Sequential Investment, Hold-up, and Ownership Structure

Juyan Zhang* and Yi Zhang†

Revised: July 2014‡

Abstract

We construct a sequential investment model to investigate individual firms' strategic choices of organizational forms when outsourcing their intermediate products. Our results indicate that as a result of the encouragement effect of sequential complementary investments, sequential investment alleviates the underinvestment caused by the hold-up problem. Thereafter, we analyze the impact of sequential investment on the choice of ownership structure. We show that contrary to the result of the standard property rights theory, strictly complementary assets could be owned separately.

JEL classification: D23, F1, L22

Keywords: Sequential Investment, Hold-up, Underinvestment, Optimal Ownership Structure

---

*SUFE; zhangjuyan@gmail.com.

†Singapore Management University; yizhang@smu.edu.sg.

‡We thank Huan Wang and seminar participants at UC Davis, University of Hong Kong, Singapore Management University, Peking University, Xiamen University, Spring 2010 Midwest Economic Theory Meeting, and the Second Singapore Economic Theory Workshop for helpful comments and suggestions. Yi Zhang is grateful to Singapore Management University research grant C244/MSS7E007 for financial support. Juyan Zhang is grateful to Southwestern University of Finance and Economics 211 Project research grant for financial support. The usual disclaimer applies.

1 Introduction

We live in a world of globalization. International trade and foreign direct investment (FDI) are among the fastest growing economic activities. In the fast expansion of merchandise trade, there has been an even faster growth of trade in intermediate products. This phenomenon, closely related to the growing fragmentation of production, has been investigated from various perspectives, such as "international vertical specialization" (Yi 2003), "international production sharing" (Yeats 2001), and "outsourcing" (Helpman 2006). Helpman (2006) points out that "the growth of input trade has taken place both within and across the boundaries of the firm, i.e., as intrafirm and arms-length trade." The choice of organizational form by individual firms when outsourcing naturally emerged: ***integration*** or ***non-integration***.[1]

When a final good producer outsources its intermediate products to some supplier, relationship specific investments naturally occur sequentially. For instance, the final good producer may initiate the design and development, followed by the supplier's effort in acquiring raw materials. We follow the framework of property rights theory from Grossman and Hart (1986) and Hart and Moore (1990) (hereinafter GHM). With incomplete contract, which arises due to causes such as unforeseen contingencies and inability of enforcement, relationship-specific investments are distorted by the hold-up problem and are therefore insufficient. In GHM, relationship-specific investments are simultaneously invested. In contrast, based on Hart (1995), we construct a sequential hold-up model, in which relationship-specific investments are sequentially invested, to investigate the inefficiency issue of underinvestment and individual firms' strategic choices of organizational forms when outsourcing their intermediate products.

Our results indicate that as a result of the encouragement effect of sequential complementary investment, sequential investment alleviates the underinvestment caused by the hold-up problem. Thereafter, we analyze the impact of sequential investment on the choice of ownership structure. We show that contrary to the result of the standard property rights theory, strictly complementary assets could be owned separately.

More specifically, when a final good producer initiates the proposal of outsourcing its intermediate products to some supplier, some relationship-specific pre-investments from both sides are often involved, which is a double moral-hazard problem in terms of Laffont and Martimort (2002). The final good producer chooses the optimal organizational form, which depends on the contractual environments and the specific characteristics of the intermediate products. The final good producer and the supplier have to rely on bargaining to divide the surplus of investment through the ex post renegotiation, since ex ante contracts are incomplete. With sequential investment,

[1] Helpman (2006), "... outsourcing means the acquisition of an intermediate input or service from an unaffiliated supplier, while integration means production of the intermediate input or service within the boundary of the firm."

there exists ***encouragement effect***: the final good producer may have incentive to invest more to elicit more investment from the supplier.[2] Therefore, it may be even better to give the final good producer more residual rights of control. The empirical implication is that when outsourcing, non-integration might be a better arrangement, even if the assets are strictly complementary.

Our model is related to papers on sequential investments with complementarities.[3] In particular, Nöldeke and Schmidt (1998) show that the underinvestment caused by the hold-up problem still exists under the sequential investment setting.[4] But they proceed upon neither the possible alleviation of underinvestment nor the consequent impact of sequential investment on the choice of ownership structure.[5]

Our model is also related to the literature on hold-up (see the survey of Che and Sákovics 2008). They mainly focus on the inefficiency issue due to the hold-up problem and organizational or contract remedies to achieve the first best through some ex post renegotiation design. Che and Hausch (1999) argue that it is somewhat arbitrary to assign some party the entire ex post bargaining power under the incomplete contracting environment.[6] The restriction of the "selfish"[7] nature of the relationship-specific investments also limits the efficient results in the current literature. Further, Che and Hausch show that if relationship-specific investments are "cooperative" and parties can not commit not to renegotiate, all feasible contracts

[2] Some may refer this as the Stackelberg effect (see Mai et al. 2014).

[3] For instance, Zhou and Chen (2013) study the benefit of sequentiality in the social networks. Mai et al. (2014) combine sequentiality with the notion of ownership rights separation of access and veto.

