Williamson Meets Hart: Haggling Costs and Incomplete Contracts

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Abstract

This paper introduces a cost of contracting that originates from the possibility that a contracting partner may be able to find and exploit loopholes in contractual formulations. A potential buyer and seller want to trade a widget and prior to trade the seller can make an investment to create an improved version of the widget. We assume that buyer and seller cannot be sure that this improved widget can be described accurately. To be more precise we assume that with a certain probability the seller can exploit loopholes in the contract and make an effort to create a new widget which also satisfies the requirements of the contract. The creating of this widget is inefficient, but since it cannot be distinguished from the improved widget by a third party, it allows the seller to haggle for a larger share of the surplus. We show that whenever a contract provides incentives to foster investments to improve the widget, this contract also fosters investments to create a haggling widget. We characterize conditions under which the first-best can be attained and under which the incomplete contract is optimal.

1 Introduction

The modern theory of the firm (Williamson, 1985; Hart 1995) is developed around the notion of incomplete contracts. When contracts are incomplete, transacting parties cannot protect their investments through third party enforcement, and hence must find alternative means to secure their rights. Ownership structure and organizational design arise as a response to the imperfection of such contractual arrangements. By owning more assets, for instance, one party can increase its bargaining power, and prevent being held-up by another. The assumption of incomplete contracts made by this literature also has some empirical content, beyond casual observation. Macaulay (1963) shows how businessmen often do not regulate their transactions through explicit contracts, despite being aware of the risks they incur.

Nevertheless, our understanding of what makes the use of contracts costly, and therefore undesirable, is still imperfect. Incomplete contract models are perceived to offer informal stories, based on the distinction between observability and verifiability. They have been criticised on the grounds that they lack a good foundation for the assumption of incomplete contracts. As a result, these models make ad hoc restrictions on the space of contracts available to the transacting parties. Instead, when general mechanisms are allowed, it is possible to achieve efficiency without resorting to any organizational arrangement (Moore and Repullo, 1988; Maskin and Tirole, 1999). These mechanisms involve the ex-post exchange of verifiable messages, which when designed to provide incentives for truthtelling, can be used to verify the state of the world. It should then be possible to have third party enforcement of contracts that depend on such announcements. Moreover, even though such mechanisms can be very complex, it is often possible to have simple, more realistic contracts that achieve the same goal in specific environments (Aghion et al., 2002; Edlin and Reichelstein, 1996; Noldeke and Schmidt, 1995; and Reiche, 2006, are some examples).

This paper argues that contracting can indeed be costly when trading partners can engage in rent seeking behaviour to circumvent the original purpose of the contract. Often, a court cannot verify the fulfilment of contractual obligations, for instance when it cannot precisely say whether a widget to be exchanged satisfies the requirements laid out in the contract. This can happen if quality is hard to verify by a third party. Then, the seller can deceive the buyer by trying to sell a widget that is of lower quality than anticipated, to benefit from a lower cost of production. A contract that is supposed to encourage the seller to engage in efficiency enhancing investments can have the opposite effect of what was originally intended. The seller might engage in rent-seeking by investing in welfare decreasing alternatives that, instead, serve the purpose of pretending he fulfilled the contractual obligations, in order to extract a larger share of the surplus.

There are many ways in which a contract can be circumvented. For instance, by hiring a lawyer to discover loopholes in the contract: changes in the design of the widget that are permitted by the contract (or, at least, not forbidden by it), but that do not achieve the goal of improving the value of the transaction, but rather increase the bargaining power of the seller. This is most relevant when the investment undertaken by the parties serves the purpose of creating a new, more efficient widget, since an innovation is hard to describe in advance.

To model this intuition, we consider a buyer and a seller that would like to exchange a widget in the future. The seller can invest in innovation, and such innovation creates a new widget offering a higher surplus from the transaction (subsequently refereed to as the improved widget). However, the seller may also invest in creating an inefficient, but cheap widget (called the haggling widget). Crucially, the quality of the widgets, although observable by the two parties, cannot be verified in court. The seller may be able to use this widget to haggle for a better price with the buyer. When no contract exists, the buyer would never accept to buy the haggling widget. As a result, the seller never wants to waste resources in this inefficient haggling. However, when the contract specifies the trade of a widget, the seller could create such widget to force a renegotiation of the price. If the contract does not foresee this possibility, it can lead to a very inefficient outcome, where the seller only undertakes the inefficient investment.

More interesting is the case in which the contracting parties foresee the possibility that the seller could undertake either type of investment. The mechanisms can then try to elicit ex-post which widget has been created. We show, however, that if ex-post renegotiations ensure an efficient outcome, this is a very hard undertaking. There is an extreme conflict of interest between the buyer and the seller. Whenever there is a widget around, the buyer wants to claim it is the bad one to force a low price, while the seller has an incentive to claim the opposite. The only way to resolve the disagreement is for the contract to offer rents to the seller to admit wrongdoing when the haggling widget has been created, thereby giving the seller incentives to create it ex-ante.

We show that any contract that has to rely on buyer and seller announcements of what widget the seller puts up for trade, whenever it creates incentives for welfare increasing innovation, it necessarily creates incentives for socially undesired rent-seeking activities as well. The optimal mechanism has to trade-off higher investments in efficient innovation and rent-seeking activities. And as a result, the first best cannot generally be attained. Furthermore, when rent-seeking becomes very costly, it can make the value of contracting become very small. In such a case, incentives for efficient innovation under the optimal mechanism resemble what they are in the absence of any contract.

The model delivers an endogenous cost of writing a contract, based on the efforts of the seller to extract rents from it. Williamson (1985) argues that the existence of incomplete contracts creates incentives to waste resources in order to appropriate the rents that have not been allocated contractually. Our results suggest that rent-seeking may indeed be contractually unavoidable, and indeed exacerbated by a contract, inducing parties to sign a more incomplete contract than they would have in the absence of such activities. Hence, rent-seeking itself may be a reason behind the cost of using contracts, providing a foundation for the incomplete contract framework in Hart (1995), used in most of this literature.

Recent work has shown that there are instances in which allowing for general mechanisms offers little value to the parties when such contracts must implement an ex-post efficient outcome. This is the case in complex environments (Segal, 1999), or when the transactions involve cooperative or ambivalent investments (Che and Hausch, 1999; and Reiche, 2006). This paper offers yet another reason that does not rely on having a complex environment, or a particular type of investment.

Moreover, most of the literature on the hold-up problem has focused on models in which the nature of the good to be traded is contractible. Although the optimal transaction may depend on the state of the world, this only affects the efficient quantity to be traded. And in such scenario, several contractual arrangements can provide solutions to the hold-up problem (Aghion et al., 2002; Edlin and Reichelstein, 1996; Noldeke and Schmidt, 1995).[1] Nevertheless, contractual disputes often arise not just because of disagreements on quantities, but from discrepancies about the actual nature of the good to be traded. And because the quality of trading opportunities is often hard to describe, or even foresee, conflicts are potentially larger. Focusing on the availability of various trading opportunities of different value, as in our model, can capture these conflicts more accurately. Segal (1999) and Reiche (2006) do follow this alternative modelling strategy as well. However, the widgets available for trade are exogenous in their setups, while they are endogenous in

[1] Although cooperative investments are enough to render contracts useless even in such a framework (Che and Hausch, 1999).

ours.

