Global Trends in IPO Methods:

Book Building vs. Auctions

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Book Building vs. Auctions

There has been a major world trend in the 1990s towards the use of book building for initial public offerings (IPOs), whereas IPO auctions are surprisingly rare. I document these patterns and explain them through models of both book building and a discriminatory auction in an environment where the number of investors and the accuracy of investors' information is endogenous. Auctions can be considered a subset of book building where the issuer pre-commits to certain price and allocation rules. I examine the results of surrendering flexibility and find that, for both methods, the seller's expected revenue is equal to the expected value of the shares sold minus the expected costs of information acquisition. However: 1) the expected number of shares sold, and thus the expected proceeds, is higher for book building, since auctions carry a greater risk of undersubscription; and 2) book building, unlike auctions, allows the issuer to control spending on information acquisition, and thus to control expected proceeds. Auctions are most likely to be used when pre-existing, "serendipitous" information about the issuer is widely dispersed among investors.

1. Introduction

Auctions have been a successful selling method for centuries and are common today for a wide variety of objects and services, including art objects, real estate, construction contracts, telecommunications bandwidth, mineral rights, produce and flowers. With the recent expansion of the world wide web, internet auctions now seem to be used to sell practically everything. For financial securities, auctions have been enormously useful for the largest, deepest, most liquid markets – those for U.S. and Japanese government bonds.

For initial public offerings (IPOs), auctions have been used for years in many countries and have recently been introduced to the U.S. Outside the U.S., auctions were a well established selling method for IPOs in most parts of the world long before book building (the primary U.S. method) was introduced. Extensive theoretical research has established the superiority of auctions as a selling method in a wide range of circumstances (although usually in a private values framework). Preliminary empirical research on IPOs indicates that auctions might lead to less underpricing than book building[1]. And yet, when I searched for countries in which the auction method was regularly and freely chosen over all other IPO methods (including book building), I was unable to find even one such country.

The two countries in which auctions are still the primary IPO method are Israel and Taiwan. Book building is banned in Israel and it is restricted in Taiwan (see section 2.2 for more details). Japan, France and Argentina abandoned auctions once unrestricted book building was introduced (although auctions are still used occasionally in France, especially on the unregulated over the counter market). Italy, Portugal, Singapore, Switzerland and the U.K. tried and then gave up on auctions even before book building was established locally. Book building spread around the globe in the 1990s, but it is not entirely accurate to blame it for the absence of auctions, since auctions have always run a distant second to the public offer (a.k.a. fixed price, open offer or universal offer) method for IPOs.

Thus, we have a puzzle. Why has the auction method, which has been so extraordinarily popular in so many other settings and which was better established than book building in most IPO markets at the beginning of the 1990s, been so strikingly unpopular with

[1] Results so far are actually mixed. Beierlein (2000), Kaneko and Pettway (2001) and Derrien and Womack (2000) find less underpricing for auctions, while Kutsuna and Smith (2001) and Chahine (2001) cast doubt on these conclusions for Japan and France, respectively. Derrien and Womack do not analyze pure book building IPOs separately, so their results may have been influenced by French regulatory restrictions on the timing of hybrids during their sample period.

firms going public? What advantages have allowed a complicated, obscure method such as book building (which was virtually nonexistent outside of North America before the 1990s) to sweep the globe?

To answer these questions, I model both book building and a discriminatory[2] (pay what you bid) auction for the same environment, one in which the number of investors and the accuracy of investors' information is endogenous. I show that, for both the book building and auction models, the seller's expected revenue[3] is equal to the expected value of the shares sold minus the aggregate information acquisition costs. In other words, for both methods, the IPO shares sold are underpriced by just enough, on average, to compensate investors for their evaluation costs[4].

Thus the two methods appear to be equivalent in terms of their expected proceeds, but the apparent similarities mask two key differences. First, the issuer/underwriter has substantial control over information acquisition through book building, but little or no control in an auction. Since the degree of underpricing is based on investor spending on evaluation, book building gives the issuer greater control over the expected proceeds from the issue. This control can be used either to minimize underpricing, or to induce investors to more carefully evaluate the issue, resulting in a more accurate issue price.[5]

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[2] I chose a discriminatory auction because of the free rider problem with uniform price auctions, a problem that has previously been overlooked but that has, in practice, caused major problems for IPOs. A discussion of this problem and a few examples of its effects are in the conclusion.

[3] I use the term seller's expected revenue because it is standard in the auction literature, although the funds received from a stock issue are proceeds, not revenue.

[4] There is a popular misconception that auctions should always lead to zero underpricing. Cammack (1991), Spindt and Stolz (1989) and Goldreich (1998) demonstrate that there is underpricing even in auctions of U.S. Treasury securities. If U.S. Treasury securities, for which there are such close and readily available substitutes to be used in the pricing process, cannot be auctioned without some underpricing, then it is not surprising that IPO auctions lead to underpricing, given the difficulty and cost of evaluating new issues. In addition to the previously mentioned studies of Japan and France, underpricing in IPO auctions has been shown by Kandel, Sarig and Wohl (1999) for Israel and Liu, Wei and Liaw (2002) for Taiwan.

[5] I show that the ability to control information expenditures is valuable even to an issuer that cares only about maximizing the proceeds of the issue (because book building allows the issuer to minimize underpricing in this case). However, there are many reasons why the issuer (and underwriter) would value accurate pricing of an issue. First, Sherman (2000) shows that an issuer preference for price accuracy arises endogenously if uninformed investors are more risk averse than informed investors. Other reasons include better investment choices, underwriter reputation, issuer signaling, liquidity, and lawsuit avoidance (see Sherman and Titman, 2001). Last, for agency reasons, managers may feel that their future job performance is more likely to be judged fairly if the initial price is more accurate.

Moreover, whether or not one believes that the issuer *wants* this feedback, it is clear that book building *is* an information gathering process – that it involves an information flow from investors to the issuer and underwriter, as well as vice versa - since the final price and quantity of IPO shares depend on responses received during the book building process. Since it is relatively easy under book building to design an offering to discourage costly evaluation (for instance, by allocating a very small number of shares to a wide range of investors

In other words, book building gives issuers greater flexibility. For issuers with a strong preference for price accuracy, auctions may lead to too little evaluation and thus too much remaining uncertainty. On the other hand, for issuers whose primary goal is to minimize underpricing, auctions may lead to too many resources being spent on evaluation, with issuers paying for this through lower average bid prices. The disadvantage of auctions is not that they always lead to either too much or too little evaluation (or underpricing), it is that they seldom, except by chance, lead to the optimal level. Auctions are a "one size fits all" approach, whereas book building allows customized solutions.

The second difference between the two methods is that the expected number of shares sold is higher for book building, because there is a greater chance of undersubscription in an auction. With book building, the underwriter co-ordinates the number of investors that will participate, guaranteeing that a sufficient number (but not too many) are involved[6]. With an auction, an issuer simply sets the reservation price and waits to see what happens. Because auctions sell fewer shares on average, expected IPO proceeds are strictly higher for book building, holding constant the amount spent on information acquisition.

The riskiness of auctions, relative to book building, is a major factor in their lack of popularity. Section 3.4 gives examples of IPO auctions that have led to undersubscription, and the conclusion gives examples of uniform price IPO auctions that have led to overpricing (i.e. to price drops in early aftermarket trading). Given the relatively small number of IPO auctions in the past, it is surprisingly easy to find examples of IPO auction "disasters". Book building allows the underwriter to co-ordinate the number of both informed and uninformed investors, ensuring that enough investors have an incentive to participate in and scrutinize the issue, and

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with no possible connection to the company), the fact that issues are allocated in a way that encourages costly evaluation seems to imply that the information is valued.

In the auction literature, it is well established that potential bidders sometimes pay to collect information. For example, test drilling can be very expensive but is often done before auctions of offshore oil tracts. The standard assumption in the auction literature is that the seller does not value the information collected. However, the auction of IPO shares is different from most auctions because the buyer and seller will have a continuing relationship – the buyers will become part-owners in the company, along with the sellers (who will also manage the firm, essentially working for the buyers).

[6] The ability to co-ordinate entry also allows underwriters to eliminate the "winner's curse" faced by investors. This adverse selection problem, first noted for IPOs by Rock (1986), causes bidders in a discriminatory auction to lower their bids and requires the issuer in a public offer to underprice in order to attract uninformed investors (although Chowdhry and Sherman, 1996b, shows that the common practice of favoring small over large orders reduces this problem). With book building, if the investment bank handles many IPOs sequentially, it can prevent this adverse selection problem for uninformed investors by allocating a relatively fixed proportion of shares in each offering to a regular group of investors, preventing informed investors from "cherry-picking" only the best.

preventing random free riders from overwhelming the process. For risk averse entrepreneurs that have an enormous investment in their company, the reduced risk of book building may be attractive even *if* it comes at the cost of greater underpricing (and it's not clear, based on the empirical evidence so far, that auctions automatically lead to less underpricing).

Last, I identify circumstances under which auctions may have an advantage. From an information-gathering perspective, auctions are more likely to be optimal if pre-existing, "serendipitous" information about the issuer is widely dispersed among investors. Thus, auctions are more likely to be chosen for privatizations, for companies with a large but scattered customer and/or employee base and, in general, for companies and industries that are well established and well understood. On the other hand, if the auction method is chosen by a small, obscure company in an industry that investors are not familiar with, the choice may signal that the issuer is trying to discourage investors from closely scrutinizing the offering.

This paper extends and updates the work of Loughran, Ritter and Rydqvist (1994) on the institutional detail of IPOs in various countries. Loughran et al also present data to show that underpricing of IPOs exists to some extent in virtually all countries and for many issue methods. Cornelli and Goldreich (2001) examine a unique data set of international book building allocations and find that the underwriter favors both regular investors and investors that supply information on the value of the issue.

