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# Uncertainty and Specific Investment with Weak Contract Enforcement

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## **Abstract**

The relationship between price uncertainty and specific investment is examined in a dynamic model that integrates the theories of real options and investment holdup. Because of weak contract enforcement, bilateral firms cannot use a contract to govern their bilateral investment and exchange relationship. These firms instead rely on an implicit self-enforcing agreement, and they reduce the investment distortion by negotiating an ex ante transfer (i.e., the investment expense of one firm is partially paid for by the other firm). In the absence of uncertainty, the ex ante transfer ensures that investment hold-up is fully eliminated. Our main result is that uncertainty introduces an inefficiency into the ex ante transfer bargaining game, which in turn causes an inefficiently long delay in investment. This linkage between higher uncertainty and longer inefficient investment delay has particular relevance for developing and transition economies where high uncertainty and weak contract enforcement is common.

*JEL Classification:* D23, L14

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## 1. Introduction

Uncertainty and weak contract enforcement are two defining features of many developing and transition economies. It is well understood that these features constrain investment and thus economic growth. There is an extensive literature on the negative impact of uncertainty on investment. Although this discussion goes back a long way, most recently the general argument is made in the real option literature (e.g., Dixit and Pindyck's 1994). Specifically, uncertainty causes a firm facing an irreversible investment decision to delay the decision until the net present value of the investment is sufficiently positive, and greater uncertainty generally causes a longer delay. Applications to developing and transition countries are, for example, Vonnegut (2000), Altomonte and Pennings (2004), and Ninh et al. (2004) who suggest that high levels of uncertainty cause investment delays in these economies because of real option effects.

Another strand of the literature focuses on the role of contract enforcement problems in causing low investment. If complete and fully enforceable contracts cannot be used to govern bilateral investment and exchange relationships, then investment may be inefficiently low due to "hold-ups" (e.g. Klein et al. 1978; Williamson 1983; Grossman and Hart 1986; Tirole 1986; Hart and Moore 1988). A firm engaged in bilateral exchange may under-invest in a specific asset if it worries that its partner will behave opportunistically after the investment costs are sunk. The importance of this factor in transition countries is emphasized by Blanchard (1997) and Blanchard and Kramer (1997) who argue that low investment is due to "disorganization" within supply relationships resulting from weak contract enforcement and asset specificity.<sup>1</sup>

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<sup>1</sup> A related argument is made by Svensson (1998) and Johnson et al. (2002) who blame low investment in developing and transition economies on weak property rights.

An important part of the literature on hold-ups has focused on how incomplete contracts can be written that potentially solve the problem of under-investment by allowing ex post exchange to be renegotiated to the efficient outcome (e.g., Aghion and Bolton, 1992; Che and Hausch, 1999). Moreover, in situations where contracts cannot be enforced, bilateral agreements between firms can be made self-enforcing (e.g., Grout 1984; Koss and Eaton 1997 and Schnitzer 1999). As part of a self-enforcing agreement, bilateral firms can use ex ante transfers (sometimes referred to as co-payments) to sustain investment and increase collective welfare. With an ex ante transfer, the non-investing firm pays for part of the sunk investment costs, which efficiently changes the ex post incentives during contract renegotiation (Williamson 1983). Koss and Eaton (1997) explain that an ex ante transfer must be specific to the investment (i.e., Williamson's *mutual reliance relationship* must be achieved) and thus might be in the form of the non-investing firm supplying the investing firm with investment components or inputs that can be used by the investing firm only if the specific investment take place. Gow and Swinnen (2001) provide empirical evidence of the connection between ex ante transfers and specific investments in a transition environment.

These different strands of literature have made convincing cases for the importance of both factors as causes of underinvestment. However, as pointed out above, most developing and transition countries are characterized by the simultaneous existence of weak contract enforcement *and* high uncertainty. An unanswered question is how both effects interact with each other and to what extent the simultaneous occurrence of both factors has a mitigating or a reinforcing effect on underinvestment. The studies on the impact of holdups on investment with self-enforcing contracts do not allow for the

emergence of real options because the models are static rather than dynamic and/or price uncertainty is assumed away. Similarly, real option models do not allow for investment distortions due to asset specificity and imperfect contracting.

In this paper, we address this issue by developing a model of the interaction and joint effect of uncertainty and weak contract enforcement on investment and then derive the implications of this interaction. In particular, we model this interaction by integrating a continuous-time real options model with a two-stage holdup model of specific investment, where firms attempt to reduce the investment distortion by negotiating an ex ante transfer.

Our approach goes beyond previous attempts to integrate an incomplete contracting model and a real option model. Sanchez (2003) describes a joint model of transaction costs and real options, but it is done in the context of organizational theory, and has little relevance for the analysis at hand. Dynamic theories of bilateral exchange with incomplete contracting are now emerging, but real options are typically not considered (Che and Sakovics 2004, Smirnov and Wait 2004, Pitchford and Snyder 2001).<sup>2</sup> Another innovation of our approach compared to Koss and Eaton (1997), which provides the starting point for our analysis, is that we allow for non-cooperative bargaining rather than cooperative bargaining over the size of the ex ante transfer.

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<sup>2</sup> Che and Sakovics (2004) use a dynamic model of investment and bargaining where firms are able to continue to invest until they agree on the terms of trade. They find that the standard result of underinvestment due to holdup does not emerge if firms are sufficiently patient, and investment distortions are due to binding individual rationality constraints rather than the surplus sharing rule. Smirnov and Wait (2004) allow for sequential investment, in which case one firm makes the initial investment and the contract is negotiated for the investment by the second firm. As compared to the standard case of simultaneous investment, sequential investment results in an additional source of holdup because it will increase the cost of investment delay. Pitchford and Snyder (2001) examine a non-contractual solution to the holdup problem with gradual investment.