The rest of the paper is organized as follows. Section 2 presents in a very simple example the main intuition of the paper. Section 3 presents the setup of the model. As a benchmark, we solve for the first best and no contract cases in section 4. We derive the main results of the paper in section 5, and section 6 concludes.

2 An Illustrative Example

A simple example can illustrate the effects that haggling activities aimed at exploiting contractal shortcomings can have on the value of a contract. Consider a buyer that would like to purchase a widget from a seller, and denote this widget by R. The widget costs c_R to produce and offers value v_R. A very simple spot contract, specifying that the widget be traded at a price of $p_R \in [c_R, v_R]$ is enough to guarantee efficiency (namely, that the transaction takes place). Moreover, if the transaction must take place in the future, this contract would still work.

In the spirit of the property rights literature, consider what happens if the seller can make a specific investment prior to the production of the widget to improve the value of the transaction. In particular, suppose that the seller can pay a cost of κ_I to create (invent) a new improved widget (I) with a production cost of c_I and a value of $v_I = v_R$, such that $c_I + \kappa_I < c_R$.[2] Suppose, also, that inefficient outcomes resulting from a contract are renegotiated to an efficient outcome, and that the buyer has all the bargaining power. Now, a simple spot contract is not enough to induce the seller to invest in creating the new trading opportunity, since the buyer captures all the rents generated by the investment. However, a new contract can still be designed to achieve the efficient investment. The

[2] Notice that the increase in welfare comes from a reduction in the production cost. Che and Hausch, 1999, refer to this type of investments as selfish.

contract specifies that the buyer must pay a price of $p \in [c_R, v_R]$, and the seller is allowed to produce either widget. Since this contract fixes the price for the seller, she will have all the gains from cost reduction, and hence, will invest efficiently.[3]

This last contract, however, can potentially do very badly. Suppose that the seller discovers that by investing κ_H he can create yet a third widget (H) which is useless to the buyer, but cheap to produce ($c_H < c_I$), and a third party cannot distinguish it from I. This widget would never be transacted in a spot transaction. Nevertheless, the seller can use this widget to pretend she has an improved one, which she would be entitled to deliver to the buyer, obtaining a profit of $p - c_H$. The buyer would then ask to renegotiate the contract, asking for the R widget to be delivered, and leaving the seller with the same payoff. As long as $\kappa_H < \kappa_I$, he will prefer to create this bad widget and pretend it is the improved one. And this creates a loss of efficiency. First, because the improved widget is not created, despite being efficient to do so. But secondly, because the seller pays the cost of inventing the second widget, despite never being traded, since the buyer chooses the regular widget instead. We can therefore think of this investment as a haggling cost, or the cost of being opportunistic, in the spirit of the transaction costs literature. The seller pays for it, despite being inefficient, in order to increase her share of the rents.

This example shows that contracts that seem to implement efficient outcomes in a robust manner, may indeed be quite fragile when parties can affect the likelihood of the future contingencies in a way that is not foreseen ex-ante. It is still unclear, however, how much of this can be overcome if the parties realize that this might happen, and want to design a contract to prevent this inefficient rent-seeking. Suppose now that the parties

[3] There are other contracts that would achieve an efficient investment in this case. Another example is the following: if the seller can show there are two widgets, the buyer can choose which one to buy, and must pay a price of $p_I = p_R + \kappa_I$; otherwise, if the seller shows only one widget, the transaction price must be p_R. When shown two widgets, the buyer will pick R, to force the seller to renegotiate, and capture the benefit from the lower production cost of I. As a result, the seller will get a payoff of $p_I - c_R$. Now, if the seller invests in creating the improved widget, he gets a higher price for it, to cover at least the cost κ_I.

realize that the seller can invest in either the creation of valuable trading opportunities, or fake ones, used for the sole purpose of obtaining rents from the contract. If $\kappa_H \geq \kappa_I$, we can still achieve the first best with the previous contract. However, when $\kappa_H < \kappa_I$, there is no contract that induces the seller to invest in creating the improved widget. To see this, suppose that the seller can create at most one new widget (creating both the good and the bad may be excessively costly, for instance). Then, the contract must be able to induce the seller to tell which widget he has created. Nevertheless, we show that any outcome arising from a contract that induces truthtelling can also be implemented with a contract of the following form: the seller gets a price p_R if there is only one widget, and p_I if there are two, but the buyer chooses which to purchase. For any such contract, when $\kappa_H < \kappa_I$, either no new widget is created (if $p_I - p_R < \kappa_H$), or H is (if $p_I - p_R \geq \kappa_H$). If we try to give the seller incentives to invent the improved widget (by increasing p_I), he will always find it more profitable to invent the bad one instead. In this case, it is optimal to leave the contract incomplete, and let the parties negotiate ex-post. This way, the improved widget is not created because the seller has no bargaining power, but the investment in the haggling one is avoided.

3 The Model

We consider a trading relationship between two risk neutral parties: a buyer, B, and a seller, S, who want to exchange one unit of a widget in the future. Initially, there is a known widget, which we call R (regular), that could be traded. This widget has a value of v_R to the buyer and it costs the seller c_R to produce.

However, before trade occurs, the seller can make an investment at a cost of κ_I to create a new widget with superior quality and/or lower production costs. If she decides to make the investment the seller can produce and trade the widget, which we call I (for improved). When this happens, we assume that it is still possible to trade the original R widget, so two trading opportunities exist. The improved widget has a value of v_I, and production costs of c_I with $v_I - c_I > v_R - c_R$.

For our model to reflect the idea that I cannot be perfectly described in any contract and consequently that there is no guarantee that I is indeed created when given incentives to do so, we assume that the seller can also decide to make an investment at a cost κ_H to create another widget H (for haggling). If the seller decides to make this investment, she can produce and trade widget H. And the contract cannot distinguish between I and H, i.e. the identities of H and I are not verifiable. Therefore, the seller can deliver H to claim the rents allocated to the buyer by the contract for the creation of I. Implicit in this formulation is the assumption that even when the parties may have a good idea of what the I widget could look like, or what it might achieve, they cannot perfectly describe this in a way that rules out that a different (inferior) widget that cannot attain the expected goals is created as a substitute. We interpret the investment in the creation of H as an investment in rent seeking: there is no social benefit in having H (as we will assume shortly), but the seller may still obtain private gains from it.

Buyer and seller cannot foresee at the time of writing the contract how potential contractual formulations could be circumvented: what characteristic being described about I is not accurate, or what performance measure can be deceived, and in what way. Otherwise they could describe I in a verifiable way. Nevertheless, they understand that these innovations may occur, and can foresee what their payoff implications would be. Accordingly, we assume that this haggling widget H has a value of v_H, and production costs of c_H and that it is inferior to the existing one R, i.e. we assume $v_R - c_R > v_H - c_H$. Furthermore, the widget H entails low production costs for the seller: $c_H < c_R$ and $c_H < c_I$.[4] The cost

[4] The assumption that v_H and c_H are known ex-ante (and thus can be foreseen by both parties) is not critical. We could assume that v_H and c_H are realisations of random variables that become known after the

vector (κ_I, κ_H) is revealed to the seller before making the investment decisions and cannot be observed by the buyer or a third party. It is the realisation of a random variable which can take values in $[0, \infty]^2$ and has a commonly known distribution given by the cdf F and density function f.

