# Preplay Communication; Participation Restrictions, and Efficiency in Initial public Offerings

**Chester Spatt and Sanjay Srivastava**
Carnegie Mellon University

***The extent to which the observed procedures for selling new issues are efficient is studied. We show that a posted-price mechanism, in conjunction with nonbinding preplay communication and participation restrictions, leads to an allocation of the security (and payment) that maximizes the seller's expected revenue, given the informational constraints imposed by the optimizing incentives of the potential buyers.***

Consider a firm that is going public for the first time. While potential investors may have some information about the cash flows of the enterprise, for issues not previously traded there often is considerable residual uncertainty concerning the market's valuation of these cash flows. Consequently, we expect strategic considerations to be important in the market for unseasoned issues. Two questions arise: what is ah optimal mechanism for selling such securities and how do procedures followed in practice relate to optimal mechanisms?

We gratefully acknowledge the comments of the editor (Michael Brennan), the referee (Milt Harris), and participants at presentation of this article at the Federal Reserve Bank of Atlanta, Haifa University, and the J. J. B. Hilliard and W. L Lyons Symposium on Static and Dynamic Issues in Finance at Indiana University and the financial support of the National Science Foundation. Address correspondence to Professor Chester Spatt, Graduate School of Industrial Administration. Carnegie Mellon University, Pittsburgh. PA 15213.

*The Review of Financial Studies* 1991 Volume 4, number 4, pp. 709–726

The underpricing of new issues has been the subject of considerable recent attention.[1] However, the mechanism by which initial issues are sold has largely been ignored except by Benveniste and Spindt (1988). We believe that it is difficult to understand the causes of underpricing, and other questions relating to initial issues, without first analyzing the specific institutional mechanism by which these securities are sold. For instance, an important feature of initial public offerings of securities in the financial market is that the securities are offered to prospective buyers at a posted (fixed) price.[2] A single-stage posted-price mechanism does not utilize any information about realized buyer valuations[3] in setting the issue price and is generally inefficient (in the sense of not maximizing the seller's expected revenue subject to the informational constraints of the environment). If a pure posted-price mechanism were used, then underpricing would not be surprising in the sense that the highest valuation bidder would not always receive the stock; however, this would raise the deeper issue of why such a mechanism was employed. A second feature of the observed institution is that only a select group of buyers is approached [see Fuller and Farrell (1987, p. 19) and Benveniste and Spindt (1988)]. Limiting access in this fashion seems unintuitive and by itself could also lead to underpricing [e.g., Blazenko and Boyle (1989)). These features then raise the question of why issuers of securities utilize a posted-price mechanism in initial public offerings and limit the access of some prospective buyers.

We show in this article that these two features of the observed institutional mechanism are quite consistent with the optimal way to sell initial issues if we take seriously a third important aspect of the observed. mechanism. An initial issue is usually preceded by a tremendous amount of informal communitition between the investment banker placing the issue and prospective buyers prior to the allocational stage of the offering.' Such communication can transmit considerable information, and, as we show, can result in an optimal allocation of initial issues.

[1]The literature on underpricing in initial public offerings includes Allen and Faulhaber (1989), Benveniste and Spindt (1988, 1989), Grinblatt and Hwang (1989), Ritter (1984). Rock (1986), and Welch (1989).

[2]Benveniste and Spindt (1988) offer a discussion of the fixed-price aspect of observed offerings. Baron (1982) studies the optimal contract between the issuer and Investment banker in the context of a fixed-price offering.

[3]The posted-price mechanism only utilizes the information about the prior distribution of buyer valuations.

[4]See Fuller and Farrell (1987, p. 17). Baron (1982). and Benveniste and Spindt (1988). Uttal (1986). in the context of Microsoft going pubic, describes the process of **preplay** communication and **the** determination of the **group** of **final buyers.**

Our main result is that the posted-price mechanism, augmented by nonbinding preplay communication and participation restrictions, implements an allocation of the security (and payment) that maximizes the seller's expected revenue given the informational constraints imposed by the optimizing incentives of the potential buyers.[5,6] The intuition behind our general result can be illustrated by showing how preplay communication and participation restrictions allow the posted-price mechanism to reproduce a second-price auction. The augmented posted-price mechanism works in two stages. In the communication stage, each potential buyer and the seller declare a reservation price. In the second stage, the seller offers the good at a fixed price equal to the larger of his declared reservation price and the second highest reservation price declared by the buyers. By restricting access to this offer to only those buyers whose declared reservation price was the highest among those declared by all buyers, the seller can eliminate underreporting in the first stage. Hence, when the second-price auction is optimal, the augmented posted-price mechanism is also optimal. We show that preplay communication and participation restrictions allow the posted-price mechanism to achieve an optimal auction in more general settings, even when the second-price auction may not be optimal and when the form of the optimal auction is unknown (see Section 3).

We do not focus upon other observed features of initial public offerings, such as the rationing of securities in equilibrium, though our analysis is consistent with rationing in the offering in that there is some type of purchaser who would be indifferent to purchase, but is not approached in equilibrium. We also abstract from the role of underwriters and the structure of the contract between the firm and its underwriter. Our analysis also does not focus upon the nature and causes of underpricing in initial public offerings. In order to study underpricing in the context of an optimal mechanism, it would appear necessary to incorporate a resale market into the model.

