Timing of investments, holdup and total welfare

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Abstract

We explore holdup with simultaneous and sequential investment. With simultaneous investment both investors are held up. With sequential investment contracting becomes possible after the project has commenced, so the second investor avoids being held up. If the investments are independent sequential investment: increases costs of delay; reduces the incentive for the first player to invest; and increases the second player's incentive to invest. The paper shows the timing of investment can act as an additional form of holdup; if they have the option when to invest, a party may choose the regime that does not maximize total welfare.

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1 Introduction

When trading parties must make relationship-specific investments and contracts are incomplete, the so-called hold-up problem can arise. As shown in the literature, if at renegotiation a party does not anticipate receiving the full marginal benefit from his investment, he will not invest efficiently ex ante (see Hart and Moore 1988, for example). Of course, where possible parties will develop institutions and contracts that help alleviate holdup. For instance, MacLeod and Malcomson (1993) argued that a fixed-price contract that will not be renegotiated can ensure efficient investment. Aghion, Dewatripont and Rey (1994) showed that if parties can contract on the renegotiation process the hold-up problem can be avoided. In a similar manner, Nöldeke and Schmidt (1995) used option contracts to resolve the hold-up problem.

Several papers recently have shown how sequencing of investments can help alleviate holdup. For example, Neher (1999) demonstrated that staged financing of a project allows the investor's collateral to increase over time, along with the accumulation of tangible physical assets. The process can be designed so that the entrepreneur does not have an incentive to renegotiate. This can allow some projects to proceed that would not be possible with up-front financing. Che (2000) showed that, under certain circumstances, the Stackelberg-type sequencing of investment could overcome holdup. Che (2000) assumed: outside option bargaining at renegotiation and that the first mover had all the bargaining power.[1] Admati and Perry (1991) showed two parties can overcome the free-rider problem by financing a public good in stages.

[1]Also see De Fraja (1999).

However, it is not always the case that sequencing of investments improves welfare. To explore this issue we develop a model in which two parties are each required to make a specific investment to complete a project. Two alternative timing regimes are possible. First, the parties can invest simultaneously. In the usual manner, as contracts are initially incomplete, renegotiation occurs after both parties have sunk their investments. Following renegotiation, the project is completed and the payoffs are realized. Alternatively, the parties can invest one after the other in a Stackelberg-type arrangement. It is assumed that when the first investment is sunk contracting on the second investment becomes possible. This set-up is similar to Grossman and Hart (1986), who assumed that contracting became possible after the two parties made their initial investment. Similarly, in Neher (1999) investment facilitated more complete contracting by converting intangible human capital into physical assets. As a consequence, with the sequential regime after the first player has invested the parties will renegotiate and the second party will invest according to the agreed contract, completing the project.

As an example, consider two firms making a joint location decision when there is a positive externality. The firms can either locate simultaneously or one party could wait and invest after the first firm has sunk their investment. Similarly, two parties working on a joint project, such as writing a report or engaging in research, may invest simultaneously or sequentially. Both parties could invest together, before renegotiating over the surplus. Alternatively, one party could invest first, before the other party invests.

When the investments are independent the model identifies three basic trade-offs between the regimes. First, the sequential system enlarges (relative to simultaneous investments) delay costs by increasing the length of time before the project matures. Second, the sequential system reduces the first player's incentive to invest, vis-a-vis the simultaneous system, because of the longer time between when his investment is made and when the returns are realized. Third, the sequential system enhances the incentive for the second player, who does not suffer holdup, to invest efficiently, which is not the case with simultaneous investments.

The ultimate impact on total surplus is a combination of these trade-offs. We show that under different circumstances either regime of investment maximizes welfare. Moreover, despite the simplicity of the model, no simple relationship between the welfare effects of the two regimes exists, as there is no restriction on how these three trade-offs interact. However, given that the simultaneous regime encourages the first player to invest, if this player's contribution is relatively more important than the other player's contribution the simultaneous regime is preferred. In the same way, the sequential regime is preferred when the second investor's contribution is relatively more important, provided both players are sufficiently patient. Similarly, if a party is not responsive to the incentives provided by one timing regime, the regime that maximizes the other party's incentive to invest is preferred. These predictions are similar in nature to the property-rights predictions of Hart (1995).

An implication of the model presented in this paper is that when parties cannot contract on timing, allowing the possibility of sequencing investment can create an inefficiency. Consider the case where one party must invest at the start of the project while the other party can invest at the same time (simultaneous investment) or wait until the first party has invested (sequential investment). Sequential investment allows the second party to avoid being held up as she invests after contracting is possible. The second party will choose this option when it provides her with higher surplus. However, the sequential regime weakens the bargaining position of the first party, reducing his incentive to invest. Thus, the possibility of sequential investment can reduce welfare, relative to the situation when only the simultaneous regime is available.[2]

The outline of the paper is as follows. Section 2 introduces the model while Section 3 investigates parties' investment choices under the alternative timing regimes. These alternative timing regimes have implications for surplus generated (Section 4). Section 5 explores how one party (the seller) may choose the timing regime that does not maximize surplus. This will occur when her interests differ sufficiently from the first-best incentives. Section 6 concludes the paper. Details of two examples are provided in the appendix.

