1-2013

# Ex Post Destruction in the Hold-up Problem

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# Ex Post Destruction in the Hold-up Problem*

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Revised: January 2013

**Abstract**

We investigate whether or not ex post destruction can solve the hold-up problem. After clarifying the difference between ex post destruction and non-trade when negotiation breaks down, we show that the option of ex post destruction is not sufficient to enhance ex ante efficiency. In particular, only if the information about the spitefulness of the supplier is coarse enough, will the option of ex post destruction alleviate the inefficiency of underinvestment caused by the hold-up problem.

JEL classification: C72, L14

Keywords: Destruction, Hold-up, Underinvestment, Incomplete Information

*We are grateful to Bo Chen and Eddie Zhang for their helpful feedback. The usual disclaimer applies.

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***– where ignorance is bliss, 'Tis folly to be wise.***

***Thomas Gray,* Ode on a Distant Prospect of Eton College**

# 1 Introduction

According to Che and Sákovics (2008), "hold-up arises when part of the return on an agent's relationship-specific investments is ex post expropriable by his trading partner." With an incomplete contract, which arises due to causes such as unforeseen contingencies and the inability of enforcement, relationship-specific investments are distorted by the hold-up problem and are therefore insufficient.

In the current literature on hold-up, the parties end up with non-trade payoffs (outside option) if ex post negotiation breaks down. However, the real world is filled with stories of "destruction" – behavior that harms both parties so that they are worse off than in the outside option if ex post negotiation breaks down. An example can be found in Sobel (2005): recently fired employees engaging in sabotage such as ruining computer systems before they leave their offices. This type of destructive behavior is costly for both the employers and the employees.

Our main question of inquiry is: if there exists an option of "destruction," will the inefficiency of underinvestment caused by hold-up be alleviated? We construct a simple hold-up game in the following context: (1) only one party (the supplier) invests ex ante; (2) the other party (the buyer) makes a take-it-or-leave-it offer during the ex post negotiation; (3) the supplier has the option of "destruction" if the ex post negotiation breaks down.

If the supplier is "selfish," who maximizes her own ex post payoff, the option of ex post destruction does not eliminate the inefficiency of the hold-up problem. Obviously, as destruction is costly for the supplier, the "selfish" supplier will never destruct. If, instead, the supplier is "spiteful," who will reject an offer below some threshold and engage in some "destruction" behavior,[1] then the buyer may have an incentive to propose an offer greater than or equal to the threshold value to induce the supplier to invest ex ante.

We show that with the "spiteful" supplier, under complete information, only if the supplier's spitefulness is sufficiently high (the threshold value is greater than or equal to the ex ante investment cost), will the supplier have the incentive to invest ex ante. In this case, the option of ex post destruction is irrelevant because no offer from the buyer to the supplier is below the threshold.

In contrast, in the case of **symmetric incomplete information**, i.e., both the supplier and the buyer are uninformed about the spitefulness of the supplier, only if

[1] In this sense, the threshold represents the spitefulness of the supplier. The higher the threshold, the more spiteful the supplier.

the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. In this case, the option of ex post destruction will enhance the likelihood of ex ante investment, simply because, with the "destruction" option, the buyer is willing to offer more to the supplier ex post, to avoid possible "destruction" by the supplier. In this sense, the possibility of "destruction" may become an incentive to enhance efficiency in bilateral relationships with hold-up.

Further, in the case of **asymmetric incomplete information**, i.e., the supplier knows her own spitefulness while the buyer does not, we will have the similar result as in the symmetric incomplete information case. Only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. However, in this case, the option of ex post destruction is irrelevant. Intuitively, since the supplier is informed, she will not invest ex ante if her own spitefulness value is greater than the anticipated ex post offer from the buyer. Therefore, even with the option of "destruction" ex post, there is no "destruction" at all at the equilibrium and thus the stimulation from the option of "destruction" is also absent.[2]

Third, if the buyer does not know whether or not the supplier is informed, the supplier may have an incentive to pretend to be uninformed even if she is informed. If the buyer believes that the supplier is also uninformed, the buyer will bargain less aggressively and offer more if the "destruction" option exists as in the symmetric incomplete information case.

In summary, the option of ex post destruction is not sufficient to enhance ex ante efficiency. Only if the information is "coarse" enough about the spitefulness of the supplier, more specifically if the buyer is uninformed and believes that the supplier is also uninformed, will the option of ex post destruction alleviate the inefficiency of underinvestment caused by the hold-up problem.[3] Indeed, lack of knowledge may result in happiness. Sometimes it is beneficial not to know something. It is more advantageous for you to make a threat if you are uninformed. If your opponent believes this, your threat becomes more convincing.