The main result of our paper is that, beyond the simple addition of both effects, uncertainty reinforces the investment delay caused by the hold-up problem by reducing the effectiveness of the negotiated ex ante transfer. Effectiveness diminishes because firms negotiate less efficient ex ante transfers with higher uncertainty, and this inefficiency magnifies the distortion in investment incentives. In general, negotiated transfers are not fully effective at eliminating the investment distortion in an uncertain environment, and the effectiveness of the transfer declines with higher levels of price uncertainty. Only in the extreme case of no uncertainty does the transfer eliminate the investment distortion.

Our findings have important implications. First, they may help to explain the dramatic investment reductions in transition economies in the early period of reforms, when contract enforcement became a major problem and uncertainty increased strongly. Vice versa, it may contribute to explain the rapid increases of investment in more recent periods when uncertainty has reduced substantially and contract enforcement has improved in these countries. Second, our findings also imply that policy reforms in developing and transition economies which increase (reduce) uncertainty may have stronger negative effects on investment than previously recognized. If policy reforms, such as trade liberalization, increase (reduce) uncertainty for potential investors in countries with weak contract enforcement, the investment response may be larger than anticipated.

The paper is organized as follows. In the next section, we lay out the basic assumptions of the model and solve the ex post bargaining game. In Section 3 we create a benchmark by deriving the relationship between uncertainty and investment in a perfect

contracting environment. The investment problem for the bilateral firms is solved in Section 4 first without and then with the inclusion of ex ante transfers. The main results of the analysis, which link inefficient investment to uncertainty via inefficient bargaining over the transfer, are also presented in Section 4. Section 5 contains concluding comments.

## 2. The Model

Consider the situation of a firm, P, which is considering making an investment in an economy. Firm P would like to produce and sell into a local market a high-quality product which is currently not produced within the local region. An illustration of such a case is investments by global food and retailing companies in emerging, transition, and developing economies which have increased strongly in the recent decade (Swinnen, 2006).

The local market price for this high quality product is  $p(t) + \tau$ , where  $p(t) \in (p^L, p^H)$  is the exogenous stochastic price in a distant market at time  $t$ , and  $\tau$  is the unit transportation/import cost. We assume that processing capacity is one unit of output per unit of time and that for each unit of output, P requires one unit of a high-quality raw ingredient. For example, for high quality cheese to be sold by a dairy processing company, the company requires a supply of high-quality milk; for high-quality packaged vegetables to be sold in a modern retail chain, it needs to source high-quality vegetables.

A representative local firm, S, is currently producing only low quality raw materials (e.g., vegetables and milk for sales in the local village market) and competition is such that it currently earns zero profits. It is possible for S to shift production from low

quality products to high quality raw materials for P, but only if S makes a substantive investment. For simplicity, assume that with such an investment, production by S will exactly equal the demand requirements of P.

The high quality version of the raw material sells on the distant market at stochastic price  $w(t) \in (w^L, w^H)$  at time  $t$ . The unit transportation cost for this commodity between the local and distant market is equal to  $\tau$ , which is the same as the unit transport cost for the processed good. Thus, if P chooses to source the raw material from the distant market rather than purchasing it locally, the total price paid is  $w(t) + \tau$ . Moreover, should S make the investment to improve the quality of its output and sell the high quality raw material in the distant market rather than locally, then its unit revenue is equal to  $w(t) - \tau$ . If joint investment takes place, but the intermediate good is not exchanged locally, then the margin earned by P at time  $t$  is

$$\pi_p^n(t) = (p(t) + \tau) - (w(t) + \tau) - c = p(t) - w(t) - c \text{ and the margin earned by S is}$$

$$\pi_s^n(t) = w(t) - \tau - m, \text{ where } c \text{ and } m \text{ are the unit production costs for P and S,}$$

respectively.<sup>3</sup> Both of these margins are assumed to take on a positive value for all price realizations, which implies  $p^L - w^H > c$  and  $w^L > \tau + m$ .

The price series for  $p(t)$  and  $w(t)$  are assumed to be stationary, so as of date  $v$  the expected value of all future realizations of  $p(t)$  and  $w(t)$  equal  $p(v)$  and  $w(v)$ , respectively. Thus, as of date  $t$ , the present value of the expected stream of margins without local exchange is  $\pi_p^n(t)/\theta$  for P and  $\pi_s^n(t)/\theta$  for S, where  $\theta$  is the instantaneous

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<sup>3</sup> This assumption, which implies that S finds it more profitable to export the high quality raw material rather than forfeiting the quality premium by selling it locally, is consistent with the assumption that S earns zero profits prior to investment.



rate of discount, which is assumed to be the same for both firms. Let  $I_p^0$  and  $I_s^0$  denote the respective (fully sunk) investment costs for firms P and S, respectively. Assume that  $I_p^0 > \pi_p^n(t)/\theta$  and  $I_s^0 > \pi_s^n(t)/\theta$  for all  $p(t) \in (p^L, p^H)$  and  $w(t) \in (w^L, w^H)$ . These two assumptions imply that unilateral investment by P and S is not expected to be profitable at any price realization. Also assume that  $I_p^0 + I_s^0 < (p(t) + \tau - c - m)/\theta$  for all  $p(t) \in (p^L, p^H)$ , which implies that bilateral investment and exchange between the two firms is expected to be profitable for all price realizations. Values for  $I_p^0$  and  $I_s^0$  can be found to satisfy these various restrictions by assuming  $\tau > (p^H - p^L)/2$ . This inequality makes sense because the value of bilateral investment and exchange is fully attributable to transportation cost savings.