2 The model

There is a potentially profitable relationship between two parties who, for convenience, we label as a buyer and a seller. Specifically, if the buyer and seller invest I_1 and I_2 respectively, the two parties share surplus R. We assume that total surplus is a

[2] A similar result arises in the model presented in Smirnov and Wait (2004).

function of both investments where $R(I_1, I_2)$ is twice differentiable, non-decreasing in both variables and concave, as summarized by Assumption 1.

Assumption 1. *$R'_i = \partial R(I_1, I_2)/\partial I_i \geq 0$, $R''_{ii} = \partial^2 R(I_1, I_2)/\partial I_i^2 \leq 0$ for $i = 1, 2$ and $R''_{11}R''_{22} - (R_{12})^2 \geq 0$ where $R_{12} = \partial^2 R(I_1, I_2)/\partial I_1 \partial I_2$.*

Two alternative timing arrangements are considered. First, both players invest simultaneously at time $t = 1$, as shown in Figure 1. Initially, contracting on either investment is not possible; consequently renegotiation will occur after both investments are sunk.[3]

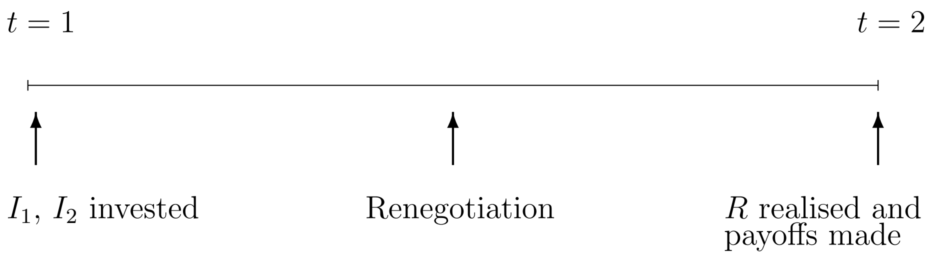

Figure 1: Simultaneous investment

Figure 2 outlines the timing of the alternative investment regime. In this regime the buyer invests I_1 at time $t = 1$, before contracting is possible. However, this investment makes contracting possible, so having observed I_1 the two parties renegotiate and contract on I_2. It is only after this that the seller makes her investment I_2. This occurs at time $t = 2$. After both investments have been made, surplus is realized and

[3]The renegotiation process is discussed below.

the payoffs to each party are made. Both parties discount future payoffs and costs with a constant discount factor per period of $\delta \in (0, 1]$. As a result, at the beginning of the project the returns from the simultaneous regime are valued at δR, while the returns with the sequential investment are worth $\delta^2 R$.

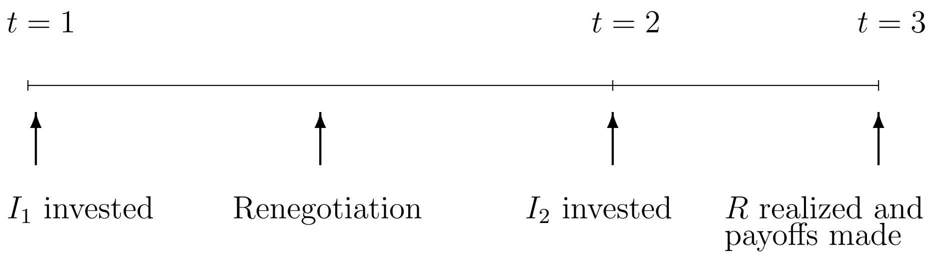

Figure 2: Sequential investment

The investments of both parties are sunk and completely specific in that they are worth zero outside the relationship. R is only available at the completion of the project and investment in the relationship is always efficient. Further, it is assumed that each party's outside option is normalized to zero.

Although investments are unverifiable ex ante, once the buyer's investment has been sunk the project becomes tangible, allowing subsequent investment to be verifiable. On the contrary, the surplus generated by the project is always unverifiable. This prevents the parties from writing surplus sharing agreements. As in Hart and Moore (1988) and MacLeod and Malcomson (1993), the two parties cannot vertically integrate to overcome their hold-up problem. Further, it is assumed that it is not possible for a court to verify the party responsible for a breakdown in trade, ruling out the option contracts suggested by Nöldeke and Schmidt (1995) to ensure first-best investments. Similarly, as the courts cannot enforce any default contract, nor can the parties commit to allocate all the ex post bargaining power to one party; the solution proposed by Aghion, Dewatripont and Rey (1994) cannot be implemented here.[4]

When the parties renegotiate they must decide how to split the available surplus. We adopt a reduced-form bargaining solution in which each party receives $\alpha_i > 0$, $i = 1, 2$ of the available surplus, where $\alpha_1 + \alpha_2 = 1$.[5] For expositional reasons we assume outside options are equal to zero.