Ljungqvist, Jenkinson and Wilhelm (2000) compare data on book building and public offer IPOs for a large number of countries. They find that book building is substantially more expensive than public offer and that it does not, by itself, reduce underpricing. However, book building leads to lower underpricing when conducted by U.S. banks and/or targeted at U.S. investors and, for "the great majority of issuers, the gains associated with lower underpricing outweigh(s) the additional costs associated with hiring U.S. banks or marketing in the U.S."[7]

In the auction literature, relatively little work has been done on endogenous entry and information purchase in a common value setting, with the notable exception of Hausch and Li (1993). Biais and Faugeron-Crouzet (2001) show that a uniform price dirty auction[8] can

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[7] Other IPO papers not elsewhere mentioned include Loughran and Ritter (2000), Habib and Ljungqvist (2001), Schultz (2001), Pichler and Wilhelm (2001), Ljungqvist and Wilhelm (2001), Maksimovic and Pichler (2001a, 2001b), Busaba (2000), Spatt and Srivastava (1991), Welch (1992), Chemmanur (1993), Chemmanur and Fulghieri (1994), Kim and Ritter (1999), Dunbar (2000), Goergen (1998), Camp and Munro (2000), Arosio, Guidici and Palear (2000), and Dewenter and Field (2001).

[8] A dirty auction, a.k.a. "leaving something on the table", is an auction where the price chosen is below the market-clearing price. In other words, the price is deliberately set below the maximum level that would allow all

prevent tacit collusion among bidders and can truthfully elicit information from investors in much the same way as book building. Parlour and Rajan (2002) also show strong similarities between dirty auctions and book building. They demonstrate that dirty auctions can reduce the winner's curse (eliciting more aggressive bids) under a variety of allocation rules, including some that allow the underwriter to discriminate between bidders. Bulow and Klemperer (1998) also show that it can be optimal in an auction to set a price at which there is excess demand.

The rest of the paper is organized as follows. Section 2 documents international patterns in issue methods. Section 3 contains models of both book building and auctions: 3.1 specifies the environment, 3.2 presents the book building model and 3.3 presents the auction model. Section 3.4 compares the book building and auction solutions, while section 3.5 discusses empirical implications. Section 4 discusses circumstances under which auctions may be superior to book building. Section 5 is the conclusion.

2. Description of IPO methods

Three methods are most common globally for IPOs – 1) public offer (a.k.a. fixed price, open offer or universal offer), in which the issue price is set first, and then orders are taken from investors who typically pay in advance for part or all of the shares that are ordered[9]; 2) a tender or auction; and 3) book building, in which the underwriters do road shows and take non-binding orders from investors before setting the issue price. Under the book building method, the underwriter has substantial control over allocations and tends, in practice, to favor regular investors and investors that provide information (see Cornelli and Goldreich, 2001).

The key difference between book building and other IPO methods is that the book building method gives underwriters control over the allocation of shares.[10] In contrast, auctions require allocations to be based on current bids, without regard to any past relationship between certain bidders and the auctioneer, and they are usually open to everyone. The public offer method normally includes "fairness rules" which limit discrimination.

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shares to be sold (which means that shares must be rationed). Dirty IPO auctions have been used in Australia, Belgium, Finland, France, Hungary, New Zealand, the United Kingdom and the United States.

[9] Best efforts, the second most common method in the U.S., bears some similarities to public offer. The main differences are that for best efforts, the number of shares to be issued may vary, and there is no set order period (the order period ends when either the full number of orders has been received, or the issuer gives up and cancels).

[10] This control is limited in the obvious ways, forbidding the underwriter from allocating shares to its own employees or their close relatives and from keeping shares to be sold at a higher price on the aftermarket. Cornelli and Goldreich (2001) find that underwriters use their discretion to favor investors that provide information.

It is the ability to allocate shares freely that makes "book building" (the advance gathering of indications of interest) possible. Under an auction or public offer system, underwriters are free to do road shows and to ask for indications of interest. However, without the ability to make allocations dependent on the information reported, there is no way for underwriters to give investors the incentive to accurately report their information.

Hybrid offerings, with separate tranches using different methods, are common. There have been hybrid auction/public offer and auction/book building IPOs, but by far the most common combination is book building/public offer. For most hybrids, book building is used to set the price and to allocate shares to institutional and foreign investors, while a public offer tranche is reserved for local retail investors who do not participate in the price-setting process.

2.1 The rise of book building

By far the strongest trend in IPO methods in the 1990s is the increased use of book building. The initial impetus for the spread of book building was the wave of privatizations, which were first made fashionable by Margaret Thatcher of the United Kingdom. Privatization became popular in most parts of the world (including formerly communist Eastern Europe) in the late 1980s and the 1990s (see Dewenter and Malatesta, 1997), with privatization IPOs dominating many national stock markets in the 1990s. Since many privatizations are too large for the local market, and since the U.S. has such large, open, liquid capital markets, issuers and underwriters around the world naturally became more familiar with the U.S. issue method.

Table 1 summarizes the IPO methods used in various countries[11]. By comparing columns, one can see from Table 1 that both book building and public offer are common worldwide, while auctions are rare. Hybrid book building/public offer is perhaps even more popular than “pure” book building. Hybrid methods have even appeared in the U.S., through underwriters such as Wit Soundview and WR Hambrecht that allocate shares to the general public through an open process using pre-specified allocation rules - i.e. through a version of the public offer method.[12] Although Sherman (2000) shows that there is a cost to hybrid rather than pure book building, underwriters and issuers may feel that it is worth the cost to allow

[11] This table is a summary of the more detailed country information in Appendix F. In Table 1, a blank in any column means that the answer, to the best of my knowledge, is no, the method was/is not used. Note that this table focuses on methods used *within* various countries. Issuers can also list elsewhere, rather than in the domestic market. Ljungqvist, Jenkinson and Wilhelm (2000) examine both international and purely domestic IPOs.

[12] WR Hambrecht uses auctions to sell IPO shares only when it is the lead underwriter. It distributes shares to retail investors in other offerings in which it is a member of the syndicate. In the U.S., Epoch Capital also distributes IPO shares to retail investors, but in a selective manner that focuses on the preferences of the issuer.

"equal access" for public relations purposes. Bierbaum and Grimm (2002) show that, in some cases, public offer may dominate auctions for the retail tranche of a book building hybrid.

2.2 Auctions

Historically, auctions have been used in a wide variety of circumstances. They are popular for government bonds and are often used in privatizations. For IPOs, however, auctions are surprisingly rare, as can be seen from the last column of Table 1. Although many countries allow them and some have required them, there are few, if any, countries where auctions have been consistently popular even after the introduction of book building.

The rarity of IPO auctions is not due to unfamiliarity. Auctions were used in Italy, Portugal, Switzerland and the U.K. in the 1980s, and in Singapore in the 1990s, but were voluntarily abandoned in all of these countries even before book building was introduced. In Japan and France, auctions were used for many years but vanished almost immediately in Japan and dried up gradually in France (except on the unregulated over the counter market) once unrestricted book building was allowed. Argentina abandoned auctions for privatization IPOs after a bad experience in 1992.

Auctions are still used frequently in Taiwan, where book building is allowed but not used. However, market participants blame regulatory restrictions for the lack of book building[13]. Auctions are also the primary method in Israel, where book building is prohibited. Hybrid book building/auctions on the exchange were used in Chile (because of regulations requiring an auction tranche). It is possible that IPO auctions will be used in Peru in the future, even though book building has been gaining popularity there. Because IPO markets in Peru, Chile and throughout South America have been slow for the past few years[14], it is hard to predict whether auctions will re-emerge in that region once the markets recover.

[13] The restriction is that book building can only be used when the majority of the shares sold are new shares, whereas auctions can only be used when the majority of the shares are existing shares sold by current stockholders. It is commonly believed that issuing new shares in an IPO leads to much greater regulatory scrutiny and a long delay. So, most companies planning an IPO in Taiwan first issue new shares to existing stockholders, who then sell the shares to the public in the IPO.

[14] Delistings have greatly outnumbered new listings in Brazil, Argentina and Chile. Chile's last IPO was in 1997.

Table 1. Country patterns in IPO methods

	Book Building			Public Offer		Auction
	Used at least sometimes	**Dominant or gaining popularity**	Hybrid BB/PO used	Used in past	Used today (not incl. hybrids)	Used today
Europe						
Austria	yes	**yes**	yes	yes	?	
Czech Republic				yes	yes	?
Finland	yes	**yes**	yes	yes	yes	
France	yes	**yes**	yes	yes		occasionally
Germany	yes	**yes**	yes	yes		
Hungary	yes	**yes**	yes	yes	yes	
Ireland	yes		yes	yes	yes	
Italy	yes	**yes**	yes	yes		
Netherlands	yes	**yes**	yes	yes		
Norway	yes	**yes**	yes	yes		occasionally
Portugal	yes	**yes**	yes	yes	yes	
Spain	yes	**yes**	yes			
Sweden	yes	**yes**	yes	yes	yes	
Switzerland	yes	**yes**	yes	yes		
United Kingdom	yes	**yes**	yes	yes	yes	
N. & S. America						
Argentina	yes	**yes**	yes			
Barbados				yes	yes	
Brazil	yes	**yes**	?	yes	yes	
Canada	yes	**yes**	yes			
Chile	yes	**yes**				hybrid
Mexico	yes			yes	?	
Paraguay				yes	yes	
Peru	yes	**yes**	yes	yes	yes	occasionally
United States	yes	**yes**	yes			occasionally
Asia/Pacific						
Australia	yes	**yes**	yes	yes		
Bangladesh				yes	yes	
China	yes	**yes**	yes	yes	yes	
Hong Kong	yes	**yes**	yes	yes	yes	
India	yes		yes	yes	yes	
Indonesia				yes	yes	
Japan	yes	**yes**	yes			
Korea	yes	**yes**	yes	yes		
Malaysia				yes	yes	
New Zealand	yes	**yes**	yes	yes	yes	
Philippines		**yes**	yes	yes	?	
Singapore	yes		yes	yes	yes	
Sri Lanka				yes	yes	
Taiwan				yes	yes	yes
Thailand				yes	yes	
Africa/Middle East						
Kenya				yes	yes	
Israel				yes	yes	yes
Jordan				yes	yes	
South Africa	yes		yes	yes		
Turkey				yes	yes	

In summary, out of more than 40 countries, I have not been able to find even one in which auctions are dominant *even though book building is freely available*. In the many countries that do not restrict issuers to a particular method, auctions are relatively rare, although they are still used sporadically in parts of Europe. Most of the countries that experimented with auctions in the 1990s or 1980s abandoned them within a few years. In the few places where auctions are still used frequently, there are legal restrictions on the book building method.