The model is described in Section 1. An example illustrating our results is offered in Section 2, while our main result is given in Section 3. Some concluding comments are provided in Section 4.

---

[5] A mechanism design approach to initial public offerings was previously taken by Benveniste and Spindt (1988), who also describe the observed mechanism. Their analysis takes the initial communications of potential buyers as binding and does not explain the use of a posted-price mechanism.

[6] There are many mechanisms that are allocationally equivalent. The mechanism design formulation is not sufficiently powerful to identify a unique optimal institutional structure. Instead, the theory precludes a variety of institution as inefficient. In this sense, an observed structure can be shown to be either consistent or inconsistent with the theory. An interesting analogy is to the irrelevancy theory of capital structure, in which the firm's capitalization cannot be Inconsistent with the theory in a perfect market.

## 1. The Model

We consider the simple case in which there is a single (indivisible) unit of stock to be sold.[7] There are $n$ potential, buyers. The set of possible types of buyer $i$ is given by $T_i$, where a *type* for buyer $i$ is a private signal to $i$ concerning the value of the stock. For convenience, we assume $T_i \subseteq [0, 1]$, for all $i$, and let $T = T_1 \times T_2 \times \cdots \times T_n$. The *valuation* of buyer $i$ is a real number $v_i(t) \in [0, 1]$, where $t = (t_1, \ldots, t_n) \in T$ is the vector of all buyer types or signals. Note that the value to buyer f can depend on the signals of all buyers, so that our model allows for common or correlated values. Payoffs are defined as follows: Given a vector of types $t$, if bidder $i$ pays $y_i$, then the payoff to $i$ is $v_i(t) - v_i$, if $i$ receives the stock, and $-y_i$, otherwise. Note that this formulation allows a buyer to pay without receiving the stock. This is a broad description of the feasible trading mechanisms. However, in obtaining our results for general auction environments, we will assume that the buyer does not pay without receiving the stock. In the example of Section 2, this assumption is not imposed, but there exists an optimal auction (sealed-bid, second-price) satisfying the restriction that only the winning bidder pays.

Since buyer types are privately observed, we model the uncertainty of buyer $i$ about the types of the other buyers by a distribution function $F_i(t_{-i} \mid t_i)$, where $t_{-i}$ is the $(n - 1)$-vector of the types of all buyers except $i$. As implied by the notation, the distribution can be influenced by the type of buyer $i$, so our model allows for correlated types. We assume that the functions $v_i$ and $F_i$ are all common knowledge, and that the $F_i$ all arise from a common prior distribution $F$ on $T$.

The seller's valuation of the stock is assumed to be common knowledge, and we normalize this valuation to zero.

### 1.1 The-posted-price mechanism

As noted in the introduction, there are three features of the observed institutional mechanism upon which we focus. These are the posted price, the ability of the seller to restrict participation, and preplay communication. We start by modeling the first two features, and later introduce preplay communication.

We model the posted-price mechanism with participation restrictions by a simultaneous-move game[8] in which the seller announces

[7] It is straightforward to extend the analysts to multiple units, where each bidder has a constant willingness to pay per unit (both this reservation price and the number of units a bidder will accept can vary across bidders). The major restriction we need to impose is that the optimal mechanism does not Involve price discrimination by the seller, since the revenue from such a mechanism cannot be realized by a posted-price mechanism (without variable entry fees).

[8] The assumption of a simultaneous-move game is important to our analysis. We discuss this in detail in Section 4.

a price p that he is willing to accept for the stock and a set of buyers with whom he is willing to trade, $I \subseteq \{1, 2, \ldots, n\}$. Each potential buyer $i$ announces the maximum price $p_i$ that he is willing to pay for the security. If $\{i \in I \mid p_i \geq p\} \neq \emptyset$, then trade occurs, the purchase price is that posted by the seller, and the stock is allocated randomly accordingly to a uniform distribution among these bidders, Otherwise, no trade occurs.

Formally, a strategy for buyer i is a function $\sigma_i: T_i \to [0, 1]$, where $p_i = \sigma_i(t_i)$ denotes the maximum price buyer $i$ is willing to pay given that his type is $t_i$. A strategy for the seller, denoted by $\sigma_0 = (p, I)$, is the choice of $p \in [0, 1]$ and a set $I \in 2^n$, where $2^n$ is the set of all subsets of $(1, 2, \ldots, n\}$. Given a strategy profile $\sigma = \{\sigma_0, \sigma_1, \ldots, \sigma_n\}$, we denote by $\pi_i(\sigma, t)$ the probability that f receives the stock given $t$, so that

$$\pi_i(\sigma, t) = \frac{1}{\#\{j: \sigma_j(t_j) \geq p \text{ and } j \in I\}} \quad \text{if } \sigma_i(t_i) \geq p \text{ and } i \in I, \tag{1}$$

and zero, otherwise. The expected utility to buyer $i$ of type $t_i$ given a strategy profile $\sigma$ is

$$U_i(\sigma, t_i) = \int \pi_i(\sigma, t)[v_i(t) - p]\, dF_i(t_{-i} \mid t_i). \tag{2}$$

The expected payoff to the seller is

$$U_0(\sigma) = p \sum_{i=1}^{n} \int \pi_i(\sigma, t)\, dF(t). \tag{3}$$

Definition 1. $\sigma$ is an equilibrium to the posted-price mechanism without communication if.

$$\text{(i)} \qquad U_0(\sigma) \geq U_0(\sigma_0', \sigma_1, \ldots, \sigma_n), \qquad \text{for all } \sigma_0',$$

and

$$\text{(ii)} \qquad U_i(\sigma, t_i) \geq U_i(\sigma_0, \sigma_1, \ldots, \sigma_{i-1}, \sigma_i', \sigma_{i+1}, \ldots, \sigma_n, t_i), \quad \text{for all } i, t_i, \text{ and } \sigma_i'.$$

**1.2 Auctions.**

The posted-price mechanism described above is only one of many mechanisms a seller could use to sell the stock. Our interest is in studying the extent to which a seller could do better by employing an alternative mechanism. To study this formally, we turn now to a description of an auction.