3 Simultaneous and sequential investments

As contracts are incomplete when investments are made simultaneously both parties know that renegotiation will occur. Consequently, they adjust their investments from the first-best level accordingly. The buyer and seller choose I_1 and I_2 in order to maximize

$$\max_{I_i} \alpha_i \delta R(I_1, I_2) - I_i. \tag{1}$$

where $i = 1, 2$. Here, the returns are discounted by δ because they are only available after one period. Renegotiation occurs after both investments have been sunk; as a consequence each party anticipates receiving one half of the available surplus. As a

[4] As noted by Aghion, Dewatripont and Rey (1994), Hart and Moore (1988) focus on "at-will" contracts; we make a similar assumption here.

[5] This reduced-form bargaining solution can be thought of relating to an extensive form bargaining game.

result, the first-order conditions for the buyer and seller are

$$R_i' = \frac{1}{\alpha_i \delta} \tag{2}$$

where $i = 1, 2$.

Let the buyer's and seller's investment choices with the simultaneous regime be denoted by $\widehat{I}_1$ and $\widehat{I}_2$ respectively. These values solve equation 2 for each party respectively. The solutions are unique because of Assumption 1.[6]

Now consider the case in which investments are made sequentially. With the sequential regime the buyer invests I_1 at time $t = 1$. Following renegotiation, at time $t = 2$ the seller chooses I_2. Consequently, the buyer sets I_1 to maximize

$$\max_{I_1} \alpha_i \delta[\delta R(I_1, I_2) - I_2] - I_1. \tag{3}$$

The first-order condition for this problem is

$$R_1' = \frac{1}{\alpha_i \delta^2}. \tag{4}$$

The seller, who sets her investment level after observing I_1 and renegotiating with the buyer will maximize

$$\max_{I_2} \alpha_i \delta[\delta R(I_1, I_2) - I_2]. \tag{5}$$

The first-order condition for this maximization problem is

$$R_2' = \frac{1}{\delta}. \tag{6}$$

[6]To guarantee the existence of a solution, without loss of generality, we also assume that there is an $I_i > 0$ for which $R_i' = 0$ for $i = 1, 2$.

Let the buyer's and the seller's levels of investment be $\widetilde{I}_1$ and $\widetilde{I}_2$ when contracts are made sequentially. These values are the solution to the system of equations 4 and 6. Again, the solutions are unique.

Finally, define I_1^* and I_2^* as the first-best level of investment with the simultaneous regime. Similarly, let I_1^{**} and I_2^{**} be the first-best investment levels with the sequential regime.[7]

4 Timing of investment and total welfare

Following Hart and Moore (1988), to explore the issue of timing and total welfare we assume each investment has no influence on the marginal productivity of other player's investment, that is

Assumption 2. $R_{12}^{''} = 0$.

Remark 1. *If* $R_{12}^{''} = 0$*, it follows that* $R = f_1(I_1) + f_2(I_2)$*, where* $f_i^{'} > 0$ *and* $f_i^{''} \leq 0$ *for* $i = 1, 2$.

In this framework three separate effects can be isolated that, when combined, determine the relative advantage of either timing regime. First, consider the costs of delay. Let the total surplus ex ante with simultaneous investment be S_{sim} and the total surplus ex ante when investment is sequential be S_{seq}. For two fixed levels of

[7]The first-best level of investments solve the following system of equations: $R_1^* = R_2^* = \frac{1}{\delta}$ for the simultaneous regime; and $R_1^{**} = \frac{1}{\delta^2}$ and $R_2^{**} = \frac{1}{\delta}$ for the sequential regime.

$\overline{I}_1$ and $\overline{I}_2$

$$S_{\text{sim}} = \delta R(\overline{I}_1, \overline{I}_2) - \overline{I}_1 - \overline{I}_2 > \delta^2 R(\overline{I}_1, \overline{I}_2) - \overline{I}_1 - \delta \overline{I}_2 = S_{\text{seq}}. \tag{7}$$

As sequential investment delays the payoff an extra period, the surplus from simultaneous investment is greater than with sequential investments when I_1 and I_2 are fixed: the costs of delay always favor simultaneous investment. Further, the relative payoff of simultaneous investments is increasing as the players become more impatient. This effect is summarized below.

Effect 1. *The costs of delay reduce the surplus generated by sequential investment relative to the surplus with simultaneous investments.*

Second, consider the buyer's investment decisions under both regimes. Examining the first-order conditions in equations 2 and 4, $\widehat{R}_1' = \frac{1}{\alpha_1 \delta} \leq \widetilde{R}_1' = \frac{1}{\alpha_1 \delta^2}$. Given the assumption of concavity and monotonicity of R:

$$\widehat{I}_1 > \widetilde{I}_1. \tag{8}$$

The sequential investment regime delays the collection of returns by the buyer: this reduces the incentive for the buyer to invest.[8]

Effect 2. *Relative to sequential investment, the simultaneous regime increases the incentive for the buyer to invest in I_1.*

[8] Note that both $\widehat{I}_1$ and $\widetilde{I}_1$ are below the first-best level. With simultaneous investments $\widehat{R}_1' = 1/(\alpha_1 \delta) > R_1' = 1/\delta$, meaning that $\widehat{I}_1 < I_1^*$. Similarly, with sequential investment, $\widetilde{R}_1' = 1/(\alpha_1 \delta^2) > R_1' = 1/\delta^2$, meaning that $\widetilde{I}_1 < I_1^{**}$.