Several types of auctions have been used. Brazil, Japan, the Netherlands, Singapore, Taiwan and the U.K. have used discriminatory (pay what you bid) auctions, while Argentina, Australia, Brazil, Finland, France, Israel, New Zealand, Norway, Peru, Portugal, Singapore, Turkey, the U.K. and the U.S. have used uniform price auctions[15]. Chile uses an auction on the exchange, which is similar to an English (open, ascending bid) auction. Dirty auctions (where the price is set below market-clearing) have been used in Australia, Belgium, Finland, France, Hungary, New Zealand, the United Kingdom and the United States, and have been especially common for IPOs in Belgium, France and the U.K.

A recent exception to the disappearance of IPO auctions is the use of uniform price auctions to sell IPO shares through the internet. W.R. Hambrecht distributed its sixth U.S. IPO through an online auction in May, 2001, while Ord Minnett's eCapital[16] distributed shares in two Australian IPOs through a similar method. Both underwriters use uniform price, sealed bid dirty auctions[17], although eCapital called its process a "book build". In South Korea, several

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[15] In financial markets, uniform price auctions are sometimes (mistakenly) called Dutch auctions. A Dutch auction is an open, descending bid auction, such as the method that is often used to sell flowers and produce in the Netherlands: First a high price is called out, then progressively lower prices are called until someone agrees to purchase at least some of the units. Those units are sold at that price and then the auction is restarted, often at a somewhat higher price, and the price continues to descend until all units are sold. In the end, units may be sold at many different prices. Thus, the closest sealed-bid equivalent to a Dutch auction would be a discriminatory, not a uniform price, auction.

[16] The two auctions, for Health Communications Network (HCN) and ChaosMusic, occurred in 1999. Since then, Ord Minnett merged with Chase and J.P. Morgan, and eCapital appears to be closed, reportedly because both auctions led to overpricing, thanks to free riders.

[17] Hambrecht allows dirty auctions, at the discretion of the issuer, but only one issuer has exercised this option so far. Andover.net was priced on Dec. 7, 1999 at $18 per share, although the market clearing price in the auction was $24. Andover apparently chose to "leave something on the table" only to avoid a delay in completing the IPO. So far, other Open IPO auctions seem to have been priced as high as possible (although I was unable to get a definite answer on whether its last auction, Briazz, was priced below clearing; Briazz priced at the bottom of its range and winning bidders received approximately 70% of their orders). There has also been one hybrid book building/auction in the US, for Instinet, priced on May 23, 2001. The price was set and most of the shares were allocated through book building, but bidders in the auction portion, managed by WR Hambrecht, each received about 13.4% of their bid, provided that their bid was at or above the issue price of $14.50.

Direct Public Offerings have used internet auctions, although this method cannot legally be used if the company wants to list on the KSE or KOSDAQ.

2.3 Public Offer

As can be seen from Table 1, the public offer method is very common worldwide, at least in terms of the number of countries that use it. It is becoming less common, particularly for larger issues and in larger, more active markets. Chowdhry and Sherman (1996a) point out that two features of public offers tend to lead to greater underpricing, relative to the book building method: 1) the need to set the price farther in advance (increasing the risk that an offer will fail due to "information leakage") and 2) the common requirement that investors pay in advance for their entire order, with the issuer typically allowed to keep the interest on these funds (there is a recent trend towards requiring only partial "installment" payments that will mitigate this effect). In addition, Sherman (2000) shows that the use of public offer even for one tranche of a hybrid offering, where book building is used to set the price, can lead to higher underpricing than with pure book building.

Nevertheless, public offer remains popular and unlikely to vanish completely. It is an efficient, low cost way to distribute shares to retail investors, avoiding the high fixed costs of road shows (Ljungqvist, Jenkinson and Wilhelm, 2000, document the lower direct costs). It doesn't rely on long term relationships between the underwriter and investors, as does book building. The pay in advance feature allows orders to be collected from many unknown investors without a risk of subscriber defaults, and it often has the added benefit of generating float for the issuer. For relatively inactive markets such as Barbados, which had only 3 IPOs in 1994, none in 1995 and 2 in 1996, the public offer method has strong cost advantages.

3. The Model

To compare book building to auctions, I first define what qualifies as an auction. The term "auction" is used loosely in a variety of settings that involve some sort of feedback ("bids") on the value of the auctioned object(s), and published research on auctions seldom, if ever, gives a general definition. The key distinction between book building and auctions is that, with book building, the underwriter can refuse any order for any arbitrary reason. With auctions, the auctioneer is expected to follow pre-set rules and is not allowed to allocate based on past personal relationships. Therefore, the definition of an auction in this paper is that

allocations are determined solely by bids[18]. In other words, any two bidders that place the same bids are expected to receive the same allocations.

I analyze both book building and auctions for the same environment. The auction is a discriminatory (pay what you bid), multi-unit, common value auction with endogenous entry and information acquisition. The book building model extends previous work by characterizing the optimal solution when the issuer is allowed to price-discriminate, and by endogenizing the accuracy level of individual investors' signals. Investors choose the amount of time and attention to devote to scrutinizing the firm, knowing that greater attention tends to lead to greater accuracy. The issuer selects both the number of investors that will be allowed to participate and the accuracy of each investors' information, setting prices and allocations in order to induce investors to purchase the optimal amount of information.

3.1 The environment

The environment is the same for both models. The issuer requires a fixed amount of capital and plans to sell a fixed number of shares, X. If it raises more than is needed, any excess will be paid to the original shareholders. The issuer is risk neutral and maximizes the expected proceeds minus f(P(·,0)), a term which reflects the possibility of price inaccuracy. In other words, the issuer prefers higher to lower expected proceeds, but also prefers a more accurate valuation of the issue[19]. P(·,0) is the probability that the true state is not discovered. I assume that $f(P(\cdot,0)) > 0$ for all $P(\cdot,0) \in \{0, 1\}$, $f'(\,) > 0$, $f''(\,) < 0$, $f(0) = 0$ and $f(1)$ is sufficiently large, relative to the cost of the information ($C(\alpha)$), that the underwriter will always choose to induce investors to purchase at least some information.

There are two dates. The market price at date two, the initial trading date, reflects the true state, high (*h*) or low (ℓ). On date two, the value per share given state j, $j \in \{h, \ell\}$, is s^j. For simplicity and without loss of generality, $s^h = 1$ and $s^\ell = 0$. State *h* occurs with probability θ. Thus, the expected value per share is $s^m = \theta\, s^h + (1 - \theta)\, s^\ell = \theta$.

There are N investors with access to both capital and information ("informed investors"). They must purchase their information, paying $C(\alpha)$ dollars for a signal that has

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[18] Parlour and Rajan (2002) take the opposite approach, using the term auction in a broader sense that includes book building, public offer, best efforts and other IPO methods as subsets or types of auctions. While this is a reasonable approach, it leads to the problem of what term to use for "traditional" auctions.

[19] Reasons why the issuer might prefer more accurate valuation are discussed briefly in the introduction. Moreover, I show that the extra flexibility of book building benefits even an issuer that does not value greater

probability α of revealing the true state (H if *h* or L if ℓ). With probability 1 - α the investor receives a neutral signal (M). There is zero probability that the investor gets a false high or low signal (H if ℓ or L if *h*).[20] $C(\alpha)$ is twice differentiable, strictly increasing and strictly convex for $\alpha \in (0, 1)$, and $C(0) = 0$. Assume $N > X$, so it is possible for informed investors to purchase the entire issue. There is also a plentiful supply of uninformed investors (investors that are unable to purchase information, or at least cannot obtain information at a competitive price).

All investors have an alternative investment with an expected net rate of return of r, which to simplify notation is set equal to 0. Investors that wish to participate in the IPO must pay a fixed entry cost $e > 0$, which can be thought of as a dead weight "bid preparation" cost or as a fixed cost of evaluation.

The unconditional probabilities of state *h* occurring and of none of the K informed investors receiving signals H or L are $P(h,0) = \theta (1 - \alpha)^K$ and $P(\ell,0) = (1-\theta) (1 - \alpha)^K$. The unconditional probability that none of the K investors receive informative signals is $P(\cdot,0) = P(h,0) + P(\ell,0) = (1 - \alpha)^K$. The conditional probability that 0 of the K-1 other investors will receive an H or L signal is $P'(h,0) = P'(\ell,0) = P'(\cdot,0) = (1 - \alpha)^{K-1}$. The unconditional probability of state *h* occurring and of k of the K informed investors receiving signal H is:

$$P(h, k) = \theta \binom{K}{k} \alpha^k (1 - \alpha)^{K-k}$$

Similarly, P(entry = i) is the probability that i of N potential auction bidders will choose to enter the auction (given that the probability of entry by each individual is p):

$$P(\text{entry} = i) = \binom{N}{i} p^i (1 - p)^{N-i}$$

3.2 The book building solution

To match the essential feature of book building, I assume that the underwriter controls the allocation of shares. The underwriter can and will communicate with shareholders before setting the issue price, choosing an allocation and pricing scheme that gives investors an

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price accuracy, since the flexibility can be used to minimize underpricing.