Our paper is related to Ng (2011), which proposes that the ex post ability to destroy the relationship-specific investment can solve the hold-up problem. However, in Ng (2011), there is no distinction between the payoffs following "destruction" and non-trade if negotiation breaks down. We point out that destruction must be some behavior harming both parties so that if ex post negotiation breaks down, they will be worse off than in the outside option. In particular, destruction must be costly for the party who destructs. In other words, when the supplier "destructs," not only the buyer but also the supplier suffers payoff losses. That is, when destructing, the

[2]The notion of equilibrium we use is perfect Bayesian equilibrium.

[3]There are some studies that compare games with and without added punishment schemes. For example, Fehr and Gächter (2000) report the empirical evidence that prospects of cooperation are greatly improved if there exists an option to punish defectors, even though punishment is costly for the punishers in a one-shot context.

supplier punishes the buyer at the supplier's own cost, as assumed below.[4]

**Assumption 1** *Suppose if negotiation breaks down, the non-trade payoffs for the supplier and the buyer are* $(a, b)$*. Then, if the supplier engages in some "destruction" behavior, the payoffs for the supplier and the buyer will be* $(a - X, b - Y)$*, where* $X > 0, Y > 0$*.*

Our paper is also related to the literature of behavioral game theory, which suggests that fairness (Fehr and Schmidt 1999) or reciprocity (Dufwenberg and Kirchsteiger 2004) may affect inefficiency of the hold-up problem. For example, Dufwenberg, Smith, and Van Essen (2013) argue that vengeance (negative reciprocity) may alleviate the inefficiency caused by the hold-up problem, provided that the investor holds the residual rights of control if ex post negotiation breaks down.[5] von Siemens (2009) investigates a model of private information in which the seller knows her own type as either "selfish" or "fair-minded." Therefore the seller's investment plays a role of signalling that entails incentives for investment.[6]

The rest of the paper is organized as follows. Section 2 discusses the case where the the supplier is "selfish." Section 3 investigates the case where the supplier is "spiteful." The model is extended further to investigate the case with incomplete information in section 4. Section 5 concludes.

## 2 "Selfish" Supplier

Consider a trading relationship between a buyer and a supplier, who are both risk neutral. At date 0, the supplier decides whether or not to make an investment that costs her $c > 0$. Investment $(I)$ enables her to split a pie of size $y$ with the buyer in the subsequent period. Assume there is no discounting and it is socially efficient to invest, i.e., $c < y$. If the supplier does not make the investment $(O)$, they both get nothing.

[4]The efficiency result in Ng (2011) is crucially rooted on the assumption that if the supplier is indifferent between destructing and not destructing, she will destruct. Here, with the costly destruction as assumed in assumption 1, the possibility of tie-breaking is ruled out and thus there is no room of the tie-breaking rule as specified in Ng (2011).

[5]In Dufwenberg, Smith, and Van Essen (2013), the residual value for the investor (player 1) is normalized to zero, while the residual value for the opponent (player 2) is $(1-\alpha)v_2$, where $\alpha \in [0, 1]$. If ex post negotiation breaks down, player 1 punishes player 2 at player 1's own cost by forgoing the "consolation payoff" $t$, which is less than the residual value.

[6]In our model, the investment from the supplier (the seller in von Siemens' setting) is binary. Therefore, there is no role of signaling as in von Siemens (2009). Further, von Siemens (2009) assumes behavioral costs for the "fair-minded" seller if she accepts the unfair offer below some threshold. In contrast, we focus on the option of ex post destruction, in which the supplier rejects an offer below some threshold and engage in some "destruction" behavior to punish the buyer at the supplier's own cost.

If at date 0 the supplier invests, at date 1 the buyer makes a take-it-or-leave-it offer, $p \geq 0$. Then at the following date 2 the supplier has two options: to accept the offer ($A$), or to reject the offer ($R$). If the supplier accepts the offer, they will split the pie according to the offer and the game ends. Rejecting an offer ends the game and they will stay with their own non-trade payoffs, which are normalized to zero. The game tree is illustrated in the left panel of Figure 1.