An auction specifies a possible sale of the stock and a transfer from the buyer(s) to the seller. In its most general form, an auction is represented by a collection of functions $\{\rho_i(t), \eta_i(t)\}$, where $\rho_i(t)$ denotes the probability that buyer $i$ gets the stock when the realized vector of types is $t$, and $\eta_i(t)$ is the transfer from buyer $i$ to the seller. Note that this specification only describes the outcome to a trading process, but as yet does not specify the process itself. For example, the outcome of a posted-price mechanism can be represented as an auction as follows. Let $\sigma$ be an equilibrium to the posted-price mechanism without communication. Then, $\rho_i(t) = \pi_i(\sigma, t)$ and $\eta_i(t) = p$ if buyer $i$ gets the stock. In general, however, there are many different mechanisms a seller might employ. We adopt the more general formulation of auctions so as to be able to analyze the maximal expected payoff to the seller. Of course, we will have to impose some restrictions on the auctions we study, and we turn to these next.

Since the $\rho_i$ are probabilities, we require that

$$\rho_i(t) \geq 0, \qquad \text{for all } i \text{ and } t,$$

and

$$\sum_i \rho_i(t) \leq 1, \qquad \text{for all } t.$$

Given an auction, the expected payoff to type $t_i$ of buyer $i$ is

$$W_i(\rho, \eta, t_i) = \int_{T_{-i}} [v_i(t)\rho_i(t) - \eta_i(t)]\, dF_i(t_{-i} \mid t_i). \tag{5}$$

Consistent with our broad description of the feasible trading structures, this allows the possibility that a bidder pays without receiving the good. Recalling that the valuation of the seller is normalized to zero, the expected payoff to the seller is

$$W_0(\rho, \eta) = \sum_i \int_T \eta_i(t)\, dF(t). \tag{6}$$

We impose the following additional restrictions on auctions. First, we require that an auction must be (interim) individually rational so that

$$W_i(\rho, \eta, t_i) \geq 0, \qquad \text{for all } i \text{ and } t_i. \tag{7}$$

This says that for each $i$, given the signal $t_i$, each bidder (not just the actual purchaser) is willing to participate in the auction. Second, we require that it be incentive compatible. Letting

$$W_i(\rho, \eta, t_i, \tau_i) = \int_{T_{-i}} [v_i(t)\rho_i(\tau_i, t_{-i}) - \eta_i(\tau_i, t_{-i})]\, dF(t_{-i} \mid t_i), \tag{8}$$

incentive compatibility requires that

$$W_i(\rho,\eta,t_i,t_i) \geq W_i(\rho,\eta,t_i,\tau_i), \qquad \text{for all } i,\ t_i, \text{ and } \tau_i. \tag{9}$$

The interpretation of $W_i(\rho,\eta,t_i,\tau_i)$ is straightforward. It denotes the expected payoff to buyer $i$ when he receives the signal $t_i$ but acts as if he received the signal $\tau_i$. The revelation principle [e.g., Myerson (1981)] implies that if the seller employs some mechanism to sell the stock, then the probabilities of sale and the transfers resulting from any Bayesian equilibrium to the mechanism must satisfy (9). An auction that satisfies (4), (7), and (9) is called a *feasible auction.*

*Definition 2.* An auction $\{\rho,\eta\}$ is *realized* by the posted-price mechanism if there exists an equilibrium to the posted-price mechanism, say $\sigma$, such that $U_0(\sigma) = W_0(\rho,\eta)$.

This states that the ex ante payoff to the seller from some equilibrium to the posted-price mechanism is the same as that from the auction. The question of interest, then, is whether an optimal auction can be realized by the posted-price mechanism, where the following definition holds.

*Definition 3.* An auction $\{\rho,\eta\}$ is *optimal* it is feasible and maximizes $W_0(\rho,\eta)$ over the set of feasible auctions;

It is generally not the case that the posted-price mechanism will realize an optimal auction. We illustrate this next by considering a special case.

## 2. An Extended Example

While our main result holds in quite general settings (see Section 3), the underlying intuition can be developed in the context of an extended example. Consider the special case in which for all $i$, $v_i(t) = t_i$, $T_i = [0,1]$, and $F_i(t_{-i} \mid t_i) = F(t_{-i})$. This is the case of private values, independent types, and symmetric buyers. In this case, it is well-known [see Myerson (1981)] that if a monotonic ‘hazard rate property (which we assume for this example) is satisfied,. then a sealed-bid second-price auction with a seller’s reserve price is an optimal auction. This auction requires buyer $i$ to submit a bid $b_i$ and the seller to submit simultaneously a reserve price $b_0$. Let $b$ be the highest bid and $b$ the second highest bid submitted by the buyers. If $b \geq b_0$, then the stocks is randomly allocated at price $max\{b_0, b)$ to the buyers bidding $b$. If $b < b_0$, then the seller retains the stock. Note that no payment is made by buyers who do not receive the stock. We will show that the allocation achieved by this optimal auction cannot always be realized by the posted-price mechanism.

