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"Agency Problems and Commitment in Delegated Bargaining"

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Agency Problems and Commitment in Delegated Bargaining

Abstract

In the context of (one-sided) delegated bargaining, we analyze how a principal (a seller) should design the delegation contract in order to provide proper incentives for her delegate (an intermediary) *AND* gain strategic advantage against a third party (a buyer). We consider situations in which there are both moral hazard and adverse selection problems in the delegation relationship and every player is risk neutral. In the absence of commitment effect, a linear contract is optimal. When delegation contracts have commitment value, the seller can gain substantially by imposing a minimum price, above which she pays the delegate a commission. It is shown that the interaction between commitment (through minimum price) and incentives depends on the nature of the agency problem. Incentives and commitment are substitute when the delegate's unobservable effort improves his bargaining position, but are neither substitute or complement when his effort increases chances of finding a buyer. In most cases, the seller's strategic manipulation of the delegation contract may cause bargaining failures between the delegate and the buyer. We also derive comparative statics of the model.

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1 Introduction

In many economic situations, delegates are hired to play games on behalf of their principals. Consider the owner of a car dealership, who hires sales managers to sell cars to customers. Between the owner and her managers, there often exist various types of agency problems (moral hazard, adverse selection and combinations of both), with which the principal-agent literature has extensively dealt. However, in most of this literature, the game the agent is hired to play with other parties (e.g., bargaining between sales managers and car buyers) is suppressed in the studies of optimal agency contracts (the agent' actions alone determine the principal's payoff subject to perhaps exogenous randomization by nature). On the other hand, since Schelling [39], it has long been recognized that the principal may gain strategic advantages against a third party by properly designing a contract for the agent. In the context of car dealership, the agency contract between the dealership owner and her sales manager may affect how the sales manager and car buyers bargain and hence ultimately the terms of trade. A large amount of subsequent work has investigated when this commitment effect can arise and its implications in various economic situations.[1] But not much attention has been paid to the interactions between agency problems and commitment considerations in the delegation relationship. In this paper, we analyze such interactions in an important class of delegation games, delegated bargaining.

Specifically, we study the following one-sided delegation game. A seller of one indivisible good hires a delegate (an intermediary) to sell the good for her. They sign a contract, which becomes public knowledge. At the time the agency contract is signed, neither the seller nor the delegate knows the valuation of the (potential) buyer but they know its distribution. After exerting some unobservable "sales efforts", the delegate meets a buyer and then finds out the buyer's valuation. Then they bargain over a price, so bargaining is conducted under complete information. If the delegate and the buyer agree on a price, the buyer gets the good and makes the payment, and the delegate delivers the payment to the seller. The seller pays the delegate a wage according to the delegation contract. The seller only observes the sale revenue the delegate brings back to her. We assume that the delegate and the buyer cannot collude and the delegate cannot hide money from the seller. All the players are assumed to be risk-neutral. The model is obviously stylized, but seems to capture some of the essential features in the car dealership example and many other similar situations with trade intermediaries.

We suppose that there are both moral hazard and adverse selection problems in the delega-

[1] See, e.g., Vickers [43], Fershtman and Judd [11, 10] , Sklivas [40], Dewatripont [8], Gal-Or [14, 15, 16], Fershtman, Judd and Kalai [12], Katz [25], Hermalin [21, 22], Caillaud, Jullien and Picard [5], Martimort [32], Baye, Crocker and Ju [1], Laffont and Martimort [30], Fershtman and Kalai [13], Corts and Neher [6], Kockesen and Ok [29].

tion relationship. That is, the delegate's effort is not observable to the seller; and furthermore, the delegates can differ in their disutility of effort, which is not observable to the seller either. Ignoring the commitment effect of delegation contracts, we can characterize the seller's optimal mechanism. Using the insights of the earlier literature (e.g., Holmstrom and Milgrom [23], Laffont and Tirole [31], and McAfee and McMillan [33]), we show that a contract linear in sales revenue can implement the seller's optimal mechanism under certain mild conditions. This is done in Section 2. The case without commitment considerations serves as a useful benchmark.

We then turn to the case with commitment effect. We assume that delegation contracts are perfectly observable to potential buyers and cannot be renegotiated.[2] If the seller knew exactly the buyer's valuation, then she could achieve "full commitment" by using a "target contract". A target contract requires the delegate to get a certain price for the good, otherwise he is paid nothing or even faces some penalty. Without uncertainty, the seller can set the price target exactly equal to the buyer's valuation, which commits the delegate to get this price and leave the buyer with no surplus.[3] In reality, the seller often does not observe directly the buyer's valuation, and the agency problems make it difficult for the agent to communicate his knowledge about the buyer perfectly to the seller. In such cases the target contracts are not feasible anymore, thus the commitment power of delegation contracts is limited and the seller usually cannot achieve full commitment. In Section 3, we show that the seller can still achieve a substantial amount of commitment power by imposing a minimum price with a linear sharing contract. A minimum price can give the delegate bargaining advantage because it raises his threat point. With a standard Rubinstein bargaining model, it can be easily shown that the higher the minimum price, the higher the final sales price, *provided that the buyer's valuation is higher than the minimum price.* We derive the seller's optimal minimum price and optimal commission rate jointly. Under fairly general conditions, the seller sets a minimum price that is strictly greater than the lower bound of the buyer's valuations. This means that when the

[2]Several papers, e.g., Katz [25], Caillaud, Jullien and Picard [5], Dewatripont [8], Fershtman and Kalai [13], Corts and Neher [6], Kockesen and Ok [29], have examined whether delegation still has commitment power if delegation contracts are not perfectly observable or can be renegotiated secretly. By and large, these papers show that unobservability and renegotiation of delegation contracts *limit but do not eliminate* the commitment effects of delegation. Interestingly, asymmetric information between the principals and their delegates is usually necessary for delegation contracts to have commitment effects when renegotiation is allowed. In practice, the seller can maintain the credibility not to renegotiate delegation contracts for reputation reasons if she hires the delegate to do repeated sales with different customers or hires multiple delegates to conduct similar sales. See more discussions in Section 4.

[3]Fershtman *et al.* [12] show that with target contracts, any Pareto optimal outcome in a principals-only game can be achieved when (1) every principal can hire a delegate; (2) contracts are observable and not renegotiable; and (3) there are no agency problems. Kahenmann [24] reaches similar conclusions in the context of Rubinstein bargaining.

buyer's valuation is below this minimum price, the delegate and the buyer cannot reach a deal despite that there are positive gains from trade. We then investigate how the minimum price interacts with the commission rate to provide an optimal balance between commitment and incentive considerations.

One excuse of our focus on contracts linear in sales revenue above minimum price is simply that analysis of more complicated schemes is not tractable. This focus is also motivated by the observation that it is commonly used in real life. In car dealerships, "most salesmen are paid a commission which is usually 25-30 % of the gross profit (based on dealer invoice, not incentives) on every car they sell." (Eskeldson [9], p. 46) To us, the most interesting part of the agency contracts for car salesmen is what commission is based on. As shown in Section 2, when agency problems are the only consideration, the optimal contract requires commissions to be based on the seller's profit, i.e., sales revenue minus the seller's cost. However, in the U.S. car dealership business, the real cost of a car to the dealer is usually not its invoice price. Car manufacturers typically offer dealers "holdbacks", which pays back the dealers a certain percentage (usually 2-3 %) of the invoice prices when cars are actually sold. In addition to dealer holdbacks, car manufacturers offer many other different kinds of incentives (dealer rebates, volume discounts, credit discounts, etc.) from time to time (and can vary across dealerships). With all these provisions from car manufacturers taken into account, the real cost per car for the dealer is substantially lower than its invoice cost (of course, a small operational cost per car has to be added). Since commissions of car salesmen are calculated on the basis of invoice prices but not on dealer's real cost, car salesmen will not be willing to sell cars under invoice prices. Thus invoice prices in the car dealership example can be viewed as the minimum prices in our model, and our analysis provides a justification for using invoice prices to calculate commissions for car salesmen.

We find that the nature of the agency problem affects how the seller should optimally balance commitment and incentives. Specifically, we consider two kinds of moral hazard problems by the delegate. In the first scenario, the delegate exerts "bargaining effort" which increases his bargaining power against the buyer (e.g., doing research about the customers and the product, taking courses to improve bargaining skills). In this case, commitment through minimum prices and incentives for the delegate are *substitutes* for the seller, that is, higher minimum prices are associated with lower incentives for the delegate and hence lower effort by the delegate. As a result, high type agents are given more discretion in making deals with customers and are held responsible for the outcomes to a greater degree. In another scenario, the delegate exerts "marketing effort" which increases the chance that he finds a buyer (e.g., doing advertisement, providing good services, having clean showrooms). With "marketing effort", commitment through minimum prices and incentives for the delegate are neither substitutes nor complements. This means that for some exogenous changes in the environment, higher minimum prices are associated with higher incentives for the delegate and hence higher effort by the delegate; but for some other exogenous changes in the environment, minimum prices and incentives move in the opposite directions.

We also find that strategic delegation may lead to bargaining failures under general conditions in our model.[4] In our model, the delegate and the buyer bargain under complete information, yet sometimes they fail to reach agreements because the delegate is pre-committed by the seller to bargain aggressively all the time. This is closely related to Haller and Holden [20], who show that a heterogeneous group of people sometimes want to impose a super-majority ratification rule on the bargaining outcomes their delegate reached with a third party in order to gain strategic advantage. As a result, an agreement beneficial from the perspective of the median voter may fail to be reached. The main difference between Haller and Holden [20] and our paper is that while they focus on intra-group heterogeneity among the principals, we focus on the agency problems in the delegation relationship. Crawford [7] formulated the idea that commitment by bargainers in the presence of uncertainty can lead to bargaining failures, but he abstracted away from the commitment instruments bargainers use.[5]

Hiring a delegate to bargain with the buyers is one of the trading mechanisms used in real life (but not examined in the literature). In Section 4, we compare this mechanism with another commonly studied mechanism: standard monopoly pricing, whereby the seller commits to a fixed price (i.e., posted-price selling). Also in this section we discuss some of the factors that affects whether and how the minimum price can be credibly used as a commitment device to give the delegate bargaining advantage.

To study in more detail how the optimal mechanism responds to exogenous changes in the environment, in Section 5 we derive comparative statics of the model for the case of uniform distributions and quadratic cost functions. We present and compare results for three cases: no commitment effect, commitment effect with bargaining effort, and commitment effect with

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[4]That strategic delegation causes distortions is not new. For example, in oligopolistic competition, Fershtman and Judd [10] show that strategic delegation leads to lower price, lower profit but greater social surplus if oligopolists compete in Cournot fashion but the opposite is true if they compete in Bertrand fashion (see also Baye, Crocker and Ju [1], Vickers [43]).

[5]Studying a variation of Crawford [7], Muthoo [35] shows that without uncertainty about costs of revoking commitments, the bargaining outcome will be efficient. In another related paper, Cai [4] shows that the agency problems in the delegation relationship can cause bargaining inefficiency. Specifically, in Cai's model, a delegate bargains with a third party under complete information but faces reelection after the bargaining outcome becomes known to his constituency (principals). In this case, delay in reaching agreements can be used by the delegate as a signal to his principals that he is of "good type". In contrast to Cai [4], the agency problems in the delegation relationship do not directly cause bargaining inefficiency in our model. Rather, bargaining failures are caused by the seller's strategic manipulation of the delegation contract that commits the delegate to bargain aggressively.

marketing effort. For concreteness, Section 5 also gives some numerical examples where the model is explicitly computed. In one seemingly reasonable configuration of parameter values, there is a 39% probability that the delegate will not reach a deal with a buyer because of the seller's minimum price policy, resulting in about welfare loss of 16% of the total social surplus. In this case, the seller's expected payoff is more than 65% higher than that if she did not take advantage of the strategic value of delegation contract.

Finally, Section 6 offers some concluding remarks.

Fershtman and Judd [11] is the first model that studies how optimal contracts should respond to both agency problems and commitment considerations. Specifically, they consider a double-sided delegation game in which two managers are hired by their owners to compete with each other in an oligopolistic situation. In their model, like ours, delegation contracts are public information and not renegotiable. Unlike in our model, there is only moral hazard problem in the delegation relationship and the owners are more risk-averse than the managers are (so without commitment considerations, the owners should sell the firms to the managers). Fershtman and Judd show that to take advantage of the commitment power of the delegation contracts, the owners "over-compensate" the managers for success and thus bear more risk than efficient risk-sharing. In fact, the incentives for the managers are so strong that an owner is better off if her manager fails. Caillaud *et al.* [5] analyze a duopolistic competition model with double sided delegation in the presence of both agency problems and commitment. There is only adverse selection in their model (action is contractible) and delegation contracts are renegotiable. Caillaud *et al.* show that public but renegotiable delegation contracts still have commitment effects because they impose restrictions on the possible renegotiation outcomes in the presence of asymmetric information. The focus and analysis of their paper are quite different from ours.