We assume that only one widget is needed. Since $v_I - c_I > v_R - c_R > v_H - c_H$, the ex-post efficient trade is the improved widget if available, and the R widget otherwise. The creation and trade of the inferior haggling widget is always socially undesirable. We also assume that the seller cannot create both the I and H widgets simultaneously. We discuss the importance of this assumption in section 6.

We further assume that the outcome of the investments is private information of the seller. Nevertheless, once the seller shows a new widget to the buyer, he immediately observes its quality. However, a third party can only observe that a new trading opportunity exists, but cannot verify its quality. We also assume that it is possible to describe the R widget ex-ante, so that ex-post, a third party can verify its identity. However, since the I and H widgets have not been invented, they cannot be described in advance, and hence, a third party cannot tell them apart ex-post.[5]

contract is written. As long as for any realisation of v_H and c_H we have that $v_R - c_R > v_H - c_H$, $c_H < c_R$ and $c_H < c_I$ the relevant constraint on implementability does not depend on the precise values of v_H and c_H. Even a contract that conditions on both parties' announcements of the values of v_H and c_H would not help to relax the relevant constraint as for any value of v_H and c_H trade of the H widget is imposed neither on the equilibrium path nor off the equilibrium path for the relevant disagreement (see section 5.1 and the Appendix).

[5] Alternatively, we can also assume that it is not possible to describe the differences between these yet to be discovered widgets and the R one, so that a third party may not be able to distinguish the latter widget ex-post. This could be for several reasons. This widget may not have been created at the time the mechanism is designed, but it is known it can be produced somehow. Alternatively, the widget may already exist, but it is not possible to describe it accurately. In order to do so, it would be necessary to know in which ways other widgets can be different. Since the I and H widgets have not been invented, it may be impossible to distinguish them ex-ante (if one aspect of the R widget is not described accurately, the seller could exploit it to design the H widget so that it satisfies this description, by modifying only the aspects that are not described).

This adds an additional dimension that is not verifiable: the identity of the R widget. However, it turns out this does not make any difference to the solution of the implementation problem (see footnotes 6 and 11). And hence, we do not consider this case for simplicity.

In general, a contract is a mapping from a message space to the set of possible outcomes. We can restrict attention to truthful revelation mechanisms, in which a party's message m describes the (observable) state of the world, i.e. $m \in \{R, I, H\}$, where R denotes the state in which R is the only widget available for trade, I denotes the state where in addition there is an improved widget, and H where there is a haggling widget in addition to the R widget.[6] Then, for each pair of messages (m_B, m_S), the mechanism can specify a transfer from buyer to seller $p(m_B, m_S)$ and a probability of trade of each of the widgets $(x_1(m_B, m_S), x_2(m_B, m_S))$, such that $x_1, x_2 \geq 0$ and $x_1 + x_2 \leq 1$, where x_1 corresponds to the R widget, and x_2 to the other widget (if available). Note that the mechanism specifies no trade with positive probability if $x_1 + x_2 < 1$. To simplify notation, let $p_R = p(R, R)$, $p_I = p(I, I)$ and $p_H = p(H, H)$ denote the prices specified by the mechanism when buyer and seller agree on the state of the world (e.g. if both tell the truth).

The timing is as follows: at time $t = 0$, the two parties can write a contract which specifies the terms of trade. At time $t = 1$ the seller observes the costs of inventing each of the widgets, (κ_I, κ_H), and makes the investment decisions on both the improved and haggling widgets. At time $t = 2$, the seller observes the widgets they can trade, and decides which widgets to show as available for trade. Then, an outcome compatible with the contract is imposed on the two parties. Furthermore we assume that buyer and seller renegotiate to the (ex-post) efficient trade if this was not already prescribed by the contract (at this point, the seller may decide to show any widget she hid previously). During the renegotiation, we let the bargaining power of the seller be $\alpha < 1$, and that of the buyer be $1 - \alpha$.[7] In particular, if the contract results in an outcome which gives the seller

[6] If the R widget cannot be distinguished ex-post, the message space has to be expanded to include the elicitation of the identity of each widget, so that $m \in \{R, IR, RI, HR, RH\}$, where XY denotes the state where there are two widgets, the first being X, and the second being Y.

[7] When $\alpha = 1$, the seller gets all the rents in a renegotiation. In such a case, the first best can be easily achieved with ex-post negotiations, since no contract is necessary to protect her investments.

and buyer utilities of u_S and u_B respectively, after renegotiation the efficient widget is traded and the seller will receive a payoff of $u_S + \alpha\,(v_W - c_W - (u_S + u_B))$, and the buyer $u_B + (1-\alpha)\,(v_W - c_W - (u_S + u_B))$, where $W = I$ if the improved widget was invented and $W = R$ otherwise.

4 Two Benchmarks

This section characterizes the first best and the outcome in the absence of any contract, where the parties simply bargain ex-post over the division of the trade surplus. Both benchmarks will serve a useful comparison with our later results.

4.1 First-best

The first best outcome requires the invention and trade of the efficient widget if the social benefits of I exceed the cost κ_I, i.e. in the first best I is invented if and only if:

$$\kappa_I \leq (v_I - c_I) - (v_R - c_R)\,.$$

We assume that inventing the improved widget is socially desirable with some positive probability, i.e. $\Pr(\kappa_I \leq (v_I - c_I) - (v_R - c_R)) > 0$. Notice that the investment in creating the haggling widget generates no value. Therefore in the first best outcome H is never invented.

This outcome can easily be achieved in an environment where parties can commit not to renegotiate. For instance, a mechanism that gives the seller full bargaining power by letting her make a take-it-or-leave-it offer would be able to implement it. Since the seller would capture all the rents generated by the transaction, she would invest efficiently. Similarly, in our model with renegotiations, when $\alpha = 1$, the seller gets all the rents when bargaining with the buyer, and hence, no contract would be necessary to protect her investment.

4.2 Incomplete Contracts

When buyer and seller do not write a contract, they must bargain ex-post for the terms of trade. At that stage, the seller is only able to capture a fraction α of the rents. When no additional widget is created, the seller gets $\alpha \cdot (v_R - c_R)$; if the improved widget is created, the seller gets a share $\alpha \cdot (v_I - c_I)$; and finally, when the haggling widget is created, again the R widget is traded, giving the seller a payoff of $\alpha \cdot (v_R - c_R)$. Hence without a contract the seller will not invent H, since she would have to pay κ_H to obtain the same rents she gets without any investment. Thus the seller is only willing to invest in creating I if

$$\kappa_I \leq \alpha \left[(v_I - c_I) - (v_R - c_R) \right].$$

In particular we have that there is underinvestment in I as compared to the socially optimal investment, i.e. the ex-ante probability of inventing I is below the socially optimal probability. When there is no contract governing this relationship, the seller underinvests in the improvement of the widget, however, he sees no reason to waste resources in haggling, since there is no contract to benefit from.