[20] High or low signals may be interpreted as the detection of favorable or unfavorable information on the market value of a firm that was not discovered by the underwriter. I assume that information known by the firm and/or

incentive to purchase and report the desired amount of information. I do not impose a one price rule - the underwriter can and will charge different prices to different investors.

I assume that there are no conflicts of interest between the underwriter, who will be pricing and marketing the issue, and the entrepreneur/issuer. Both prefer a high issue price but also value price accuracy. Biais, Bossaerts and Rochet (1998) examine the other extreme, assuming that the underwriter colludes with informed investors against the issuer.

To distribute and price the issue, the underwriter enlists the help of K risk neutral informed investors, where K is chosen by the underwriter. The underwriter also prices the issue and decides how many shares to allocate to each investor. The allocation to each investor may depend on both the signal reported by that particular investor and the signals reported by other investors (i.e. on k, the number of investors out of K that report either H or L).

Informed investors may report H, L or M ("neutral"), while the uninformed "report" only U (a notational convenience to minimize the amount of separate terms introduced, since the underwriter may select different prices and allocations for informed investors reporting informative signals, informed investors reporting neutral signals, and uninformed investors). The following notation is for all $i \in \{H, L, M, U\}$, $j \in \{H, M\}$, $t \in \{M, U\}$:

$s_{i,j,k}$ = issue price to an investor that reports i when j is reported by k of K informed investors;
$q_{i,j,k}$ = allocation to an investor that reports i when j is reported by k of K informed investors;
$s_{t,M}$ = issue price to an investor that reports t when all informed investors report M; and
$q_{t,M}$ = allocation to an investor that reports t when all informed investors report M.

At date 1, the underwriter announces the price and allocation schedule and selects the informed investors who will be allowed to participate in the offering. Those investors then decide whether to purchase a signal and whether to reveal that signal to the underwriter. Next, the underwriter sets the offering prices and allocations, based on the information provided by informed investors. Any shares not allocated to informed investors may be sold to uninformed investors. At date 2 the shares begin trading and the true value per share is revealed. Below is a summary of the timing in this model.

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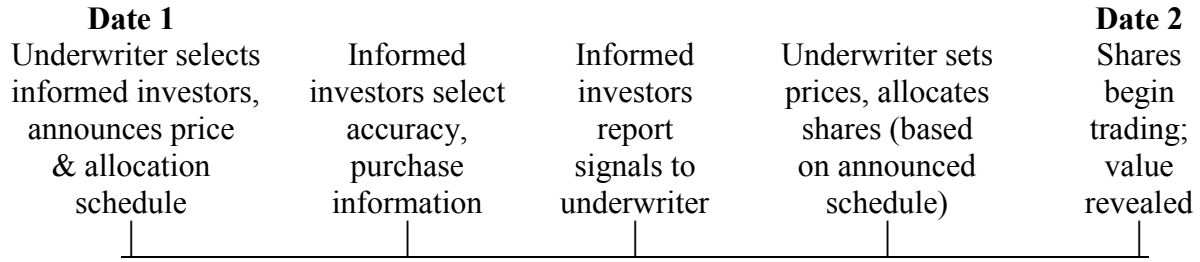
the underwriter has already been signaled to investors.



3.2.a Information reporting constraints

As part of its book building strategy, the underwriter must design an allocation and pricing schedule that elicits accurate information from investors. Since the investment bank will use the reported information to price the issue, the pricing and allocation strategy must counteract investor incentives to withhold favorable information that will lead to a higher issue price. I consider Nash equilibria where, conditioned on the underwriter's strategy, investors have an incentive to truthfully reveal their information, given their expectation that other investors will also report information accurately.

There will typically be multiple solutions to the underwriter's problem, with many sets of allocations and prices that elicit truthful revelation and give both the underwriter and investors the same expected utility. To eliminate these extraneous equilibria, I assume without loss of generality that all investors that report the same signal receive the same allocation. I also assume that the underwriter allocates zero shares to all investors who reveal conflicting signals. Although such conflicting reports will not exist within the equilibrium, this out-of-equilibrium assumption is needed to fully specify the equilibrium.

Let R(j,i) be the expected profit to an informed investor who receives signal j and reports signal i. In equilibrium, informed investors are induced to report their information truthfully, which implies that the following truth-telling constraints (described in more detail in Appendix A) must be satisfied[21]:

$$R(j,j) \geq R(j,i) \text{ for all } j, i \in \{H, M, L\} \quad (1)$$

[21] Note that the cost of acquiring information does not affect the information reporting conditions, since it is a sunk cost by the time the investor decides what signal to report. On the other hand, whether or not the investor plans to accurately report information certainly affects the incentive to purchase a signal. After all, if the investor planned to report M (or H or L) regardless of the actual signal, then there would be no reason to buy a signal.

3.2.b Participation and information collection constraints

In addition to the truth-telling conditions, constraints are needed to guarantee that informed investors choose to participate and to acquire information. The binding constraint[22] is that buying and reporting a signal offers a higher expected profit than not purchasing a signal and falsely reporting M:

$$\alpha\,\theta\,R(H,H) + \alpha\,(1-\theta)\,R(L,L) + (1-\alpha)\,R(M,M) - C(\alpha) - e \;\geq\; R(M,M).$$

This expression can be re-written as

$$\theta \sum_{k=1}^{K-1} P'(h,k)[(s^h - s_{H,H,k+1})q_{H,H,k+1} - (s^h - s_{M,H,k})q_{M,H,k}] + \theta P'(h,0)[(s^h - s_{H,H,1})q_{H,H,1} - (s^m - s_{M,M})q_{M,M}]$$
$$+ (1-\theta) \sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{L,L,k+1})q_{L,L,k+1} - (s^\ell - s_{M,L,k})q_{M,L,k}]$$
$$+ (1-\theta)\,P'(\ell,0)\,[(s^\ell - s_{L,L,1})q_{L,L,1} - (s^m - s_{M,M})q_{M,M}] \quad \geq \quad (1/\alpha)\,(C(\alpha) + e) \qquad (2)$$

We also need to guarantee that uninformed investors have an incentive to participate. Uninformed investors face no costs for participating, so they will be willing to purchase shares unless the shares are overpriced, which leads to the following set of constraints:

$$s_{U,j,k} \leq s^j \text{ and } s_{U,M} \leq s^m \text{ for all } j \in \{H, L\},\ k \in \{1,2,..,K\} \qquad (3)$$

Last, informed investors will not participate, once the state is revealed, if the shares are overpriced. This gives us our final set of investor constraints:

$$s_{i,j,k} \leq s^j \text{ and } s_{M,M} \leq s^m \text{ for all } j \in \{H, L\},\ i \in \{H, M, L\},\ k \in \{1,2,..,K\} \qquad (4)$$

3.2.c The Underwriter's Objective

As already described, the issuer/underwriter prefers higher to lower expected proceeds but also places some value on the accuracy of the issue price. The underwriter has a very large number of choice variables in this model, making presentation of the full optimization problem messy. However, some of the choice variables can be determined by substituting in from the

[22] In addition, buying a signal and reporting it must be at least as good as saving the costs e and $C(\alpha)$, and either falsely reporting H or L, or not participating at all. As long as the truth-telling constraints are satisfied, however, the return to falsely reporting H or L will never be higher than the return to falsely reporting M.

constraints already presented, thus greatly simplifying the maximization problem of the underwriter. The following proposition details basic features of the equilibrium solution:

Proposition 1: The book building equilibrium will be such that:

1) $s_{U,j,k} = s^j$ and $s_{U,M} = s^m$ for all $j \in \{H, L\}$, $k \in \{1,2,..K\}$;

2) $s_{j,L,k} = s^\ell$ for all $j \in \{L, M\}$, $k \in \{1,2,..K\}$;

3) $s_{M,H,k} = s^h$ and $s_{M,M} = s^m$ for all $k \in \{1,2,..K\}$

In other words, the underwriter will not underprice shares 1) to uninformed investors; 2) when state L is revealed; or 3) to informed investors that report a neutral signal (M). Thus, shares will be underpriced only to informed investors that report a good signal (H).

Proof: See Appendix B.

Given these features of the equilibrium, the underwriter's choice variables are K, α, and the prices and allocations for informed investors that report a good signal. These variables are chosen to maximize a utility function that is a separable function of the accuracy of the initial aftermarket price and the expected proceeds of the issue. In particular, the underwriter chooses K, the number of investors invited to participate in the offering, and α, the accuracy of each informed investor's signal, by trading off the increase in accuracy associated with a larger number of more accurate signals against a corresponding increase in the required underpricing to compensate investors for their evaluation costs. The underwriter's maximization problem is:

$$\underset{\substack{K,\ \alpha,\\ s_{H,H,k} \text{ and } q_{H,H,k}\\ \text{for } k \in \{1,2,..,K\}}}{\text{Max}} \quad X\theta - K\sum_{k=1}^{N} P(h,k))\,(s^h - s_{H,H,k})\,q_{H,H,k} - f(P(\cdot,0))$$

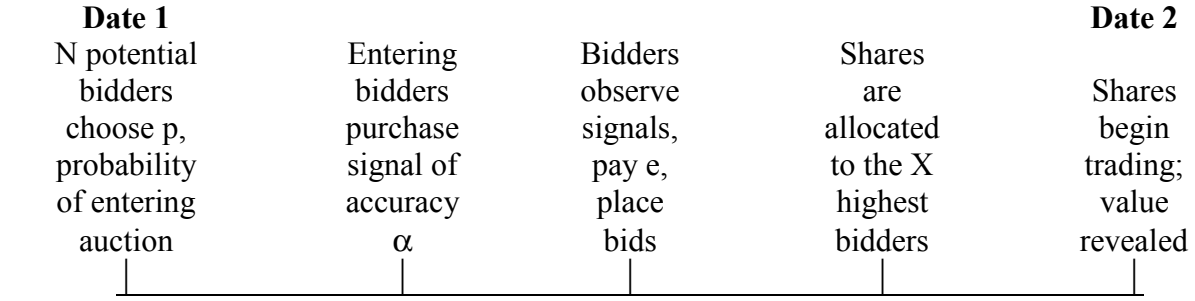
Subject to equations (1), (2), (3) (4), and the restrictions that prices and allocations cannot be negative and that exactly X shares are sold.