Before examining the bilateral investment and exchange problem, it is useful to impose more structure on the relationship between  $p(t)$  and  $w(t)$  within the distant market. Specifically, assume the following linear relationship:

$$(1) \quad w(t) = k + \gamma p(t)$$

where  $0 < \gamma < 1$ .<sup>4</sup> To ensure consistency with the previous restrictions,  $p^L - w^H > c$  and  $w^L > \tau + m$ , it is necessary to choose  $k$  such that  $\tau + m - \gamma p^L < k < p^L - \gamma p^H - c$ .

Parameter combinations can be chosen such that this restriction is satisfied.

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<sup>4</sup> This assumed relationship between  $p(t)$  and  $w(t)$  greatly simplifies the analysis. It is unlikely that a more general specification would reverse any of our main results. The key assumption is  $0 < \gamma < 1$  because, as is shown below,  $\gamma$  and  $1 - \gamma$  are the equilibrium bargaining shares for the two firms. The implied assumption of imperfect transmission between the final commodity price and raw ingredient price is appropriate for many real-world markets.

*Ex Post Bargain:* The problem facing the two firms is that they operate in an environment where a contract is prohibitively costly to enforce, and thus cannot be used to enforce the proposed terms of bilateral investment and exchange. The firms must therefore rely on an implicit self-enforcing contract to govern the exchange relationship. Specifically, each firm will anticipate the outcome of the bargaining game that will emerge after the investment costs have been sunk, and the investment decisions will depend exclusively on this anticipated outcome. We now analyze the equilibrium outcome of the non-cooperative bargaining game that takes place after S and P simultaneously sink their respective investment costs.

In non-cooperative bargaining theory, a firm's *inside* option is an important determinant of the bargaining outcome (DeMeza and Lockwood, 1998). The inside options for P and S are equal to  $\pi_p^n(t)$  and  $\pi_s^n(t)$ , respectively, because these are the unit margins that can be earned after the investment costs have been sunk, but prior to the two firms reaching an agreement on the ex post transfer price. In a standard sequential-offer non-cooperative bargaining game, with equal and relatively small rates of discount, each firm receives approximately the value of its inside option plus one half of the gains from trade, and the agreement is reached immediately (Rubinstein 1982, Sutton 1986). For the case at hand, the gains from trade equal  $2\tau$ , because S and P each save their respective transportation costs if they trade with each other rather than utilizing the distant market.<sup>5</sup>

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<sup>5</sup> Schnitzer (1999) uses a trigger strategy formulation to solve an infinitely-repeated bargaining game in her model of specific investment with an implicit self-enforcing contract. Schnitzer's bargaining outcome is equivalent to that which emerges with a conventional (one-shot) non-cooperative bargaining model. It is therefore reasonable to assume that S and P bargain just once immediately after investment. The equilibrium bargaining rule that emerges is then utilized to continually divide up the ex post surplus which evolves stochastically over time. Neither firm has an incentive to initiate a new bargaining session, because the bargaining rule that would emerge from the new session would always be the same as the original bargaining rule.

Based on this bargaining outcome, after investment occurs and an agreement is reached, S will receive at time  $t$  profit flow equal to  $\pi_S^y(t) = w(t) - m$ , and P will receive at time  $t$  profit flow equal to  $\pi_P^y(t) = p(t) - w(t) + \tau - c$ . Substituting in equation (1) allows these two equations to be rewritten as

$$(2) \quad \pi_S^y(t) = k - m + \gamma p(t)$$

and

$$(3) \quad \pi_P^y(t) = \tau - c - k + (1 - \gamma)p(t).$$

These two equations show that the parameter  $\gamma$  is key to the analysis because its value determines the allocation of the stochastic component of ex post surplus across the two firms.

Now that the ex post bargaining game has been solved, we can move back to the point in time when the firms are making their investment decisions. Specifically, an investment rule is derived for P and S at date 0, and these rules are used to calculate the expected timing of the investment. Investment rules take the form of a threshold for  $p(t)$ : invest if  $p(t)$  rises above the threshold and do not invest otherwise. We begin the next section by solving for the investment rule and the expected timing of investment when firms operate with an enforceable contract. We later compare this outcome to the case where firms operate without an enforceable contract in order to identify inefficient delay in investment.

### **3. Investment Delay without an Ex Ante Transfer**

*Investment with an Enforceable Contract:* If an enforceable and complete contract can be written to govern the investment and exchange relationship between P and S, then it is

well known that the joint investment rule will be efficient and identical to the rule utilized by P and S if they were vertically integrated. The investment problem for the two firms with a perfect contract is therefore the same as the generic single-firm investment problem, which has been studied extensively in the economics and finance literature (see Dixit and Pindyck 1994 for an overview). In the basic investment model, which was first analyzed by MacDonald and Siegel (1986), the firm optimally chooses when to pay a sunk cost  $I$  in exchange for a project with value  $V$  where  $V$  follows geometric Brownian motion (GBM). Specifically,

$$(4) \quad dV(t) = \alpha V(t)dt + \sigma V(t)dz$$

where  $dz = \varepsilon_t \sqrt{dt}$  is the increment to a Wiener process ( $\varepsilon_t$  is a standard normal random variable and  $dt$  is an infinitesimal small unit of time),  $\alpha$  is the drift parameter and  $\sigma$  is a parameter that governs the variability of  $V(t)$ .<sup>6</sup> Two important properties of  $V(t)$  are: (i)  $hV(t)$  also evolves according to equation (4) for an arbitrary constant,  $h$ ; and (ii) the expected value of  $V(t)$  discounted back to period  $T$  is  $V(T)e^{-(\theta-\alpha)(t-T)}$  when  $\theta > \alpha$ .