5 Optimal Contracting

In this section we consider the problem of designing an optimal contract to maximize the expected future welfare of the transaction. When parties can renegotiate any previous agreement, we can restrict attention to truthful revelation mechanisms that implement the efficient trade when both parties truthfully report the state of the world. On the equilibrium path, the seller will get a profit of

$$U_S = \begin{cases} p_I - c_I - \kappa_I & \text{if seller invents } I \\ p_H - c_R - \kappa_H & \text{if seller invents } H \\ p_R - c_R & \text{if seller does not invent a new widget.} \end{cases}$$

Notice that the seller invests in I if and only if:

$$\kappa_I \leq (p_I - c_I) - (p_R - c_R) \quad \text{and} \quad \kappa_I \leq \kappa_H + [(p_I - c_I) - (p_H - c_R)]\,.$$

The first inequality states that the seller prefers to invest in I rather than not to invest at all. The second states that she prefers to invest in I rather than in H. Similarly, she invests in H if and only if

$$\kappa_H < (p_H - p_R) \quad \text{and} \quad \kappa_H < \kappa_I - [(p_I - c_I) - (p_H - c_R)]\,.$$

Let $\Delta = (v_I - c_I) - (v_R - c_R)$ be the social benefit of investing in I. Similarly, we denote the seller's contractual benefit from investing in the improved widget by $\Delta_I = (p_I - c_I) - (p_R - c_R)$ and the seller's benefit from investing in the haggling widget by $\Delta_H = p_H - p_R$. The ex-ante probability of creating I is thus given by $\Pr(\kappa_I \leq \Delta_I - \max(0, \Delta_H - \kappa_H))$, the ex-ante probability of creating H is $\Pr(\kappa_H < \Delta_H - \max(\Delta_I - \kappa_I, 0))$. We thus interpret Δ_I and Δ_H as the incentives to invest in the improved or haggling widgets, respectively: the larger Δ_I (Δ_H) the higher the ex-ante probability that the I (H) widget is invented.[8]

The welfare W generated by a contract that induces truthtelling about the state of the

[8] Note that an increase in Δ_I does not necessarily lead to a strictly higher probability that I is created as $\Pr(\kappa_I \leq \Delta_I)$ might be constant over some range $(\Delta_I^*, \Delta_I^{**})$, $\Delta_I^* < \Delta_I^{**}$, and similarly for Δ_H.

world is given by:

$$W = (v_R - c_R) + \int_{\kappa_I \leq \Delta_I - \max(0, \Delta_H - \kappa_H)} (\Delta - \kappa_I) \cdot dF - \int_{\kappa_H < \Delta_H - \max(\Delta_I - \kappa_I, 0)} \kappa_H \cdot dF. \quad (1)$$

In order to increase the (ex-ante) probability of inventing the improved widget, more incentives to invest in I should be provided, i.e. the price p_I when the state is I should be increased relative to the price p_R. In contrast, in order to deter the inefficient investment in the haggling widget, the mechanism should lower the price in state H, relative to that of R (i.e., Δ_H should be low). As we will see in the next section, the fact that the outcome of the investment is not verifiable by a third party constrains the set of prices p_R, p_I, p_H that can support truthtelling. In particular not all combinations of Δ_I and Δ_H are feasible. We say that a contract is optimal if it maximises welfare among the set of all possible contracts that support truthtelling (are incentive compatible). The next subsection derives these incentive compatibility constraints which are used in Subsection 5.2 to derive the optimal contract.

5.1 Resolving Disagreements

The necessity to induce parties to be truthful about the state of the world imposes constraints on the set of contracts that can be implemented.[9] In this section we show that the existence of a haggling widget improves the seller's bargaining position. If the quality of the widgets is not verifiable, she could pretend to have the improved widget whereas indeed she trades the haggling widget, thus decreasing the buyer's (and improving the own) threat point in the renegotiations. Therefore, in general, the seller profits from investment in the creation of the haggling widget as long as κ_H is sufficiently small. We provide here an

[9] General conditions for implementation when agents can renegotiate (and cannot commit not to renegotiate) are derived in Maskin and Moore (1999). A formulation of these conditions that more directly applies to our environment can be found in Segal (1999).

informal discussion of the constraints this imposes on the implementation problem. The formal derivations are left to the Appendix.

Notice that whenever one party deviates (unilaterally) from truthtelling, there is a disagreement between the buyer's and seller's report. To assure that in equilibrium both agents report the true identities of available widgets, the mechanism needs to be able to punish any possible (one-sided) deviation. In order to achieve this, the designer has several instruments. She can set transfer prices and/or enforce the exchange of widgets in a way that punishes the deviator.[10] However, this typically imposes constraints on the equilibrium prices p_I, p_R and p_H, and hence, the outcomes that can be sustained are constrained by the ability to resolve the disagreements that arise when the buyer or seller lie about the true state. There are two possible disagreements: either $(m_B, m_S) = (I, H)$ or $(m_B, m_S) = (H, I)$. Note that since we assumed R to be verifiable, the only information that needs to be elicited is the identity of any newly created widget.[11] In both, buyer and seller disagree on the type of widget that has been invented. In essence, this is a disagreement on the right metric to measure the quality of the widgets. Consequently, buyer and seller also disagree on the efficient action: in the first, the buyer claims they should trade R, while the seller wants to trade the new widget; in the second, the opposite is true.

The first disagreement, (I, H), can arise for two reasons: either the true state is I, and the seller is lying, or the state is H and the buyer is lying. Notice that in both cases, the

[10] Note that any payments that the designer imposes on one party will have to go to the other, since ex-post renegotiations would prevent any waste.

[11] If the identity of the R widget cannot be verified ex-post, the message game is complicated by the fact that there may be two widgets to be traded: R plus either I or H. The mechanism then must elicit the identity of each of the widgets. As a result, there are potentially more disagreements. Nevertheless, most disagreements are easily resolved. There is only one disagreement which is binding, corresponding to the announcement $(m_B, m_S) = (HR, IR)$. In this disagreement buyer and seller agree on the identity of the R widget, and hence, it is irrelevant whether the identity of this widget can be verified (in the worst disagreement, they indeed agree on which is the R widget). Notice that this disagreement is analogous to the second one described in the main text.

liar is making a claim against his own interests: the buyer claiming the new widget being better than it actually is, or the seller claiming it is worse. A simple way of avoiding this disagreement would be to increase the equilibrium payoff for the seller in the I state, and for the buyer in the H state. But this amounts to increasing p_I and decreasing p_H, which goes in the direction of what the implementation problem would require to achieve the first best. As a result, this disagreement can be easily resolved, without imposing restrictions on the set of outcomes that can be implemented.

The second disagreement, however, is harder to resolve, and hence, imposes restrictions on the implementation problem. As before, there are only two ways to arrive at this disagreement. Either the buyer lies when the state is I, or the seller lies when the state is H. Now, however, each of the parties is distorting the truth in their own interest: either the buyer is trying to make the new widget look worse than it is, or the seller is exagerating its quality.

We show in the Appendix that enforcing the exchange of a widget (either R or the new one) cannot discourage misreporting. Hence, lying can only be prevented by specifying no trade after such a disagreement and appropriately setting payments $p(H, I)$, p_I and p_H. In particular the buyer's payoff from truthtelling when the true state is I (in which case the contract specifies trade of the improved widget at price p_I) must be (weakly) larger than his payoff if he reports H. In such case, the contract specifies that he pays $p(H, I)$ and no widget is traded. But the subsequent renegotiation would give him a share $(1 - \alpha)$ of total benefits from trading the improved widget. Thus truthtelling requires that

$$v_I - p_I \geq -p(H, I) + (1 - \alpha) \cdot (v_I - c_I).$$

Similarly, to prevent the seller from reporting I, when the true state is H we must have that

$$p_H - c_R \geq p(H, I) + \alpha \cdot (v_R - c_R).$$

The price $p(H, I)$ is also a limited instrument to induce truthtelling. Increasing $p(H, I)$ relaxes the buyer's constraint, making it more costly for him to lie, but at the expense of making the seller more willing to lie. Since both constraints must be satisified, the only way to relax them simultaneously is by increasing $v_I - p_I$ or $p_H - c_R$. The first means a decrease in p_I, and hence, the seller's payoff in case she invents the improved widget. Alternatively, the second means an increase in p_H, and hence, the seller's payoff if she invents the haggling widget. The intuition is straightforward: in order to induce truthtelling, the mechanism needs to give rents to the buyer to admit when the seller did the right investment (lowering the payoff of the seller), and for the seller to admit when she engaged in rent seeking (increasing her payoff from doing it). Both of these alternatives go against the direction needed for efficiency.