[4] They assume if trade does not occur, the party not controlling the assets gets nothing. In our model, we follow Hart (1995) assuming more general non-trade payoffs, which allow the payoff of the party not controlling the assets to depend on both the ownership structure and its own investment. Further, they show that under some specific assumptions option-to-own contracts achieve the first-best with sequential investment decisions. In this paper, we stick with the standard property rights theory that no contract is possible ex ante beyond the ownership arrangement of the physical assets.

[5] Smirnov and Wait (2004) provide a model, in which investments can be made simultaneously or sequentially. They show that the overall welfare may be detrimental due to the cost of delay. In their alternative investment regime (sequential investment), renegotiation occurs after the leader makes the relationship-specific investment. In contrast, in Nöldeke and Schmidt (1998) and our model, the timing of investment is exogenously given and contracting is impossible on both relationship-specific investments. Consequently, renegotiation will only occur after both relationship-specific investments are sunk. Further, Smirnov and Wait (2004) assume the outside options for both parties are zero and there is no role of ownership structure.

[6] In our model, the ex post bargaining power is endogenously determined by the strategic choices of organizational forms of individual firms.

[7] "Selfish" refers to one party's relationship-specific investment has no direct externalities to other parties. De Fraja (1999) claims that the first best is achieved if the investments are made sequentially and the first-mover has the entire bargaining power for the contract signed in between the investments of the two parties. Che (2000) argues this efficiency result depends crucially on the "selfish" nature of the relationship-specific investments.

are worthless.[8] In contrast, our model assumes relationship-specific investments are sequentially invested and "cooperative". We focus on the impact of sequential investment on inefficiency issue of underinvestment and individual firms' strategic choices of organizational forms.[9]

The rest of the paper is organized as follows. Section 2 provides the setup of a modified Hart (1995) property rights theory model and shows that sequential investment alleviates the underinvestment caused by the hold-up problem. Section 3 investigates the impact of sequential investment on the choice of ownership structure. Section 4 concludes.

2 The Model

Follow the setup of Hart (1995). There is a final good producer $M1$ and a supplier $M2$. There are two physical assets, $a1$ and $a2$, which are associated to $M1$ and $M2$ respectively. At date $t = 1$, they agree on the ownership structure, i.e., who owns the firm. No further contractual arrangement is possible at this stage. Then, at date $t = 1.1$, $M1$ invests the relationship-specific investment i; at date $t = 1.2$, $M2$ invests the relationship-specific investment e. $C_1(i)$ and $C_2(e)$ represent the cost of the investments. Finally, at date $t = 2$, $M1$ and $M2$ renegotiate. If there is an agreement on the price of the intermediate products, intermediate products are produced, and payment and transfer are proceeded. Otherwise, if the renegotiation breaks down, they will receive their own non-trade payoffs. The timing of the model is illustrated in Figure 1.

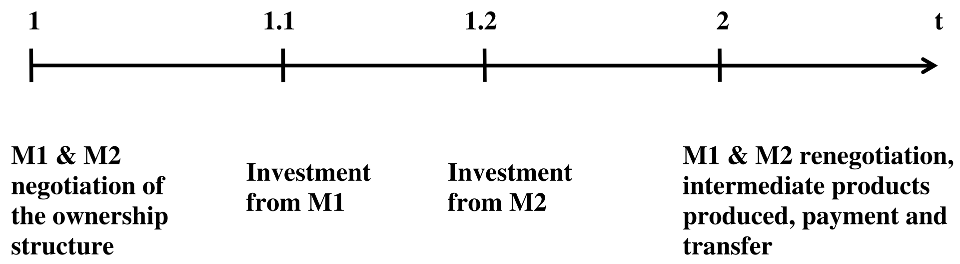

Figure 1: Timing

Let A represent the assets that $M1$ owns and B represent the assets that $M2$

[8] Maskin and Tirole (1999) provide a broader efficiency result.

[9] Che and Sákovics (2004, 2007) consider a dynamic setting, in which the timing of investment and bargaining is chosen endogenously by the parties. They show that the presence of dynamics alters the nature of the incentive problems, which produces much different implications on the contractual or organizational remedies against hold-up. By contrast, in our model, the timing of investment and bargaining is exogenous.

owns. Therefore, (A, B) represents the ownership structure, where $A \bigcap B = \emptyset$ and $A \bigcup B = \{a1, a2\}$.[10] The ownership structure could be one of the following:

- Non-integration: $M1$ owns $a1$ and $M2$ owns $a2$, $(A, B) = (\{a1\}, \{a2\})$
- Type 1 integration: $M1$ owns $a1$ and $a2$, $(A, B) = (\{a1, a2\}, \emptyset)$
- Type 2 integration: $M2$ owns $a1$ and $a2$, $(A, B) = (\emptyset, \{a1, a2\})$

If trade occurs, the ex post surplus is $R(i, e)$.[11] If trade does not occur, the non-trade payoffs for $M1$ and $M2$ are $r_1(i; A)$ and $r_2(e; B)$ respectively. We make the following assumptions for any ownership structure (A, B).