In the current model, assume that  $p(t)$  follows GBM with  $\alpha = 0$  (i.e., zero drift to ensure price stationarity), variance parameter  $\sigma$  and reflecting barriers at  $p(t) = p^L$  and  $p(t) = p^H$ .<sup>7</sup> Let  $\Phi_i(T)$  denote the date  $T$  expected discounted flow of post-investment profits for firm  $i \in \{S, P\}$ , assuming that joint investment takes place at time  $T$ . Using equations (2) and (3), it follows that

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<sup>6</sup> This specification implies that at any given point in time, the change in the logarithm of  $V(t)$  is normally distributed over the next infinitesimally small increment of time, and the parameters of this normal distribution are independent of the current value for  $V(t)$ .

<sup>7</sup> Because  $p(t)$  is subject to lower and upper reflecting barriers, we should not use the standard real option solution techniques, which assume no barriers. We nevertheless ignore this constraint and apply the standard solution techniques in order to obtain an analytical solution. There is no apparent reason to expect that this simplification will reverse the main qualitative results of this paper.

$$(5) \quad \Phi_s(T) = \frac{k-m}{\theta} + \frac{\gamma}{\theta} p(T)$$

and

$$(6) \quad \Phi_p(T) = \frac{\tau-c-k}{\theta} + \frac{(1-\gamma)}{\theta} p(T).$$

Let  $\Phi(T) = \Phi_p(T) + \Phi_s(T)$  denote the combined post-investment profits for the pair of firms who jointly choose to invest at time  $T$ . If the two firms with a perfect contract had only a now-or-never investment opportunity at date 0, then they would choose to invest because, as was assumed earlier,  $\Phi(0) - I_p^0 - I_s^0 > 0$ . With the option to defer the investment decision, real option theory tells us that joint investment will take place at time  $t$  only if  $\Phi(t) - I_p^0 - I_s^0$  takes on a sufficiently large positive value because the option to defer the investment decision is valuable for the pair of firms.

$$\text{Let } V(T) = p(T)/\theta \text{ and } V_0 \equiv V(0) = P(0)/\theta. \text{ It follows from equations (5) and (6)}$$

that

$$(7) \quad \Phi(T) = \frac{\tau-c-m}{\theta} + V(T).$$

The problem facing the pair of firms with a perfect contract is to determine when it is optimal to pay a sunk cost  $I^0 \equiv I_s^0 + I_p^0$  in exchange for a flow of profits with expected value at time  $t$  equal to  $\Phi(t)$ . Recalling the first property of GBM described above, an equivalent problem for the firms is determining when it is optimal to pay a sunk cost

$$I \equiv I_0 - \frac{\tau-c-m}{\theta} \text{ in exchange for a cash flow with discounted expected value } V(t) \text{ given}$$

that  $V(t)$  follows GBM with variance parameter  $\sigma$ . This problem is identical to the one

first examined by McDonald and Siegel (1996), and which is analyzed in detail by Dixit and Pindyck (1994, pp. 136-144).

Following Dixit and Pindyck's analysis, beginning with  $V(0) = V_0$  at date 0, the perfect-contract investment rule for P and S is to invest only if  $V(t) \geq V^*$  where

$$(8) \quad V^* = \frac{\beta}{\beta-1} I$$

and

$$(9) \quad \beta = \frac{1}{2} + \left( \frac{1}{4} + 2 \frac{\theta}{\sigma^2} \right)^{\frac{1}{2}}.$$

Equation (9) shows that  $\beta > 1$  when  $\sigma > 0$ , which implies from equation (8) that  $V^* > I$ .

In other words, P and S should only invest if the expected present value of the investment is sufficiently positive. If this investment rule is followed, the date 0 value of the investment opportunity can be expressed as

$$(10) \quad F(V_0) = (V^* - I) \left( \frac{V_0}{V^*} \right)^\beta.$$

*Expected Delay with an Enforceable Contract:* The expected delay in investment due to option value can be measured in several ways such as the expected date of investment, probability that investment takes place by a pre-specified date and the expected discount factor. For this analysis, we measure investment delay with the expected discount factor because of its mathematical convenience.<sup>8</sup> An expression for the expected discount factor

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<sup>8</sup> The expected time of investment is not defined for this problem because of the  $\alpha = 0$  assumption. An expression for the expected discount factor is presented below and its imputed time of investment is shown to be an increasing function of  $\sigma$ . The probability that a geometric Brownian motion,  $V(t)$ , starting at  $V_0$  and moving with zero drift, hits an optimally-chosen upper boundary,  $V^*$ , and triggers investment

for the firms with a perfect contract and which utilize the optimal investment rule can be written as (see Dixit and Pindyck 1994 pp. 315-16):

$$(11) \quad E \left\{ e^{-\theta T^*} \right\}_C = \left( \frac{V_0}{V^*} \right)^\beta .$$

Let  $T_C^*$  be the value of  $T$  which solves  $e^{-\theta T} = \left( \frac{V_0}{V^*} \right)^\beta$ . For the remainder of the analysis we shall refer to  $T_C^*$  as the *imputed* measure of investment delay when P and S operate with a perfect contract, and note that imputed delay is inversely related to the expected discount factor. Because imputed delay is closely related to the standard measures of delay discussed above, we shall use it for the remainder of the analysis. Equations (9) and (10) can be differentiated to show that a higher level of uncertainty, as measured by  $\sigma$ , simultaneously increases  $V^*$  and decreases  $\beta$ , but the net effect of  $\sigma$  on the expected discount factor is positive. Consequently, higher uncertainty raises imputed delay for the pair of firms who operate with a perfect contract.