Under the posted-price mechanism, it is a dominant strategy for each potential buyer to declare his true valuation since the potential buyer's declared valuation does not influence the price he would pay for the security $(p)$, but only whether he receives the security given his declared valuation. The maximization by agent $i$ implies he would. like to be allocated the, security if and only if $t_i \geq p$, so that under the mechanism $i$ sets $p_i = \sigma_i(t_i) = t_i$. Notice that specifying $p_i > t_i$ does not raise the probability that $i$ receives the security in any circumstance in which he wishes to receive it. Similarly, it is a dominant strategy for the seller not to exclude any bidders from participation [i.e., the seller sets $I = \{1,2, \ldots, n\}$]. In the posted-price mechanism, the realized transaction price is just the seller's declaration and is not influenced by the actual buyer signals. A risk-neutral seller sets his price to maximize the product of the price and the resulting probability of selling the security. This probability is the likelihood that the highest buyer valuation (the first-order statistic of buyer valuations) is at least equal to the seller's offer, because each buyer's declaration equals his valuation.[9]

It is well-known that the posted-price mechanism is typically inefficient for the seller since there is a positive probability that the second highest buyer valuation strictly exceeds the price posted by the seller (in our posted-price mechanism). As a result, the expected revenue to the seller is not maximized since higher expected revenue could be obtained by treating the seller's optimal posted price as his reserve price in a second-price auction with a reserve price.[10] The comparison is only strengthened by using an optimal reserve price in the second-price auction. Therefore, the posted-price mechanism is typically inefficient.

## Equilibrium with communication

We now illustrate the main result of this article, that is, that the sealed-bid second-price auction with a reserve price can be realized by the augmented posted-price mechanism in which players communicate prior to playing the posted-price mechanism. In fact, adding one round of public preplay communication to the mechanism is sufficient to achieve an efficient equilibrium.

[9] The second-price auction with a reserve price also e-mails the buyers declining their true valuations, but in the auction the transaction price depends on the actual private valuations of the buyers as well as on the reserve price of the seller. In particular, the price at which the stock is sold can exceed the reservation price submitted by the seller.

[10] Note that in the second-price auction, it is also an equilibrium for all buyers to report their types truthfully. The assumptions that the density $f$ strictly positive and that there are at least two

In order to examine the effect of preplay communication, we augment the simultaneous-move posted-price mechanism with a prior stage of nonbinding preplay communication. Each player (including the seller) publicly declares a valuation for the object in this nonbinding stage and then the simultaneous-move posted-price mechanism is played. The seller's second-stage strategy is the price he quotes and the set of traders with whom he will deal. These may depend upon the nonbinding "cheap talk" declarations of bidders. In the second stage, each buyer specifies the maximum price he would pay.[11]

Formally, we let $M_i = [0, 1]$ denote the message space for $i$, $i = 0, 1, \ldots, n$, and let $M = M_0 \times M_1 \times \cdots \times M_n$ denote the aggregate message space. A strategy for a buyer now consists of two functions, $\sigma_i^1: [0,1] \to M_i$, where $\sigma_i^1(t_i)$ is the message of $i$ in the communication stage, and $\sigma_i^2: [0,1] \times M \to [0,1]$, which denotes the maximum price buyer $i$ is willing to pay conditional on his valuation and all the messages sent by, all agents. The seller's strategy consists of $\sigma_0^1$, an element of $M_0$, and $\sigma_0^2: M \to [0,1] \times 2^n$, which denotes the price charged by the seller and the bidders with whom the seller is willing to trade conditional on the messages sent by all agents, $m$.[12] Note that we are assuming that all messages are publicly observed.

The notion of equilibrium we employ is that of a perfect Bayesian equilibrium. Let $F(t_j \mid m)$ denote the distribution of $t_j$ conditional on the first-period message $m$, where the updating is based upon Bayes' rule given the first-stage strategies $\sigma^1$. A *perfect Bayesian equilibrium* then requires that all strategies form a Bayesian equilibrium at the first stage (relative to the priors given by $F$), and that, given any configuration of messages, say m, the second-stage strategies form a Bayesian equilibrium relative to the updated beliefs, $F(t_j \mid m)$.

---

bidders imply that there is a positive probability that the second highest buyer valuation strictly exceeds the posted price charged by the seller. To demonstrate this, note that the optimal posted price solves

$$\max_p p[1 - F(p)^n].$$

The derivative of the objective is $1 - F(p)^n - pnF(p)^{n-1}f(p)$. At $p = 1$, this expression reduces to $-nf(1) < 0$. Hence, the objective is decreasing at the highest possible bidder valuation so that the optimal posted price is strictly below the highcst possible bidder valuation (and there is a positive probability that the second highest bidder valuation exceeds the optimal posted price). Of course, if $n = 1$, the posted-price mechanism (at the seller's optimal reserve price) is an optimal auction.

[11] Farrell (1985) and Grossman and Perry (1986) first examined the role of preplay communication. The introduction of preplay communication can expand the set of equilibria, by allowing coordination of player strategies, while retaining the equilibria without communication.