3.3 The auction model

In this section I will determine the bidding strategies and entry probability in a multi-unit, sealed bid, discriminatory auction, given the environment described in section 3.1. For simplicity, I assume that shares are allocated to bidders even if the number of bids is less than

X, the available number of shares, and that each bidder can only bid for one share [23]. I analyze a discriminatory auction to avoid the free rider problem inherent in uniform price auctions. As discussed in section 2.2, both discriminatory and uniform price auctions have been used for IPOs in the past.[24]

In this model, both the number of bidders and the precision of each bidder's information is endogenous. Each potential bidder chooses p, the probability that the bidder will choose to enter the auction, and α, the accuracy of the information purchased. There are N potential bidders for the X available shares. The timing is as follows:



I do not specify the issuer's maximization problem for the auction because, although the issuer has the same preferences as with book building, it does not have any choice variables. The rules of the auction do not allow the issuer to choose either the issue price or individual allocations. Sherman (2001) discusses the possibility that the issuer can adjust e, N or the type of auction (discriminatory vs. uniform price) to affect the outcome, although such discretion would be greatly limited in most countries.

Before the auction begins, bidders chose the symmetric equilibrium pair (p, α) (for sufficiently large N) such that

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[23] Limiting bidders to one share each may have some effect on the equilibrium, although this is more likely to be a problem with a uniform price rather than a discriminatory auction. Allowing bidders to place multiple bids at different prices can lead to bid-shaving in a uniform price auction (see, for instance, Ausubel and Cramton, 1998b). The likelihood of collusion may also change (Back and Zender, 1993) The choice of uniform price vs. discriminatory auction may affect the number of units for which people would like to bid (Tenorio, 1997).

[24] There has been much work done comparing uniform price and discriminatory auctions, with varying results. In a wide range of settings, particularly with private values, a uniform price auction maximizes the seller's expected revenue. However, when entry is endogenous, a uniform price auction may also lead to a higher probability of failure (i.e. of an insufficient number of bids). In a single unit auction, Hausch and Li (1993) show that the choice between a first and a second price auction also affects the seller's expected revenue through the amount of information collection. There may also be differences in the likelihood of collusion.

$$g(\alpha,p) = \frac{\alpha\theta\,[1 - \theta + \theta\,(1 - p))^{N-X}]}{\theta + (1 - \theta)\,(1 - p\alpha)^{X-N}} + (1 - \alpha)\,\theta\,(1 - p)^{N-X} - C(\alpha) - e = 0$$

$$h(\alpha,p) = \frac{\theta\,[1 - \theta + \theta\,(1 - p))^{N-X}]}{\theta + (1 - \theta)\,(1 - p\alpha)^{X-N}} - \theta\,(1 - p)^{N-X} - C'(\alpha) = 0$$

where $g(\alpha,p)$ is the expected profit of a bidder who acquires information of accuracy α and $h(\alpha,p)$ is the derivative of the bidder's expected profit function with respect to α, given that the other bidders hold their choice of α fixed. We can define:

$$w(\alpha,p) \equiv g(\alpha,p) - \alpha\, h(\alpha,p) = \theta\,(1 - p)^{N-X} + \alpha\, C'(\alpha) - C(\alpha) - e.$$

This expression is useful because it is monotone in α (whereas $g(\alpha,p)$ is not). In finding an equilibrium, we can replace the condition $g(\alpha,p) = 0$ with the condition $w(\alpha,p) = 0$. If N is too small, then all potential bidders will enter and bidders will choose α such that $h(\alpha,1) = 0$. Assume that $C'(0) < (\theta-e)(1-\theta)$. The solution to the auction is as follows.

Proposition 2: In the first stage of the auction, potential bidders decide whether or not to enter, and they choose their information accuracy. The unique symmetric equilibrium takes one of two forms.

1) If N is sufficiently low relative to X (i.e. if the number of potential entrants is small enough), then $p = 1$ and α satisfies $h(\alpha,1) = 0$.

2) Otherwise, α and p uniquely solve $h(\alpha,p) = 0$ and $w(\alpha,p) = 0$.

In the second stage of the auction, the bidding, bidders that receive the signal L do not bid, those with signal M draw a bid from the cumulative bidding distribution $M(b;\alpha,p)$ and bidders that observe signal H draw a bid from $H(b;\alpha,p)$.

Proof: See Appendix C.

The two cumulative bidding distributions are also given in Appendix C. Bidders in this model bid in distinct intervals. Those that receive a low signal bid zero, while those that receive a neutral signal will randomize over a range from zero to an upper bound of $m(\alpha,p)$, where $m(\alpha,p) < \theta$. Those that receive a high signal will randomize over the interval from $m(\alpha,p)$ to $n(\alpha,p)$, where $n(\alpha,p) < 1$. Thus, the upper limits of the optimal bidding ranges for

investors that receive either an M or H signal are always strictly less than the expected values given those signals, meaning that the auction always leads to underpricing.

The bidders' ex ante expected profits are zero. Even though the cost of information is a sunk cost by the time the bidder submits his bid in stage 2, the choice of the entry probability p in stage 1 depends on information costs. The expected number of bidders entering the auction will be sufficiently low for the bidders to recover their cost of evaluation. The seller ends up indirectly paying for the evaluations of the investors through a lower expected selling price.

3.4 Comparison of the book building and auction solutions

Both the book building and the auction equilibria involve underpricing. The following proposition lays out the expected proceeds under each method.

> **Proposition 3:** The book building and auction solutions will result in the following expected proceeds or "seller's expected revenue", SER_{BB} for book building and $SER_{Auction}$ for the auction:

$$SER_{BB} = \theta X - K[C(\alpha) + e] \tag{5}$$

$$SER_{Auction} = \theta X \left(1 - \sum_{i=0}^{X-1} P(\text{entry} = i) \left(1 - \frac{i}{X} \right) \right) - p N [C(\alpha) + e] \tag{6}$$

> *Proof*: See Appendix D.

A comparison of equations (5) and (6) demonstrates the similarities and differences of the two methods. For both, the expected value of the shares for sale is θX (X shares worth, on average, θ each). Both SERs are reduced by the last term, the expected information expenditures of $C(\alpha) + e$ per investor. The information costs vary both through α, which is chosen endogenously, and through the expected number of investors. For book building, the underwriter selects K investors. For the auction, the expected number of bidders is equal to N, the number of potential investors, times p, the equilibrium probability of entry of each bidder. In addition, the first term of $SER_{Auction}$ is more complicated than the θX from SER_{BB}, because it is possible that fewer than X shares will be sold. Thus, the auction expected proceeds are lowered by the probability of undersubscription.

In other words, for both methods the expected proceeds are equal to the expected value of the shares sold, minus the expected information costs of the investors. In this sense, the

book building and auction solutions at first seem to be equivalent, but there are two key differences: 1) the greater ability to control information expenditures, and thus control expected proceeds, with book building; and 2) the possibility of undersubscription in the auction, which strictly lowers expected proceeds.

I illustrate these differences through a simple numerical example. Consider two otherwise identical issuers that differ only in their relative preferences for greater accuracy vs. a higher expected issue price[25]. In other words, the two issuers have two different functions for f(P(·,0)), the value of information. Let $\theta = 0.5$, $C(\alpha) = 0.2\alpha^3$, $e = 0.005$, $X = 3$ and $N = 5$. The preferences for price accuracy are: $f(P(\cdot,0)) = 0.2\ (P(\cdot,0))^{0.5}$ for Issuer 1, who has only a slight preference for more information and $f(P(\cdot,0)) = 2.0\ (P(\cdot,0))^{0.5}$ for Issuer 2, who has a stronger preference for information.

The solution to this example is shown in the table below. The underpricing given is the amount needed to compensate investors for their cost of information, as a percentage of the expected value of all shares being offered (i.e. without adjusting for undersubscription)[26]. The "information level" = 1 - P(·,0) = the probability that the true state is revealed.

	Underpricing		Information Level		Probability of
	Issuer 1	Issuer 2	Issuer 1	Issuer 2	Undersubscription
Book building	1.1%	13.4%	32.0%	97.1%	0.0%
Auction	5.6%	5.6%	83.0%	83.0%	32.8%

Investors do not receive excess returns under either method. In that sense, auctions are fairly efficient and may, in some cases, give the issuer a near-optimal solution (ignoring the risk of undersubscription). However, near-optimality of the auction solution occurs only by chance. If the outcome does not match the issuer's preferences, the issuer has little alternative.

In this case, the auction solution for both issuers involves underpricing of 5.6% and an 83% probability that the true value of the project will be revealed. With book building, on the other hand, the underwriter can match the information-gathering preferences of each issuer, offering 1% underpricing and a 32% information level to the issuer that is primarily concerned

[25] Readers skeptical of the idea that issuers might value anything other than the highest possible expected proceeds may choose to focus only on the solution for the issuer that puts very little weight on price accuracy.

[26] In other words, the expected underpricing for the auction will be strictly greater than the amount shown, because the expected number of shares sold is less than X, due to the possibility of undersubscription. I present the numbers in this way to try to separate out the two effects. The actual underpricing level is given later.

with a high issue price, and 13% underpricing and a 97% information level to the issuer with a stronger preference for price accuracy. Note that, even if an issuer does not value price accuracy and cares only about maximizing the issue price, the flexibility of book building is valuable because it allows the underwriter to minimize underpricing. Thus, this advantage of book building does not apply only to issuers that desire information from investors.