For the seller the relative incentives to invest with simultaneous and sequential investments are given by equations 2 and 6. Again, because of Assumption 1,

$$\widehat{I}_2 < \widetilde{I}_2. \tag{9}$$

With simultaneous investment the seller is held up. With sequential investment, however, the seller invests after renegotiation, thus avoiding any hold-up problems. In fact, the sequential investment level chosen by the seller equals the first-best level, so that $\widetilde{I}_2 = I_2^{**}$. This is the advantage of the sequential regime over simultaneous investment. Effect 3 summarizes this discussion.

Effect 3. *The sequential investment regime increases I_2 to its first-best level.*

Effect 2 states that the simultaneous regime increases I_1. Effect 3 suggests that the sequential regime increases I_2. To assess the impact of an increase in either investment on total welfare, isolated from the costs of delay, consider S_{sim} relative to an augmented S_{seq}, termed U_{seq}, that has the same discount structure as the simultaneous system. U_{seq} ignores the additional discounting of R and of I_2 that occurs because of the additional period. In this case:

$$S_{\text{sim}} = \delta f_1(\widehat{I}_1) - \widehat{I}_1 + \delta f_2(\widehat{I}_2) - \widehat{I}_2. \tag{10}$$

where the level of investments are determined by equation 2. Similarly, using equations 4 and 6

$$U_{\text{seq}} = \delta f_1(\widetilde{I}_1) - \widetilde{I}_1 + \delta f_2(\widetilde{I}_2) - \widetilde{I}_2. \tag{11}$$

The relative incentives to invest for the seller and buyer are summarized in the following lemma.

Lemma 1. $\delta f_1(\widetilde{I}_1) - \widetilde{I}_1 < \delta f_1(\widehat{I}_1) - \widehat{I}_1$ *and* $\delta f_2(\widetilde{I}_2) - \widetilde{I}_2 > \delta f_2(\widehat{I}_2) - \widehat{I}_2$.

Proof. The first-best investment level of I_1, that is I_1^*, satisfies $f_1^{'} = \frac{1}{\delta}$. For $I_1 < I_1^*$, $f_1^{'}(I_1) \geq \frac{1}{\delta}$ because $f_1^{''}(I_1) \leq 0$. For $I_1 < I_1^*$, $[\delta f_1(I_1) - I_1]' \geq 0$, hence $\delta f_1(I_1) - I_1$ is a non-decreasing function $\forall\ I_1 \in [0, I_1^*)$, which means $\delta f_1(\widetilde{I}_1) - \widetilde{I}_1 < \delta f_1(\widehat{I}_1) - \widehat{I}_1$. A similar argument applies to I_2. $\square$

Lemma 1 indicates that increasing I_1 towards its first-best level always increases the surplus it generates. The same argument applies to I_2. From Lemma 1 we can say that the surplus generated by I_1 is greater with the simultaneous regime. Similarly, the surplus generated by I_2 is greater with the sequential regime.

In terms of total surplus, the ultimate trade-off between simultaneous and sequential systems depends on these three effects: costs of delay incurred with the sequential regime favor simultaneous investments; the sequential system reduces the buyer's contribution to total surplus as compared with the simultaneous system; and, finally, the sequential system increases the incentive for the seller to invest, increasing her contribution to total surplus. Two of these effects work in favor of the simultaneous system and one works in favor of the sequential system. Proposition 1 summarizes this discussion.

Proposition 1. *There are three factors that affect the total surplus generated by the simultaneous system relative to the total surplus that will be generated by the sequential system: (Effect 1) costs of delay favor the simultaneous system; (Effect 2) the simultaneous regime increases the buyer's incentive to invest, increasing his contribution to total surplus; and (Effect 3) the sequential regime increases the seller's* *incentive to invest, relative to the simultaneous regime.*

The combined impact of these three effects can be complicated. Note, however, that the three effects each depend on δ: the costs of delaying the return of surplus another period directly relate to δ; the level of I_1 depends on δ as the two relevant first-order conditions are $\widetilde{R}_1' = 1/(\alpha_1\delta^2)$ and $\widehat{R}_1' = 1/(\alpha_1\delta)$; and the two first-order conditions for the choice of I_2 are $\widetilde{R}_2' = 1/\delta$ and $\widehat{R}_2' = 1/(\alpha_2\delta)$. However, if $\delta = 1$ the first two of these effects disappear. The only remaining effect is that sequential investment allows the seller to avoid being held up, increasing her incentive to invest. Thus, if $\delta = 1$, $S_{\text{sim}} < S_{\text{seq}}$. As R is a continuous function it follows that there is a neighborhood for δ close to 1 where the surplus from sequential investment exceeds the surplus generated with simultaneous investments. This is summarized in the following remark. The point is also illustrated in example 2 in the appendix.