[12] Since the buyers can compute the seller's reserve price, the mechanism an be reformulatedwithout any communication by the seller. We adopt this formulation because it seems to us more natural in the context of the sealed-bid auction.

A strategy profile now denotes a pair of functions for each agent, one for each stage of the game. At the second stage, the probability that buyer $i$ receives the stock is

$$\pi_i(\sigma; m, t) = \frac{1}{\#\{j: \sigma_j^2(t_j, m) \geq p(m) \text{ and } j \in I(m)\}} \quad \text{if } \sigma_i^2(t_i, m) \geq p(m) \text{ and } i \in I(m), \tag{10}$$

and zero, otherwise, where $p(m)$ and $I(m)$ are the choices of the seller given $m$. Given any $m$, the expected payoff to the buyer at the second stage is

$$U_i(\sigma; m, t_i) = \int \pi_i(\sigma; m, t)[t_i - p(m)]\, dF(t_{-i} \mid m), \tag{11}$$

while the expected payoff to the seller is

$$U_0(\sigma; m) = p(m) \sum_{i=1}^{n} \int \pi_i(\sigma; m, t)\, dF(t \mid m). \tag{12}$$

We then require that for each player, the second-stage strategies are a best response to the second-stage strategies of all other players given any $m$. Following Definition 2, we say that an auction $\{\rho, \eta\}$ is *realized* by the posted-price communication mechanism if there exists an equilibrium to the posted-price mechanism with preplay communication such that the ex ante payoff to the seller is the same as in the auction.

At the first stage, the expected payoff to buyer $i$ is simply the expectation of $U_i(\sigma; m, t_i)$ over $m$, recognizing that $m$ depends on the valuations of all players via the first-stage strategies. The expected payoff to the seller is similarly computed. Of course, the equilibrium to the posted-price game analyzed earlier continues to be an equilibrium to the augmented game because it is an equilibrium for all parties to ignore the "cheap talk" from the first stage and play strategies equivalent to those in the posted-price game.

A more interesting equilibrium to the augmented posted-price mechanism is as follows. In the first stage, each potential buyer declares his true reservation price and the seller announces his optimal reserve price (for a sealed-bid second-price auction). In the second stage the seller sets his price equal to the maximum of the second highest bidder declaration in the first stage and the preplay reserve price he previously declared and chooses $I(m)$ to contain only those bidders who reported the highest valuation in the first stage, provided this maximum valuation is at least the reserve price. In the second stage, buyers who are excluded from participation bid zero, while those who are not excluded offer exactly the anticipated posted price given the seller's strategy, *p(m)*.[13]

To verify that the strategies described above constitute an equilibrium, we first examine the second stage. Let *m* be any first-stage declaration. Consider the position of the seller given that the buyers are following the above second-stage strategies. Suppose $q_1(m) < \bar{p}$. Then, any deviation by the seller from $(p(m) = \bar{p}, I(m) = \emptyset)$ does not change his payoff since all -buyers are bidding zero. If $q_1(m) \geq$ *p*, then all buyers who are making positive bids are bidding *p(m)*. Changing *I(m)* to some *I* does not affect the payoff as long as $I \cap I(m) \neq \emptyset$. Otherwise, the seller's payoff falls to zero. Raising *p* above p(m) drops the seller's revenue to zero, while lowering *p* also results in a strict loss of revenue. Thus, the seller's strategy is a best response to the strategy of the buyers. For a buyer not in *I(m)*, any deviation does not affect his payoff. A buyer with $t_i < p(m)$ and $i \in I(m)$ can only lose by changing his bid from zero. Finally, if $i \in I(m)$ and $t_i \geq$ *p(m)*, lowering the bid cannot increase *i's* payoff, while increasing the bid does not affect Es payoff. Hence, for any first stage *m*, these strategies form an equilibrium in the second stage.

In the first stage, the expected payoff to a buyer, given the strategies of all other players, is exactly the same as in the second-price auction, and truthful revelation of type is thus a best response. Finally, the seller maximizes his expected revenue (and attains the efficient auction) by selecting the optimal reserve price. The seller's communication in the initial stage is important because of its influence upon

[13] Formally, $\sigma_i^1(t_i) = t_i$, for $i = 1,\ldots,n$ and all $t_i \in [0,1]$, and $\sigma_0^1 = \bar{p} =$ optimal reserve price for the seller in **a** sealed-bid second-price auction. Let

$$q_1(m) = \max_i\{m_i\} \qquad \text{and} \qquad q_2(m) = \max_i\{m_i \mid m_i \neq q_1(m)\}.$$

The seller's second-stage strategy is

$$\sigma_0^2(m) = \{p(m), I(m)\},$$

where

$$p(m) = \max\{\bar{p}, q_2(m)\}$$

and

$$I(m) = \begin{cases} \emptyset, & \text{if } q_1(m) < \bar{p}, \\ \{i \mid m_i = q_1(m)\}, & \text{otherwise.} \end{cases}$$

The strategy for buyer *i(i* - 1 ....,*n)* is

$$\sigma_i^2(t_i, m) = \begin{cases} p(m), & \text{if } t_i \geq p(m) \text{ and } i \in I(m), \\ 0, & \text{otherwise.} \end{cases}$$

the reservation price declared by a successful buyer in the allocational stage.