The auction solution isn't quite as efficient as book building, even for an issuer with "in between" preferences that happen to fit fairly well. To see this, consider an issuer whose preferences are such that $f(P(\cdot,0)) = 0.224\ (P(\cdot,0))^{0.5}$. The book building solution in this case would be 5.6% underpricing and an 86% information level – in other words, the same level of underpricing and slightly greater price accuracy, compared to the auction. The expected total spending on information (and thus, the underpricing) is the same, but those costs are spread across five investors for the book building solution, because K = 5 is most efficient for this particular combination of fixed and variable information costs. Since the underwriter controls K, it can always select the optimal participation level. With the auction, the expected number of bidders is only three, although the actual number of bidders could be anywhere from 0 to 5.

This brings me to the second key difference between book building and auctions: auctions are riskier. With book building, there is no risk that the issue will fail, since the underwriter will recruit a sufficient number of investors[27]. Book building can be seen in part as a co-ordination mechanism to ensure entry of the optimal number of participants. With auctions, the *expected* number of bidders may be optimal, but ex post there is still a chance that too few bidders will show up, and the auction will be undersubscribed.[28]

In my example, there is roughly a 33% probability that the number of bids will be strictly less than the number of shares available (a 24% chance of 2 bidders, 8% chance of 1 bidder and 1% chance of no bidders). After adjusting for the risk of undersubscription, the

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[27] Of course there is a risk, with either book building or an auction, that the shares will be revealed to have low value and will be priced accordingly. This means that book building IPOs may "fail" in the sense that the issuer may decide that the price guaranteed by the underwriter is too low and may withdraw the issue. Benveniste, Busaba and Guo (2000) show that about 14% of U.S. IPOs were withdrawn or postponed in 1989-94. In the U.S., firm commitment IPOs are also sometimes converted to best efforts IPOs because the underwriter will not guarantee a sufficiently high price at the final pricing meeting, and the entrepreneur prefers to take his chance on the market, rather than lock in a low price or give up altogether.

[28] In practice, many countries require IPOs to be fully or partially underwritten (meaning that the underwriter guarantees the proceeds), regardless of the issue method - book building, auction or public offer. With auctions, underwriting usually means guaranteeing the purchase of all shares at the minimum or reservation price. Thus, the issuer can often insure against losses due to undersubscription, but this does not eliminate the cost, it only evens out the distribution of that cost, reducing the uncertainty.

issuer's total expected revenues are 20.0% below the expected value of the shares for sale, rather than only 5.6% below. In other words, the total expected underpricing for the auction in my example is 20%, once both effects are considered.

My example involves a small number of potential bidders, so it's possible that the risk of undersubscription more or less disappears with a large numbers of bidders, due to the "law of large numbers". However, the number of bids must be compared to the number of eligible bidders. For Taiwan's discriminatory IPO auctions, the average number of bidders is around 1,150 (Liu, Wei and Liaw, 2002). More than 16 million adults are eligible to bid in each auction. Therefore, if the participation rate of the eligible population shifts by just seven-one thousandths of one percent in either direction, bids will either almost double or almost vanish[29].

Jenkinson and Mayer (1988) report that half (3 out of 6) of U.K. privatization tenders between 1982 and 1987 were undersubscribed (while one was 500% oversubscribed). In 1994, the auction tranche of Sunright, the last IPO auction in Singapore, was 82% undersubscribed (i.e. bids equaled only 18% of available shares), even though the public offer tranche a few days earlier had been oversubscribed. In August of 2000, the Chunghwa Telecom IPO auction in Taiwan was only 72% subscribed, leaving 80.8 million shares unsold. These examples show that the risk of undersubscription exists for IPO auctions (although a few examples cannot prove the magnitude of the problem).

As for the effect of undersubscription, it clearly tends to lower the issuer's expected proceeds, holding information expenditures constant, as discussed in the following proposition.

Proposition 4: Holding expected evaluation costs constant, $SER_{BB} > SER_{Auction}$.

Proof: See Appendix E.

Thus, the extra uncertainty of auctions leads to lower expected utility even for a risk neutral issuer. If issuers or investors are risk averse, auctions are at a greater disadvantage. The risk to investors in an auction comes from the fact that each investor must decide whether or not to enter and how much information to purchase without knowing whether or not he/she will receive shares. Each potential bidder factors in the probability that, *ex post*, either too few bidders will enter and the auction will fail, or too many bidders will enter and bid away all

[29] In addition, large average numbers of bidders will not eliminate the risk of undersubscription if there is some co-ordination, or "leakage" of information, as discussed in Chowdhry and Sherman (1996a).

potential profits (see Levin and Smith, 1994). In either of these cases, the bidder may end up paying to evaluate the issue, only to receive nothing.

3.5 Empirical implications

These results give us some empirical implications on underpricing levels for auctions versus book building. First, because book building offers lower risk for both issuers and investors, it should lead to less underpricing (holding information costs constant), as shown in Proposition 4. The long term relationships modeled in Sherman (2000) also imply that book building will lead to less underpricing, relative to auctions. On the other hand, the flexibility that book building gives issuers, in terms of controlling information expenditure, could lead to either more or less underpricing, depending on the preferences of the issuer.

One implication is that issue methods should not be judged based purely on underpricing levels. In my models, a major advantage of book building is that underpricing can be tailored to the preferences of each individual issuer, and can adapt to the circumstances of various countries or time periods. Auctions give issuers little choice – you simply offer up the shares and hope for the best – whereas book building gives issuers and underwriters more control over the process. If issuers choose to use that control to induce higher levels of information collection, and thus higher underpricing, this by itself should not be interpreted as evidence that the issuer is worse off[30].

Suppose a country changes its regulations to switch from auctions to book building, and average underpricing increases after the switch. According to my models, this would be evidence that auctions had previously been leading to inefficiently low levels of information collection and that issuers are now exercising their option to "purchase" more information (through higher levels of underpricing). Both Kutsuna and Smith (2001) and Kaneko and Pettway (2001) examine Japanese IPOs before and after the introduction of book building and conclude that average underpricing was higher under book building than under the hybrid

[30] However, evidence of collusion among underwriters might imply that issuers were being made worse off, since the book building method relies so heavily on the underwriter. For instance, Chen and Ritter (1999) offer evidence that underwriting fees in the U.S. do not respond to competition. This by itself is inconclusive, since underwriters might be competing on other dimensions. There is also evidence that underwriters allocate shares in hot issues to regular investors based on their general relationship, rather than allocating based exclusively on the current issue, or even based exclusively on repeated IPO participation. Again, this by itself is not evidence that issuers are being "cheated", since any side-benefits that an underwriter expects to receive from handling an IPO will be factored into the general package of fees and services that it offers to an issuer.

discriminatory auctions that had been used before (although Kutsuna and Smith show that the difference is small after adjusting for skewness and for the 1999 stock market rally).

Kutsuna and Smith also found that, when auctions were required in Japan, some small, high risk but high quality issuers were shut out of the market completely. In addition, they found evidence of greater book building flexibility in the size of issues: "Small issues appear to be more possible under book building, as are issues that are large relative to issuer size" (p. 22). This fits my claim that an auction is a "one size fits all" approach that is not as flexible as book building in adjusting to suit the needs of a variety of issuers.

4. When are auctions optimal?

My analysis so far has considered only information acquisition, which is appropriate for a new, young company that is not widely known by potential investors. Before investors will get involved with such an offering, they must expend time and energy to find out even the basics. Inducing costly evaluation may be less necessary for a company that is already widely known. For instance, if the IPO firm is an established company with a wide customer base, there may be many potential investors who already have some knowledge of the company. This is what Subrahmanyam and Titman (1999) call serendipitous information.

Small pieces of serendipitous knowledge by a large number of investors (each of whom, say, bought a doughnut from the issuer) are not always an adequate substitute for detailed attention to the prospectus and financial statements by professional investors. But in some cases, such pre-existing knowledge may be sufficient and much cheaper to collect. The optimal solution to the Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990) serendipitous information reporting models is to draw in as many investors as possible, driving underpricing to approximately zero, whereas the Sherman and Titman (2001) information acquisition model shows that underpricing cannot be driven to zero if there is a cost to evaluation.

Even in a model with serendipitous information, a key feature of book building is that the underwriter decides which investors will participate. What if the underwriter cannot observe which investors have been endowed with serendipitous information? Or, what if it is expensive to track down a sufficient number of these investors? It might be more efficient, in this case, to allow the investors to self-select through an open process such as a discriminatory auction (but perhaps not through a uniform price auction, where self-selection is more likely to

attract free riders). This information-gathering trade-off is similar to that modeled in Sherman (1992) for best efforts versus firm commitment IPOs.

Therefore, if there is a sufficient number of investors with serendipitous information, a discriminatory auction may be preferred to book building because of the lower fixed costs of reaching a large, dispersed investor group. This leads me to the following prediction:

An open auction is most likely to be optimal for:

- large, well established companies;
- companies with a large, dispersed customer or employee base;
- industries that are well established and widely understood.

This set of circumstances is most likely to occur for privatizations. When a country privatizes the local telephone company, for example, there are many investors with at least some direct, pre-existing knowledge of the issuer. Allowing potential investors to decide whether or not to bid, and how much to bid, may be a very efficient, incentive compatible way of inducing them to reveal their information. This may explain why IPO auctions have been most popular for privatizations. Similarly, companies that have chosen to use the W.R. Hambrecht IPO auction method have discussed wanting to reach their customers: Peet's wanted to market to its coffee drinkers; Andover.net wanted to reach the 2 million Linux developers that used Slashdot.

On the other hand, while this implies that regulators should allow the auction method and that we might see it chosen at least occasionally, it also implies that the "Open IPO" internet approach of getting "everyone" involved in every IPO may be asking for trouble. If there is a cost to information, and particularly if an issuer is small, risky and generally hard to evaluate, then lowering entry costs and opening up the process discourages investors from doing serious evaluation, and it increases the probability that free riders will eventually overwhelm the process (the free rider problem is discussed in more detail in the conclusion).