Remark 2. *There is a small enough ε such that for any $\delta \in (1-\varepsilon, 1]$, $S_{sim} < S_{seq}$; that is, the surplus from sequential investments exceeds that produced with simultaneous investments.*

It is not possible, however, to establish that the relative difference between the surplus from sequential and simultaneous investments is monotonically increasing in δ. With general functions, the relationship between δ, I_1 and I_2 and total surplus, R can be complicated. Example 3 in the Appendix provides a particular illustration.

Remark 3. *There is no monotonic relationship between the surplus from the simultaneous and sequential systems as δ changes.*

Further, it is worth noting that when the investments are strategic complements ($R_{12} > 0$) or strategic substitutes ($R_{12} < 0$) the same three effects outlined in proposition 1 determine the relative welfare of the simultaneous and sequential regimes, provided that the investments are not strong strategic complements or substitutes.[9]

Finally, to conclude this section consider the (second-best) optimal timing of investments.

From effects 2 and 3 above, sequential investments favor I_2 while simultaneous investments favor I_1. As a consequence, when I_1 is very important relative to I_2 the simultaneous investment system is preferred over sequential investments. Using similar reasoning, when I_2 is very important relative to the unimportant I_1 the sequential system is favored over the simultaneous investment system, provided both parties are sufficiently patient. This result parallels Proposition 2(B) in Hart (1995). Hart argued that when one investment was unproductive asset ownership would be organized as to give the other party as much incentive to invest as possible.

Again, following Hart (1995), if a party's level of investment is invariant to the timing regime adopted, the timing of investment should be structured to maximize the incentive for the other party to invest. The only complication in the model presented here is that the cost of delay also needs to be taken into account. For example, if the generation of additional surplus from more efficient investment by the seller with the sequential regime does not outweigh the costs of delay, the simultaneous system should still be adopted.

[9] For details, see Smirnov and Wait (2001).

5 Holdup and the choice of investment regime

Thus far we have considered the relative merits of the various timing arrangements in terms of total welfare. The focus shifts here to explore the incentive for the seller, acting in self-interest, to choose the investment regime that does not maximize total surplus. Implicit in this discussion is the assumption that the buyer must invest at the beginning of the project. This might arise, for example, if the buyer's investment is actually in developing a blueprint for the project. As a result, only the seller has the opportunity to delay her investment and follow up the buyer.[10]

There is a trade-off for the seller when she chooses between the two regimes. As simultaneous system encourages the buyer to invest, this may allow the seller to capture more surplus during renegotiation. Further, the simultaneous regime avoids the additional delay costs. However, sequential investment allows the seller to invest without the fear of holdup. The seller will choose the regime that maximizes her welfare. Where her interests differ sufficiently from the first-best incentives the seller will adopt the 'wrong' system, reducing total welfare.

To further investigate the incentives of the seller assume that $R_{12} = 0$ and $\alpha_1 = \alpha_2 = 1/2$. The seller will choose the system (and the level of investment) that maximizes her surplus, regardless of the effect on total welfare. Moreover, the buyer can correctly anticipate the seller's choice of regime.

With simultaneous investments, total welfare is $\delta\widehat{R} - \widehat{I}_1 - \widehat{I}_2$. The seller, of course,

[10]See Smirnov and Wait (2001a) for a discussion relating to the case when each party can invest either first or last.

will set I_2 to maximize $\frac{\delta}{2}\widehat{R} - \widehat{I}_2$. Denote the seller's objective function under the simultaneous regime as v_{sim}; that is, $v_{sim} = \frac{\delta}{2}\widehat{R} - \widehat{I}_2$. This allows the total welfare generated with simultaneous investments to be written as $2v_{sim} + \widehat{I}_2 - \widehat{I}_1$.

With sequential investments total welfare is $\delta^2\widetilde{R} - \delta\widetilde{I}_2 - \widetilde{I}_2$ while the seller's objective function is $\frac{\delta^2}{2}\widetilde{R} - \frac{\delta}{2}\widetilde{I}_2$. Denote the seller's objective functions under sequential investment as v_{seq}: that is, $v_{seq} = \frac{\delta^2}{2}\widetilde{R} - \frac{\delta}{2}\widetilde{I}_2$. This means that total surplus generated with sequential investments is $2v_{seq} - \widetilde{I}_1$.

Now assume these potential payoffs for the seller are also equal so that $v_{sim} = v_{seq}$. Given $\varepsilon = \widehat{I}_2 - \widehat{I}_1 + \widetilde{I}_1 > 0$, simultaneous surplus will be greater than the surplus from sequential investments. It is possible, however, to perturb v_{seq} such that $v_{seq} > v_{sim}$ while it remains true that simultaneous surplus exceeds the surplus with sequential investments, as $2v_{sim} + \varepsilon > 2v_{seq}$. In this case the seller will opt for the sequential regime even though total surplus is maximized with the simultaneous regime. The above discussion is summarized in the proposition below. An illustration is provided by example 1.