*Investment without an Enforceable Contract:* When S and P operate without a contract, then each firm independently calculates and uses its own investment rule. However, because both firms must invest for bilateral exchange to take place, it is the rule of the firm with the longest delay that determines the actual timing of the investment. Let

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before time  $T$  equals  $2N \left( \left( \ln(V_0) - \ln(V^*) \right) \left( \sigma \sqrt{T} \right)^{-1} \right)$  where  $N(\cdot)$  is the cumulative density function for a standard normal random variable (see Sarkar 2000 for details). Simulation results confirm that, independent of  $T$ , the probability of investment is a decreasing function of  $\sigma$  for a wide range of parameter values (e.g., when  $\theta \geq .05$  and  $(V_0 - I) \geq .1(V^* - I)$ ). Because higher uncertainty increases the time of investment imputed from the expected discount factor and decreases the probability of investment for a wide range of parameter values, it is reasonable to use the expected discount factor as a measure of delay in our analysis.

$$V_s(t) = \frac{\gamma}{\theta} p(t) \text{ and } V_p(t) = \frac{1-\gamma}{\theta} p(t). \text{ As well, let } I_s = I_s^0 - \frac{k-m}{\theta} \text{ and } I_p = I_p^0 - \frac{\tau-c-k}{\theta}.$$

It follows from the analysis of the previous section that the investment problem facing firm  $i \in \{S, P\}$  is to determine the point at which it is optimal to pay a sunk cost  $I_i$  in exchange for a cash flow with discounted expected value  $V_i(t)$  given that  $V_i(t)$  follows GBM with variance parameter  $\sigma$ . The investment trigger for firm  $i \in \{S, P\}$  is therefore

$$V_i^* = \frac{\beta}{\beta-1} I_i \text{ (the firms share a common solution value for } \beta \text{ because the GBM for } V_i(t)$$

is the same for both firms).

Noting that  $V_s(0) = \frac{\gamma}{\theta} p_0$  and  $V_p(0) = \frac{1-\gamma}{\theta} p_0$ , it follows from equation (11) that

the expected discount factors when S and P respectively determine the time of investment can be expressed as

$$(12) \quad E\left\{e^{-\sigma T^*}\right\}_s = \left(\frac{\frac{\gamma}{\theta} p_0}{\frac{\beta}{\beta-1} I_s}\right)^\beta \quad \text{and} \quad E\left\{e^{-\sigma T^*}\right\}_p = \left(\frac{\frac{1-\gamma}{\theta} p_0}{\frac{\beta}{\beta-1} I_p}\right)^\beta.$$

Let  $T_N^* \in \max(T_S^*, T_P^*)$  where  $T_S^*$  and  $T_P^*$  are the respective imputed delays, defined analogous to  $T_C^*$  in the previous section.  $T_N^*$  is the imputed delay for the pair of firms that operate without a contract given the restriction that the firm with the longest delay determines the time of joint investment.

Because a contract cannot be used to allocate ex post surplus to the two firms based on shares of total sunk investment expense, a gap will generally exist between the preferred timing of investment across the two firms (i.e., one firm will want to invest



earlier than the other). Recalling that  $\gamma$  is a parameter from the pricing function given by equation (1), equation (11) reveals that  $T_S^* = T_P^*$  only when  $\gamma = \gamma^*$  where

$$(13) \quad \gamma^* = \frac{I_S}{I}.$$

It is easy to show that  $T_S^* > T_P^*$  when  $\gamma < \gamma^*$  and  $T_S^* < T_P^*$  when  $\gamma > \gamma^*$ . In the first case, S delays investment longer than that preferred by P and in the second case P is the cause of the excessive delay. This result is the dynamic equivalent of the conventional holdup problem.

Here, we focus only on the case where S is the cause of the excessive delay in investment -- the results for the opposite case are symmetric. As well, it is useful to focus on the case where the standard holdup result emerges (i.e., no investment takes place) in the absence of uncertainty. Both of these assumptions, together with the assumption that the expected net present value of the joint investment is collectively positive, can be summarized as follows.

*Assumption 1:*  $\gamma < \gamma^*$  (i.e., S is the cause of the inefficient delay) and  $1 < \frac{V_0}{I} < \frac{\gamma^*}{\gamma}$ .

*Investment Delay without an Enforceable Contract:* Before completing the model by incorporating bargaining over the transfer, it is useful to discuss the relationship between price uncertainty and investment delay in the absence of ex ante bargaining. Assumption 1 implies that with no price uncertainty and with no ex ante bargaining, firms P and S never invest even though joint investment is collectively profitable. In other words, in the absence of uncertainty the standard hold-up result emerges alone and so investment does not take place. As price uncertainty increases, there is some chance that, despite the

hold-up constraint, price will rise to a high enough level to trigger joint investment by S and P. In general, higher price uncertainty will further decrease investment delay when two firms operate without an enforceable contract and do not negotiate an ex ante transfer. On the other hand, if the two firms did have an enforceable contract, then the opposite situation emerges: zero investment delay is optimal in the absence of price uncertainty, and investment delay further increases as price uncertainty increases.<sup>9</sup>

#### 4. Investment Delay with an Ex Ante Transfer

In order to increase expected profits, P can induce S to invest earlier by paying for a portion of S's sunk investment cost.<sup>10</sup> The extent that P is individually willing to increase the transfer in order to reduce the investment distortion must be determined. Moreover, it may be the case that S will successfully negotiate a relatively large transfer, in which case its ex ante investment share will fall below its ex post surplus share, and then P will be the cause of the excessive delay in investment. Koss and Eaton (1997) derive the optimal transfer in a cooperative bargaining framework, whereas we use a non-cooperative approach, which fully accounts for individual incentives and the fact that a contract cannot be used to link the transfer with post-investment revenue shares.