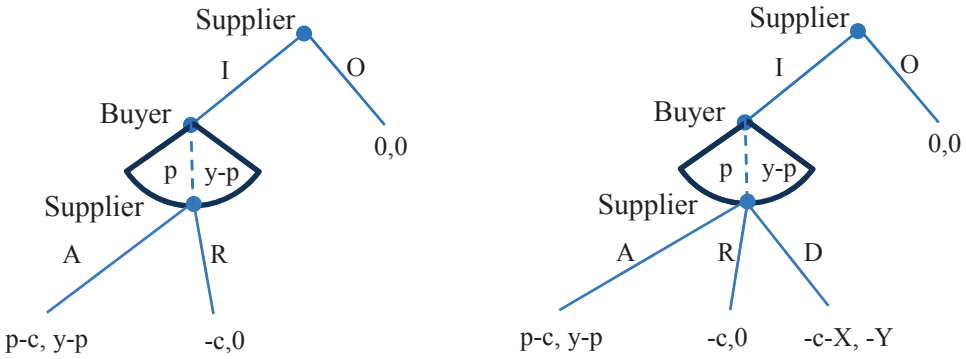


Figure 1: Game tree without and with the "destruction" option

Suppose now the supplier has the third option: instead of accepting the offer ($A$) or rejecting the offer ($R$), the supplier could engage in some "destruction" behavior ($D$). If the supplier does so, the payoffs for the supplier and the buyer will be $(-X, -Y)$ on top of their non-trade payoffs, where $X > 0, Y > 0$, as assumed in Assumption 1. The game tree with the "destruction" option is illustrated in the right panel of Figure 1.

The following proposition shows that if the supplier is "selfish," who maximizes her own ex post payoff, the option of ex post destruction does not eliminate the inefficiency of the hold-up problem.

**Proposition 1** *For the "selfish" supplier, "destruction" ($D$) is strictly dominated by rejecting the offer ($R$) in the subgame following buyer's offer.*

As $X > 0$, $-c > -c - X$. The "selfish" supplier will never destruct. Anticipating this, the buyer will only offer the minimum amount to the supplier.[7] Backward to the beginning of the game, as long as the offer is less than the cost of the investment, there is no incentive for the "selfish" supplier to invest ex ante. The following result summarizes the inefficiency with the "selfish" supplier.

**Result 1** *With the "selfish" supplier, ex ante there is no investment.*

[7] As pointed out by Fehr and Schmidt (1999), if there is a smallest money unit $\epsilon$, then the buyer may offer $p = \epsilon$ to the supplier ex post, other than $p = 0$ in the continuous case.

## 3 "Spiteful" Supplier

Suppose now the supplier is "spiteful," who will reject an offer below some threshold $T \in [0, y]$ and engage in some "destruction" behavior to punish the buyer at the supplier's own cost, if the option of "destruction" exists.[8] The game trees without and with the "destruction" option for the "spiteful" supplier are illustrated in Figure 2.

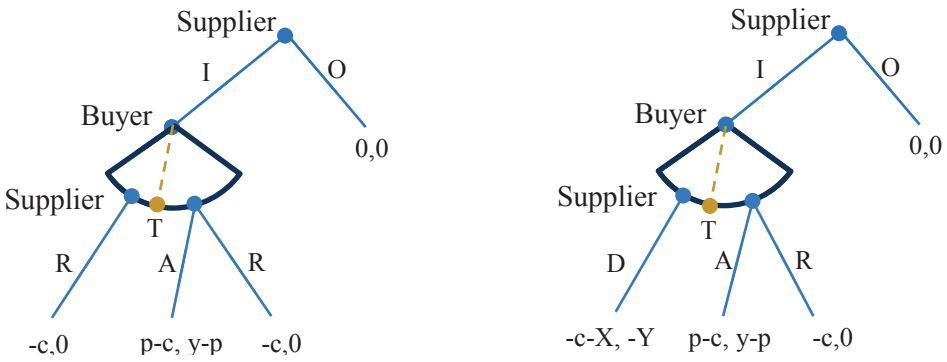


Figure 2: Game tree for the "spiteful" supplier without and with the "destruction" option

Now consider the case with complete information: both the supplier and the buyer know the spitefulness of the supplier. The following proposition shows that only if the supplier's spitefulness is sufficiently high (the threshold value is greater than or equal to the ex ante investment cost), will the supplier have the incentive to invest ex ante. In this case, the option of ex post destruction is irrelevant.