2 The Basic Model Without Commitment Effect

The model consists of three *risk-neutral* parties: a seller (P), a delegate (D), and a buyer (B). The seller hires the delegate to sell a good to the buyer. The cost of the good to the seller is normalized to be zero. The delegate's reservation utility is U_0. At the time the seller contracts with the delegate, the valuation of the buyer for the good is unknown to both the seller and her delegate. Their common belief about the valuation is given by a probability distribution $G(s)$ with an everywhere positive density function $g(s)$, where $s \in [\underline{s}, \bar{s}]$ ($0 \leq \underline{s} < \bar{s}$) is the buyer's valuation.

For tractability, we suppose that when the delegate meets the buyer, the delegate finds out the buyer's valuation. So they bargain over a price without any information problem. The exact bargaining game will be specified later. For now, let us just say that the delegate can get a share of r of the total surplus for the seller in the equilibrium of the bargaining game. We assume that before bargaining with the buyer, the delegate can exert efforts to increase revenue for the seller. We consider two kinds of effort in this paper. The first is "bargaining effort", which increases the delegate's share for any fixed surplus. In this case we write the delegate's share r as a function of his effort e; and we assume that for all e, $r(e) \in (0,1)$, $r'(e) > 0$ and $r''(e) \leq 0$. Another type of effort is "marketing effort", which increases the probability that the delegate finds a buyer. Conditional on finding a buyer, the delegate will get a fixed share of r_0. We write the probability of finding a buyer p as a function of the delegate's marketing effort; and assume $p(e) \in (0,1)$, $p'(e) > 0$ and $p''(e) \leq 0$. For a fixed surplus s, the expected price the delegate can get in the case of bargaining effort is $x = r(e)s$ while in the case of marketing effort is $x = r_0 p(e)s$, so there is no real difference in the expected price between these two types of efforts. Indeed, in this section we ignore the commitment effect of delegation contracts, the two cases are identical (and we will use the bargaining effort interpretation). But in the next section, when commitment effect is present, the two cases will yield somewhat different results.

The delegate incurs effort cost of $C(e,t)$, where t is his "type" that characterizes his disutility of effort. We make the following standard assumptions on $C(e,t)$: (i) $C(e,t)$ is strictly increasing and convex in e, $C_e = \partial C/\partial e > 0$ and $C_{ee} = \partial^2 C/\partial e^2 > 0$; and (ii) higher types have lower effort cost and lower marginal effort cost, that is, $C_t = \partial C/\partial t < 0$ and $C_{et} = \partial^2 C/\partial e \partial t < 0$. The seller does not observe either the effort or the type of the delegate. Therefore, there are *both moral hazard and adverse selection* in the delegation relationship. At the time the seller is contracting with the delegate, the seller knows that the delegate's type is drawn from a distribution function $F(t)$ with density function $f(t) > 0$ for every $t \in [\underline{t}, \bar{t}]$, the domain of t.

Throughout the paper, we make the following standard assumption on $F(t)$:

Assumption 1 *The distribution of types $F(t)$ satisfies the monotone hazard rate property, that is, $f(t)/[1 - F(t)]$ is increasing in t.*

This assumption is satisfied by common distributions, such as uniform or log-normal.

For simplicity, we also make the following technical assumptions:

Assumption 2 *(i) C_{et} is a negative constant; (ii) $r'(e)$ and $p'(e)$ are positive constants.*

These two technical assumptions ensure that the agent's expected payoff function is concave. The results presented in the paper will not be affected if alternatively we make more general but less intuitive assumptions involving C_{eet}, C_{ett}, r'' and p''. By Part (ii), we will write $r(e) = r_0 + r'e$ and $p(e) = p_0 + p'e$, where r' and p' are positive constants.

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We assume that all the three players are risk-neutral. Suppose the total surplus is s, and the delegate obtains x (i.e., the price is x) for the seller, and the seller pays the delegate a wage of w. Then the seller's utility is $U_P = x - w$, the delegate gets a utility of $U_D = w - C(e,t)$, and the buyer's utility is $U_B = s - x$.

The timing of the game is as follows. At date 0, the seller (she, henceforth) hires a delegate (he, henceforth), whose type is unknown to her. She offers a menu contract to him, which is observable and non-renegotiable. At date 1, the delegate decides whether to continue the game or quit. If he stays in the game, then at date 2, he chooses an effort level e. At date 3, the delegate meets the buyer, learns the buyer's valuation of the good, and they bargain over a price. Finally, once a deal is reached, the delegate gives the sale revenue to the seller, who then pays the delegate according to their contract. Throughout the game, the seller can only observe the sale revenue. This implicitly assumes that the delegate and the buyer cannot collude, otherwise it would be easy for the buyer to hide some of the revenue. While collusion between the delegate and the buyer is a real concern for the seller and is an interesting issue to analyze, it is beyond the scope of this paper and thus assumed away. In some cases, reputation concerns of the delegate or legal constraints may help control collusive behavior of the delegate.

Now we turn to the specification of the bargaining game. The main results of this paper hold for the standard alternating-offer bargaining games such as Rubinstein [38] or Binmore, Rubinstein and Wolinsky [2] and equivalently the cooperative solution concept Nash Bargaining Solution.[6] For concreteness, we adopt the bargaining game of Binmore, *et al.* [2]: they alternate in making offers and there is a small exogenous probability ρ_d (respectively, ρ_b) that bargaining will break down whenever the delegate (respectively, the buyer) rejects an offer. When bargaining breaks down, the total surplus disappears (e.g., out of his own control, one bargainer walks out of the room and never returns). With this bargaining game, the effect of the delegate's bargaining effort is to reduce ρ_d (that is, having better control over the bargaining process). Bargaining could last infinite rounds if there is no agreement or breakdown. Suppose the delegate moves first by making an offer to the buyer.

When the delegate bargains with the buyer on behalf of the seller, how much the delegate will get in equilibrium can be affected by the contract between the seller and the delegate. Our main focus in this paper is precisely on how this commitment consideration affects the design of the delegation contract. To make meaningful comparisons, in this section, we first analyze the optimal contract design problem while ignoring the commitment effect. So for now, we suppose that for some reason the buyer bargains with the delegate as if the delegate were representing himself. This could happen when the buyer does not know whether the delegate

[6]See Osborne and Rubinstein [37] for discussions about the link between non-cooperative alternating-offer bargaining games and the Nash Bargaining Solution.

is representing himself or acting as the agent for the seller.[7]

After meeting a buyer, suppose the delegate finds out that the buyer's valuation is s. The following lemma is a standard result from Binmore et al. [2]:

Lemma 1 *When the delegate represents himself, the bargaining outcome in the unique subgame perfect equilibrium is such that the delegate and the buyer reach an agreement without delay and the sales price is* $x = rs$, *where* $r = \rho_b/[1-(1-\rho_b)(1-\rho_d)]$.

Since the equilibrium share of the delegate r decreases in ρ_d, it increases in his bargaining effort e, which was assumed before. Alternatively, we could use the standard Rubinstein bargaining model, which would have $r = (1-\delta_b)/(1-\delta_d\delta_b)$, where δ_d and δ_b are the discount factors of the delegate and the buyer respectively. Then the effect of delegate's bargaining effort would be to increase δ_d (i.e., improving patience). Or, we could use the Nash Bargaining Solution and suppose the seller's relative bargaining power is r while the buyer's is $1-r$, then maximizing $rln(x) + (1-r)ln(s-x)$ gives $x = rs$.

For future comparisons, let us consider first the case in which both the delegate's effort and type are observable to the seller. For a delegate of type t, the seller asks him to exert effort $e(t)$ and pays him a wage that covers his effort cost and his reservation utility. So $w(t) = C(e(t),t) + U_0$. Then the seller's expected profit is simply $EU_P = \int_{\underline{s}}^{\bar{s}}[r(e)s - w(t)]dG(s) = r(e)E(s) - C(e,t) - U_0$, where $E(s) = \int_{\underline{s}}^{\bar{s}} sdG(s)$. So the optimal effort $e_{FB}(t)$ for the seller satisfies the following condition:

$$r'E(s) = C_e(e_{FB}(t),t) \tag{1}$$

where subscripts are partial derivatives with respect to the corresponding variable (that is, $C_e = \partial C/\partial e$). By our assumptions, the second-order condition is satisfied and the solution to Equation (1) is unique. Also the optimal effort $e_{FB}(t)$ increases in the delegate's type t. Note that since both the delegate's effort and type are observable, there is no need to make wage contingent on sale revenue.

When the seller does not observe the delegate's effort and type, the optimal contract design problem can be analyzed in the mechanism design framework. By the revelation principle, it is without loss of generality to focus on direct revelation mechanisms in which the delegate is provided proper incentives to reveal his type truthfully and behave obediently. In a direct revelation mechanism, a seller's mechanism consists of a wage schedule $w(\hat{t},x)$ that depends on the delegate's announced type $\hat{t}$ and the sale revenue x he eventually brings back, and a

[7] Fershtman and Kalai [13] show that when the third party (here the buyer) either does not know whether or not the delegate is representing himself or simply does not observe the details of the contract, no commitment effect is still a trembling hand sequential equilibrium.

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recommendation of effort level $e(\hat{t})$ that depends only on his announced type $\hat{t}$. Given the seller's mechanism, the delegate of type t chooses an announcement of type $\hat{t}$ and an effort level to maximize his expected utility $U_D = \int_{\underline{s}}^{\bar{s}} w(\hat{t}, x)dG(s) - C(e,t)$.

Formally, the seller's problem is to find a wage schedule $w(\hat{t}, x)$ and a recommendation $e(\hat{t})$ that solves

$$\max_{\{w(t,x),e(t)\}} EU_P = \int_{\underline{t}}^{\bar{t}} \int_{\underline{s}}^{\bar{s}} [x - w(t,x)]dG(s)dF(t) \tag{2}$$

subject to

(i) $(t, e(t)) \in argmax_{\{\hat{t},e\}}\ U_D = \int_{\underline{s}}^{\bar{s}} w(\hat{t},x)dG(s) - C(e,t)$

(ii) $U_D(t) = \int_{\underline{s}}^{\bar{s}} w(t,x)dG(s) - C(e(t),t) \geq U_0$, $\forall t$

(iii) $x = r(e(t))s$, $\forall s$

Condition (i) is the incentive compatible constraint for the delegate. It states that he finds it optimal to report his true type and to choose the recommended level of effort. The interim participation constraint (condition (ii)) requires that the optimal contract has to ensure the delegate at least his reservation utility. Finally, condition (iii) describes the bargaining outcome for every possible buyer's valuation when the commitment effect of delegation contract is ignored.

The mechanism design problem can be solved in two steps. In the first step, we characterize the conditions for an optimal mechanism; and then in the second step we find contracts that implement the optimal mechanism. The results of this section and their derivation closely follow McAfee and McMillan [33] (see also Laffont and Tirole [31]).

To characterize the conditions for an optimal mechanism, suppose the seller can observe the delegate's effort but not his type and therefore can force upon him an effort schedule $e(\hat{t})$. Then the IC condition (i) is reduced to truth-telling only. Using the Envelope Theorem and integration by parts, one can simplify the mechanism design problem to (technical details in the Appendix):

$$\max_{\{e(t)\}} \int_{\underline{t}}^{\bar{t}} \left\{ r(e)E(s) - C(e,t) + C_t(e,t)[\frac{1-F(t)}{f(t)}] \right\} dF(t) - U_0 \tag{3}$$

Let $e^*(t)$ be a solution to Equation (3). Then it has to satisfy the following first-order condition:

$$r'E(s) = C_e(e^*,t) - C_{et}[\frac{1-F(t)}{f(t)}] \tag{4}$$

The following proposition gives the (sufficient) conditions for an optimal mechanism.

Proposition 1 *If a wage contract $w(\hat{t},x)$ can induce the delegate to (i) truthfully reveal his type, and (ii) choose $e^*(t)$, and guarantees him the reservation utility, then the mechanism $\{w(\hat{t},x), e^*(t))\}$ is optimal.*

Proof: See the Appendix.