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<sup>9</sup> These results can be established formally using equation (11) and the first expression in equation (12). No uncertainty implies  $\beta \rightarrow \infty$  by equation (9), in which case, given Assumption 1, the expected discount factor becomes infinitely large with a contract and converges to zero without a contract (thus  $T_C^* \rightarrow 0$  and  $T_N^* \rightarrow \infty$ ). As  $\sigma$  increases,  $\beta$  decreases, which reduces the value of equation (11) and increases the value of the first expression in equation (12). These two results imply that  $T_C^*$  continually increases and  $T_N^*$  continually decreases as  $\sigma$  is increased. However,  $T_N^* - T_C^* \geq 0$  for all values of  $\sigma$ .

<sup>10</sup> Assume that the specificity restrictions on this transfer, which were discussed in the Introduction, are satisfied.

*Individually-Preferred Transfers:* Before deriving the equilibrium transfer, it is useful to derive the transfers that P and S individually prefer, which obviously guide the offers and counteroffers of these two firms in the bargaining game. Let  $\Omega$  denote the size of the transfer that P provides to S. Notice that if  $\Omega = \Omega^{**}$  where  $\Omega^{**} = I_S - \gamma I$ , then S's post-transfer share of the total investment expense is equal to  $\gamma$ , which implies that the investment incentives facing both firms are identical to that with a perfect contract. If both firms find it in their self interest to agree on an ex ante transfer of size  $\Omega = \Omega^{**}$ , then the distortion will be eliminated and investment timing will be efficient.

Suppose  $\Omega \leq \Omega^{**}$ , in which case S will choose an investment delay that is equal to or longer than that preferred by P. The corresponding expected discount factor for the two firms can be obtained by modifying equation (12) and written as follows:

$$(14) \quad E\left\{e^{-\theta T^*}\right\}_{\Omega \leq \Omega^{**}} = \left( \frac{\frac{\gamma}{\theta} P_0}{\frac{\beta}{\beta-1} (I_S - \Omega)} \right)^\beta.$$

On the other hand, if  $\Omega \geq \Omega^{**}$ , then P will choose a delay that is equal to or longer than that preferred by S, in which case the expected discount factor for the two firms can be expressed as

$$(15) \quad E\left\{e^{-\theta T^*}\right\}_{\Omega \geq \Omega^{**}} = \left( \frac{\frac{1-\gamma}{\theta} P_0}{\frac{\beta}{\beta-1} (I_P + \Omega)} \right)^\beta.$$

It can easily be shown that the individually-optimal transfer for P involves  $\Omega \leq \Omega^{**}$  whereas the opposite is true for S. Thus, using equations (8), (10) and (14), and

noting that  $V(t) = \frac{1}{\gamma} \frac{\beta}{\beta-1} (I_S - \Omega)$  when investment is triggered, the value of the

investment opportunity for P with a transfer of size  $\Omega \leq \Omega^{**}$  can be expressed as:

$$(16) \quad F_P(P_0, \Omega)_{\Omega \leq \Omega^{**}} = \left( \frac{1-\gamma}{\gamma} \frac{\beta}{\beta-1} (I_S - \Omega) - I_P - \Omega \right) E \left\{ e^{\sigma T^*} \right\}_{\Omega \leq \Omega^{**}}.$$

Similarly, the value of the investment opportunity for S with a transfer of size  $\Omega \geq \Omega^{**}$  can be expressed as

$$(17) \quad F_S(P_0, \Omega)_{\Omega \geq \Omega^{**}} = \left( \frac{\gamma}{1-\gamma} \frac{\beta}{\beta-1} (I_P + \Omega) - (I_S - \Omega) \right) E \left\{ e^{\sigma T^*} \right\}_{\Omega \geq \Omega^{**}}.$$

Let  $\Omega_P^*$  and  $\Omega_S^*$  denote the individually optimal transfers from the perspective of P and S, respectively. The expressions for these two variables are obtained by the maximizing equations (16) and (17) with respect to  $\Omega$ :

$$(18) \quad \Omega_P^* = \frac{(1-\gamma)\beta - \gamma}{\beta - \gamma} I_S - \frac{\gamma\beta}{\beta - \gamma} I_P$$

and

$$(19) \quad \Omega_S^* = \frac{\beta(1-\gamma)I_S + (1-\gamma(\beta+1))I_P}{\beta - 1 + \gamma}.$$

Note that it is possible for  $\Omega_P^* < 0$ , which implies that it is optimal for P to receive a transfer from S rather than making a transfer to S.

Equations (18) and (19) provide us with important insights. Use  $\Omega^{**} = I_S - \gamma I$

along with equations (17) and (18) to show that  $\Omega^{**} - \Omega_P^* = \frac{\gamma^2 I}{\beta - \gamma}$  and

$\Omega_S^* - \Omega^{**} = \frac{(1-\gamma)^2 I}{\beta - (1-\gamma)}$ . Notice that  $\Omega_P^* \rightarrow \Omega^{**}$  and  $\Omega_S^* \rightarrow \Omega^{**}$  as  $\sigma \rightarrow 0$  (recall that

$\beta \rightarrow \infty$  as  $\sigma \rightarrow 0$ ). As well,  $\Omega^{**} - \Omega_p^*$  and  $\Omega_s^* - \Omega^{**}$  are both increasing functions of  $\sigma$ .