This equilibrium results in an allocation and seller revenue identical to that in a sealed-bid second-price auction with a reserve price. Myerson has shown in his "regular" case[14] that this allocation is efficient, maximizing expected seller revenue subject to the incentive constraints of the potential buyers. Hence, 'our posted-price mechanism with preplay communication supports-the optimal outcome.

Note that the buyer with the maximal valuation could be playing a weakly dominated strategy in the second stage. In the equilibrium described above, when the second stage is reached and the maximal bidder valuation exceeds the seller's posted price, it never hurts this buyer to bid slightly more than the price announced by the seller, and could be beneficial (for instance, if the seller posts a price slightly higher- than the second price). This weak dominance disappears if there is even the slightest opportunity cost to bidding. Suppose, for instance, that if a buyer bids an amount, say $q$, he forgoes an amount $\epsilon q$. Then, it does not weakly dominate to bid an amount greater than the price 'posted by the seller.[15]

We have assumed that the first-stage messages are publicly observed. However, this is not essential. The property we require is that the winning bidder be able to compute $p(m)$ prior to playing the posted-price mechanism. Our results also could be derived with the communication structure in which ail buyers communicate with each other, and then communicate privately with the seller. This structure complicates the description of the equilibrium, but does not alter the intuition or result.

An Interesting feature of the analysis is the way in which the bidder's indication' of interest (valuation) during the cheap talk influences whether he is approached during the allocational phase. Two features ensure that the bidders' incentives during the cheap talk are analogous to those in a second-price auction with a reserve price. The first is that the bidder is approached by the seller and is able to purchase only if he declares the highest valuation during the cheap-talk phase. The second is that the seller chooses the higher of the second highest valuation and the reserve price for the selling price.

We now show. by example that if the seller is not able to restrict

---

[14] The regular case is one in which the prior distributions satisfy an increasing hazard rate property.

[15] An alternative formuladon of the game that would preclude the weak dominance problem in our equilibrium is for each buyer to declare a single price at which he is willing to purchase (Instead of a maximum). In this modified specification. the stock is sold only if a buyer's price equals the seller's in the second stage. In this form, the equilibrium of interest is sustained. but the buyer's behavior is no longer weakly dominated. We do not focus upon this specification of the game In the text because it is a less natural description of the observed process.

access in the allocational stage, then buyers will not bid truthfully in the communication stage (assuming truthfulness by the other bidders). We assume that there are two bidders, whose valuations are drawn independently from $f(x) = 2x$, for $x \in [0, 1]$, so that the density is linear increasing over the unit interval. We let $p$ denote the optimal reserve price and suppose that bidder 1 possesses the largest possible valuation (i.e., $t_1 = 1$). We then show that without participation restrictions it is not optimal for bidder 1 to reveal truthfully his valuation during the preplay communication (it is advantageous to declare a valuation of $p$, the seller's optimal reserve price, rather than 1). (Note that $p < 1$ is a consequence of the optimal reserve price being In the interior of the support of the density.) If the valuation of bidder-2, $t_2$, is below the reserve price $p$, then under the assumed equilibrium structure bidder 1 is allocated the stock at price $p$ with probability 1 (independent of whether his preplay report is $p$ or 1). In the case $t_2 \in [p, 1]$, bidder 1 receives the security at price $t_2$ with probability 1 in the second stage (assuming bidder 2 does not elect to purchase the security when he is just indifferent)[16] when he reports a value of 1 during the preplay communication and receives the security at price $p$ with probability .5 when he reports a value of $p$. The expected payoff to bidder 1 of truthfulness is then

$$\int_p^1 (1 - t_2)2t_2\,dt_2 = \frac{1}{3} - p^2 + \frac{2}{3}p^3 \tag{13}$$

and the expected payoff to bidder 1 of reporting $p$ *is*

$$.5 \int_p^1 (1 - p)2t_2\,dt_2 = .5(1 - p)(1 - p^2). \tag{14}$$

Therefore, nontruthful behavior is optimal if and only if

$$.5(1 - p - p^2 + p^3) > \tfrac{1}{3} - p^2 + \tfrac{2}{3}p^3, \tag{15}$$

which is equivalent to $(p - 1)^3 < 0$, which follows from $p < 1$.[17] This illustrates the importance to our equilibrium of the ability of the seller to utilize the preplay declarations to determine which bidders to approach in the allocational stage. In contrast, in the mechanism without preplay communication, exclusion of some bidders is generally not optimal.

[16] If bidder 2 does elect to purchase the security when he is indifferent, then the analysis is more direct. Since bidder 2 always purchases when $t_2 \in [p, 1]$, It is in bidder 1's interest to reduce his first-stage declaration in order to reduce the actual selling price (in this case, bidder 1 does not have his probability of purchasing the security reduced because bidder 2 purchases, although indifferent).

[17] It is straightforward to solve for $p$ [see Myerson (1981)].

## 3. The General Case

The augmented posted-price mechanism can actually realize an optimal auction in settings more general than the example discussed above. The general case does not require buyer types to be independent and also allows for common values. We begin by discussing the types of restrictions that we must impose on an auction in order for the optimal auction within this class to be realized by the augmented posted-price mechanism. Interestingly, this optimality of the augmented posted-price mechanism and the resulting allocations can be established even though the form of the optimal auction may not be known.