Adding these two inequalities and rearranging terms, we obtain a constraint in terms of the social and contractual incentives: $\Delta_I \leq \Delta_H + \alpha\Delta$. This constraint says that the contractual benefit the seller obtains from inventing the improved widget cannot be larger than her contractual benefit from inventing the haggling widget plus $\alpha\Delta$, the seller's benefit from inventing I in the absence of any contract. Therefore, whenever $\Delta_H = 0$ (the seller is not given any incentive to invent H), the best the contract can achieve is to implement the incomplete contract outcome. Furthermore, in order to increase the incentives to invest in the improved widget beyond what the incomplete contract can obtain, we must increase Δ_H above zero, which usually induces some incentives to invest in H (i.e. it induces incentives for rent-seeking).

Since any optimal contract minimizes the amount of investment in creating H, there is always an optimal contract for which the constraint will be binding, i.e. for which we have that $\Delta_I = \Delta_H + \alpha\Delta$.[12] In what follows we focus attention on optimal contracts and therefore we assume that

$$\Delta_I = \Delta_H + \alpha\Delta. \tag{2}$$

In the appendix we show that this condition is also sufficient for implementability. To simply notation we describe a contract by the incentives it provides to invest in the haggling widget Δ_H. It should be clear, however, that there are multiple ways to write out a contract that induces the incentives Δ_H and $\Delta_I = \Delta_H + \alpha\Delta$ (i.e. there are various ways to choose $(p(m_B, m_S), x_1(m_B, m_S), x_2(m_B, m_S))$ to induce certain levels of Δ_I and Δ_H).

5.2 Costly Haggling as a Constraint on Contracting

As discussed above, the incentive compatibility constraint (2) imposes a relation between the incentives to create the improved and the haggling widgets. Increasing the incentives to invest in the improved widget can only be encouraged if at the same time incentives for the haggling widget go up as well, potentially resulting in inefficient rent-seeking. Thus in general the optimal mechanism will trade-off a lower investment in the invention of I for a lower investment in the invention of H and thus the first best cannot typically be obtained. This is not true, however, if the invention of the haggling widget is particularly difficult, i.e. it is likely to be very costly. In this case, incentive compatibility does not impose strong constraints on the implementation problem and increasing the incentives Δ_H does not induce any inefficient investments. As a result, we may be able to provide first-best incentives. To simplify notation define the lowest level of incentives to invest in I that result in first best investment in I by $\widetilde{\Delta} := \min\{x|\ \Pr(\kappa_I \le x) = \Pr(\kappa_I \le \Delta)\}$.

[12] Note that if the distribution of (κ_I, κ_H) has full support, then any optimal contract will necessarily satisfy $\Delta_I = \Delta_H + \alpha\Delta$.

Proposition 1 *The first best can be implemented if and only if*

$$\Pr\left(\kappa_H \geq \min\left(\widetilde{\Delta} - \alpha\Delta, \kappa_I - \alpha\Delta\right)\right) = 1.$$

If there exist $\varepsilon > 0$ such that for all $(\kappa_I, \kappa_H) \in [\Delta - \varepsilon, \Delta + \varepsilon] \times [\Delta - \alpha\Delta - \varepsilon, \Delta - \alpha\Delta]$ we have $f(\kappa_I, \kappa_H) > 0$ then the optimal mechanism results in lower ex-ante probability of inventing the improved widget than in the first best.

Proof. Suppose that $\Pr\left(\kappa_H \geq \min\left(\widetilde{\Delta} - \alpha\Delta, \kappa_I - \alpha\Delta\right)\right) = 1$, and set $\Delta_I = \widetilde{\Delta}$, and $\Delta_H = \widetilde{\Delta} - \alpha\Delta$. Clearly, Δ_I and Δ_H satisfy the truthtelling constraint. Moreover, as $\Pr\left(\kappa_H < \min\left(\widetilde{\Delta} - \alpha\Delta, \kappa_I - \alpha\Delta\right)\right) = 0$, we cannot have that $\kappa_H < \Delta_H$ and $\kappa_H < \kappa_I + \Delta_H - \Delta_I$ simultaneously, and hence H is never invented. Furthermore, the I widget is invented whenever $\kappa_I \leq \Delta$. To see this, notice that $\kappa_I \leq \Delta$ implies that $\kappa_I \leq \widetilde{\Delta}$, since $\Pr\left(\kappa_I \in \left[\widetilde{\Delta}, \Delta\right]\right) = 0$. But this means that $\kappa_I \leq \Delta_I$, and hence the seller is willing to invent it. Also, $\kappa_H \geq \min\left(\widetilde{\Delta} - \alpha\Delta, \kappa_I - \alpha\Delta\right) = \kappa_I - \alpha\Delta = \kappa_I + \Delta_H - \Delta_I$, and hence the seller prefers to invent I, rather than H. Therefore, I is indeed created for any $\kappa_I \leq \Delta$.

To show the other direction, suppose now that there exists a mechanism that implements the first best. We can characterize it by Δ_H, since it must satisfy the truthtelling constraint, and hence, we can set $\Delta_I \leq \Delta_H + \alpha\Delta$. Moreover, the mechanism should not provide incentives to invest in innovating H. This implies that investing in innovation of H is unprofitable or less profitable than investing in I, i.e. $\Pr(\kappa_H \geq \min(\Delta_H, \kappa_I + \Delta_H - \Delta_I)) = 1$. Furthermore, it should induce an innovation in I whenever $\kappa_I \leq \Delta$. Since we have that $\Pr\left(\kappa_I \in \left[\widetilde{\Delta} - \varepsilon, \widetilde{\Delta}\right]\right) > 0$ for any $\varepsilon > 0$, we must have $\Delta_I \geq \widetilde{\Delta}$, or $\Delta_H \geq \widetilde{\Delta} - \alpha\Delta$. Therefore, $\Pr\left(\kappa_H \geq \min\left(\widetilde{\Delta} - \alpha\Delta, \kappa_I - \alpha\Delta\right)\right) \geq \Pr(\kappa_H \geq \min(\Delta_H, \kappa_I + \Delta_H - \Delta_I)) = 1$.