**Proposition 2** *With the "spiteful" supplier, under complete information, if $T \geq c$, we have a unique equilibrium, in which the supplier invests at date 0 and the buyer offers $p = T$ at date 1; if $T < c$, we have a unique equilibrium, in which the supplier does not invest at date 0. These hold for both the cases without and with the "destruction" option.*

Intuitively, the existence of the spiteful supplier, who will either "reject" or "destruct" if the offer is less than $T$, enables the supplier to threaten the buyer not to fully exploit her ex post. Therefore, the buyer has an incentive to propose an offer $p = T$ ex post.[9] Back to the beginning of the game, as long as, $T \geq c$, the supplier has the incentive to invest ex ante. In this case, the option of ex post destruction is irrelevant because no offer is less than $T$. The underinvestment caused by the

[8] If $T = 0$, then the supplier becomes "selfish" as in the previous section.

[9] $p > T$ is not necessary, as $p = T$ is sufficient to induce the supplier to "accept" the offer.

hold-up problem is only partially solved, as there is no investment ex ante if $T < c$. The following result summarizes the inefficiency with the "spiteful" supplier under complete information.[10]

**Result 2** *With the "spiteful" supplier, under complete information, only if the spitefulness of the supplier is sufficiently high, will the supplier have the incentive to invest ex ante.*

# 4 Incomplete Information

Now consider the case with incomplete information. Suppose the prior belief about the spitefulness of the supplier follows some distribution. Following Fehr and Schmidt (1999), assume a fraction $s$ of suppliers are "selfish" with $T = 0$, while the remaining fraction $1 - s$ of suppliers are "spiteful" to various degrees $T \in (k, y)$, which follows some continuous distribution: $T \sim F$, with the density $f$, where $k \in (0, y)$. In addition, assume the density function $f$ decreases in $T$ to capture the idea that the supplier is less likely to be strongly "spiteful."[11]

There are two scenarios: (1) symmetric incomplete information, in which both the supplier and the buyer are uninformed about the spitefulness of the supplier; (2) asymmetric incomplete information, in which the supplier knows her own spitefulness, while the buyer does not.

## 4.1 Symmetric Incomplete Information

Under symmetric incomplete information, both the supplier and the buyer are uninformed. Their decision will be based on the prior belief. First, consider the case without the "destruction" option. Given the supplier invests at date 0, at date 1 if

[10] An example is found in Mario Puzo's classic novel *The Godfather*. The Bocchicchio Family serves the role of "the hostages" prior to meetings between the heads of the families. In Book Five, Chapter 20, this is described in details.

> The Bocchicchio Family was unique in that, once a particularly ferocious branch of the Mafia in Sicily, it had become an instrument of peace in America. ... the Bocchicchio Family became negotiators and hostages in the peace efforts of warring Mafia families. ... A strain of stupidity ran through the Bocchicchio clan, or perhaps they were just primitive. ... They had only two assets. Their honor and their ferocity. ... a Bocchicchio never forgot an injury and never left it unavenged no matter what the cost.

[11] In reality, from the supplier's point of view, the "fair" ex post offer from the buyer has to at least cover the ex ante investment cost. An example of the distribution is the beta distribution: $Beta(1, \beta)$ with the support $(c, y)$, where $\beta > 1$.

the buyer offers $p$, only the supplier with $T \leq p$ will accept the offer. The supplier with $T > p$ will reject the offer.[12] The buyer's problem at date 1 is as follows.

$$\max_{p} \quad s(y-p) + (1-s)\int_0^p (y-p)f(T)\mathrm{d}T$$

The first order condition is

$$-s + (1-s)[-F(p) + (y-p)f(p)] = 0 \tag{1}$$

Suppose $p^*$ satisfies the first order condition above.

In contrast, with the "destruction" option, given the supplier invests at date 0, at date 1 if the buyer offers $p$, only the supplier with $T \leq p$ will accept the offer. The supplier with $T > p$ will reject the offer and engage in some "destruction" behavior. The buyer's problem at date 1 is as follows.

$$\max_{p} \quad s(y-p) + (1-s)\left[\int_0^p (y-p)f(T)\mathrm{d}T + \int_p^y -Yf(T)\mathrm{d}T\right]$$

The first order condition is

$$-s + (1-s)[-F(p) + (y-p+Y)f(p)] = 0 \tag{2}$$

Suppose $p^{**}$ satisfies the first order condition above.

The following lemma shows that with the "destruction" option the buyer is willing to offer more to the supplier ex post, to avoid possible "destruction" by the supplier.

**Lemma 1**

$$p^{**} \geq p^*$$

**Proof.** See Appendix. ■

The following proposition shows that under symmetric incomplete information, only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. In this case, the option of ex post destruction will enhance the likelihood of ex ante investment. Simply because, with the "destruction" option, the buyer is willing to offer more to the supplier ex post, to avoid possible "destruction" by the supplier. In this sense, the possibility of "destruction" may become an incentive to enhance efficiency in bilateral relationships with hold-up.

