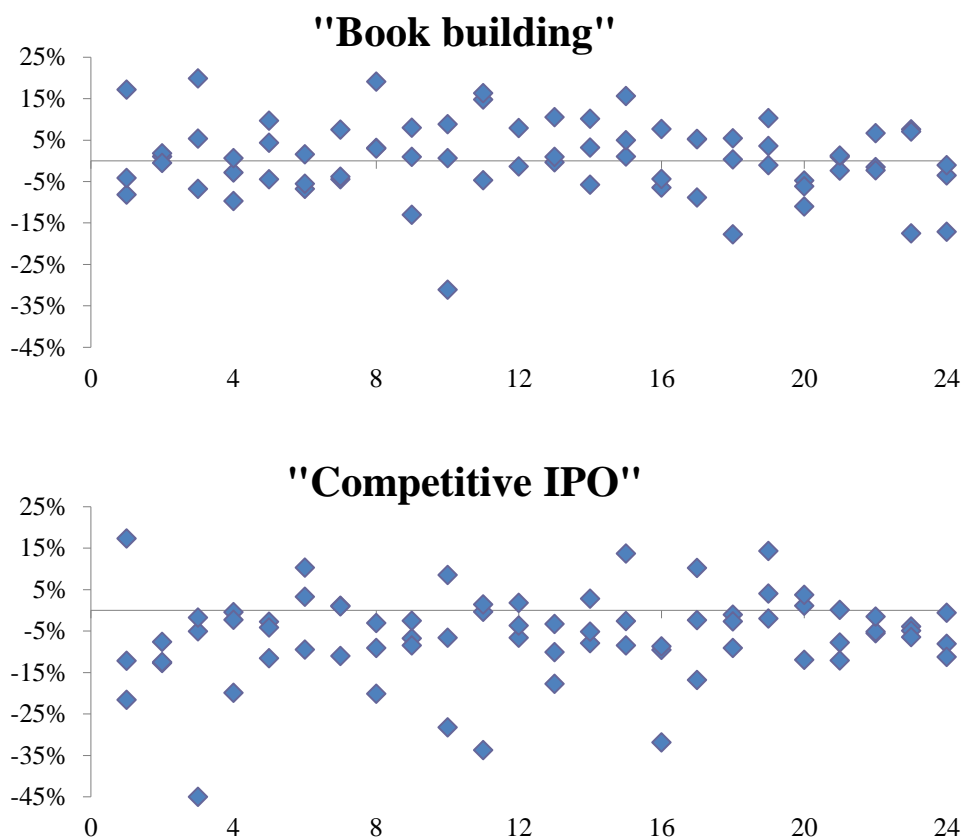


Figure 2
Initial returns from the first to the twenty-fourth round

There could be potential learning effects resulting from the different weighting of the information subjects receive. Participants may solve a Bayesian updating problem before bids are submitted because they receive two pieces of information in each round: the private signal (S_i) and the preliminary price range (LPR , UPR), which is public. They may revise their expectations as they receive new information about their performance and their learning may lead to better decisions (ARROW, 1962; GROSSMAN, KIHLSSTROM, MIRMAN, 1977; KIHLSSTROM, 1974). In this article, better decisions refer to price only, and not other qualitative aspects described in Stigler (1961), even though Bayesian updating is not the only form to analyze learning. Kahneman and Tversky (1972) mention that people may not follow principles of probability (Bayes' normative) when judging the likelihood of uncertain events. Charness and Levin (2005) affirm that people may also use heuristics as reinforcement and combinations

of both Bayesian and reinforcement rules. The experimental design herein does not allow the exam of these forms of learning.