One last question is whether the choice of an auction over book building should be seen as a good or a bad signal. For a company that is widely known, choosing an auction may be a good signal. However, if a small, obscure start-up chooses the auction method, it might be trying to avoid giving investors too much incentive to thoroughly scrutinize the stock.

5. Conclusion

This paper documents a global trend towards the use of the book building method for IPOs. In the 1980s, book building was used primarily in North America. By the end of the 1990s, it was also the dominant method in Europe, Asia and Latin America, at least for larger issues. The public offer (a.k.a. fixed price or open offer) method is becoming less common worldwide but continues to be popular in smaller countries that rely mainly on retail investors. Auctions are rare. Although I found a few countries where auctions are still used for IPOs, closer examination revealed that either: 1) there were regulatory restrictions that prevented or limited the use of book building; or 2) auctions had lost popularity, being steadily (sometimes rapidly) replaced by book building. I could find no countries where auctions remained dominant despite free availability of book building.

In this paper, I model both book building and a discriminatory auction for the same environment, endogenizing the number of investors and the accuracy of their information. The issuer's expected proceeds under the two methods are similar, except for two key differences: book building carries less risk for both issuers and investors, leading to less underpricing (even under risk neutrality); and it gives issuers more control over information expenditures, and thus more control over underpricing. From a regulatory standpoint, auctions are a subset of book building in which the issuer pre-commits to certain pricing and allocation rules. Thus, my comparison illustrates the advantages and disadvantages of giving up flexibility by pre-committing to auction rules.

My models predict that, as a country switches from auctions to book building, an increase in underpricing should be interpreted as a sign that the auction method was, on average, leading to too little scrutiny of new issues. The new book building regime should lead to a wider range of intentional underpricing levels, and to a wider range of companies going public. My models do not support the popular belief that auctions should *always* lead to lower expected underpricing, and they predict that issuers will prefer book building to auctions regardless of the direction of the change in underpricing levels.

My models focus on the case where there is a cost to developing information (for instance, investors must read the prospectus and think about the company in order to arrive at a good estimate of its value). If there is valuable "serendipitous" information held by a large number of potential investors that are scattered and hard to locate, then an auction may have

advantages. Thus, the auction method is more likely to be chosen by issuers that have a broad customer and/or employee base and that are in an established, widely-understood industry.

One problem that is not analyzed here is the free rider problem, which is severe for both book building and uniform price auctions because of the one price rule. By forcing issuers to charge the same price to everyone, regulations that prohibit price discrimination make it difficult for issuers to compensate investors for their information costs without also giving large excess returns to free riders[31]. Under book building, underwriters devote substantial time and effort to withholding shares from those who will "flip" or "stag" them. Flippers are a problem, not primarily because they are willing to sell shares quickly (the underwriter wants liquidity in the aftermarket, after all), but because they are trying to take advantage of the high average initial returns of IPOs without giving the underwriter anything in exchange. In other words, they are free riders, and much of the investment bank's effort is devoted to weeding them out of the investor pool[32].

With uniform price auctions, the underwriter has virtually no power to block free riders[33]. If potential investors expect IPO shares to be underpriced, they can avoid the cost of evaluating an issue by simply placing an extremely high bid. In a uniform price auction, this guarantees that they will receive shares at the "market clearing" price from the auction. However, if too many bidders follow this strategy, the shares will be overpriced. Since auctions have no natural co-ordination of bidders (as in book building), there is nothing preventing such an outcome from occurring eventually, especially for a procedure such as W.R. Hambrecht's Open IPO that is designed to open up the process to as many people as possible.

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[31] Sherman (2000) shows that underwriters can reduce but not eliminate the excess returns of free riders in a repeated setting.

[32] This implies that underwriters will try to prevent unauthorized flipping for hot as well as cold issues. Flipping is sometimes seen as a problem only for cold issues that are receiving price support. However, if the investment banker is trying to prevent some investors from free riding off of the information production of others, he will be more concerned about flipping of hot issues. Ljungqvist, Nanda and Singh (2001) get a similar result in a model through irrationally exuberant "sentiment" investors. See Aggarwal (2000), Boehmer and Fishe (2001) and Fishe (2001) for more information on flipping in IPOs.

[33] One possible approach, which is explored in Sherman (2001), is to impose entry costs, but there are several problems with this. First, this is not a very flexible tool. Second, explicit entry fees paid to the underwriter or issuer would probably be prohibited by most governments. Third, indirect entry fees may impose large dead-weight costs without directly encouraging information production. A creative approach to this problem has been used by a German online investment bank. Net.IPO requires each potential investor to correctly answer a series of questions on the issuer in order to participate in the public offer tranche of a hybrid book building IPO. This imposes an entry cost while also encouraging independent evaluation of the issue.

There are many examples of overpricing in uniform price IPO auctions. Jenkinson and Mayer (1988) report that, of 26 mostly uniform price tender offers in the United Kingdom from 1983-1986, the average initial return was –2.2%. Thus, on average the price fell when trading began, in spite of the fact that U.K. tenders often "leave something on the table" by pricing below the market-clearing level. In Singapore in 1994, people joked that IPOs had been struck with "tenderitis" – a tendency for shares sold through uniform price auctions (tenders) to trade below their auction price within their first few days of trading[34].

In Argentina in March 1992, the "disastrous" Telecom privatization was blamed on free riders in the "Dutch" auction system, who "pushed up their price to make sure they would get shares". Many retail investors, upset at losing money on what had seemed like a sure thing, pulled out of the stock market completely, causing a market crash, subsequent extreme volatility and the cancellation of up to 20 other planned equity issues. As a result, Argentina gave up IPO auctions and began using book building for privatizations[35]. I leave it to future research to compare the free rider problems of book building and uniform price auctions.

More research is needed on auctions in a multi-unit, common value setting with costly information and endogenous entry. For instance, do "dirty" auctions (where the issue price is set below market-clearing) provide underwriters with sufficient flexibility, at least under certain circumstances? Biais and Faugeron-Crouzet (2001) and Parlour and Rajan (2002) show that dirty auctions have advantages in a setting with serendipitous private information, but these results have not yet been extended to a more general setting in which investors have to expend effort to learn about a new issue. Further analysis of dirty auctions may explain why only one of the six issuers that have so far used the W.R. Hambrecht auction method has chosen to "leave something on the table".

The French Offre à Prix Minimal is a dirty auction that also has procedures to limit free riding – the highest bids may be thrown out, at the auctioneer's discretion, and the entire

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[34] "New strategies needed for future IPOs", Ven Sreenivasan, Singapore Straits Times, p. 13, February 3, 1995.

[35] "Argentina masters the art of privatization" by Danielle Robinson, *Euromoney,* Jul 1993; p. 24. Argentina had successfully completed several auctions before the Telecom disaster. In fact, it was the positive initial returns in the first few privatizations that convinced average investors that IPO auctions were a free lunch. Note that the risk of major overpricing and thus a dramatic crash may be like the "peso problem" – a low probability event that may not show up except in very large samples, but that deters issuers because the event is sufficiently negative. One could argue that excessive overpricing should be considered positive, from the issuer's standpoint, but issuers in general (as well as underwriters and especially regulators) seem to dislike seeing stock prices plummet during secondary market trading, perhaps for behavioral reasons. The free rider problem may also be path-dependent and thus more likely to show up after several successive IPO auctions result in substantial initial price run-ups.

auction may be cancelled (with the issuer starting again through a public offer) if demand is "too high". Thus, the unique features of French IPO auctions offer a potential solution to both the winner's curse and the free rider problems. A Vickrey (1961) auction might be even more efficient at solving these same problems. Ausubel and Cramton (1998a) show that Vickrey auctions have "important theoretical advantages" over both discriminatory and uniform price auctions, but they involve somewhat complicated pricing formulas[36].

More research is also needed on hybrid methods, which are becoming increasingly common. By the end of the 1990s, hybrid book building/public offer may have become the most common IPO method worldwide, despite the fact that hybrids are still rare in the U.S. Little work has been done on how hybrids differ from pure book building.

Last, there is a need for future empirical research on IPO methods. The possibility that forcing issuers to use auctions may prevent some issuers from going public should be examined for other countries besides Japan. For instance, Israel is one of the last countries that still prohibits book building, and its IPO market has been dormant for several years.[37] A related question is whether the IPO issuer mix has changed in countries such as France that made a more gradual transition from predominantly auctions to predominantly book building. The "customized" approach allowed by book building should lead to a wider range of deliberate underpricing levels, and to a wider range of issuers being able to access equity markets.

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[36] This leads to the more general question of whether the problems with IPO auctions can be fixed, since it seems foolish to simply discard a method that has worked so well in other settings. The answer depends largely on one's definition of an "auction". My approach in this paper is to define auctions as a subset of book building in which the issuer pre-commits to allocation rules based only on current bids. If a much broader definition of auctions is used, then there can be no doubt that an optimal auction can be designed. However the result is likely to be something much closer to book building than to the types of procedures most people currently think of as auctions.

[37] On the other hand, Latin American IPO markets have also been quiet for the last few years, and most Latin American countries allow book building. The Israeli and Latin American companies that have gone public in the last 5-6 years have generally chosen to do so in the U.S., using book building.

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Appendices

Appendix A. Information reporting or truth-telling constraints.

The full set of six truth-telling or information reporting constraints are given below, expanding equation (1). These conditions are discussed in Section 3.2.b.