[12] Assume, once the buyer makes the take-it-or-leave-it offer, the spitefulness of the supplier will be realized and the supplier will make decision based on her true spitefulness, even though she is uninformed ex ante. This says that one will get to know one's true self in the crucial moment eventually.

**Proposition 3** *With the "spiteful" supplier, under symmetric incomplete information, we have two scenarios.*

**Without the "destruction" option:** *if $p^* \geq c$, we have a unique equilibrium, in which the supplier invests at date 0 and the buyer offers $p = p^*$ at date 1; if $p^* < c$, we have a unique equilibrium, in which the supplier does not invest at date 0, where $p^*$ is from equation 1.*

**With the "destruction" option:** *if $p^{**} \geq c$, we have a unique equilibrium, in which the supplier invests at date 0 and the buyer offers $p = p^{**}$ at date 1; if $p^{**} < c$, we have a unique equilibrium, in which the supplier does not invest at date 0, where $p^{**}$ is from equation 2.*

Intuitively, under symmetric incomplete information, based on the prior belief, at date 1 the buyer offers $p^*$ (or $p^{**}$) from equation 1 (or equation 2) without (or with) the "destruction" option. Back to the beginning of the game, as long as, $p^*$ (or $p^{**}$) $\geq c$, the supplier has the incentive to invest ex ante. Since $p^{**} \geq p^*$ from lemma 1, the option of ex post destruction enhances the likelihood of ex ante investment. Still, the underinvestment caused by the hold-up problem is only partially solved, as there is no investment ex ante if $p^*$ (or $p^{**}$) is less than $c$. Further, beyond the ex ante inefficiency, we could have ex post inefficiency. If the realization of the supplier's spitefulness $T > p^*$ (or $p^{**}$), the supplier will reject the offer and engage the in some "destruction" behavior. The following result summarizes the inefficiency with the "spiteful" supplier under symmetric incomplete information.

**Result 3** *With the "spiteful" supplier, under symmetric incomplete information, only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. The option of ex post destruction enhances the likelihood of ex ante investment. Furthermore, we could end up with ex post inefficiency, if the realization of the supplier's spitefulness is sufficiently high.*

### 4.2 Asymmetric Incomplete Information

Under asymmetric incomplete information, only the supplier knows her own spitefulness, while the buyer does not. And the buyer knows that the supplier knows her own spitefulness. The following proposition shows that under asymmetric incomplete information, we have the similar result as in the symmetric incomplete information case. Only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. However, in this case, the option of ex post destruction is irrelevant.

**Proposition 4** *With the "spiteful" supplier, under asymmetric incomplete information, if $p^* \geq c$, we have a unique equilibrium, in which the supplier with $T \leq p^*$ invests at date 0 and the buyer offers $p = p^*$ at date 1; if $p^* < c$, we have a unique equilibrium, in which the supplier does not invest at date 0, where $p^*$ is from equation 1. These hold for both the cases without and with the "destruction" option.*

**Proof.** See Appendix. ■

Intuitively, under asymmetric incomplete information, the supplier will not invest ex ante if her own spitefulness value is greater than the anticipated ex post offer from the buyer at date 1. Therefore, even with the option of "destruction" ex post, there is no "destruction" at all at the equilibrium. Based on the prior belief, at date 1 the buyer offers $p^*$ from equation 1. Back to the beginning of the game, as long as, $p^* \geq c$, the supplier with $T \leq p^*$ has the incentive to invest ex ante. Still, the underinvestment caused by the hold-up problem is only partially solved, as there is no investment ex ante if $p^* < c$. Contrary to the symmetric incomplete information case, there is no ex post inefficiency, as there is no "destruction" at all at the equilibrium. Meanwhile, the stimulation from the option of "destruction" is also absent. The following result summarizes the inefficiency with the "spiteful" supplier under asymmetric incomplete information.

**Result 4** *With the "spiteful" supplier, under asymmetric incomplete information, only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. The option of ex post destruction is irrelevant.*

### 4.3 Asymmetric Incomplete Information – A Variation

Consider a variation from the asymmetric incomplete information in the previous section. Let's still assume that only the supplier knows her own spitefulness, while the buyer does not. However, now assume that the buyer does not know that the supplier knows her own spitefulness and the buyer believes that the supplier is also uninformed.