Assume now that $f(\kappa_I, \kappa_H) > 0$ for all $(\kappa_I, \kappa_H) \in [\Delta - \varepsilon, \Delta + \varepsilon] \times [\Delta - \alpha\Delta - \varepsilon, \Delta - \alpha\Delta]$. Clearly a contract cannot be optimal if it induces a higher probability of inventing I than in the first best. Welfare, given a contract $\Delta_H \leq (1-\alpha)\,\Delta$, is

$$\begin{aligned} W(\Delta_H) &= \int_0^{\alpha\Delta+\Delta_H} \int_{\max(0,\kappa_I-\alpha\Delta)}^{\infty} (\Delta-\kappa_I)\cdot f(\kappa_I,\kappa_H)\cdot d\kappa_H\cdot d\kappa_I \\ &\quad - \int_0^{\Delta_H} \int_{\alpha\Delta+\kappa_H}^{\infty} \kappa_H \cdot f(\kappa_I,\kappa_H)\cdot d\kappa_I\cdot d\kappa_H \end{aligned}$$

and therefore

$$\frac{\partial W}{\partial \Delta_H} = \int_{\Delta_H}^{\infty} (\Delta-\Delta_H-\alpha\Delta)\cdot f(\Delta_H+\alpha\Delta,\kappa_H)\cdot d\kappa_H - \int_{\Delta_H+\alpha\Delta}^{\infty} \Delta_H\cdot f(\kappa_I,\Delta_H)\cdot d\kappa_I$$

and

$$\left.\frac{\partial W}{\partial \Delta_H}\right|_{\Delta_H=\Delta-\alpha\Delta} = -\int_{\Delta}^{\infty} (1-\alpha)\cdot(\Delta-\alpha\Delta)\cdot f(\kappa_I,\Delta-\alpha\Delta)\cdot d\kappa_I.$$

and we have that in the optimal contract $\Delta_H < (1-\alpha)\,\Delta$. This implies that $\Delta_I < \Delta$. ■

In order to get the first best, we must have $\Delta_I = \widetilde{\Delta}$, so that the contractual benefits of the seller equal the social benefit. However, this implies that $\Delta_H = \widetilde{\Delta} - \alpha\Delta$, but the seller must not invest in inventing H. This can only happen when the return from an investment in H never exceeds the cost κ_H or when investing in I is more profitable than investing in H. In particular, the first best can be achieved if either the cost of invention of the haggling widget always exceeds its benefits (i.e. if $\kappa_H \geq \Delta_H = (1-\alpha)\,\Delta$ with probability 1) or if the gains from inventing I always exceed the gains from inventing H (i.e. if $\Delta_H - \kappa_H \leq \Delta_I - \kappa_I$ with probability 1). Nevertheless, in most cases, the first best cannot be achieved.

The next Proposition shows that in many environments a simple option contract can implement the second best outcome.

Proposition 2 *Suppose that $\alpha\cdot(v_I - v_R) \leq (1-\alpha)\cdot(c_R - c_I)$. Then, the second best can be implemented with the following contract: the seller sells at a price p_O if no new widget* *is created, and at a price p_N otherwise;the new (shown) widget or the already known widget R.*

Proof. *We need to show that for any possible value of Δ_H we can construct a contract of this form such that $\Delta_I = \Delta_H + \alpha\Delta$. Assume first that there was no innovation. Then they must trade the R widget at a price of p_O. If the seller invented one widget, she will always show it. Otherwise, if it was optimal to hide it, she would not have invented it. Suppose the seller creates H and shows it. The buyer will choose R since $v_R - p_N \geq v_H - p_N + (1-\alpha) \cdot [(v_R - c_R) - (v_H - c_H)]$ is always satisfied. When the seller creates I, the buyer will also choose R whenever $v_I - p_N \leq v_R - p_N + (1-\alpha)\,[(v_I - c_I) - (v_R - c_R)]$, which is satisfied if and only if $\alpha \cdot (v_I - v_R) \leq (1-\alpha) \cdot (c_R - c_I)$. Hence, when the seller creates H her payoff is $p_N - c_R$ and when she creates I her payoff is $p_N - c_R + \alpha\Delta$, since the buyer chooses R in either case. Thus in an equivalent truthful revelation mechanism we have that $p_H = p_N$ (recall that $p_H - c_R$ is the seller's payoff in the revelation mechanism when H is created) and that $p_I = p_N - c_R + \alpha\Delta + c_I$ (recall that $p_I - c_I$ is the seller's payoff in the revelation mechanism when I is created). In particular we have that $\Delta_I = \Delta_H + \alpha\Delta$. This shows that for any second best contract given by prices (p_R, p_I, p_H) setting $p_O = p_R$ and $p_N = p_H$ implements the second best outcome as well.* ■

Note that $\alpha \cdot (v_I - v_R) \leq (1-\alpha) \cdot (c_R - c_I)$ is always fulfilled for selfish investments, i.e. if we have that $v_I \leq v_R$ (which implies $c_I \leq c_R$). Then the buyer will not pick the improved widget, and consequently the seller obtains a share of the increase in total welfare Δ in the renegotiation stage. If investments are co-operative (i.e. if $v_I > v_R$) an option contract will make the buyer choose the improved widget (rather than R) as long as his bargaining power is sufficiently small. But this means that the seller's additional payoff from inventing I is not aligned with the effect of such an innovation on total welfare Δ. Consequently, a contract that results in different prices, depending on whether the I or H

widget was invented, can outperform a simple option contract.

This proposition also makes clear the contracting trade-off. In general, the optimal contract gives incentives to invest in both, H and I, and thus results in socially undesirable rent-seeking activities. In particular, when the conditions of the proposition are satisfied, a single price p_O is charged, irrespective of the nature of the created widget. Hence, it is clear that positive incentives for efficient investments can only be created at the expense of inefficient haggling. In the following we explore conditions that diminish the value of contracting.

Proposition 3 *Let Δ_H^* be the optimal contract when the distribution of costs has density f. Consider a function $\phi(\kappa_I, \kappa_H)$, with $f(\kappa_I, \kappa_H) + \phi(\kappa_I, \kappa_H) \geq 0$ and which satisfies one of the following two conditions:*

1. *there exists $\widehat{\kappa}_H(\kappa_I) \geq \kappa_I - \alpha\Delta$ such that $\phi(\kappa_I, \kappa_H) \leq 0$ for all $\kappa_H > \widehat{\kappa}_H(\kappa_I)$, and $\phi(\kappa_I, \kappa_H) \geq 0$ for all $\kappa_H \leq \widehat{\kappa}_H(\kappa_I)$; furthermore, $\int_0^{\overline{\kappa}_H} \phi(\kappa_I, \kappa_H) \cdot d\kappa_H = 0$ for all κ_I*

2. *there exists $\widehat{\kappa}_I(\kappa_H) \leq \kappa_H + \alpha\Delta$ such that $\phi(\kappa_I, \kappa_H) \geq 0$ for all $\kappa_I > \widehat{\kappa}_I(\kappa_H)$, and $\phi(\kappa_I, \kappa_H) \leq 0$ for all $\kappa_I \leq \widehat{\kappa}_I(\kappa_H)$; furthermore, $\int_0^{\overline{\kappa}_I} \phi(\kappa_I, \kappa_H) \cdot d\kappa_I = 0$ for all κ_H*

Then, the optimal contract when the costs have density $f(\kappa_I, \kappa_H) + \phi(\kappa_I, \kappa_H)$, $\widehat{\Delta}_H^*$, satisfies $\widehat{\Delta}_H^* \leq \Delta_H^*$.