R(H,H) ≥ R(H,M):

$$\sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{H,H,k+1})q_{H,H,k+1} - (s^h - s_{M,H,k})q_{M,H,k}]$$
$$+ \quad P'(h,0)\,[(s^h - s_{H,H,1})q_{H,H,1} - (s^h - s_{M,M})q_{M,M}] \quad \geq \quad 0 \qquad \text{(A1)}$$

R(M,M) ≥ R(M,L):

$$(1-\theta)\ \sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{M,L,k})q_{M,L,k} - (s^\ell - s_{L,L,k+1})q_{L,L,k+1}]$$
$$+ \quad \theta \sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{M,H,k})q_{M,H,k} - 0]$$
$$+ \quad P'(\cdot,0)\ \{\ (s^m - s_{M,M})\ q_{M,M} - (s^m - s_{L,L,1})\ q_{L,L,1})\ \} \quad \geq \quad 0 \qquad \text{(A2)}$$

R(H,H) ≥ R(H,L):

$$\sum_{k=1}^{K-1} P'(h,k)[(s^h - s_{H,H,k})q_{H,H,k} - 0] \ + P'(h,0)\{\ (s^h - s_{H,H,1})\ q_{H,H,1} - (s^h - s_{L,L,1})\ q_{L,L,1})\ \} \ \geq \ 0 \qquad \text{(A3)}$$

R(M,M) ≥ R(M,H):

$$\theta \sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{M,H,k})q_{M,H,k} - (s^h - s_{H,H,k+1})q_{H,H,k+1}]$$
$$+ \quad (1-\theta) \sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{M,L,k})q_{M,L,k} - 0]$$
$$+ \quad P'(\cdot,0)\ \{\ (s^m - s_{M,M})\ q_{M,M} - (s^m - s_{H,H,1})\ q_{H,H,1})\ \} \quad \geq \quad 0 \qquad \text{(A4)}$$

R(L,L) ≥ R(L,M):

$$\sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{L,L,k+1})q_{L,L,k+1} - (s^\ell - s_{M,L,k})q_{M,L,k}]$$
$$+ \quad P'(\ell,0)\,[(s^\ell - s_{L,L,1})q_{L,L,1} - (s^\ell - s_{M,M})q_{M,M}] \quad \geq \quad 0 \qquad \text{(A5)}$$

R(L,L) ≥ R(L,H):

$$\sum_{k=1}^{K-1} P'(\ell,k)[(s^\ell - s_{L,L,k})q_{L,L,k} - 0] \ + P'(\ell,0)\{\ (s^\ell - s_{L,L,1})\ q_{L,L,1} - (s^\ell - s_{H,H,1})\ q_{H,H,1})\ \} \ \geq \ 0 \qquad \text{(A6)}$$

Appendix B. Proof of Proposition 1

Proof of 1): The underwriter/issuer prefers the highest issue prices possible. The only constraints on prices to the uniformed are from the participation constraints of the uninformed, equation (3), which bind.

Proof of 2): Since $s^{\ell} = 0$, ℓ shares cannot be underpriced in this model. More generally, however, the truth telling restrictions for H will always bind before the truth-telling restrictions for L, because $s^{\ell} < s_{M,M}$ and $s^{\ell} < s_{H,H,k}$ except under extreme underpricing, whereas $s^{h} > s_{M,M}$ and $s^{h} < s_{L,L,k}$ unless there is overpricing. This makes it more efficient for the underwriter to compensate investors through underpricing of H rather than L shares.

Proof of 3): As long as prices are non-negative and no shares are strictly overpriced, equations (A5) and (A6) will not bind. Similarly, (A2) and (A3) will not bind as long as $q_{L,L,1} = 0$. Thus, of the truth-telling constraints, only (A1) and (A4) may affect the equilibrium.

Underpricing to those that report M lowers the expected proceeds of the issuer/underwriter. It will also make it easier to satisfy (A4), but in constraints (2), (A1) and (A4), only the differences between the returns to those that report H and the returns to those that report M show up. Thus, to satisfy these constraints, a decrease in the expected return to those that report H has the same effect as an increase in the expected return to those that report M. Since a decrease in expected return to those that report H is always at least as good in terms of satisfying the constraints, and it strictly dominates in terms of maximizing the underwriter's expected proceeds, it will always be strictly preferred (and therefore chosen) by the underwriter.

Appendix C. Proof of Proposition 2

First, the two cumulative bidding distributions are as follows.

M(b;α,p) is the unique positive real root of the polynomial:

$$\theta\,(1\text{-}b)\,[1\text{-}p + p(1\text{-}\alpha)\,M(b;\alpha,p)]^{N\text{-}X\text{-}1}\,[\alpha p + p(1\text{-}\alpha)\,M(b;\alpha,p)]^{X\text{-}1}$$
$$-\;b\,(1\text{-}\theta)\,[1\text{-}p + \alpha p + p(1\text{-}\alpha)\,M(b;\alpha,p)]^{N\text{-}X} \;-\; \theta\,(1\text{-}p)^{N\text{-}X}$$

for $b \in (0, m(\alpha,p)]$ and

$$H(b;\alpha,p) \;\equiv\; 1 \;-\; \frac{1}{\alpha p}\left(1 - \left(\frac{1 - \theta + \theta(1-p)^{N-X}}{(1-b)p^{X-1}\,[\theta + (1-\theta)(1-p\alpha)^{X-n}]}\right)\right)^{1/(N-X-1)}$$

for $b \in (m(\alpha,p), n(\alpha,p)]$, where

$$m(\alpha,p) \equiv \frac{\theta\,[(1-p\alpha)^{N-X} - (1-p)^{N-X}]}{1 - \theta + \theta\,(1 - p\alpha)^{n-X}}$$

$$n(\alpha,p) \equiv 1 - \frac{1 - \theta + \theta\,(1-p))^{N-X}}{\theta + (1-\theta)(1-p\alpha)^{X-N}}$$

Basically, I need to show that bidders are acting optimally through their choice of the equilibrium p, α pair in stage 1 and through the bidding strategies given for stage 2. The way p and α are chosen (i.e. such that $g(\alpha,p)$ and $h(\alpha,p)$ are zero) guarantees that they are optimal for stage 1. For stage 2, note that the expected profit to bidding $b \in (0,m]$ with signal M (recall that this is expected profit *after* information has been purchased) is:

$(1-b)\,P(W_b, V = 1|M) - b\,P(W_b, V = 0|M)$

$$= \theta\,(1-b) \sum_{i=X}^{N-1} \sum_{j=0}^{X-1} \binom{N-j-1}{i-j}\binom{X-1}{j} (1-p)^{N-1-i}\,(\alpha p)^j\,[p(1-\alpha)M(b;\alpha,p)]^i$$
$$- b\,(1-\theta) \sum_{i=X-1}^{N-1} \binom{N-1}{i} (1-p)^{N-1-i}\,[\alpha p + p(1-\alpha)M(b;\alpha,p)]^{i-X+1}$$

$$= \theta\,(1-b)\,[1-p+p(1-\alpha)\,M(b;\alpha,p)]^{N-X-1}\,[\alpha p + p(1-\alpha)\,M(b;\alpha,p)]^{X-1}$$
$$- b\,(1-\theta)\,[1-p+\alpha p + p(1-\alpha)\,M(b;\alpha,p)]^{N-x}$$

$$= \theta\,(1-p)^{N-X}$$

The expected profit to bidding $b \in (m,n)$ with signal H is

$(1-b)\,P(W_b, V = 1|H)$

$$= (1-b) \sum_{i=X}^{N-1} \sum_{j=0}^{X-1} \binom{N-j-1}{i-j}\binom{X-1}{j} (1-p)^{N-1-i}\,(\alpha p(1-H(b;\alpha,p))^j\,[p(1-\alpha\,(1-H(b;\alpha,p)))]^i$$

$$= (1-b)\,p^{X-1}\,[1-p+p(1-\alpha\,(1-H(b;\alpha,p)))]^{N-X-1}$$

$$= \frac{1 - \theta + \theta\,(1-p)^{N-X}}{\theta + (1-\theta)(1-p\alpha)^{X-N}}$$

It is straightforward to show that bidding $b \in (m,n)$ with signal M or bidding $b \in (0,m]$ with signal H would lead to a lower expected return, meaning that the bidding strategy given in Proposition 2 is optimal.

Appendix D. Proof of Proposition 3

First, I will derive SER_{BB}:

Given Prop. 1, we can rewrite (2), (A1) and (A4) (the only potentially binding constraints) as:

$$\theta \sum_{k=1}^{K} P'(h,k-1)\,(s^h - s_{H,H,k})q_{H,H,k} \quad \geq \quad (1/\alpha)\,(C(\alpha) + e) \qquad (2')$$

$$\sum_{k=1}^{K} P'(h,k-1)\,(s^h - s_{H,H,k})q_{H,H,k} \quad \geq \quad 0 \qquad (A1')$$

$$-\theta \sum_{k=1}^{K} P'(h,k-1)\,(s^h - s_{H,H,k})q_{H,H,k} + P'(\cdot,0)\,(1-\theta)\,s_{H,H,1}\,q_{H,H,1} \quad \geq \quad 0 \qquad (A4')$$

(A1') won't bind as long as (2') is satisfied, since $C(\alpha) + e > 0$. (A4) will limit the degree of overpricing, meaning that there is a feasibility limit to how much info. the issuer can purchase/induce. Equation (2) gives a minimum amount of underpricing for a given level of information collection. It will always bind, so we can substitute the amount of underpricing from (2) into SER_{BB}, giving us the equation shown in Proposition 3.

For $SER_{Auction}$:

This formula follows directly from the fact that bidders choose α and p such that $w(\alpha, p)$ (and thus $g(\alpha,p)$) equals zero (i.e. such that their ex ante expected profit equals zero).

Appendix E. Proof of Proposition 4

Since expected evaluation costs are the same for the two methods, It is sufficient to show that

$$\left(1 - \sum_{i=0}^{X-1} P(\text{entry} = i)\left(1 - \frac{i}{X}\right)\right) < 1$$

which follows from $i/X < 1$, $N \geq X$ and $\sum_{i=0}^{N} P(\text{entry} = i) = 1$.