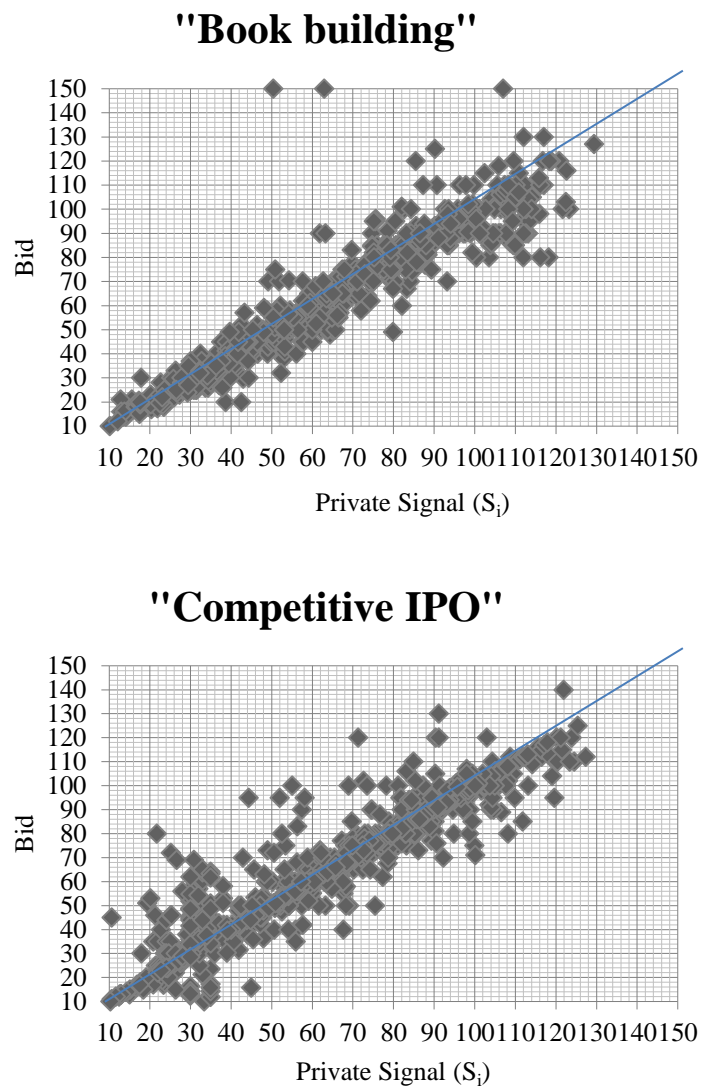


Figure 3
Scatter plot of private signals (S_i) and bids

The analysis addressed the experimental data with regards to potential rational (Bayesian) or naive reinforcement learning. Considering both types of learning, Kaustia and Knupfer (2008) and Chiang et al. (2011) suggest that investors are more likely to bid in future IPOs if they receive high returns from past IPOs. Chiang et al. (2011) state that the main difference between the two types of learning is that under a Bayesian updating scheme investors improve their bidding strategies, attaining superior performance, while under naive reinforcement inves-

tor learning leads to worse performance because they simply believe that past successes are reason enough to participate in future events, regardless of any analysis of the quality and expected return of an IPO. They become less selective about their participation in future rounds and end up obtaining lower returns.

The optimal bid is the one that yields the highest expected return to a subject. The optimal bid for each subject in each round is based on the private signal (S_i), the public price range (LPR, UPR), and on the clearing price of the round. The central value of the public price range is the public signal (PS). The price informed by the virtual auctioneer at the time a subject placed her quantity bid was the price bid in the "Dutch auction" case because subjects do not inform price bids in this IPO method. The optimal bid for a participant in a given round (B_i) is defined as the intermediate value between S_i and the public signal PS . Alternatively, $B_i = \min \{S_i, PS\}$, with no relevant change in results, which will not be reported but are available upon request.

Optimal and actual bids were compared to verify whether bidders followed the optimal strategy, how close to the optimal strategy they were, and how learning evolved through time. Investors bid by weighting the costs and benefits of acquiring information and private and public signals in the Chiang et al (2011) analysis with real data from Taiwan. Their strategy was updated conditioned on realized performance. In the setting in this study, subjects did not need to acquire information.

Table 3 shows the analysis of bid updates considering the hypotheses of Chiang et al (2011) with regards to Bayesian and naive updating. Panel A of Table 3 shows that learning occurs according to Bayesian updating and not to naive updating in "book building". The results for the Dutch auction are not conclusive about any type of learning. Overall, participants bid higher than their optimal bid under the Dutch auction (1.147 times higher) and "competitive IPO" (1.069), while lower to their optimal bid under "book building" (0.915). These proportions are significantly different from each other at the 1% level according to a Mann-Whitney non-parametric test.