Proposition 2. *As the seller's incentives differ from the first-best, she may choose the timing regime that does not maximize welfare.*

Example 1. *Consider the case when $R = 10lnI_1 + 8lnI_2$ and $\alpha_1 = \alpha_2 = 1/2$. Figure 3 plots the surplus of the seller with different investment regimes (on the Y-axis) against δ (on the X-axis). S^s_{sim} shows two times the seller's surplus when investments are made simultaneously minus $\widetilde{I}_1$. S_{seq} shows two times the surplus of the seller minus $\widetilde{I}_1$- this equals the total surplus - when investments are made sequentially. S_{sim}*

shows the total surplus of both parties with simultaneous investments. It can be seen that for $\delta > 0.8$ *(approximately) the seller will opt for the sequential system over the simultaneous option. However, from* S_{sim} *and* S_{seq} *it is only when* $\delta > 0.95$ *(approximately) that the sequential system produces more surplus than simultaneous regime. Thus, for* $\delta \in (0.8, 0.95)$ *the seller opts for the regime that does not maximize total welfare. The specific functions used are* $S_{sim}(\delta) = \delta(10\ln 5\delta + 8\ln 4\delta) - 9\delta$, $S^s_{sim}(\delta) = \delta(10\ln 5\delta + 8\ln 4\delta) - 8\delta - 5\delta^2$ *and* $S_{seq}(\delta) = \delta^2(10\ln 5\delta^2 + 8\ln 8\delta) - 13\delta^2$.

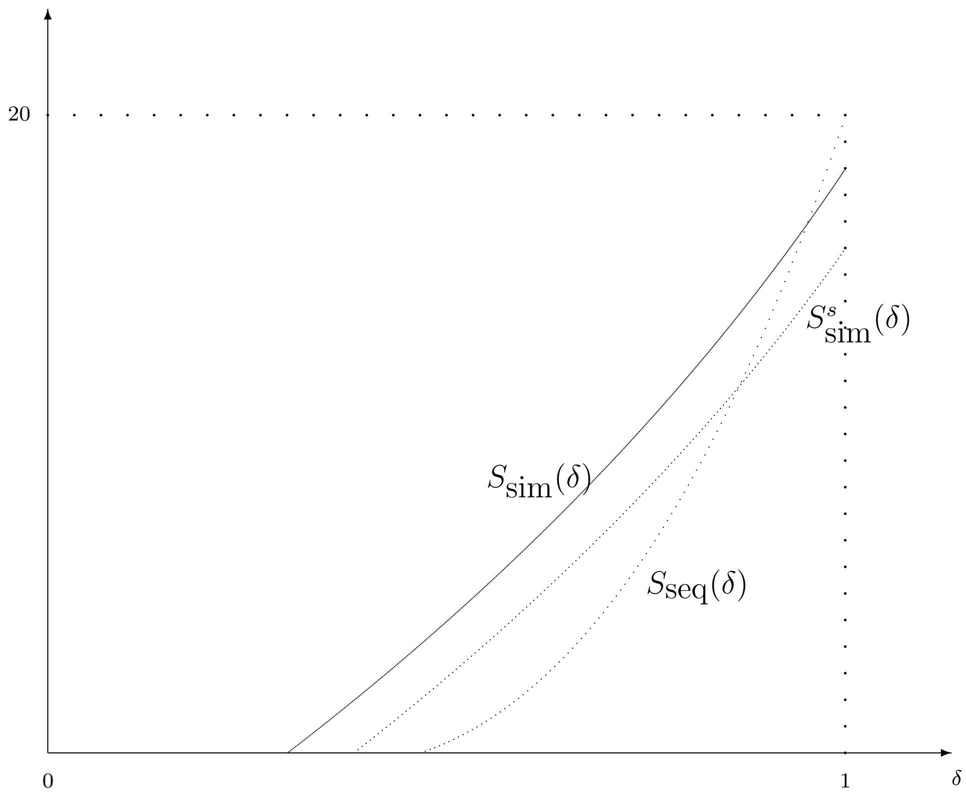

Figure 3: Illustration to example 1

If the seller opts for the inefficient investment regime the buyer's share of surplus is necessarily reduced. In the extreme the reduction in surplus may lower the buyer's utility inside the relationship below his outside option: that is $\frac{\delta}{2}[\delta R(\widetilde{I}_1, \widetilde{I}_2) - \widetilde{I}_2] - \widetilde{I}_1 < 0$. In this case the option of the sequential regime prevents trade from occurring;[11] the inability to commit to a particular timing regime (the simultaneous regime) hurts the seller as well as the buyer.