First, an important feature of the posted-price mechanism is that only the buyer who gets the stock pays for it, so that any equilibrium to the posted-price mechanism is ex post individually rational for any buyer who does not get the stock. Hence, if an auction is to be realized by the augmented posted-price mechanism, it must also satisfy this property. Second, an essential element of the augmented mechanism is that information is revealed in the communication phase, so the posterior distribution of a buyer will generally be different from the prior distributions. Hence, we need to ensure that the buyers are willing to participate in the posted-price mechanism *given these updated beliefs.* This can be ensured by assuming that the auction satisfies ex post individual rationality, which is a stronger assumption than we needed to impose in the special case of private values and independent types.

We note that in the private-value, independent-type model considered in Section 2, the second-price auction is an optimal auction that satisfies ex post individual rationality. In the general case, we do not know the form of the optimal ex post individually rational auction. Crémer and McLean (1988) show that with correlated types, the seller can frequently extract all the surplus by using a modification of the second-price auction in which buyers who do not get the stock make payments depending only on the bids of the other buyers. This auction is not ex post individually rational. If such payments are not allowed, their auction reduces to the second-price auction. This may suggest that the optimal ex post individually rational auction is the second-price auction. While we do not know the answer to this question, the results of Milgrom and Weber (1982) suggest that this may not always be the case; they show that the English auction[18] may sometimes yield higher expected revenue than the second-price auction. We believe that investigating the form of the optimal auction

[18] The English auction is an oral progressive auction in which only the winning buyer pays.

when only the winning buyer pays is an important question, since it appears that (except for entry fees) auctions ‘conducted in practice have this property.

The possibility of randomization complicates the formalization of the notion that a buyer only pays if he receives the stock. For instance, suppose that at some type vector, say $t$, all buyers indicate the same willingness to pay, and the stock is allocated by randomizing uniformly among these buyers. Then, we would have to model the randomizing device explicitly in order to determine who actually gets the stock. This can be done by letting $\Omega$ be a set of events with the uniform distribution, and letting $b_i(t, \omega) \in \{0, 1\}$ be a function that takes on the value 0, if the realization of the randomizing device is $\omega \in \Omega$ and $i$ does not get the stock, and 1, if $i$ gets the stock. The constraint that only the buyer who gets the stock pays would then be written as $\eta_i(t) = 0$, if $b_i(t, \omega) = 0$. It is notationally much simpler if we simply restrict the auction to be deterministic [i.e., $\rho_i(t) \in \{0, 1\}$, for all $i$ and $t$ ]. Our main result below can be extended to the case where we allow randomization.

The simpler formulation leads to the following three restrictions:

(i) for all $i$ and $t$, $\rho_i(t) \in \{0, 1\}$;
(ii) for all $i$ and $t$, $\rho_i(t) = 0$ implies $\eta_i(t) = 0$;
(iii) for all $i$ and $t$, $\eta_i(t) \leq v_i(t)$.

The first condition states that the auction is deterministic. The second condition says that only the winning buyer pays. The third condition imposes ex post individual rationality.

***Theorem.*** *Let $\{\rho, \eta\}$ be an optimal auction subject to (i)-(iii). Then, $\{\rho, \eta\}$ can be realized by a posted-price communication game.*

***Proof:*** Consider the following communication game. Let $M_i = T_i$ be the message space for $i$, $i = 1, \ldots, n$, and define $M = M_1 \times \cdots \times M_n$. $M_i$ is the set of messages $i$ can send at the preplay stage. We do not need the seller to communicate at this stage. The posted-price mechanism is played after the communication stage. Consider the following strategy for the seller:

$$\sigma_0^2(m) = \begin{cases} (1, \varnothing), & \text{if } \rho_i(m) = 0, \quad \text{for all } i, \\ (\eta_i(m), \{i\}), & \text{if } \rho_i(m) = 1. \end{cases} \tag{16}$$

Thus, the seller’s strategy mirrors the form of the optimal auction. If the optimal auction requires no trade when types are $m$ (note that $m \in T$), ‘the seller refuses to trade at the second stage. Otherwise, he simply sets the posted price to be the payment by the buyer who is supposed to get the stock, and only trades with that agent. The strategy $\sigma_0^2$ is well defined since we are restricting attention to deterministic auctions condition (1) above]. For buyer $i$ let

$$\sigma_i^1(t_i) = t_i, \quad \sigma_i^2(m, t_i) = \begin{cases} 0, & \text{if } \rho_i(m) = 0, \\ \eta_i(m), & \text{otherwise.} \end{cases} \tag{17}$$

This strategy has each buyer reporting his type truthfully at the preplay stage, and bidding 0 if he is not supposed to get the stock given the joint report $m$. If the optimal auction allocates the stock to i then i bids $\eta_i(m)$ after the preplay communication round.

These strategies form an equilibrium to the game. Consider first the second stage. If a buyer is excluded given that all buyers reported truthfully in the first stage, then it does not help to bid an amount greater than zero. If a buyer is not excluded, he can bid $\eta_i(m)$ and get the stock at that price; bidding a higher price does not make the agent better off. Bidding a lower price does not improve. his payoff since we are assuming that the optimal auction is ex post individually rational.