Comparing Equations (1) and (4), one can see that the optimal effort in the presence of agency problems $e^*(t)$ is lower than that under complete and perfect information ($e_{FB}(t)$) for all types but $\bar{t}$. This is because the term $C_{et}[1 - F(t)]/f(t)$ in Equation (4) is negative for all $t < \bar{t}$. This term is the information rent to the delegate. Because of asymmetric information between the seller and the delegate, the economic cost of effort to the seller consists of the direct effort cost to the delegate $C(e, t)$ and the information rent. Equation (4) then simply says that marginal benefit of effort equals marginal cost of effort. Since the information rent increases the marginal cost of effort, the optimal level of effort should be lower.

The next step is to find contracts that satisfy all the conditions in Proposition 1. Consider the following contract that is linear in sale revenue. If the delegate makes a sale, his wage is given by

$$w(\hat{t}, x) = \alpha^*(\hat{t}) + \beta^*(\hat{t})x \tag{5}$$

where $\alpha^*(\hat{t})$ and $\beta^*(\hat{t})$ are

$$\alpha^*(\hat{t}) = C(e^*(\hat{t}), \hat{t}) - \int_{\underline{t}}^{\hat{t}} C_t(e^*(\nu), \nu)d\nu - \frac{C_e(e^*(\hat{t}), \hat{t})}{r'} r(e^*(\hat{t})) + U_0$$
$$\beta^*(\hat{t}) = \frac{C_e(e^*(\hat{t}), \hat{t})}{r'E(s)};$$

and if the delegate fails to sell the good, his wage is simply $w = \alpha^*(\hat{t})$. In other words, $\alpha^*(\hat{t})$ is an up-front payment made to the delegate when signing the contract but before conducting the sale.

First we need to do a consistency check: such a linear contract should yield the bargaining outcome as assumed in the mechanism design problem in Equation (2).

Lemma 2 *With any linear contract of the form $w(\hat{t}, x) = \alpha(\hat{t}) + \beta(\hat{t})x$ where $\alpha(\hat{t})$ is an up-front payment, the bargaining game has a unique subgame perfect equilibrium with the bargaining outcome being that the delegate and the buyer reach an agreement without delay and the sales price is $x = rs$, where $r = \rho_b/[1 - (1 - \rho_b)(1 - \rho_d)]$.*

Proof: By the standard result in the literature (Rubinstein [38], Binmore *et al.* [2], Osborne and Rubinstein [37]), the bargaining game has a unique subgame perfect equilibrium in which the two bargainers will reach an agreement without delay. Let x be the equilibrium price when the delegate makes an offer and y be that when the buyer makes an offer. Then the standard argument in the literature implies that

$$\begin{aligned} s - x &= (1 - \rho_b)(s - y) \\ \alpha + \beta y &= (1 - \rho_d)(\alpha + \beta x) + \rho_d \alpha \end{aligned}$$

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Solving these two equations gives the result of the Lemma. *Q.E.D.*

Lemma 2 confirms that any linear contract (and hence the contract in Equation (5)) is consistent with the no-commitment effect assumption made in this Section. The idea is simple. The up-front payment $\alpha(t)$ does not have any impact on the bargaining process since it is sunk before the bargaining game. What matters for the bargaining game is that the delegate gets $w = \beta x$ if the agreed price is x. But the bargaining outcome with this contract is the same as when the delegate is representing himself (in which case his utility is simply x), because a change of scale in the delegate's utility does not affect his behavior. Therefore, the bargaining outcome is $x = r(e)s$, $\forall s$.

The next proposition states that this linear contract actually implements the optimal mechanism.

Proposition 2 *The linear contract presented in Equation (5) implements the optimal recommended effort $e^*(t)$ and induces truthful report of type.*

Proof: See Appendix.

The intuition for the optimality of the linear contract is as follows. The seller needs to provide incentives to the delegate for him to tell the truth and follow the recommended effort. Because of risk-neutrality, these two tasks can be separately accomplished by the linear contract: The slope of the linear contract in Equation (5) provides proper effort incentives while the constant takes care of truth-telling about type.

A simple corollary can be derived from Proposition 2:

Corollary 1 *In the optimal linear contract, the optimal effort $e^*(t)$ and the sharing term $\beta^*(t)$ are non-decreasing in type, and the constant term $\alpha^*(t)$ is non-increasing in type.*

Proof: See Appendix.

This corollary says that with the optimal linear contract, a more able delegate (who dislikes effort less) is provided stronger incentives and hence works harder than a less able one. In particular, it can be checked that the highest type delegate gets all the residual sale revenue ($\beta^*(\bar{t}) = 1$) and exerts the efficient effort ($e^*(\bar{t}) = e_{FB}(\bar{t})$). Since a more able delegate is rewarded a higher proportion of the sale proceeds, the fixed portion of his wage is smaller than that of a less able delegate. In fact, for delegates of sufficiently high types, their fixed portion is negative. The interpretation is that lower types opt for higher fixed wage and smaller commissions, while higher types choose higher commissions and pay fees to get the job (such as franchise fees). Since we assume away any commitment effect by the delegation contract in this section, it does not make a difference whether the fixed portion of the wage contract α is paid before or after the bargaining game. But for the purpose of comparison with later

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sections, we suppose α is paid up front when the delegate takes the job (accept the contract) but before bargaining with the buyer.

3 Commitment Effect Through Minimum Price

In the preceding section, we demonstrate that a linear delegation contract can implement the optimal mechanism for the seller IF delegation contracts have no commitment effect. But as the delegation literature has demonstrated, in general what kind of contracts the seller has for the delegate can affect the bargaining process between the delegate and the buyer. Hence in designing the delegation contract, the seller should take advantage of the contract's potential strategic value. In this section, we study how this commitment effect influences the seller's contract choice and explore its implications. Due to the complexity of the problem, we focus on contracts that still keep some linear structures but impose minimum prices on the delegate. Minimum prices seem to be commonly observed in practice (e.g., in car dealerships), and our analysis attempts to shed light on their optimal uses in connection with optimal delegation contracts. We analyze the case with "bargaining effort" and then the "marketing effort" case.

3.1 Bargaining Effort

The seller can do better by modifying the linear contract given in Equation (5) to take advantage of the commitment effect. Consider the following contract. If the delegate makes a deal, his wage is

$$w(\hat{t}, x) = \alpha(\hat{t}) + \beta(\hat{t})(x - z(\hat{t})); \tag{6}$$

and if he does not sell the good, his wage is $\alpha(\hat{t})$ (i.e., an up-front payment). Here $z(\hat{t})$ is a minimum price that the seller wants the delegate to obtain. According to this contract, the seller pays the delegate $\alpha(\hat{t})$ once they sign the contract. The delegate then goes to bargain with a buyer over a price. If the delegate brings back more than $z(\hat{t})$, then the seller pays him a commission β of what the delegate obtains in excess of the minimum price $z(\hat{t})$. Otherwise, if the delegate brings back less than $z(\hat{t})$, then he has to pay back money to the seller in the amount of $\beta(\hat{t})(z(\hat{t}) - x)$.[8] If the delegate does not strike a deal with the buyer, he is paid zero (he still keeps $\alpha(\hat{t})$ since it is paid before the negotiation). Remember we suppose that the seller can observe whether there is a deal and the terms of the deal if it is made. So, for example, the delegate is penalized if he sells the good for nothing ($x = 0$) but pays no penalty if he reaches no deal. Note that the contract in Equation (5) is a special case of the above contract with $z = 0$ for all $\hat{t}$.

[8] Any amount of penalty for a sale price below the minimum price will have the same effect. See Lemma 3.

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If the delegate cannot get a price above the minimum price, then he will refuse to make a deal and obtain a payoff of $\alpha(\hat{t})$. So the delegate's choice not to make a deal effectively changes the linear contract of Equation (6) into a convex contract. It is this convexity that gives bargaining advantage to the delegate. Studying more complex convex contracts is difficult because the bargaining outcomes depend on the specific shapes of the delegate's payoff function.[9]

Assuming the contract is credible to the buyer, then it will affect the bargaining between the delegate and the buyer. The bargaining outcome under this contract is reported in the following lemma.

Lemma 3 *Suppose the delegation contract is given by Equation (6). Then the equilibrium outcome from the bargaining stage is* $x = r(e)(s - z(\hat{t})) + z(\hat{t})$, $\forall s \geq z(\hat{t})$. *When* $s < z(\hat{t})$, *there will be no agreement.*

Proof: When $s < z(\hat{t})$, there is no way the delegate can get a positive wage from a deal at the same time the buyer is not worse off, so there will be no agreement in this case. Suppose $s \geq z(\hat{t})$. Again, standard arguments of bargaining theory imply that there is a unique subgame perfect equilibrium. Let x be the equilibrium price when the delegate makes an offer and y be that when the buyer makes an offer. Then

$$\begin{aligned} s - x &= (1 - \rho_b)(s - y) \\ \alpha + \beta(y - z) &= (1 - \rho_d)[\alpha + \beta(x - z)] + \rho_d \alpha \end{aligned}$$

Solving these equations yields $x = r(s - z(\hat{t})) + z(\hat{t})$, where $r = \rho_b/[1 - (1 - \rho_b)(1 - \rho_d)]$. *Q.E.D.*

From Lemma 3, we can see that when $s \geq z(\hat{t})$, the seller gains an additional amount of surplus $(1 - r(e))z(\hat{t})$ purely from the commitment effect. And this commitment value is larger when the minimum price z is set higher, as long as it is not too high to prevent a deal. The idea is simple. Define $\tilde{s} = s - z(\hat{t})$. The delegate has to get at least $z(\hat{t})$ for the seller in order to get paid. So the "real" surplus he and the buyer can bargain over is $\tilde{s}$, of which the delegate should get $r(e)\tilde{s}$ given their relative bargaining power. Lemma 3 also points out the potential cost of using a minimum price as a commitment device. That is, the seller may go over the board and set a too high price target that prevents the delegate from reaching a deal with the buyer.

[9] Haller and Holden [20] present a simple example showing that convexifying the delegate's payoff function is always beneficial. They also offer several explanations why such contracts are not realistic. Long ago Sobel [41] pointed out that if bargainers were allowed to choose their payoff functions among concave functions, choosing linear functions would be a dominant strategy.

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If the seller sets a minimum price $z \in [0, \underline{s}]$, then for any possible s the delegate and the buyer will reach a deal. Since commitment comes without cost for $z \in [0, \underline{s}]$, it seems that the seller should seek the maximum amount of commitment in this range. This intuition is verified in the following lemma.

Lemma 4 *For any $z < \underline{s}$, the seller can get a greater expected payoff by increasing the minimum price z. Therefore, the seller should set the minimum price not less than $\underline{s}$ for every $\hat{t}$.*

Proof: See Appendix.

Since the contract analyzed in the previous section corresponds to $z = 0$, Lemma 4 implies that the contract is not optimal for the seller when delegation contracts have commitment power.

Now the central question is whether the seller wants to set a minimum price higher than $\underline{s}$. The seller's mechanism design problem can be stated as

$$\max_{\{\alpha(t),\beta(t),e(t),z(t)\}} EU_P = \int_{\underline{t}}^{\bar{t}} \left\{ \int_{z(t)}^{\bar{s}} [x - \beta(t)(x - z(t))]\, dG(s) - \alpha(t) \right\} dF(t) \quad (7)$$

subject to

(i) $(t, e(t)) \in argmax_{\{\hat{t},e\}}\ U_D = \alpha(\hat{t}) + \beta(\hat{t}) \int_{z(\hat{t})}^{\bar{s}} (x - z(\hat{t}))dG(s) - C(e,t)$

(ii) $U_D(t) \geq U_0$, $\forall t$

(iii) $x = r(e(t))(s - z(t)) + z(t)$, for $s \geq z(t)$, and 0 otherwise

(iv) $z(t) \in [\underline{s}, \bar{s}]$ for all t

As before, this problem can be solved in two steps. First we find the conditions for the optimal effort $e^B(t)$ and minimum price $z^B(t)$, (where the superscript B stands for "bargaining effort"). Following similar technical steps as in the proof of Proposition 1, we can rewrite the problem as:

$$\max_{\{e(t),z(t)\}} \int_{\underline{t}}^{\bar{t}} \left\{ r(e)E[s - z | s \geq z] + z[1 - G(z)] - C(e,t) + C_t(e,t)[\frac{1 - F(t)}{f(t)}] \right\} dF(t) - U_0 \quad (8)$$

where the argument (t) is suppressed in e and z, $E[s - z|s \geq z] = \int_z^{\bar{s}} [s - z]dG(s)$ and $z \in [\underline{s}, \bar{s}]$.