Therefore, we are back to the symmetric incomplete information case. Based on the prior belief, at date 1 the buyer offers $p^*$ (or $p^{**}$) from equation 1 (or equation 2) without (or with) the "destruction" option. Since $p^{**} \geq p^*$ from lemma 1, the option of ex post destruction enhances the likelihood of ex ante investment. Still, the underinvestment caused by the hold-up problem is only partially solved, as there is no investment ex ante if $p^*$ (or $p^{**}$) $< c$. However, contrary to the symmetric incomplete information case, there is no ex post inefficiency, as the supplier knows her own spitefulness. If the spitefulness of the supplier $T > p^*$ (or $p^{**}$), the anticipated ex post offer from the buyer at date 1, the supplier will not invest ex ante. Therefore,

even with the option of "destruction" ex post, there is no "destruction" at all at the equilibrium. The following result summarizes the inefficiency with the "spiteful" supplier under the variation of the asymmetric incomplete information.

**Result 5** *With the "spiteful" supplier, under the variation of the asymmetric incomplete information, only if the prior belief of the supplier's spitefulness is sufficiently strong, will the supplier have the incentive to invest ex ante. The option of ex post destruction enhances the likelihood of ex ante investment. However, there is no ex post inefficiency.*

Intuitively, if the buyer does not know whether or not the supplier is informed, the supplier may have an incentive to pretend to be uninformed even if she is informed. If the buyer believes that the supplier is also uninformed, the buyer will bargain less aggressively and offer more if the "destruction" option exists as in the symmetric incomplete information case.

# 5 Concluding Remarks

We investigate whether or not ex post destruction can solve the hold-up problem. We construct a simple hold-up game and show that the option of ex post destruction is not sufficient to enhance ex ante efficiency. In particular, only if the information about the spitefulness of the supplier is coarse enough, more specifically if the buyer is uninformed and believes that the supplier is also uninformed, will the option of ex post destruction alleviate the inefficiency of underinvestment caused by the hold-up problem.

The major conclusion is that sometimes it is beneficial not to know something. It is more advantageous for you to make a threat if you are uninformed. If your opponent believes this, your threat becomes more convincing. If, instead, you get informed and your opponent knows that you know your own true type, you may not have the courage or resolution to run the risks of investing in a potentially profitable project. However, if your opponent does not know whether or not you are informed, you may have the incentive to pretend to be blurred.

# Appendix

### Proof of Lemma 1

Take the derivative with respect to $Y$ on both sides of equation 2.

$$-\frac{dF(p)}{dp}\frac{dp}{dY}+\left(-\frac{dp}{dY}+1\right)f(p)+(y-p+Y)\frac{df(p)}{dp}\frac{dp}{dY}=0$$

where $\frac{dF(p)}{dp} = f(p)$. Rearrange and we have

$$\frac{dp}{dY} = \frac{f(p)}{2f(p) - (y - p + Y)\frac{df(p)}{dp}}$$

Since $f(p) \geq 0$ and $\frac{df(p)}{dp} \leq 0$ as assumed, we have $dp/dY \geq 0$. $Y > 0$ implies $p^{**} \geq p^*$ from equation 1 and 2. ■

**Proof of Proposition 4**

Consider the case with the "destruction" option. Given the supplier invests at date 0, at date 1 if the buyer offers $\widetilde{p}$, only the supplier with $T \leq \widetilde{p}$ will accept the offer. As the supplier is informed about the spitefulness of herself ex ante, she will not invest at date 0 if $T > \widetilde{p}$. Therefore, the buyer's problem at date 1 is as follows.

$$\max_{\widetilde{p}} \quad s(y - \widetilde{p}) + (1 - s) \int_0^{\widetilde{p}} (y - \widetilde{p}) f(T) \mathrm{d}T$$

Note, the buyer's problem remains the same for both the cases without and with the "destruction" option, as the supplier will not invest ex ante if her own spitefulness value is greater than the anticipated ex post offer from the buyer at date 1. Therefore, even with the option of "destruction" ex post, there is no "destruction" at all at the equilibrium.

Solving the optimization problem above, we have the first order condition same as equation 1 and subsequently the same solution $p^*$. Therefore, if $p^* \geq c$, we have a unique equilibrium, in which the supplier with $T \leq p^*$ invests at date 0 and the buyer offers $p = p^*$ at date 1. If, instead, $p^* < c$, the anticipated ex post offer from the buyer at date 1 does not cover the cost of investment, the supplier will not invest at date 0. ■

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