It can be calculated that at the first stage, the expected payoff to buyer $f$, given that the other buyers and the seller are following these strategies, is exactly the same as in the optimal auction. Further, any deviation from $\sigma_i$ changes expected payoffs in exactly the same way as in the auction. Since the optimal auction is incentive compatible, it follows that σ is an equilibrium to the two-stage game. Finally, since it leads to the same outcomes, the ex ante payoff to all buyers and to the seller is also exactly the same. ■

It can now be seen that the result can be extended to auctions that are not deterministic in the sense of (i) above; as long as the auction is ex post individually rational, the expected payoffs from the posted price in the second stage can be matched exactly to those in the optimal auction by explicitly modeling the randomization device. Suppose that when the realized vector of types is $t$, the optimal auction allocates the stock with equal probability. to buyers in $I \subseteq \{1, 2, \ldots, n\}$, but only the buyer who gets the stock pays. The complication that arises is that different buyers in the set $I$ may be charged different prices, so that the seller may not be able to determine the posted price without knowing the outcome of the randomization. This can be handled in two ways. First, we could modify the game slightly and let the seller perform the randomization prior to setting the price. Then, if $m = t$, the seller can perform the randomization over the set $I$, and then trade only with the buyer who is supposed to get the stock given the outcome of the randomization. A second, perhaps more satisfactory way, is to restrict the auction to eliminate 'this problem [i.e., assume that $\eta_i(t) = \eta_j(t)$, for all $i,j \in I$]. This latter condition is satisfied by the second-price auction.

## 4. Concluding Comments

Our central result shows that the posted-price mechanism; in conjunction with preplay communication, can lead to efficient allocation of initial issues. While the efficient solution (in allocational terms) depends upon the underlying distributions of types, the actual mechanism is nonparametric.

An important assumption in our analysis is that of simultaneous play by the bidders and seller. This imposes enough commitment on the bidders that they cannot accept an out-of-equilibrium offer by the seller at a higher price (but still below the reservation value of this buyer). It may seem more natural to assume that the seller moves first. Then the seller could charge the highest reported valuation, in which case truthful reporting at the earlier stage would not be an equilibrium. In such a setting, we would generally not expect there to be an equilibrium In pure strategies. However, we believe that a result similar to ours could then be established by considering. a repeated game played between an underwriter and potential buyers, in which case coordinated responses by the buyers could forestall any attempt by the seller to deviate from charging the second highest price. We should also caution that it is not clear that the assumption of simultaneous moves is unrealistic. For example, the description by Uttal (1986) of the process by which Microsoft went public and the empirical fact that many new issues are presold provide some justification for the assumption of simultaneous moves.

Our analysis yields a potential explanation of why a seemingly inefficient mechanism, used in practice, may in fact be optimal. While we have examined the role of preplay communication in a specific context, it would appear that informal communication Is central to the allocation of financial assets more broadly. For example, an interesting aspect of the trading system on the NYSE is that floor traders frequently approach the specialist with a nonbinding "indication of interest." This raises the general issue of: what features of actual trading mechanisms make preplay communication valuable.

[19] Hagerty and Rogerson (1987) examine prior-Independent mechanisms in the context of bilateral bargaining.

**References**

Allen, F., and G. Fauhaber, 1989, "Signaling by Underpricing In the IPO Market," *Journal of Financial Economics,* 23, 303-323.

Baron, D., 1982, "A Model of the Demand for Investment Banking, Advertising and Distribution Services for New Issues," *Journal of Finance,* 37, 955-976.

Benveniste, L, and P. Spindt, 1988, "Bringing New Issues to Market: A Theory of Underwriting." unpublished Manuscipt.

Benveniste, L., and P. Spindt, 1989, "How Investment Bankers Determine the Offer Price and Allocation of New Issues," *Journal of Financial Economics* 24, 343-361.

Blazenko, G., and P. Boyle, 1989, "Pricing an Initial Public Offering," unpublished manuscript.

Crémer, J., and R. McLean, 1988, "Full Extraction of the Surplus in Bayesian and Dominant Strategy Auctions," Econometrica, 56, 1247-1258.

Farrell, J, 1985, "Credible Neologisms In Games of Communication," Working Paper 386, MIT.

Puller, R.. arid J. Farrell, Jr., 1987, Modern Investments and Security Analysis, McGraw-Hill, New York.

Grinblatt, M., and C. Hwang, 1989, "Signalling and the Pricing of New Issues," *Journal of Finance,* 44, 393-420.

Grossman, S., and M. Perry, 1986, "Perfect Sequential Equilibrium." *Journal of Economic Theory,* 39, 97-119.

Hagerty, K., and W. Rogerson, 1987, "Robust Trading Mechanisms," *Journal of Economic Theory,* 42, 94-107.

Milgrom, P., and R. Weber, 1982, "A Theory of Auctions and Competitive Bidding," *Econometrica,* 50, 1089-1122.

Myerson, R., 1981. "Optimal Auction Design," *Mathematics of Operations Research,* 6, 58-73.

Ritter, J., 1984, 'The 'Hot Issue' Market of 1980," *Journal of Business* 57, 215-240.

Rock; K., 1986, 'Why New Issues Are Underpriced," *Journal of Financial Econometrica* 15, 187-212.

Uttal, B.. 1986, "Inside the Deal that Made Bill Gates $350,000,000," *Fortune* (July 21), pp. 23 28, 32, 33.

Welch, I., 1989; "Seasoned Offerings, Imitation Costs, and the Underpricing of Initial Public Offerings," *Journal of Finance,* 44, 421-449.