Proof. *Let $\widehat{f}(\kappa_I, \kappa_H) = f(\kappa_I, \kappa_H) + \mu \cdot \phi(\kappa_I, \kappa_H)$. Then, it suffices to show that welfare is submodular in (Δ_H, μ) under either of the conditions of the proposition. Differentiating the welfare function we obtain:*

$$\frac{\partial W}{\partial \Delta_H} = [(1-\alpha)\Delta - \Delta_H] \cdot \int_{\Delta_H}^{\infty} \widehat{f}(\Delta_H + \alpha\Delta, \kappa_H) \cdot d\kappa_H - \Delta_H \cdot \int_{\Delta_H + \alpha\Delta}^{\infty} \widehat{f}(\kappa_I, \Delta_H) \cdot d\kappa_I$$

If we further differentiate with respect to μ*, we obtain:*

$$\frac{\partial^2 W}{\partial \mu \partial \Delta_H} = [(1-\alpha)\,\Delta - \Delta_H] \cdot \int_{\Delta_H}^{\infty} \phi\,(\Delta_H + \alpha\Delta, \kappa_H) \cdot d\kappa_H - \Delta_H \cdot \int_{\Delta_H+\alpha\Delta}^{\infty} \phi\,(\kappa_I, \Delta_H) \cdot d\kappa_I$$

Under condition 1, $\int_{\Delta_H}^{\infty} \phi\,(\Delta_H + \alpha\Delta, \kappa_H) \leq 0$ *since* $\phi\,(\Delta_H + \alpha\Delta, \kappa_H) > 0$ *for* $\kappa_H < \Delta_H$ *and integrates to zero in the full range. Furthermore,* $\phi\,(\kappa_I, \Delta_H) \geq 0$ *for all* $\kappa_I \geq \Delta_H + \alpha\Delta$*. Hence,* $\frac{\partial^2 W}{\partial \mu \partial \Delta_H} \leq 0$*, and welfare is submodular in* (Δ_H, μ)*. A similar argument yields the same result under condition 2.* ■

Roughly, the previous result shows that if low costs for creating H become more likely (and high costs become less likely) the optimal contract will provide less incentives for innovation (in H and I). This is because for the social planner a given level of incentives Δ_H is more costly if κ_H is more likely to be low. Then the probability that H is created, i.e. the probability of rent seeking, is higher. Similarly, if high costs for creating I become more likely the optimal contract will provide lower incentives for the creation of I and H. In order to induce the same level of innovation (in I) it is necessary to increase Δ_I (and thus Δ_H). A decrease in Δ_H makes the contract closer to the incomplete contract, which does not induce any incentives to invest. In the following we address the question whether the trade-off between inducing more incentives to invent I and reducing the incentives to invest in H can diminish the value of contracting to a point, where the trading partners prefer not to have any contractual formulations, i.e. to have the (most) incomplete contract (and then rely on efficient negotiations after innovation has or has not taken place). Such an incomplete contract is characterised by $\Delta_H = 0$ and $\Delta_I = \alpha\Delta$ and the question of whether the incomplete contract is optimal is equivalent to the question of whether $\Delta_H = 0$ is the maximiser of (1). Intuitively, when $\Delta_I = \alpha\Delta$ incentives to innovate in the improved widget are below the socially optimal level (which is achieved if $\Delta_I = \Delta$ and $\Delta_H = 0$). Thus the incomplete contract can only be optimal if any increase of the incentive to innovate in I (i.e. Δ_I) beyond $\alpha\Delta$ comes at such a high cost of adjusting Δ_H (to $\Delta_H = \Delta_I - \alpha\Delta$) that this increase does not improve total welfare. The next result gives a sufficient condition for this to be true when the distributions of κ_I and κ_H are independent. Let $f(\kappa_I, \kappa_H) = f_I(\kappa_I) \cdot f_H(\kappa_H)$ and denote by r_I and r_H the hazard rates of f_I and f_H, respectively.

Proposition 4 *Suppose that the costs κ_I and κ_H are independent, and their hazard rates r_I and r_H satisfy $[(1-\alpha)\Delta - k] \cdot r_I(k + \alpha\Delta) \leq k \cdot r_H(k)$ for all $k \in [0, (1-\alpha)\Delta]$. Then, the incomplete contract is optimal.*

Proof. *Denote by $W(\Delta_H)$ the welfare that results from Δ_H (and $\Delta_I = \Delta_H + \alpha\Delta$). For the incomplete contract to be optimal, it must be the case that $W(\Delta_H) \leq W(0)$ for all $\Delta_H > 0$. When costs are independent, we can write:*

$$
\begin{aligned}
& W(\Delta_H) - W(0) \\
= & \int_{\alpha\Delta}^{\Delta_H + \alpha\Delta} \int_{\kappa_I - \alpha\Delta}^{\infty} (\Delta - \kappa_I) \cdot f(\kappa_I, \kappa_H) \cdot d\kappa_H \cdot d\kappa_I - \\
& - \int_0^{\Delta_H} \int_{\kappa_H + \alpha\Delta}^{\infty} \kappa_H \cdot f(\kappa_I, \kappa_H) \cdot d\kappa_I \cdot d\kappa_H \\
= & \int_{\alpha\Delta}^{\Delta_H + \alpha\Delta} (\Delta - \kappa_I) \cdot [1 - F_H(\kappa_I - \alpha\Delta)] \cdot f_I(\kappa_I) \cdot d\kappa_I - \\
& - \int_0^{\Delta_H} \kappa_H \cdot [1 - F_I(\kappa_H + \alpha\Delta)] \cdot f_H(\kappa_H) \cdot d\kappa_H \\
= & \int_0^{\Delta_H} \{((1-\alpha)\Delta - \kappa) \cdot [1 - F_H(\kappa)] \cdot f_I(\kappa + \alpha\Delta) - \kappa \cdot [1 - F_I(\kappa + \alpha\Delta)] \cdot f_H(\kappa)\} \cdot d\kappa,
\end{aligned}
$$

where the last step follows from the change of variables $\kappa = \kappa_I - \alpha\Delta$ and $\kappa = \kappa_H$. The assumption that $[(1-\alpha)\Delta - k] \cdot r_I(k + \alpha\Delta) \leq k \cdot r_H(k)$ implies that the integrand is non-positive. As a result, the last integral cannot be positive for any $\Delta_H \in [0, (1-\alpha)\Delta]$, and hence, the incomplete contract is optimal. ■

A marginal increase in Δ_H increases the likelyhood of creating the improved widget by $[1 - F_H(\kappa_I - \alpha\Delta)] \cdot f_I(\kappa_I)$, generating a benefit of $(\Delta - \kappa_I)$. At the same time, this also increases the probability of inducing the haggling widget by $[1 - F_I(\kappa_H + \alpha\Delta)] \cdot f_H(\kappa_H)$, creating a cost of κ_H. For the incomplete contract to be optimal, the costs must outweigh the benefits. Notice that the marginal cost of increasing Δ_H beyond the incomplete contract is zero, whereas the marginal benefit $(\Delta - \kappa_I)$ is strictly positive. As a result, the probability of having a cost κ_I around $\alpha\Delta$ must be arbitrarily small, and it is only allowed to rise gradually, as the cost κ_H increases, and the benefit $\Delta - \kappa_I$ decreases.

6 Contracting When There Are Multiple Widgets

Throughout the paper, we have assumed that the seller can only create one new widget. This is a convenient assumption that simplifies our analysis. And we want to consider now the generality of our conclusions when this is relaxed.