By point-wise differentiation of Equation (8), and assuming interior solutions (i.e., $z^B \in (\underline{s}, \bar{s})$), $e^B(t)$ and $z^B(t)$ must satisfy the following first-order conditions:

$$r' E[s - z^B | s \geq z^B] = C_e(e^B, t) - [\frac{1 - F(t)}{f(t)}]C_{et} \quad (9)$$

$$(1 - r(e^B))(1 - G(z^B)) - z^B g(z^B) = 0 \quad (10)$$

From Equation (10), one can see that z^B must be less than $\bar{s}$, since $\partial EU_P / \partial z = -\bar{s} g(\bar{s}) < 0$ at $z = \bar{s}$.

To implement the optimal mechanism, the next step is to find the optimal α and β that induce the delegate to report his true type and then choose the desired level of effort e^B. Let $\alpha^B(\hat{t})$ and $\beta^B(\hat{t})$ in contract (6) be such that:

$$\begin{aligned} \alpha^B(\hat{t}) &= C(e^B(\hat{t}),\hat{t}) - \int_{\underline{t}}^{\hat{t}} C_t(e^B(\nu),\nu)d\nu - \frac{C_e(e^B(\hat{t}),\hat{t})}{r'}r(e^B(\hat{t})) + U_0 \\ \beta^B(\hat{t}) &= \frac{C_e(e^B(\hat{t}),\hat{t})}{r'E[s - z^B(\hat{t})|s \geq z^B(\hat{t})]} \end{aligned} \tag{11}$$

The next proposition says that the contract (11) implements the optimal level of effort $e^B(t)$.

Proposition 3 *The linear contract (11) with the optimal minimum price $z^B(t)$ implements the recommended effort $e^B(t)$ and induces the delegate to report his true type.*

If the seller's optimal minimum price turns out to be $\underline{s}$, then the first-order condition for the optimal effort, Equation (9), is reduced to

$$r'[E(s) - \underline{s}] = C_e(e^B, t) - [\frac{1 - F(t)}{f(t)}]C_{et} \tag{12}$$

Denote this solution by $\tilde{e}(t)$.

Proposition 4 *Suppose for some $\tilde{t} \in (\underline{t}, \bar{t}]$, $1 - r(\tilde{e}(\tilde{t})) > \underline{s}g(\underline{s})$. Then the seller will set the optimal minimum price $z^B(t)$ above $\underline{s}$ for any delegate of type in $[\underline{t}, \tilde{t}]$. As a result, delegates of these types fail to reach agreement with the buyer with positive probability. In particular, if $\tilde{t} \geq \bar{t}$, then all delegates face a positive probability of bargaining failure.*

Proof: First note that $\tilde{e}(t)$ is non-decreasing in t. Since r is increasing in e, $1 - r(\tilde{e}(t)) > \underline{s}g(\underline{s})$ for any $t \in [\underline{t}, \tilde{t}]$. Suppose that the seller chooses $z^B = \underline{s}$ and $\tilde{e}(t)$ as in Equation (12) for some $t \in [\underline{t}, \tilde{t}]$. From the first-order condition (10), the seller can increase her expected payoff by choosing a minimum price $z > \underline{s}$. Contradiction. *Q.E.D.*

Proposition 4 points out that the seller's strategic use of delegation contracts may result in bargaining failures. Note that the condition in Proposition 4 is sufficient but not necessary. To understand this condition, let us suppose that the buyer's valuation s is uniformly distributed on $[\underline{s}, \bar{s}]$. If $\underline{s} = 0$ or $\bar{s}$ is very large and $1 - r$ is bounded from below, then for any $t \in [\underline{t}, \bar{t}]$, the seller sets a minimum price above $\underline{s}$. Otherwise, let $r(\tilde{e}(\tilde{t})) = k$ and the condition in Proposition 4 is equivalent to $(1.5 - k)\Delta s > E(s)$ where $\Delta s = \bar{s} - \underline{s}$ and $E(s) = (\bar{s} + \underline{s})/2$. So Proposition 4 roughly says that when the dispersion in the buyer's valuation is large relative to the expected gain from trade, the seller is more likely to set a minimum price higher than the buyer's minimum valuation. Intuitively, the more uncertain the seller is about the buyer's valuation,

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the more likely she wants to "over-commit" the delegate in order to ensure a relatively high price in most states of the world. On the other hand, if the expected valuation is high relative to the dispersion of valuation, then the seller does not want to risk losing potential profitable deals by over-committing the delegate. To see this last point, consider the converse of Proposition 4. From Equation (10), it is clear that if the valuation distribution satisfies $sg(s)/[1 - G(s)] \geq 1$ for every s, then the seller will always set $z^B = \underline{s}$. For uniformly distributed valuation, this condition simplifies to $2\underline{s} \geq \bar{s}$, or $E(s) \geq 1.5\Delta s$. So when the uncertainty about valuation is relatively small, the seller will set $z^B = \underline{s}$.

The next proposition shows the relationship between the optimal effort and minimum price.

Proposition 5 *In the seller's optimal mechanism, the optimal effort level $e^B(t)$ is non-decreasing in the delegate's type, and the optimal minimum price $z^B(t)$ is non-increasing in the delegate's type. Therefore, higher type delegates are given more chance of success in agreement and work harder than lower types.*

Proof: See the Appendix.

The key to understanding Proposition 5 is that commitment through minimum price and the delegate's effort are *substitutes* for the seller. An easy way to see this is through the bargaining outcome equation $x = r(e)(s - z) + z$. Clearly, the marginal revenue of effort decreases in the minimum price z. More formally, one can see from Equation (8) that the seller's expected payoff function $EU_P(e, -z, t)$ is supermodular in $(e, -z, t)$. By the monotone comparative statics (see Milgrom and Shannon [34]), $e^B(t)$ and $-z^B(t)$ must be non-decreasing in t. Intuitively, Proposition 5 says that since it is relatively easier to induce a more able delegate to work hard and get a good price, the seller will impose a smaller minimum price for him to reduce the chance of no deal.

3.2 Marketing Effort

Now we suppose that the delegate's effort is spent on marketing to attract or find a buyer. The delegate finds a buyer with probability $p(e) \in (0, 1)$, where $p(e) = p_0 + p'e$. For simplicity, the delegate's bargaining power relative to the buyer is assumed to be fixed and equals $r_0 \in (0, 1)$.

We still focus on linear contracts with minimum prices as in Equation (6). Clearly Lemma 3 from Section 3.1 applies here for a constant r_0. But the seller will get a positive price and pay the delegate a commission only when the delegate finds a buyer. It is also easy to see that Lemma 4 holds for marketing effort as well, that is, the seller will set a minimum price no less than $\underline{s}$. Commitment with a minimum price equal to $\underline{s}$ is costless to the seller, so she should take advantage of it. Again the central question is whether the seller wants to set a minimum price above $\underline{s}$. To answer this question we have to analyze the following optimal mechanism problem:

$$\max_{\{\alpha(t),\beta(t),e(t),z(t)\}} EU_P = \int_{\underline{t}}^{\bar{t}} \left\{ p(e) \int_{z(t)}^{\bar{s}} [x - \beta(t)(x - z(t))]\, dG(s) - \alpha(t) \right\} dF(t) \tag{13}$$

subject to

(i) $(t, e(t)) \in argmax_{\{\hat{t},e\}}\ U_D = \alpha(\hat{t}) + p(e)\beta(\hat{t}) \int_{z(\hat{t})}^{\bar{s}} (x - z(\hat{t}))dG(s) - C(e,t)$

(ii) $U_D(t) \geq U_0$, $\forall t$

(iii) $x = r_0(s - z) + z$, for $s \geq z$, and 0 otherwise

(iv) $z(t) \in [\underline{s}, \bar{s}]$ for all t

Notice that the delegate's expected payoff is the same as in the case of bargaining effort with $r(e)$ being replaced by $r_0 p(e)$. The only difference with problem (7) is how the delegate's effort affects the seller's expected payoff. Bargaining effort increases only the share from the revenue *net* of the minimum price, while marketing effort increases the probability of getting a certain amount of revenue *including the minimum price*.

As before, this problem can be solved in two steps. First we find the conditions for the optimal effort $e^M(t)$ and minimum price $z^M(t)$ (where M stands for "marketing"). Using the same technical steps as in the proof of Proposition 1, we can rewrite the problem as:

$$\max_{\{e(t),z(t)\}} \int_{\underline{t}}^{\bar{t}} \left\{ p(e)\Big[r_0 E[s - z | s \geq z] + z[1 - G(z)]\Big] - C(e,t) + C_t(e,t)[\frac{1 - F(t)}{f(t)}] \right\} dF(t) - U_0 \tag{14}$$

Let $e^M(t)$ and $z^M(t)$ be the level of effort and minimum price that solve this problem. We assume interior solution for z^M. By point-wise differentiation of Equation (14), $e^M(t)$ and $z^M(t)$ must satisfy the following first-order conditions:

$$p'\Big\{r_0 E[s - z^M | s \geq z^M] + z^M[1 - G(z^M)]\Big\} = C_e(e^M, t) - [\frac{1 - F(t)}{f(t)}]C_{et}(e^M, t) \tag{15}$$

$$p(e^M)\Big[(1 - r_0)(1 - G(z^M)) - z^M g(z^M)\Big] = 0 \tag{16}$$

The second step is to find the contract coefficients α^M and β^M that satisfy the IC and participation constraints and that implement the optimal effort e^M. Let $\alpha^M(\hat{t})$ and $\beta^M(\hat{t})$ in contract (6) be such that:

$$\begin{aligned} \alpha^M(\hat{t}) &= C(e^M(\hat{t}), \hat{t}) - \textstyle\int_{\underline{t}}^{\hat{t}} C_t(e^M(\nu), \nu)d\nu - \frac{C_e(e^M(\hat{t}), \hat{t})}{p'} p(e^M(\hat{t})) + U_0 \\ \beta^M(\hat{t}) &= \frac{C_e(e^M(\hat{t}), \hat{t})}{r_0 p' E[s - z^M(\hat{t}) | s \geq z^M(\hat{t})]} \end{aligned} \tag{17}$$

The next proposition states that the contract (17) together with the minimum price $z^M(t)$ induces the delegate to exert the recommended effort $e^M(t)$.

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Proposition 6 *The linear contract (17) with the optimal minimum price $z^M(t)$ implements the recommended effort $e^M(t)$ and induces the delegate to report his true type.*

Proof: See the Appendix.

Comparing Equations (10) and (16), one can see that the first-order conditions for the optimal minimum price are very similar in the two cases of bargaining and marketing effort. The main difference is that in the case of marketing effort, the minimum price can be solved from Equation (16) alone, and only depends on the distribution of the buyers' valuations and the delegate's relative bargaining power but not on the delegate's effort. The minimum price is also independent of the delegate's type. Similar to Proposition 4, we have the following result:

Proposition 7 *If $1 - r_0 > \underline{s}g(\underline{s})$, then the seller will set a minimum price above $\underline{s}$ for every delegate. Thus, with positive probability, the delegate and the buyer will not make a deal.*

This proposition says that, as in the case of bargaining effort, the seller's strategic manipulation of the delegation contract may cause bargaining failures between the delegate and the buyer. It is easy to see that when the buyer's valuation is disperse relative to the expected gains of trade, then the seller's optimal minimum price will be more likely to exceed the buyer's lowest valuation.

Unlike in the case of bargaining effort, commitment through minimum prices and incentives are *no longer substitutes* with marketing effort. In fact, since the minimum price can be solved from Equation (16) alone, the minimum price and effort do not display either substitute or complementary relations.

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4 Discussions

4.1 Comparison with Other Trading Mechanisms

Hiring a delegate to bargain with consumers is one of the trading mechanisms used in real life. Another commonly used mechanism is posted-price selling, whereby the seller commits to a fixed price. The optimal fixed price for the seller, τ, maximizes the expected profit

$$\max_{\{\tau\}} EU_P = \int_{\tau}^{\bar{s}} \tau dG(s) = \tau[1 - G(\tau)]$$

So τ is given by

$$1 - G(\tau) = \tau g(\tau) \tag{18}$$

This is the standard monopoly pricing formula. Comparing it with Equations (10) and (16), one finds that the optimal posted price τ is greater than the minimum prices as long as the delegate's bargaining power (measured by his share r) is positive. And the difference between the optimal posted price τ and the optimal minimum price increases in the delegate's bargaining power. When the delegate has zero bargaining power ($r = 0$), then the minimum price coincides with the optimal posted price. In this case, the delegate does not bring in additional sales revenue to the seller. On the other hand, when the delegate's bargaining power is very large (r approaches one), the optimal minimum price goes to $\underline{s}$, and trade is almost efficient. In this case, the final sales price is close to the buyer's valuation. So the outcome resembles a perfectly discriminating monopolist.