In other words, both firms individually prefer the efficient transfer in the absence of uncertainty, but as uncertainty increases, the individually optimal transfer falls below the efficient transfer for P and rises above the efficient transfer for S. It is this linkage between uncertainty and a divergence in the preferred level of transfer for the two firms that gives rise to the main result of our paper. In effect, uncertainty has created a prisoners' dilemma for the pair of firms in the ex ante bargaining game.

*Equilibrium Transfer:* With uncertainty, P prefers a transfer smaller than  $\Omega^{**}$  and S prefers a transfer greater than  $\Omega^{**}$ , so the two firms must bargain over the actual amount of the transfer. Let  $\Omega^*$  denote the equilibrium transfer, which is determining in a non-cooperative bargaining game. In Rubinstein's (1982) non-cooperative bargaining framework,  $\Omega^*$  is equal to the equilibrium offer of the firm which is allowed to make the first offer (i.e., has the first-mover advantage). It is not important for our analysis to specify whether P or S makes the first offer. It is sufficient to note that  $\Omega^* \in (\Omega_p^e, \Omega_s^e)$  where  $\Omega_p^e$  and  $\Omega_s^e$  denote the equilibrium offers for P and S, respectively.

Rubinstein's (1982) procedure for calculating the equilibrium of a non-cooperative bargaining game is to make player A indifferent between accepting the equilibrium offer of player B and waiting one period, in which case the equilibrium offer of player A will be accepted by player B.<sup>11</sup> An analogous restriction is imposed on player B. Let  $\delta = e^{-\theta\lambda}$  be the time cost of delay, which is assumed to be the same for the two firms ( $\lambda$  is the length of time between bargaining rounds). Recall that S determines

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<sup>11</sup> It is possible to use this procedure for our analysis because both the inside and outside options for the two firms equal zero during the bargaining game.

the timing of investment when  $\Omega = \Omega_p^e$  because  $\Omega_p^e < \Omega^{**}$  and P determines the timing of investment when  $\Omega = \Omega_s^e$  because  $\Omega_s^e > \Omega^{**}$ . The equation which implies that P is indifferent between accepting an offer of  $\Omega = \Omega_s^e$  and waiting one period to have its offer of  $\Omega = \Omega_p^e$  accepted by S can be written as

$$\begin{aligned}
(21) \quad & \left( \frac{\beta}{\beta-1} (I_p + \Omega_s^e) - (I_p + \Omega_s^e) \right) \left( \frac{(1-\gamma)V_0}{\frac{\beta}{\beta-1} (I_p + \Omega_s^e)} \right)^\beta \\
& = \delta \left( \frac{1-\gamma}{\gamma} \frac{\beta}{\beta-1} (I_s - \Omega_p^e) - (I_p + \Omega_p^e) \right) \left( \frac{\gamma V_0}{\frac{\beta}{\beta-1} (I_s - \Omega_p^e)} \right)^\beta
\end{aligned}$$

The analogous equation for S can be written as

$$\begin{aligned}
(22) \quad & \left( \frac{\beta}{\beta-1} (I_s - \Omega_p^e) - (I_s - \Omega_p^e) \right) \left( \frac{\gamma V_0}{\frac{\beta}{\beta-1} (I_s - \Omega_p^e)} \right)^\beta \\
& = \delta \left( \frac{\gamma}{1-\gamma} \frac{\beta}{\beta-1} (I_p + \Omega_s^e) - (I_s - \Omega_s^e) \right) \left( \frac{(1-\gamma)V_0}{\frac{\beta}{\beta-1} (I_p + \Omega_s^e)} \right)^\beta
\end{aligned}$$

The joint solution to equations (21) and (22) provide us with the desired solution values for  $\Omega_p^e$  and  $\Omega_s^e$ .

*Result 1:  $\Omega^* \rightarrow \Omega^{**}$  as  $\sigma \rightarrow 0$  and  $|\Omega^* - \Omega^{**}|$  increases as  $\sigma$  increases. In words, the equilibrium transfer converges to the efficient transfer as uncertainty tends to zero, and the absolute gap between the equilibrium transfer and the efficient transfer increases as uncertainty increases.*

*Proof:* We present the proof only for the special case where  $\gamma = \frac{1}{2}$ .<sup>12</sup> Let

$\Delta_P = \Omega^{**} - \Omega_P^e$  and  $\Delta_S = \Omega_S^e - \Omega^{**}$ . With  $\gamma = \frac{1}{2}$ , the solution to equations (21) and (22)

is  $|\Omega^* - \Omega^{**}| = \Delta_P = \Delta_S = \frac{(1-\delta)I}{2((2\beta-1)\delta-1)}$ . It follows immediately from this equation that

$|\Omega^* - \Omega^{**}| \rightarrow 0$  as  $\sigma \rightarrow 0$  and  $\beta \rightarrow \infty$ . Moreover,  $|\Omega^* - \Omega^{**}|$  increases as  $\sigma$  increases

because  $\beta$  is a decreasing function of  $\sigma$ . Q.E.D.

*Inefficient Investment Delay:* Result 1 is expected given our previous finding that P and S individually prefer the efficient transfer without uncertainty, and respectively prefer a lower and higher transfer with uncertainty. We will explain the intuition for both of these results below. But first, the main result of our analysis is presented.