6 Conclusion

This paper develops a model in which two parties can invest in a mutually beneficial project at the same time (simultaneous investment) or they can choose to invest one after the other (sequential investment). It is assumed that contracting on any future investment becomes possible after some investment has been made as it allows the project to become more clearly defined. Consequently, the advantage of the sequencing of investments is that it allows the party that has delayed making their investment to avoid being held up. The disadvantage of staging is that it reduces the incentive to invest of the first mover. This can also have feed-back effects on the second party's investment depending on the relationship between the two investments. In addition, sequencing of investment lengthens the time from the start of the project until the returns are realized, reducing the ex ante value of total surplus when parties discount future returns. The relative advantage of the sequential versus the simultaneous investment regime depends on the precise nature of these trade-offs. Two principles

[11] Note that provided $\frac{\delta}{2}R(\widehat{I}_1, \widehat{I}_2) - \widehat{I}_1 > 0$, the buyer would have opted into the relationship if only the simultaneous regime were available.

apply, however, provided the parties are sufficiently patient: first, the regime that favors the most important investment in terms of its contribution to total surplus is preferred; and, second, if one investment is invariant to the regime adopted, the optimal timing of investment will be the regime that maximizes the incentive for the other party to invest.

Much of the emphasis in the existing literature has focused on how staging investments can improve welfare when there are incomplete contracts or when parties are unable to commit. In the model presented in this paper it is demonstrated that, in some cases, the option of sequencing investments can reduce welfare. It is shown that under certain conditions a party will opportunistically opt for the sequential regime, reducing total surplus. We interpret this possibility as a new form of holdup and term it 'follow up'.

7 Appendix

Example 2. *Consider the case when* $R(I_1, I_2) = \alpha ln I_1 + \beta ln I_2$ *and* $\alpha_1 = \alpha_2 = 1/2$. *Figure 4 shows the four different surpluses for both simultaneous and sequential investments when contracts are both complete and incomplete.*[12] *First note that* S^*,

[12] With simultaneous investment and complete contracts the first-order conditions are $\frac{I_1}{\alpha} = \frac{I_2}{\beta} = 1/\delta$. When contracts are incomplete and investments are simultaneous the first-order conditions are $\frac{I_1}{\alpha} = \frac{I_2}{\beta} = 2/\delta$. When investments are sequential and contracts complete: $\frac{I_1}{\alpha} = 1/\delta^2$ and $\frac{I_2}{\beta} = 1/\delta$. Finally, when investments are sequential and contracts incomplete the first-order conditions are: $\frac{I_1}{\alpha} = 2/\delta^2$ and $\frac{I_2}{\beta} = 1/\delta$. The specific functions used assume $\alpha = \beta = 5$: that is $S^*(\delta) = 10\delta(\ln 5\delta - 1)$, $S_{\text{sim}}(\delta) = 10\delta(\ln 5\delta - 0.5 - \ln 2)$, $S^{**}(\delta) = 5\delta^2(\ln 5\delta^2 - 1) + 5\delta^2(\ln 5\delta - 1)$ and

the total surplus when investment is contractible and simultaneous, and S^{**}*, the total surplus when both investments are contractible but made sequentially, are equal when* $\delta = 1$ *as there are no costs of delay. Second, consider the surplus generated when contracts are incomplete.* S_{sim} *represents the total surplus with simultaneous investment, while* S_{seq} *represents the total surplus with the sequential regime. With low values of* δ*,* S_{sim} *exceeds* S_{seq}*. However, for values of* δ *greater than about* 0.9*,* $S_{seq} > S_{sim}$*; that is, the total surplus from sequential investments exceeds the total surplus with the simultaneous regime.*