In general cases where the delegate has positive but not full bargaining power, the trade outcome falls in between posted-price selling and perfectly discriminating monopoly pricing. Perfectly discriminating monopoly pricing requires that the monopolist knows every buyer's valuation and can commit to a take-it-or-leave-it price offer to buyers. When the buyer's valuation is not observed, what we study in this paper is an alternative to posted-price selling, namely, the seller hires a delegate to find out the buyer's valuation and bargain over a price. This trading mechanism removes some of the rigidity in posted-price selling, and thus the use of the delegate improves trade efficiency. Since the minimum price decreases in the delegate's bargaining power, the efficiency gain associated with the use of delegate increases in his bargaining power. Of course, whether the seller gets more profit by hiring the delegate relative to posted-price selling also depends on the delegate's bargaining power, the cost of hiring him, and the distribution of the buyer's valuation.[10]

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4.2 Commitment Power of Agency Contracts

A critical question in the delegation literature is whether and when a delegation contract can be credibly used as a commitment device. Here we briefly discuss some of the factors that may affect the credibility of the contracts studied in the preceding section as a commitment device.

Recall that the commitment effect in our model comes from the minimum price only. As Lemma 3 shows, neither the fixed wage nor the commission rate of the delegate's compensation contract affects the bargaining outcome. So the key to the question of credibility is whether the buyer can be convinced that the minimum price is indeed the limit of the delegate's discretion over price. How can the buyer be sure that the delegate is not lying about the minimum price? What is to prevent the delegate and the seller from rescinding the minimum price, especially when the buyer's valuation is just below it?

Not Perfectly Observable Contract. If the delegation contract is not perfectly observable to the buyer, the delegate may have a tendency to claim that a minimum price close to the

[10]Wang [44] compares seller self-bargaining with posted-price selling in a different model.

buyer's valuation is set by the seller. But this tendency may destroy the credibility of using the minimum price as a commitment device. So whether unobservable delegation contracts have any commitment value in our model is not clear. A thorough analysis would start by specifying the buyer's prior belief about the minimum price (whether it is set, and how much it is) and then study the bargaining game with such asymmetric information on the buyer's part. This is beyond the scope of this paper. But if we still assume that the delegate knows the buyer's valuation, we can use the results from Gul, Sonnenschein and Wilson [19] and Gul and Sonnenschein [18] to show that under fairly reasonable conditions the minimum prices can be revealed rather quickly in equilibrium, which implies that unobservable minimum prices still have considerable commitment power. The main problem, however, is that such bargaining models under asymmetric information often yield multiple equilibria. Moreover, if the delegate does not perfectly know the buyer's valuation, things become completely intractable.

As mentioned before, Katz [25], Fershtman and Kalai [13], Corts and Neher [6], Kockesen and Ok [29], and many others have addressed the issue of whether unobservable contracts can still serve as a credible commitment device. Depending on the other party's belief, these papers find that unobservable contracts can still have commitment value when some equilibrium refinements are used. This suggests that our results are valid to some extent even when minimum prices are not perfectly observed by the buyers.

Renegotiable Delegation Contracts. A related credibility issue arises if the seller and the delegate can renegotiate the delegation contract.[11] In our model, renegotiation can be especially relevant when the delegate finds out that the buyer's valuation is below the minimum price. A Pareto improvement is readily available if the minimum price in the delegate's compensation contract is lowered. But if renegotiation is possible in such cases, then there is no strong reason why it cannot be in any other cases.

To maintain the credibility of the minimum price, the seller and the delegate may rely on reputation effects (see discussions below) or other sorts of institutions. In the case of car dealership, the dealer invoice price (and other related contractual provisions between car manufactures and car dealers) can be thought of an institutional innovation to maintain credibility with the help of car manufacturers.[12]

[11] See, e.g., Dewatripont [8] and Caillaud *et al.* [5] for analysis of commitment effect when delegation contracts are renegotiable.

[12] Alternatively, car manufactures would simply sell cars to car dealerships at lower prices. It seems difficult to justify going through all the troubles of those contractual provisions (e.g., holdbacks and other incentives) if not for commitment purposes. Contracts between car makers and dealers are franchise contracts, and there are many other important considerations (e.g., competition among dealers), see, e.g., Klein and Murphy [28], Klein [27] and Tirole [42]. See also Bresnahan and Reiss [3] for an early empirical work on pricing practices between

Reputation in Multi-Unit Sale. In situations such as car dealerships, the delegate is hired to sell same products over time. Our model and our results extend easily to the case in which there are N potential buyers with identical and independent distribution of valuations. On the credibility issue (which our model does not directly address), repeated sales may make it easier for the seller and the delegate to commit to a minimum price than a single-unit sale. When information about prices from past trades is available to later buyers (e.g., through word of mouth communication or consumer reports), the delegate and the seller may have incentives to stick to the minimum price despite short-term gains from trading with low-valuation buyers.

Reputation with Multiple Delegates. Similar reputation effects can arise when the seller hires multiple delegates to conduct sales (e.g., one person owns several dealerships, each of which is run by a manager). If the seller renegotiates with one manager, then it is hard not to renegotiate with other managers, which can reduce the total profit for the seller.

5 Comparative Statics and Numerical Examples

In this section we want to derive comparative statics of the model that may be useful in certain applications. In doing so, we need to specify the model a little more further. Specifically, suppose the buyer's valuation is uniformly distributed in $[\underline{s}, \bar{s}]$ and the delegate's type is uniformly distributed in $[\underline{t}, \bar{t}]$. The revenue share the delegate can get is given by $r(e) = r_0 + r'e$ in the case of bargaining effort. The parameter r_0 is the share the delegate can get without extra unobservable effort, and the parameter r' measures how productive the delegate's bargaining effort is (marginal revenue of effort equals $r'E(s)$). To ensure $r(e) \leq 1$, the meaningful range for bargaining effort is constrained to $[0, (1 - r_0)/r']$. On the other hand, in the case of marketing effort, the revenue share the delegate can get is a constant r_0, and the probability of finding a buyer is $p(e) = p_0 + p'e$. In this case, the effort is constrained to $e \leq (1 - p_0)/p'$ to ensure that $p(e) \leq 1$. The delegate's cost function is: $C(e, t) = \gamma_1(\bar{t} - t)e + \gamma_2 e^2$, with γ_1 and γ_2 both positive constants. Finally, we let $U_0 = 0$.

For concreteness, we will solve the model numerically with the following parameter values. The buyer's valuation is uniform on $[10, 950]$, and the delegate's type is uniform on $[0, 1]$. In the bargaining effort case, the delegate's bargaining share is $r(e) = 0.3 + 0.1e$, and $e \in [0, 7]$. In the marketing effort case, the bargaining share is $r_0 = 0.5$. The probability function is $p(e) = 0.3 + 0.1e$, and $e \in [0, 7]$. Under both interpretations, the effort cost function is $C(e, t) = 8(1 - t)e + 12e^2$. In this case, the total expected surplus from trade is 480.

car manufacturers and dealers.

5.1 No Commitment Effect

If delegation contracts do not have any commitment effect, our analysis in Section 2 shows that the seller's optimal effort schedule should maximize

$$(r_0 + r'e)E(s) - 2\gamma_1(\bar{t} - t)e - \gamma_2 e^2$$

where $E(s) = (\bar{s} + \underline{s})/2$. From Equations (4) and (5), the seller's desired level of effort and the commission rate of the delegation contract can be easily found as

$$e^* = \frac{r'E(s)}{2\gamma_2} - \frac{\gamma_1(\bar{t} - t)}{\gamma_2}$$
$$\beta^* = 1 - \frac{\gamma_1(\bar{t} - t)}{r'E(s)}$$

The solution to our numerical model is given in Table 4.[13] In this case, since the delegate and the buyer will always make a deal, the total expected surplus from trade is 480, which is shared by the seller, the delegate and the buyer. The seller obtains an expected surplus of 169.6, and the buyer gets an expected surplus of 256. The remainder is the delegate's expected wage payment of 54.4, of which 40 is his expected effort cost and 14.4 his expected information rent.

The comparative statics are straightforward and are summarized in Table 1.

Table 1: Comparative Statics: No Commitment

Increase in	t	$\bar{t}$	r'	$E(s)$	γ_1	γ_2
e^*	↑	↓	↑	↑	↓	↓
β^*	↑	↓	↑	↑	↓	–

These results are easy to understand. Since higher type delegates have lower marginal effort costs, optimal effort (and hence incentives through commission rate) should increase in type. The marginal revenue of effort is the product of r' and the expected total surplus $E(s)$. Hence, holding other things fixed, increase in r' or the expected total surplus will lead to higher commission rates and greater effort. The parameter r' measures the importance of effort. When $r' = 0$, the moral hazard problem disappears. In this case, $\beta^* = 0$ and $e^* = 0$, and the seller pays the delegate a fixed wage equal to his reservation utility. On the other hand, the parameter γ_2 measures the difficulty of inducing high effort for any given type of delegate, hence has the opposite effect on the optimal effort as r'. The commission rate β^* is

[13] The detailed solutions to the numerical model are presented in several Tables at the end of the paper.

independent of γ_2 because the "physical" effort cost $\gamma_2 e^2$ is compensated by the fixed payment α^*.

Holding other things fixed, increase in $\bar{t}$ means that the degree of adverse selection is greater between the seller and the delegate and hence makes it harder to induce truth-telling from the delegate. Consequently, ceteris paribus, the higher $\bar{t}$, the lower the optimal effort and commission rate. To see this more clearly, consider the extreme case in which $\bar{t}$ collapses to $\underline{t}$ so that there is no adverse selection. Then $t = \bar{t} = \underline{t}$, so $\beta^* = 1$ and $e^* = r'E(s)/(2\gamma_2) = e_{FB}$. This is simply the standard result that the efficient outcome (for the seller) can be achieved with a sell out contract when there is moral hazard and the agent is risk-neutral.

The parameter γ_1 measures the intensity of agency problem between the seller and the delegate. Higher γ_1 means that different delegates differ more in their dislike of effort, which leads to higher information rents. Consequently, other things being equal, the seller would want to set a higher commission rate and induce greater effort from the delegate when γ_1 is lower. When $\gamma_1 = 0$, the delegate's type does not matter, and the seller should sell the good to the delegate.

5.2 Bargaining Effort

Now suppose delegation contracts have commitment power and the delegate exerts bargaining effort. From Section 3.1, for every type t, the seller's desired effort and minimum price should maximize

$$
\begin{aligned}
U_{P,t} &= (r_0 + r'e)\frac{(\bar{s} - z)^2}{2\Delta s} + z\frac{\bar{s} - z}{\Delta s} - 2\gamma_1(\bar{t} - t)e - \gamma_2 e^2 \\
&= (r_0 + r'e)\frac{(E(s) + \frac{\Delta s}{2} - z)^2}{2\Delta s} + z\frac{(E(s) + \frac{\Delta s}{2} - z)}{\Delta s} - 2\gamma_1(\bar{t} - t)e - \gamma_2 e^2
\end{aligned}
$$

We write $\bar{s} = E(s) + \Delta s/2$, where $\Delta s = \bar{s} - \underline{s}$, because we would like to separate out the effects of changes in the expected surplus and changes in the uncertainty (dispersion) of valuations.

The closed form solutions for the optimal effort and minimum price are not readily available from the first-order conditions (which lead to cubic equations of e and z). Table 5 gives the solution for our numerical example. In this case, the optimal effort is much lower than the case with no commitment. Moreover, the optimal minimum price is set in between [365, 390]. This implies that the chance of bargaining failure is about 39 %. Because of the commitment effect, the seller's expected payoff jumps to 281.33, more than 65 % higher than that in the case of no commitment effect. The delegate's effort cost and information rent are both much lower. The buyer is also screwed, getting an expected payoff of 115, which is less than half of that in the case of no commitment. Bargaining failures cause welfare loss of about 76, about 16 % of the total expected surplus.

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We derive comparative statics results for the case of bargaining effort (details in the Appendix), which are summarized in Table 2 below.

Table 2: Comparative Statics: Bargaining Effort

Increase in	t	$\bar{t}$	r'	$E(s)$	Δs	γ_1	γ_2
e^B	↑	↓	↑	↑	↓	↓	↓
z^B	↓	↑	↓	↑/↓	↑	↑	↑
β^B	↑	↓	↑	↑	↓	↓	↓

The cells with two arrows indicate ambiguous comparative statics.

The comparative statics of e^B and β^B with respect to $\{t, \bar{t}, r', E(s), \gamma_1, \gamma_2\}$ are the same as in the case with no commitment effect, and have the same interpretations as given in the previous subsection.