*Result 2: Given Assumption 1, and assuming that P and S negotiate a transfer in an ex ante non-cooperative bargaining game, inefficient investment delay, as measured by  $T_N^* - T_C^*$ , increases as uncertainty increases.*

*Proof:* Result 1 shows that  $\Omega^* \rightarrow \Omega^{**} = I_S - \gamma I$  as  $\sigma \rightarrow 0$ . If this expression is substituted into equation (12), the resulting expression is identical to equation (11). Consequently, there is no inefficient delay in investment as  $\sigma \rightarrow 0$ . With  $\sigma > 0$ , then the first expression in equation (12) is relevant if  $\Omega^* = \Omega_P^e$  and the second expression is relevant if  $\Omega^* = \Omega_S^e$ . In both cases, equation (11) takes on a larger value than equation

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<sup>12</sup> It is straight-forward to analytically establish the result that  $\Omega^* \rightarrow \Omega^{**}$  as  $\sigma \rightarrow 0$  for the general case where  $\gamma \neq \frac{1}{2}$ . Numerical simulations confirm that the second part of Result 2 also holds for values for  $\gamma$  other than  $\frac{1}{2}$ .

(12) given that  $|\Omega^* - \Omega^{**}| > 0$  with  $\sigma > 0$  from Result 1. Moreover, this difference in values is an increasing function of  $\sigma$  given that  $|\Omega^* - \Omega^{**}|$  is an increasing function of  $\sigma$  from Result 1. The difference in the values of equations (11) and (12) is positively related to  $T_N^* - T_C^*$ . Q.E.D.

Result 2 emerges because uncertainty creates a prisoners' dilemma situation in the ex ante bargaining game between P and S, which in turn causes an inefficient bargaining outcome. Specifically, P and S choose a suboptimal transfer, and regardless of whether this transfer is inefficiently low (if P has the first-mover advantage in the bargaining game) or inefficiently high (if S has the first-mover advantage in the bargaining game), the result is the same: the delay in investment is inefficiently long. Greater price uncertainty results in a less efficient equilibrium transfer and consequently more inefficient delay in investment.

What remains to be explained is why greater price uncertainty causes P to lower its equilibrium transfer offer and S to increase its equilibrium transfer offer. We will explain the first outcome only because the argument for the second outcome is symmetric. The marginal benefit for S from receiving a marginally higher transfer from P is lower with higher uncertainty. Because of this lower marginal benefit, the extent that S reduces investment delay given a marginally higher transfer from P is less at higher levels of uncertainty. A smaller reduction in investment delay for a marginally higher transfer implies that P's marginal value of the transfer is lower with higher uncertainty. This lower marginal value reduces the value of P's optimal transfer and equilibrium-offer transfer.



Why is a marginally higher transfer less valuable for S with greater uncertainty?

The reason is the same as why a marginally lower investment expense is less valuable for an integrated firm at higher levels of uncertainty. If equation (8) is substituted into equation (10) and the resulting expression differentiated with respect to  $I$ , then it can be shown that  $\frac{dF}{dI} = -E\left(e^{-\theta r^*}\right)$ . In other words, the marginal value of lower investment expense for an integrated firm is equal to the expected discount factor. It was previously established that the expected discount factor is smaller with higher uncertainty, so the marginal value of lower investment expense must also be lower with higher uncertainty. Uncertainty increases the option value, and the higher option value increasingly diminishes the benefit of an immediate reduction in investment expense.

## 5. Conclusions

In this paper we focus on a specific bilateral exchange situation where an downstream processor and an upstream supplier engage in bilateral investment and exchange to capture rents, which are generated by spatial separation of two markets and costly transportation. The two firms operate in a weak contracting environment, which implies that all agreements must be implicit and self-enforcing. Relative to a perfect contracting environment, the value of the supplier's option to delay the investment decision is inefficiently high because the share of the ex post surplus that accrues to the supplier is low relative to the supplier's ex ante share of total investment expense. Conversely, the value of the processor's option to delay the investment decision is inefficiently low. To address this imbalance, the processor pays for a portion of the

supplier's investment expense (i.e., an ex ante transfer). The equilibrium level of this transfer is determined as the outcome of a non-cooperative bargaining game.

The main result of this analysis is that outcome of the ex ante transfer bargaining game is efficient, and thus investment is efficient, in the absence of uncertainty. Ex ante bargaining is inefficient in the presence of uncertainty, which in turn implies that the delay in investment is inefficiently long in the presence of uncertainty. Moreover, the delay increases continually as uncertainty increases. Uncertainty creates a prisoners' dilemma situation for the bargaining firms, and without the ability to contract, the inefficiency associated with the prisoners' dilemma cannot be avoided. The reason why the difference between the equilibrium transfer and the efficient transfer increases with added uncertainty is because the real option reduces the marginal value of the transfer for the recipient firm. Higher uncertainty implies a higher value for the real option and thus a lower marginal value of the transfer.

The model used in this paper is admittedly stylized and constructed for a specific situation where the gains from investment are exclusively due to savings in transportation costs. Nevertheless, similar results would likely emerge in a more general model that integrates real options and bilateral exchange with weak contract enforcement. It has previously been recognized that real option effects help to explain the negative relationship between uncertainty and investment in transition and developing economies. Our finding strengthens this negative relationship by accounting for the interactive effects of weak contract enforcement and uncertainty. Our main message for policy makers is that uncertainty and weak contract enforcement are complementary constraints, and so policy reforms designed to increase investment should account for this connection.

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