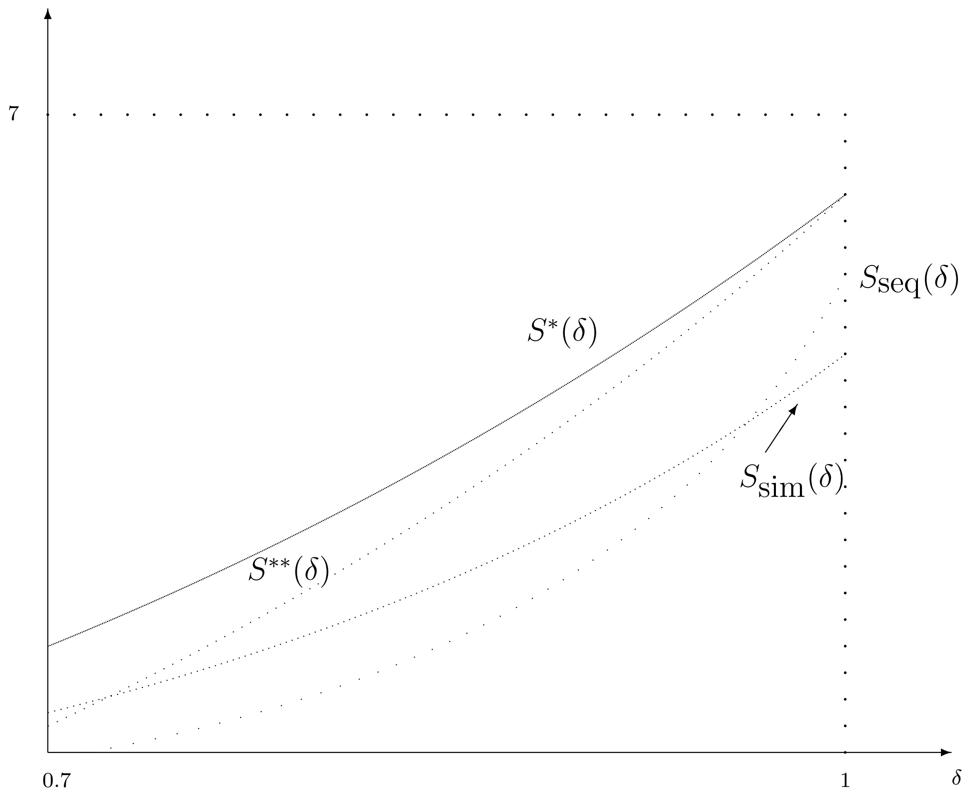

Figure 4: Illustration to example 2

$S_{\mathrm{seq}}(\delta) = 5\delta^2(\ln 5\delta^2 - 0.5 - \ln 2) + 5\delta^2(\ln 5\delta - 1)$.

Example 3. *As an example consider the following explicit function where:* $f_1 = aI_1^e$ *and* $f_2 = bI_2^c$. *Here, consider the case when* $a = 11$, $b = 10$, $c = 0.3$ *and* $e = 0.7$. *Additionally assume* $\alpha_1 = \alpha_2 = 1/2$. *Using the explicit solutions to each party's first-order condition, the total utility generated with simultaneous investment can be written as a function of* δ: $S_{sim}(\delta) = a\delta\left(\frac{ea\delta}{2}\right)^{\frac{e}{1-e}} - \left(\frac{ea\delta}{2}\right)^{\frac{1}{1-e}} + b\delta\left(\frac{cb\delta}{2}\right)^{\frac{c}{1-c}} - \left(\frac{cb\delta}{2}\right)^{\frac{1}{1-c}}$. *Similarly, the total surplus with sequential investment is:* $S_{seq}(\delta) = a\delta^2\left(\frac{ea\delta^2}{2}\right)^{\frac{e}{1-e}} - \left(\frac{ea\delta^2}{2}\right)^{\frac{1}{1-e}} + b\delta^2(cb\delta)^{\frac{c}{1-c}} - \delta(cb\delta)^{\frac{1}{1-c}}$. *Figure 5 compares these two surpluses. First, there is clearly a non-monotonic relationship between* δ *and the difference between* $S_{sim}(\delta)$ *and* $S_{seq}(\delta)$. *Second, the two functions cross twice, once when* δ *is close to* 0 *and another time when* δ *is close to 1.*

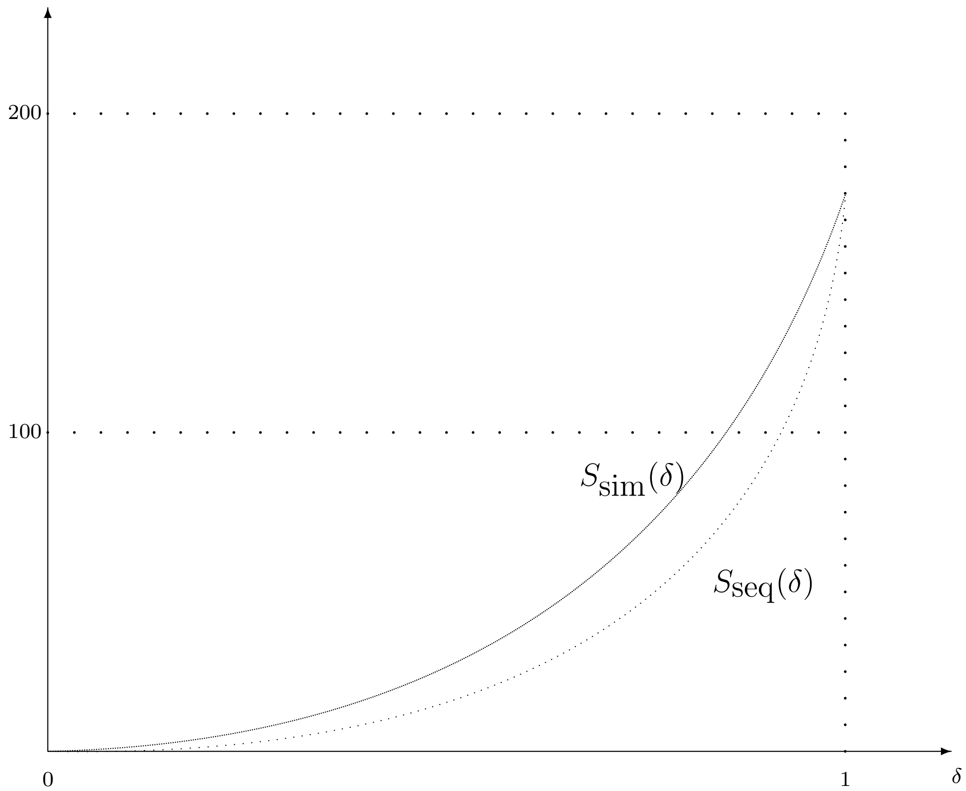

Figure 5: Illustration to example 3

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