A new implication from commitment effect is that now the delegate's optimal effort and his incentives (measured by β^B) are lower if uncertainty about the buyer's valuation increases (i.e., Δs increases while holding $E(s)$ fixed). Without commitment effect, uncertainty about the buyer's valuation does not matter because both the seller and the delegate are risk-neutral. With commitment effect, the seller sets a minimum price z^B that can be higher than the buyer's lowest valuation. When $E(s)$ is fixed and the dispersion of valuation Δs increases, the buyer's lowest valuation must decrease. It follows that more likely the buyer's valuation falls below a fixed minimum price. Moreover, the optimal minimum price will increase in this case (see below). Thus, the probability of bargaining failure increases. As a result, the expected return to bargaining effort is reduced, thus leading to lower effort and lower incentives.

Another set of comparative statics results in Table 2 concerns the minimum price. In Section 3.1 we show that incentives and minimum prices are substitutes (Proposition 5) and they move in opposite directions as the delegate's type changes. In fact, this is also true with respect to $\bar{t}$, r', γ_1 and γ_2 (see the Appendix). Basically, when agency problems are more severe and hence it is more costly to induce efforts (higher $\bar{t}$, γ_1 and γ_2), then the seller will substitute incentives for commitment by increasing the minimum price. On the other hand, when effort is more productive (higher r'), then the seller will reduce the minimum price. When the expected surplus $E(s)$ increases (holding Δs fixed), there are two opposite effects on the minimum price. On one hand, effort is more productive, hence the minimum price should go down. On the other hand, since both $\underline{s}$ and $\bar{s}$ increase, the cost of commitment (i.e., no deal) decreases while the benefit of commitment increases, so the minimum price should go up. The net effect of $E(s)$ on z is thus ambiguous. For example, if effort is not very productive (low r') or is costly (high γ_2) or uncertainty about valuation Δs is relatively high, then the second effect dominates so the minimum price increases in $E(s)$. When the dispersion of valuation Δs increases (holding $E(s)$ fixed), the marginal cost of using minimum prices becomes relatively smaller than the marginal benefit. Therefore, minimum price increases in Δs. Moreover, effort will go down, also leading to higher minimum price.

5.3 Marketing Effort

Now we turn to the case of marketing effort. From Section 3.2, for every type t, the seller's desired effort and minimum price should maximize

$$U_{P,t} = (p_0 + p'e)\left[r_0 \frac{(E(s) + \frac{\Delta s}{2} - z)^2}{2\Delta s} + z\frac{(E(s) + \frac{\Delta s}{2} - z)}{\Delta s}\right] - 2\gamma_1(\bar{t} - t)e - \gamma_2 e^2$$

It is easy to check that the optimal effort, the minimum price and the slope of the contract are given by

$$\begin{aligned} e^M &= \frac{p'[E(s) + \frac{\Delta s}{2}]^2}{4\gamma_2(2 - r_0)\Delta s} - \frac{\gamma_1(\bar{t} - t)}{\gamma_2} \\ z^M &= \frac{1 - r_0}{2 - r_0}[E(s) + \frac{\Delta s}{2}] \\ \beta^M &= \frac{2 - r_0}{r_0} - \frac{2\gamma_1(\bar{t} - t)(2 - r_0)^2 \Delta s}{r_0 p'[E(s) + \frac{\Delta s}{2}]^2} \end{aligned}$$

The solution to our numerical example is presented in Tables 6 (no commitment) and 7 (commitment).

Unlike the bargaining effort case, now the optimal effort is higher with commitment than without commitment, that is, incentives and commitment are complements in this example. Consequently, the probability of finding a buyer is higher with commitment, and the commission rate is much higher (greater than 2), which resembles the results in Fershtman and Judd [11, 10] that managers are "over-compensated" on the margin in equilibrium. The seller imposes a minimum price of 316, resulting in a 33% chance of bargaining failure. The welfare loss from bargaining failures is about 11% if holding effort fixed, about 3% if compared to the case under no commitment. The seller's expected utility increases from 74 to 103 (around 40%) due to both the commitment and incentive effects. The buyer is again the victim of the seller's commitment scheme, seeing his expected utility plunge from 88 to 43.

The comparative statics are summarized in Table 3.

The comparative statics of effort e^M and commission rate β^M are basically the same as in the case of bargaining effort. The minimum price now is independent of all the variables except the buyer's valuations (and the delegate's bargaining power r_0). Furthermore, the minimum

Table 3: Comparative Statics: Marketing Effort

Increase in	t	$\bar{t}$	p'	$E(s)$	Δs	γ_1	γ_2	
e^M	↑	↓	↑	↑	↓	↓	↓	
z^M	–	–	–	↑	↑	–	–	
β^M	↑	↓	↑	↑	↓	↓	–	

price and effort are positively related when the expected valuation changes, but negatively related when the dispersion of valuation increases.

6 Conclusion

In this paper we develop a framework that can be used to analyze the interactions between agency problems and commitment effect in delegated bargaining situations. Among other things, we find that the seller's strategic manipulation of the delegation contracts can cause bargaining failures between her delegate and the buyer. Furthermore, the interactions between incentives and commitment depend on the nature of the agency problem: they are substitutes in the case of bargaining effort but not in the case of marketing effort. We also derive comparative statics of the model, some of which may possibly lead to testable implications. Empirical work is badly needed for the delegation literature, because, to our best knowledge, there has been no empirical study providing evidence on the existence of strategic delegation despite a large number of theoretical works.

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7 Appendix

Proof of Proposition 1: Let EU_P be the seller's expected utility when she pays the delegate a wage $w(\hat{t}, x)$, that is,

$$EU_P = \int_{\underline{t}}^{\bar{t}} E[x - w(\hat{t}, x)]dF(t) = \int_{\underline{t}}^{\bar{t}} \{r(e)E(s) - E[w(\hat{t}, x)]\} dF(t) \tag{19}$$

and let $U_D(\hat{t}, t)$ be the type-t delegate's utility when he announces type $\hat{t}$, which is

$$U_D(\hat{t}, t) = E[w(\hat{t}, x)] - C(e, t) \tag{20}$$

where the expectation $E[.]$ in these two equations is taken over the random variable s.

Consider a seller's effort recommendation $e(\hat{t})$. Suppose the delegate follows it. The IC condition reduces to truth-telling only. The first-order condition with respect to the delegate's type announcement is

$$\frac{\partial U_D(\hat{t}, t)}{\partial \hat{t}}|_{\hat{t}=t} = 0$$

Let $U_D(t) = U_D(t, t)$ be the delegate's utility when he reports his true type. The total derivative of $U_D(t)$ with respect to his type report can be obtained from the Envelope Theorem as follows

$$\frac{dU_D(\hat{t}, t)}{dt}|_{\hat{t}=t} = \frac{\partial U_D(\hat{t}, t)}{\partial \hat{t}}|_{\hat{t}=t} + \frac{\partial U_D(\hat{t}, t)}{\partial t}|_{\hat{t}=t} = \frac{\partial U_D(\hat{t}, t)}{\partial t}|_{\hat{t}=t} = -C_t(e, t)$$

where the last equality comes from Equation (20). Since this is a total derivative the delegate's utility can be reconstructed by integrating this equation with respect to his type.

$$U_D(t) = U_D(\underline{t}) - \int_{\underline{t}}^{t} C_t(e, \nu)dF(\nu) \tag{21}$$

So, from Equations (20) (evaluated at the delegate's true type) and (21) we can solve for the wage schedule as follows

$$E[w(t, x)] = U_D(t) + C(e, t) = U_D(\underline{t}) - \int_{\underline{t}}^{t} C_t(e, \nu)dF(\nu) + C(e, t)$$

Plugging the wage schedule into the seller's expected utility function (Equation (19)) gives

$$EU_P = \int_{\underline{t}}^{\bar{t}} \left\{ r(e)E(s) - C(e, t) + \int_{\underline{t}}^{t} C_t(e, \nu)dF(\nu) \right\} dF(t) - U_D(\underline{t}) \tag{22}$$

Next, integrating by parts the second term of the integral yields

$$\int_{\underline{t}}^{\bar{t}}\int_{\underline{t}}^{t} C_t(e,\nu)dF(\nu)dF(t) =$$

$$= \left[-(1-F(t))\int_{\underline{t}}^{t} C_t(e,\nu)dF(\nu)\right]_{\underline{t}}^{\bar{t}} + \int_{\underline{t}}^{\bar{t}} [\frac{1-F(t)}{f(t)}]C_t(e,t)dF(t) =$$

$$= \int_{\underline{t}}^{\bar{t}} [\frac{1-F(t)}{f(t)}]C_t(e,t)dF(t) \tag{23}$$

Note that if the seller ensures a type-$\underline{t}$ delegate a utility $U_D(\underline{t}) = U_0$, the interim participation constraint is satisfied for all types. The reason is that the delegate's expected utility function (Equation (21)) is increasing in t since C_t is negative. Hence the seller should set $U_D(\underline{t}) = U_0$.

Using Equation (23) and $U_D(\underline{t}) = U_0$, one can rewrite Equation (22) as

$$EU_P = \int_{\underline{t}}^{\bar{t}} \left\{ r(e)E(s) - C(e,t) + C_t(e,t)\frac{1-F(t)}{f(t)} \right\} dF(t) - U_0$$

This is Equation (3). Note that the seller has to pay the delegate his effort cost, his reservation utility and some information rent. The seller will choose an effort recommendation that maximizes her expected payoff. Differentiating point-wise with respect to effort, we get the following first-order condition for $e^*(t)$:

$$r'E(s) - C_e(e^*,t) + \frac{1-F(t)}{f(t)}C_{et} = 0$$

This is Equation (4). The second-order condition is clearly satisfied because the integrand in Equation (3) is concave in e: r' is a constant, $C_{ee}(.,t) > 0$, and C_{et} is a constant. *Q.E.D.*

Proof of Proposition 2: For later reference, notice that effort $e^*(t)$ is non-decreasing in type. From Equation (4), it is clear that the "total" marginal cost of effort decreases with type (the inverse of the hazard rate decreases with type and C_{et} is negative). By the monotone comparative statics (Milgrom and Shannon [34]), effort must be non-decreasing in t.

If the seller offers the delegate the contract (5), the delegate's utility when he exerts effort e and reports $\hat{t}$ is

$$\begin{aligned} U_D(\hat{t},e,t) &= C(e^*(\hat{t}),\hat{t}) + \frac{C_e(e^*(\hat{t}),\hat{t})}{r'}[r(e) - r(e^*(\hat{t}))] - \\ &\quad - \int_{\underline{t}}^{\hat{t}} C_t(e^*(\nu),\nu)d\nu - C(e,t) + U_0 \end{aligned} \tag{24}$$

The first-order conditions are the following:

$$\begin{aligned}
\frac{\partial U_D(\hat{t}, e, t)}{\partial e} &= C_e(e^*(\hat{t}), \hat{t}) - C_e(e, t) = 0 \\
\frac{\partial U_D(\hat{t}, e, t)}{\partial \hat{t}} &= \frac{[r(e) - r(e^*(\hat{t}))]}{r'} \frac{d}{d\hat{t}} C_e(e^*(\hat{t}), \hat{t}) = 0
\end{aligned}$$

They are satisfied at $\hat{t} = t$ and $e = e^*(t)$. The second-order conditions for a maximum are also satisfied since the delegate's profit is concave in effort and the determinant of the second-order matrix is positive.

$$\frac{\partial^2 U_D(t, e, t)}{\partial e^2} \frac{\partial^2 U_D(t, e, t)}{\partial t^2} - \left(\frac{\partial^2 U_D(t, e, t)}{\partial e \partial t} \right)^2 = -C_{et} \frac{d}{dt} C_e(e^*(t), t) \geq 0$$

This last inequality holds because of the following equation (derived from Equation (4)):

$$\frac{d}{dt} C_e(e^*(t), t) = C_{et} \frac{\partial}{\partial t} [\frac{1 - F(t)}{f(t)}] \geq 0 \tag{25}$$

Q.E.D.

Proof of Corollary 1: That $\beta^*(t)$ is non-decreasing in type can be checked from Equation (25). In the beginning of the proof of Proposition 2 we showed that the effort is non-decreasing in type. From the definition of $\alpha^*(t)$ (Equation (5)),

$$\frac{\partial \alpha^*(t)}{\partial t} = -\frac{r(e^*(t))}{r'} \frac{d}{dt} C_e(e^*(t), t) \leq 0$$

Q.E.D.