As discussed in the main text, the optimal mechanism must satisfly $\Delta_H = \Delta_I - \alpha\Delta$. This constraint, in turn, discourages the seller from trying to invent both H and I at the same time, and hide one before playing the mechanisms. Suppose the seller created both widgets. Then she could hide H and show only I to the buyer. They would therefore agree to trade I at a price p_I, as the mechanism states. In this case, H would be useless, and the seller would rather avoid the cost of inventing. Instead, the seller could hide I and show only H. They would then agree to trade R at a price p_H. And later, the seller could show I to the buyer and ask for a renegotiation, capturing the rents $\alpha\Delta$. Doing this, the seller obtains a payoff of $p_H - c_R + \alpha\Delta - \kappa_I - \kappa_H$. But this is dominated by the invention of I alone, which would yield a payoff of $p_I - c_I - \kappa_I = p_H - c_R + \alpha\Delta - \kappa_I$, where the equality follows from the truthtelling constraint.

A final possibility is that the seller shows both I and H to the buyer before playing the mechanism. In such a case, the mechanism should also specify what happens in this state of the world. Nevertheless, since the seller can hide H, she can guarantee herself the payoff from the I state, and hence could never be punished. Still, the mechanism could offer more to the seller, to encourage the creation of both I and H. To see the usefulnes of such strategy, consider the initial example. We showed there that whenever $\kappa_H < \kappa_I$, no contract can induce the creation of the improved widget, since the seller would always prefer to create H, instead. Nevertheless, if the contract specified a high payoff to the seller for inventing both, it could achieve this objective. Notice, however, that the same message still applies: in order to give incentives for efficient investments, the contract must also give incentives for rent seeking; and furthermore, the incomplete contract may still be optimal, since as long as $\kappa_H > \Delta - \kappa_I$, creating both widgets is still less desirable than having no investment.

There is yet another reason to be skeptical about the use of contracts that reward the creation of both I and H. Just like we argued at the beginning that contracts that reward the creation of I may suffer from investments in H, rewarding the creation of both I and H may lead, instead, to the creation of multiple haggling widgets. Therefore, when two new widgets are available, we may still have to elicit whether there is an improved widget among them, resulting in further truthtelling constraints. To avoid having to make the same argument multiple times, it is then natural to consider a model where multiple widget creation is either not possible, or not encouraged by the contract.

7 Conclusion

Transactions involving some kind of innovation are usually difficult to describe in advance in a way that allows the parties involved to verify the quality of the innovation, and hence prevent opportunistic behavior. This paper argues that any mechanism that is robust to ex-post renegotiations will find it difficult to elicit whether the innovation is valuable or not. And as a result, the party responsible will necessarily have to be rewarded both for useful as well as for useless innovations. Mechanisms are typically costly to use, and hence cannot generally achieve the first best. Indeed, if the cost of the useless innovations is sufficiently high, the value of contracting may become low, or even zero.

The model is useful for understanding the barriers to contracting. When parties can engage in activities aimed at creating new contingencies that were not foreseen in advance, using a contract may have unwanted consequences. And even when parties foresee that these activities may take place, the optimal contract cannot prevent them completely.

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8 Appendix

In this appendix we derive the implementability constraint (2). Prices $p(m_B, m_S)$ and probabilities of trade $(x_1(m_B, m_S), x_2(m_B, m_S))$ (recall that x_1 denotes the probability with which the R widget is traded) have to be specified such that truthtelling occurs in a Nash-equilibrium. Necessary and sufficient conditions for this are given in Theorem 0 in Segal: for any report (m_B, m_S) with $m_B \neq m_S$ the contract has to be specified such that misreporting makes an agent worse-off than truthtelling. As the state R is observable, we cannot have that $m_B = R$ and $m_B \neq m_S$ or that $m_S = R$ and $m_B \neq m_S$. Assume first that $m_B = I$ and $m_S = H$. Applying Theorem 0 in Segal (1999), implementability requires that there exists $p(I, H)$ and $(x_1(I, H), x_2(I, H))$ such that the following two constraints are fulfilled for the seller and the buyer respectively

$$\begin{aligned} p_I - c_I &\geq p(I,H) - x_1(I,H)\, c_R - x_2(I,H)\, c_I \\ &\quad + \alpha\left[(v_I - c_I) - x_1(I,H)(v_R - c_R) - x_2(I,H)(v_I - c_I)\right], \\ v_R - p_H &\geq -p(I,H) + x_1(I,H)\, v_R + x_2(I,H)\, v_H \\ &\quad + (1-\alpha)\left[(v_R - c_R) - x_1(I,H)(v_R - c_R) - x_2(I,H)(v_H - c_H)\right]. \end{aligned}$$

Adding these constraints gives:

$$p_I - p_H \geq x_2(I,H)\left((1-\alpha)(c_H - c_I) + \alpha(v_H - v_I)\right) + (1-\alpha)(c_I - c_R) + \alpha(v_I - v_R).$$

As $c_H < c_I$ and $v_H < v_I$ the constraint is least binding for $x_2(I,H) = 1$ and we have that the two constraints can be fulfilled if

$$p_I - p_H \geq (1-\alpha)(c_H - c_R) + \alpha(v_H - v_R)$$

or

$$p_H - c_R \leq p_I - c_H - \alpha \left[(v_H - c_H) - (v_R - c_R) \right].$$

Consider now the case where $m_B = H$ and $m_S = I$. Applying Theorem 0 in Segal (1999), implementability requires that there exists $p(H, I)$ and $(x_1(H, I), x_2(H, I))$ such that the following two constraints are fulfilled for the seller and the buyer respectively

$$\begin{aligned} p_H - c_R &\geq p(H, I) - x_1(H, I) c_R - x_2(H, I) c_H \\ &\quad + \alpha \left[(v_R - c_R) - x_1(H, I)(v_R - c_R) - x_2(H, I)(v_H - c_H) \right], \\ v_I - p_I &\geq -p(H, I) + x_1(H, I) v_R + x_2(H, I) v_I \\ &\quad + (1 - \alpha) \left[(v_I - c_I) - x_1(H, I)(v_R - c_R) - x_2(H, I)(v_I - c_I) \right]. \end{aligned}$$

Adding these constraints gives:

$$p_H - p_I \geq x_2(I, H) \left((1 - \alpha)(c_I - c_H) + \alpha (v_I - v_H) \right) + (1 - \alpha)(c_R - c_I) + \alpha (v_R - v_I).$$

As $c_H < c_I$ and $v_H < v_I$ the constraint is least binding for $x_2(I, H) = 0$ and we have that

$$p_H - p_I \geq (1 - \alpha)(c_R - c_I) + \alpha (v_R - v_I)$$

or

$$p_H - c_R \geq p_I - c_I - \alpha \left[(v_I - c_I) - (v_R - c_R) \right].$$

Furthermore the calculations show that if we have that for some (p_H, p_I) the condition

$$p_I - c_H - \alpha \left[(v_H - c_H) - (v_R - c_R) \right] \geq p_H - c_R \geq p_I - c_I - \alpha \left[(v_I - c_I) - (v_R - c_R) \right] \quad (3)$$

is fulfilled then we can find a contract $(p(m_B, m_S),\ x_1(m_B, m_S), x_2(m_B, m_S))$ for which $p(I, I) = p_I$ and $p(H, H) = p_H$ that is implementable. In this sense (3) is sufficient and necessary for implementability.