Table 3

Learning and bid updating

	Dutch auction	%	Book building	%	Competitive IPO	%
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Panel A:						
Bid over optimal bid	114,7%	–	91,5%	–	106,9%	–
Panel B:						
Bids after gain	112	54,6%	178	58,6%	64	23,9%
Bids after loss	93	45,4%	126	41,4%	204	76,1%
Panel C:						
Positive updates on optimal bid	95	46,3%	181	59,5%	132	49,3%
Negative updates on optimal bid	110	53,7%	123	40,5%	136	50,7%
Positive updates on optimal bid after gain	60	53,6%	110	61,8%	32	50,0%
Negative updates on optimal bid after gain	52	46,4%	68	38,2%	32	50,0%
Positive updates on optimal bid after loss	35	37,6%	71	56,3%	100	49,0%
Negative updates on optimal bid after loss	58	62,4%	55	43,7%	104	51,0%
Gains after repetition	56	50,0%	56	59,6%	11	39,3%
Losses after repetition	56	50,0%	38	40,4%	17	60,7%
No allocation after repetition	0	–	210	–	240	–
Times subjects skipped an offer over total offers	48,4%	–	5,2%	–	3,9%	–

Note. "Dutch auction" is an open outcry descending price or clock auction. "Book building" refers to a sealed-bid uniform price auction and "competitive IPO" to a two-stage version of it. This analysis addresses sequential pairs of rounds of a subject, comparing bids of the subject in the round with allocation after the previous round with allocation. "Gain" and "loss" refer to the outcome in the first round with allocation in the pair. Positive updates, negative updates, and optimal bid are defined in the text. The bid over optimal bid proportions distributions are all significantly different from each other according to a Mann-Whitney non-parametric test at the 1% level of significance.

Panel B indicates that subjects more likely bid in the subsequent round under the "Dutch auction" and "book building" if they had a gain in the previous one. This is similar to the results reported by Chiang et al (2011) with real data from IPO auctions in the Taiwanese market. However, Panel B does not display this behavior for the "competitive IPO". In the first stage of "competitive IPO" rounds, subjects had to bid knowing that if their bank reached the highest average bid its clients would obtain greater allocations than the clients of other banks. The public signal was then computed from this average bid and they were led to believe, initially at least, that V would very likely be in this range. As this did not happen, participants may have engaged in chasing higher returns given their very low and negative returns in the initial rounds. One may argue that participants would tend to skip many rounds in "competitive IPO" given their losses but Panel B of Table 3 shows that this did not happen. However, as one reader of this paper pointed out, in the experiment they have nothing else to do but bid, while real investors have many other interests competing for their attention and efforts.

Panel C of Table 3 shows subject behavior after being allocated in a round. They more likely updated their bids positively with regards to their optimal bid after being allocated in a "book building" round (59.5% of bids following an allocation in the previous rounds after gain

and 56.3% after loss). This was not the case after allocation in a "Dutch auction" (46.3%) or "competitive IPO" (49.3%) rounds after gain. "Book building" subjects were more likely (59.6%) to face gains from bidding in a subsequent offer after learning and updating, even though it is also the most price efficient method according to Almeida and Leal (2015).

CONCLUSIONS

The evidence in this article derives from a setting in which bidders are informed and few, yet they did not attain their optimal bid and thus it is not likely that they would do so in the more complex actual IPO auctions. Investors are more likely to bid in the subsequent round if they had a gain in the previous round under the "Dutch auction" and "book building", which is similar to Chiang et al (2011). Participants were more likely to positively update their bids with regards to their optimal bid after being allocated in an offer under "book building" but not as much under the "Dutch auction" and the "competitive IPO". "Book building" was the method where learning leads to gains more often. The updating analysis suggests that learning occurs according to Bayesian updating and not to naive updating in "book building". The results for the "Dutch auction" are not conclusive about any type of learning. The "competitive IPO" emulation bid were on average higher than the optimal bid. This benefits sellers but not buyers. The "competitive IPO" reduces underpricing while maintaining certain characteristics of book building, but it is not as price efficient according to Almeida and Leal (2015). In general, the results in this article are consistent with the worldwide preference for book building.

The experimental setting and its outcomes have limitations that may be difficult to address. Experiments replace real data when they cannot be observed or are not available. A natural sequence for this work would to examine real Brazilian book building data, which underwriters keep private, as Chiang et al (2011) did. Researchers could seek a partnership with regulators in order to exam actual book building data, preserving the identity of investors, issuers, and underwriters. Researchers would need to convince regulators that a better understanding of price efficiency, bid updating, and investor learning in real book building situations could contribute to fine tune the IPO pricing method used in the country.

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