Proof of Lemma 4: Consider any direct revelation mechanism ($\alpha(\hat{t})$, $\beta(\hat{t})$, $z(\hat{t})$, $e(\hat{t})$), where $z(\hat{t}) < \underline{s}$. This mechanism gives the seller a revenue of $r(e(t))[E(s) - z(t)] + z(t)$. But the seller can do better with another mechanism which also implement the same effort recommendation $e(\hat{t})$ but imposes the minimum price equal to $\underline{s}$. Consider the following mechanism ($\tilde{\alpha}(\hat{t})$, $\beta(\hat{t})$, $\underline{s}$, $e(\hat{t})$), where $\tilde{\alpha}(\hat{t}) = \alpha(\hat{t}) + \beta(\hat{t}) r(e(\hat{t}))(\underline{s} - z(\hat{t}))$. The expected wage is the same since

$$\begin{aligned}
E[w(x, \hat{t})] &= \tilde{\alpha}(\hat{t}) + \beta(\hat{t}) E[x - \underline{s}] = \\
&= \tilde{\alpha}(\hat{t}) + \beta(\hat{t}) r(e(\hat{t}))[E(s) - \underline{s}] = \\
&= \alpha(\hat{t}) + \beta(\hat{t}) r(e(\hat{t}))(\underline{s} - z(\hat{t})) + \beta(\hat{t}) r(e(\hat{t}))[E(s) - \underline{s}] = \\
&= \alpha(\hat{t}) + \beta(\hat{t}) r(e(\hat{t}))[E(s) - z(\hat{t})]
\end{aligned}$$

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All the (IC) and (IR) conditions must be satisfied as they are in the old mechanism ($\alpha(\hat{t})$, $\beta(\hat{t})$, $z(\hat{t})$, $e(\hat{t})$). The cost to the seller is also the same, but her expected revenue increases since

$$\begin{aligned} E(x) &= r(e(t))E[s-\underline{s}]+\underline{s} = r(e(t))E(s)+[1-r(e(t))]\underline{s} > \\ &> r(e(t))E(s)+[1-r(e(t))]z(t) = r(e(t))[E(s)-z(t)]+z(t) \end{aligned}$$

Q.E.D.

Proof of Proposition 3: The type-t delegate's utility when he reports $\hat{t}$, chooses e and is paid according to contract (11) is

$$\begin{aligned} U_D(\hat{t},e,t) &= \alpha^B(\hat{t})+\beta^B(\hat{t})r(e)E[s-z^B(\hat{t})|s\geq z^B(\hat{t})]-C(e,t) \\ &= C(e^B(\hat{t}),\hat{t})+\frac{C_e(e^B(\hat{t}),\hat{t})}{r'}[r(e)-r(e^B(\hat{t}))]-\int_{\underline{t}}^{\hat{t}}C_t(e^B(\nu),\nu)d\nu-C(e,t)+U_0 \end{aligned}$$

Notice the similarity between this utility and that of Equation (24). The proof is similar to that of Proposition 2 with a change of the superscript "$*$" to the superscript "B" and a change of $E(s)$ to $E[s-z(\hat{t})|s\geq z(\hat{t})]$. The second-order condition is satisfied because $C_e(e^B(t),t)$ is non-decreasing in type. From Equation (9),

$$\begin{aligned} \frac{d}{dt}C_e(e^B(t),t) &= r'\frac{\partial E[s-z^B|s\geq z^B]}{\partial z}\frac{\partial z^B}{\partial t}+C_{et}\frac{d}{dt}\frac{1-F(t)}{f(t)} = \\ &= -r'[1-G(z)]\frac{\partial z}{\partial t}+C_{et}\frac{\partial}{\partial t}\frac{1-F(t)}{f(t)} \end{aligned}$$

Proposition 5 shows that z is non-increasing in type. Hence the first term of the equality is non-negative. From Equation (25), the second term is also non-negative.

Q.E.D.

Proof of Proposition 5: From the seller's expected payoff function in Equation (8), we can show that

$$\begin{aligned} \frac{\partial^2 EU_P}{\partial e\partial(-z)} &= r'\frac{\partial E[s-z|s\geq z]}{\partial(-z)} = r'[1-G(z)]\geq 0 \\ \frac{\partial^2 EU_P}{\partial e\partial t} &= -C_{et}\left(1-\frac{\partial}{\partial t}\frac{1-F(t)}{f(t)}\right)\geq 0 \\ \frac{\partial^2 EU_P}{\partial(-z)\partial t} &= 0 \end{aligned}$$

Therefore, $EU_P(e,-z,t)$ is supermodular, and by the monotone comparative statics, $e(t)$ is non-decreasing in t and z is non-increasing in t. *Q.E.D.*

Proof of Proposition 6: Recall that $p(e)$ in Section 3.2 has the same interpretation as $r(e)$ in Sections 2 and 3.1. The delegate's utility under contract (17) is

$$\begin{aligned} U_D(\hat{t},e,t) &= \alpha^M(\hat{t}) + \beta^M(\hat{t}) r_0 p(e) E[s - z^M(\hat{t}) | s \geq z^M(\hat{t})] - C(e,t) = \\ &= C(e^M(\hat{t}),\hat{t}) + \frac{C_e(e^M(\hat{t}),\hat{t})}{p'}[p(e) - p(e^M(\hat{t}))] - \int_{\underline{t}}^{\hat{t}} C_t(e^M(\nu),\nu)d\nu - C(e,t) + U_0 \end{aligned}$$

Next compare the delegate's utility under this contract with his utility in the proof of Proposition 2 (see Equation (24)). The rest of the proof is similar to that of Proposition 2 with a change of the superscript "$*$" to the superscript "M". The second-order condition is satisfied because $C_e(e^M(t),t)$ is non-decreasing with type. Using Equation (15), and taking into account that z^M does not change with type (from Equation (16)),

$$\frac{d}{dt}C_e(e^M(t),t) = C_{et}\frac{\partial}{\partial t}[\frac{1-F(t)}{f(t)}] \geq 0$$

Q.E.D.

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Comparative statics: Bargaining Effort (Table 2): The seller's utility for a given type t, assuming that the parameters are such that $z^B \in (\underline{s},\bar{s})$, is

$$U_{P,t} = (r_0 + r'e)\frac{(E(s) + \frac{\Delta s}{2} - z)^2}{2\Delta s} + z\frac{(E(s) + \frac{\Delta s}{2} - z)}{\Delta s} - 2\gamma_1(\bar{t} - t)e - \gamma_2 e^2$$

This function, written as $U_{P,t}(e,-z,t,-\bar{t},r',-\gamma_1,-\gamma_2)$, is supermodular since

$$\begin{aligned} \frac{\partial^2 EU_{P,t}}{\partial e \partial z} &= -r'\frac{(E(s) + \frac{\Delta s}{2} - z)}{\Delta s} < 0 \qquad \frac{\partial^2 EU_{P,t}}{\partial e \partial t} = 2\gamma_1 > 0 \qquad \frac{\partial^2 EU_{P,t}}{\partial e \partial \bar{t}} = -2\gamma_1 < 0 \\ \frac{\partial^2 EU_{P,t}}{\partial e \partial r'} &= \frac{(E(s) + \frac{\Delta s}{2} - z)^2}{2\Delta s} > 0 \qquad \frac{\partial^2 EU_{P,t}}{\partial e \partial \gamma_1} = -2(\bar{t} - t) \leq 0 \qquad \frac{\partial^2 EU_{P,t}}{\partial e \partial \gamma_2} = -2e < 0 \\ \frac{\partial^2 EU_{P,t}}{\partial z \partial r'} &= -e\frac{(E(s) + \frac{\Delta s}{2} - z)}{\Delta s} < 0 \qquad \frac{\partial^2 EU_{P,t}}{\partial z \partial t} = \frac{\partial^2 EU_{P,t}}{\partial z \partial \bar{t}} = \frac{\partial^2 EU_{P,t}}{\partial z \partial \gamma_1} = \frac{\partial^2 EU_{P,t}}{\partial z \partial \gamma_2} = 0 \end{aligned}$$

By the monotone comparative statics, e and $-z$ are non-decreasing in t and r' and non-increasing in $\bar{t}$, γ_1 and γ_2.

The equation for the commission β^B is given by

$$\beta^B = 1 - \frac{2\gamma_1(\bar{t}-t)(2-r_0-r'e)^2\Delta s}{r'[E(s)+\frac{\Delta s}{2}]^2} \tag{26}$$

This commission increases in t and r', and decreases in $\bar{t}$, γ_1 and γ_2.

The response of effort and minimum price to changes in $E(s)$ and Δs is not straightforward, but we can get some results from the first-order conditions. Combining those two conditions ((9) and (10)) we obtain the following equations (they are displayed in Figures 1 and 2):

$$\frac{r'[E(s)+\frac{\Delta s}{2}]^2}{2\Delta s(2-r_0-r'e)^2} = 2\gamma_1(\bar{t}-t) + 2\gamma_2 e \tag{27}$$

$$z = \left[1 - r_0 - r'\left\{\frac{r'(E(s)+\frac{\Delta s}{2}-z)^2}{4\gamma_2\Delta s} - \frac{\gamma_1(\bar{t}-t)}{\gamma_2}\right\}\right](E(s)+\frac{\Delta s}{2}-z) \tag{28}$$

We can see that the left-hand side of Equation (27) increases in $E(s)$ for every effort level. Hence, e^B increases in $E(s)$. On the other hand, the change in the right-hand side of Equation (28) is undetermined since

$$\frac{\partial RHS}{\partial E(s)} = 1 - r_0 - \frac{r'^2[E(s)+\frac{\Delta s}{2}-z]^2}{2\gamma_2\Delta s} + \frac{r'\gamma_1(\bar{t}-t)}{\gamma_2} \gtreqless 0$$

This is so because two opposite forces work here: effort increases in $E(s)$ (minimum price should decrease), and the net benefit of commitment increases (minimum price should increase). So we cannot say much more unless we put some additional restrictions on parameters.

From condition (10) we can show that $z = [E(s)+\Delta s/2](1-r(e))/(2-r(e))$. Hence, $[E(s)+\Delta s/2 - z] = [E(s)+\Delta s/2]/(2-r(e))$. Taking into account that effort increases in $E(s)$, this term also increases in $E(s)$. Therefore β^B increases in $E(s)$.

The left-hand side of Equation (27) decreases in Δs for every effort level because

$$\frac{\partial LHS}{\partial \Delta s} = \frac{-r'(E(s)+\frac{\Delta s}{2})(E(s)-\frac{\Delta s}{2})}{2(2-r_0-r'e)^2\Delta s^2} = \frac{-r'\bar{s}\underline{s}}{2(2-r_0-r'e)^2\Delta s^2} < 0$$

Hence, e^B decreases, and $(1-r(e))/(2-r(e))$ increases, in Δs. This last effect together with the initial increase in Δs implies that the minimum price increases.

The second term of the equation for β^B (26) is inversely proportional to the left-hand side of equation (27), so it increases in Δs. Moreover, effort decreases in Δs, which causes β^B to decrease in Δs. *Q.E.D.*

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Figure 1: First-Order Conditions for Bargaining Effort (Equation (27))

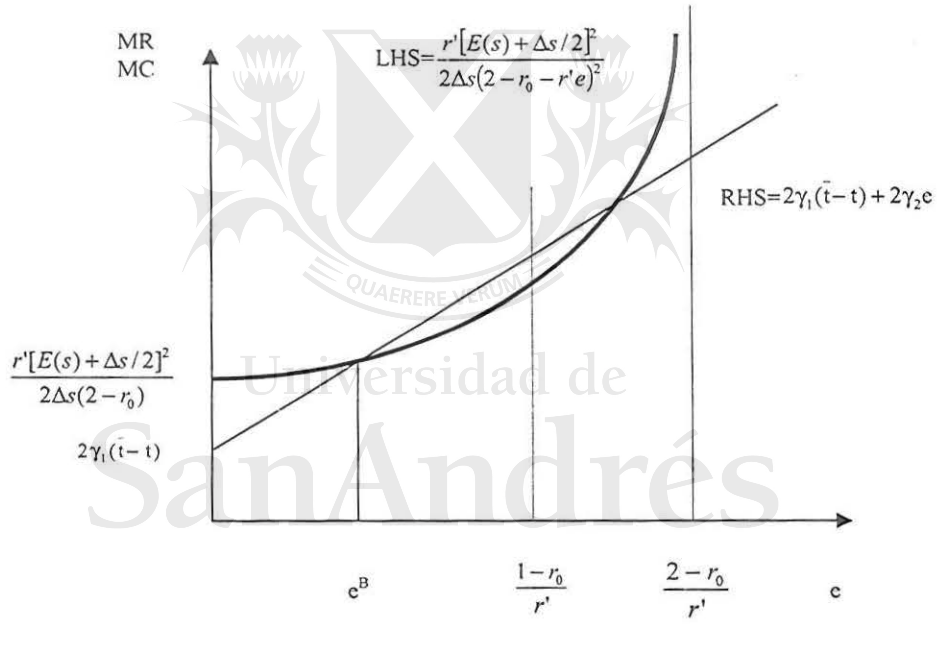

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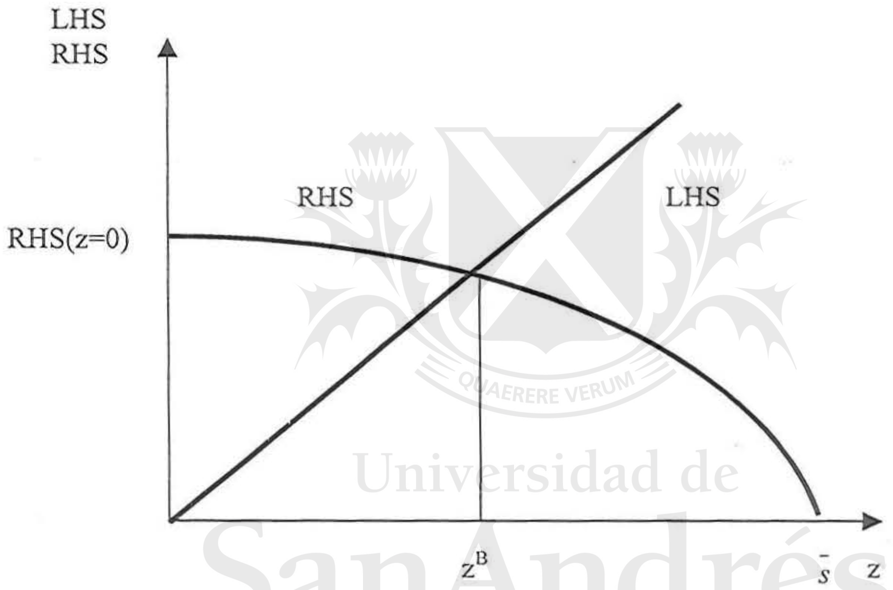
Figure 2: First-Order Conditions for Minimum Price (Bargaining Effort Case)



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The equations come from (28).

$$RHS = \left\{1 - r_0 - \frac{r'^2\left(E(s) + \Delta s/2 - z\right)^2}{4\gamma_2 \Delta s} + \frac{r'\gamma_1\left(\bar{t} - t\right)}{\gamma_2}\right\}\left(E(s) + \Delta s/2 - z\right)$$

$$RHS(z=0) = \frac{\left[(1 - r_0)\gamma_2 + r'\gamma_1\left(\bar{t} - t\right)\right]\left(E(s) + \Delta s/2\right)}{\gamma_2} - \frac{r'^2\left(E(s) + \Delta s/2\right)^3}{4\gamma_2 \Delta s}.$$

Table 4: A Numerical Example of Bargaining Effort (No Commitment, $z = 0$)

t	e*	r(e*)	β(e*)	EU_P	EU_D	C(e*)	EU_B
0	1.33	0.43	0.833	176.0	0.0	32.0	272.0
0.1	1.40	0.44	0.850	175.4	2.2	33.6	268.8
0.2	1.47	0.45	0.867	174.5	4.7	35.2	265.6
0.3	1.53	0.45	0.883	173.4	7.4	36.8	262.4
0.4	1.60	0.46	0.900	172.2	10.2	38.4	259.2
0.5	1.67	0.47	0.917	170.7	13.3	40.0	256.0
0.6	1.73	0.47	0.933	169.0	16.6	41.6	252.8
0.7	1.80	0.48	0.950	167.0	20.2	43.2	249.6
0.8	1.87	0.49	0.967	164.9	23.9	44.8	246.4
0.9	1.93	0.49	0.983	162.6	27.8	46.4	243.2
1	2.00	0.50	1.000	160.0	32.0	48.0	240.0
Ex-ante Value	**1.67**	**0.47**	**0.917**	**169.6**	**14.4**	**40.0**	**256.0**

Basic Information: $\bar{s} = 950$, $\underline{s} = 10$, $E(s) = 480$, $\Delta s = 940$, $\gamma_1 = 8$, $\gamma_2 = 12$, $r' = 0.1$, $r_0 = 0.3$, $U_D(\underline{t}) = 0$.
Revenue Function: $r(e) = r_0 + r'e$, Cost Function: $C(e,t) = \gamma_1(1-t)e + \gamma_2 e^2$.
Notation: t: type; e^*: effort; $r(e^*)$: bargaining share; $\beta(e^*)$: commission; EU_P: seller's utility; EU_D: delegate's utility; $C(e^*)$: effort cost; EU_B: buyer's utility.

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Table 5: A Numerical Example of Bargaining Effort (Commitment Effect)

t	e^B	$r(e^B)$	z^B	β^B	EU_P	EU_D	$C(e^B)$	EU_B	Surplus (*)	Welfare Loss (**)
0	0.03	0.303	390.3	0.520	282.6	0.0	0.2	116.2	399.0	81.0
0.1	0.10	0.310	387.9	0.572	283.1	0.2	0.8	116.0	400.0	80.0
0.2	0.17	0.317	385.4	0.623	283.3	0.6	1.5	115.7	401.0	79.0
0.3	0.25	0.325	383.0	0.673	283.2	1.2	2.1	115.5	402.0	78.0
0.4	0.32	0.332	380.5	0.722	283.0	2.0	2.8	115.3	403.0	77.0
0.5	0.39	0.339	378.0	0.770	282.5	3.1	3.4	115.0	404.1	75.9
0.6	0.46	0.346	375.5	0.818	281.8	4.5	4.1	114.7	405.1	74.9
0.7	0.54	0.354	372.9	0.865	280.8	6.0	4.8	114.5	406.1	73.9
0.8	0.61	0.361	370.3	0.910	279.6	7.8	5.5	114.2	407.1	72.9
0.9	0.68	0.368	367.7	0.956	278.2	9.9	6.2	113.9	408.1	71.9
1	0.76	0.376	365.1	1.000	276.5	12.1	6.9	113.6	409.2	70.8
Ex-ante Value	**0.39**	**0.339**	**377.9**	**0.766**	**281.3**	**4.3**	**3.5**	**115.0**	**404.1**	**75.9**

Probability of bargaining failure	**39.1%**
Increase in Seller's Utility with respect to no commitment	**65.9%**
Welfare Loss/Expected Surplus	**15.8%**

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Basic Information: $\bar{s} = 950$, $\underline{s} = 10$, $E(s) = 480$, $\Delta s = 940$, $\gamma_1 = 8$, $\gamma_2 = 12$, $r' = 0.1$, $r_0 = 0.3$, $U_D(\underline{t}) = 0$.
Revenue Function: $r(e) = r_0 + r'e$, Cost Function: $C(e, t) = \gamma_1(1-t)e + \gamma_2 e^2$.
Notation: t: type; e^B: effort; $r(e^B)$: bargaining share; z^B: minimum price; $\beta(e^B)$: commission; EU_P: seller's utility; EU_D: delegate's utility; $C(e^B)$: effort cost; EU_B: buyer's utility.
(*) Surplus is the sum of the delegate's cost and the seller, delegate and buyer's utility.
(**) Welfare loss is equal to Expected Surplus (480) minus Surplus. It can also be computed as the expected surplus between s and z.

Table 6: A Numerical Example of Marketing Effort (No Commitment, $z = 0$)

t	e*	p(e*)	β(e*)	EU_P	EU_D	C(e*)	EU_B	Surplus (+)
0	0.33	0.333	0.667	76.0	0.0	4.0	80.0	160.0
0.1	0.40	0.340	0.700	76.2	0.6	4.8	81.6	163.2
0.2	0.47	0.347	0.733	76.1	1.5	5.6	83.2	166.4
0.3	0.53	0.353	0.767	75.8	2.6	6.4	84.8	169.6
0.4	0.60	0.360	0.800	75.4	3.8	7.2	86.4	172.8
0.5	0.67	0.367	0.833	74.7	5.3	8.0	88.0	176.0
0.6	0.73	0.373	0.867	73.8	7.0	8.8	89.6	179.2
0.7	0.80	0.380	0.900	72.6	9.0	9.6	91.2	182.4
0.8	0.87	0.387	0.933	71.3	11.1	10.4	92.8	185.6
0.9	0.93	0.393	0.967	69.8	13.4	11.2	94.4	188.8
1	1.00	0.400	1.000	68.0	16.0	12.0	96.0	192.0
Ex-ante Value	**0.67**	**0.367**	**0.833**	**73.6**	**6.4**	**8.0**	**88.0**	**176.0**

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Basic Information: $\bar{s} = 950$, $\underline{s} = 10$, $E(s) = 480$, $\Delta s = 940$, $\gamma_1 = 8$, $\gamma_2 = 12$, $p' = 0.1$, $p_0 = 0.3$, $r_0 = 0.5$, $U_D(\underline{t}) = 0$.
Probability Function: $p(e) = p_0 + p'e$, Cost Function: $C(e,t) = \gamma_1(1-t)e + \gamma_2 e^2$.
Columns 2 and 4 are computed as those in Table 4, but replacing $r_0 p'$ for r'.
Notation: t: type; e^*: effort; $r(e^*)$: bargaining share; $\beta(e^*)$: commission; EU_P: seller's utility; EU_D: delegate's utility; $C(e^*)$: effort cost; EU_B: buyer's utility.
(+) Surplus is the sum of the delegate's cost and the seller, delegate and buyer's utility. The ex ante revenue in Expected Utilities and Surplus is the corresponding revenue times the probability of the delegate finding a buyer.

Table 7: A Numerical Example of Marketing Effort (Commitment Effect)

t	e^M	$p(e^M)$	z^M	β^M	EU_P	EU_D	$C(e^M)$	EU_B	Surplus (*)	$p(e^M)E(s)$	Loss from failure(**)	Welfare Loss v. No commitment (***)
0	0.67	0.367	316.7	2.250	106.7	0.0	10.7	39.1	156.5	176.0	19.5	3.5
0.1	0.73	0.373	316.7	2.325	106.6	1.2	11.7	39.8	159.3	179.2	19.9	3.9
0.2	0.80	0.380	316.7	2.400	106.3	2.6	12.8	40.5	162.2	182.4	20.2	4.2
0.3	0.87	0.387	316.7	2.475	105.7	4.2	13.9	41.3	165.0	185.6	20.6	4.6
0.4	0.93	0.393	316.7	2.550	105.0	6.0	14.9	42.0	167.8	188.8	21.0	5.0
0.5	1.00	0.400	316.7	2.625	104.0	8.0	16.0	42.7	170.7	192.0	21.3	5.3
0.6	1.07	0.407	316.7	2.700	102.8	10.2	17.1	43.4	173.5	195.2	21.7	5.7
0.7	1.13	0.413	316.7	2.775	101.5	12.7	18.1	44.1	176.4	198.4	22.0	6.0
0.8	1.20	0.420	316.7	2.850	99.9	15.4	19.2	44.8	179.2	201.6	22.4	6.4
0.9	1.27	0.427	316.7	2.925	98.0	18.2	20.3	45.5	182.1	204.8	22.7	6.7
1	1.33	0.433	316.7	3.000	96.0	21.3	21.3	46.2	184.9	208.0	23.1	7.1
Ex-ante Value	**1.00**	**0.400**	**316.7**	**2.625**	**102.9**	**9.1**	**16.0**	**42.7**	**170.7**	**192.0**	**21.3**	**5.3**

Probability of bargaining failure	**32.6%**
Loss from bargaining failure (**)	**11.1%**
Increase in Seller's Utility with respect to no commitment	**39.9%**
Welfare Loss/Expected Surplus	**3.0%**

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Basic Information: $\bar{s} = 950$, $\underline{s} = 10$, $E(s) = 480$, $\Delta s = 940$, $\gamma_1 = 8$, $\gamma_2 = 12$, $p' = 0.1$, $p_0 = 0.3$, $r_0 = 0.5$, $U_D(\underline{t}) = 0$.
Probability Function: $p(e) = p_0 + p'e$, Cost Function: $C(e,t) = \gamma_1(1-t)e + \gamma_2 e^2$.
Notation: t: type; e^M: effort; $p(e^M)$: probability of finding a buyer; z^M: minimum price; $\beta(e^M)$: commission; EU_P: seller's utility; EU_D: delegate's utility; $C(e^M)$: effort cost; EU_B: buyer's utility.
(*) Surplus is the sum of the delegate's cost and the seller, delegate and buyer's utility. (**) Loss from bargaining failure is equal to Expected Surplus ($pE(s)$) minus Surplus. It can also be computed as the expected surplus between s and z.
(***) Welfare Loss against No Commitment is the difference between Surplus under No Commitment and Surplus under Commitment.