Assumption 1 *$R(i, e)$, $r_1(i; A)$, and $r_2(e; B)$ are strictly concave for any ownership structure (A, B); $C_1(i)$ and $C_2(e)$ are strictly convex.*

Assumption 2 $R(i, e) \geq r_1(i; A) + r_2(e; B)$

Assumption 3

$$\frac{\partial R(i, e)}{\partial i} \geq \frac{dr_1(i; \{a1, a2\})}{di} \geq \frac{dr_1(i; \{a1\})}{di} \geq \frac{dr_1(i; \emptyset)}{di}$$
$$\frac{\partial R(i, e)}{\partial e} \geq \frac{dr_2(e; \{a1, a2\})}{de} \geq \frac{dr_2(e; \{a2\})}{de} \geq \frac{dr_2(e; \emptyset)}{de}$$

Assumption 4

$$\frac{\partial^2 R(i, e)}{\partial i \partial e} \geq 0$$

Assumption 1 is the usual assumption of the surplus functions and cost functions. Assumption 2 captures the idea that i and e are relationship-specific investments. Assumption 3 says that relationship-specificity also applies in a marginal sense, which is similar to Hart (1995).[12] Assumption 4 says that investments are complementary at the margin.

[10] There is some literature considering joint ownership (e.g. Cai 2003), in which the residual control rights of assets are shared by the its co-owners. As any assets usage must be agreed by both, joint ownership provides the fewest investment incentive (Hart 1995). In contrast, Cai (2003) introduces the general investment, in addition to the specific investment, and shows that joint ownership is optimal when specific and general investments are substitutes.

[11] In Hart (1995), the ex post surplus function is separable in relationship-specific investments, which implies that specific investments are "selfish", in terms of Che and Hausch (1999). Due to this reason, the equilibrium result under sequential investment is equivalent to that under simultaneous investment.

[12] "The marginal return from each investment is greater the more assets in the relationship, human and otherwise, to which the person making the investment has access." (Hart 1995 p.36)

Let α represent the ex post bargaining weight of $M1$, where $\alpha \in [0,1]$. The ex post payoff of $M1$ and $M2$ are

$$\begin{aligned} \pi_1(i,e;A,B) &= r_1(i;A) + \alpha[R(i,e) - (r_1(i;A) + r_2(e;B))] \\ \pi_2(i,e;A,B) &= r_2(e;B) + (1-\alpha)[R(i,e) - (r_1(i;A) + r_2(e;B))] \end{aligned} \tag{1}$$

2.1 The First-Best

In the first-best, $M1$ and $M2$ maximize the date 1 present value of their trading relationship, the ex ante surplus $S(i,e)$.

$$\max_{i,e} S(i,e) = R(i,e) - C_1(i) - C_2(e)$$

The first order conditions are

$$\begin{cases} \frac{\partial R(i,e)}{\partial i} = C_1'(i) \\ \frac{\partial R(i,e)}{\partial e} = C_2'(e) \end{cases}$$

Let (i^*, e^*) denote the solution of the optimization problem above.[13]

2.2 Simultaneous Investment (Un-observable Investment)

In the case that $M2$ cannot observe the investment i from $M1$ before his investment e, the solution is equivalent to that under simultaneous investment. Given the ownership structure (A,B) agreed at date 1, $M1$ and $M2$ choose i and e non-cooperatively at date 1.1 and 1.2. From equation 1, they maximize their own payoffs, net of investment costs.

$$\max_i \pi_1(i,e;A,B) - C_1(i) = r_1(i;A) + \alpha[R(i,e) - (r_1(i;A) + r_2(e;B))] - C_1(i)$$
$$\max_e \pi_2(i,e;A,B) - C_2(e) = r_2(e;B) + (1-\alpha)[R(i,e) - (r_1(i;A) + r_2(e;B))] - C_2(e)$$

The first order conditions are

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} = C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} = C_2'(e) \end{cases}$$

Let $(\underline{i}(A,B), \underline{e}(A,B))$ denote the solution of the optimization problem above under ownership structure (A,B).

[13] As in assumption 1, $R(i,e)$ is strictly concave and $C_1(i)$ and $C_2(e)$ are strictly convex. Therefore, the second order condition is satisfied. In addition, we assume regularity condition is satisfied and there exists a unique solution. Similarly, for the the optimization problems of the rest of the paper, second order conditions are satisfied. Again, assume regularity condition is satisfied and there exist unique solutions.

The following proposition shows that under simultaneous investment, there is underinvestment in relationship-specific investments due to the hold-up problem, which is similar to the result of the property rights theory from GHM.

Proposition 1 *Under simultaneous investment,* $\underline{i}(A, B) \leq i^*$ *and* $\underline{e}(A, B) \leq e^*$*,* $\forall (A, B)$*.*

Proof. See the Appendix. ■

The response functions and the equilibrium investment pairs under simultaneous investment and at the first best are illustrated in Figure 2. Here, $i^*(e)$ is the response

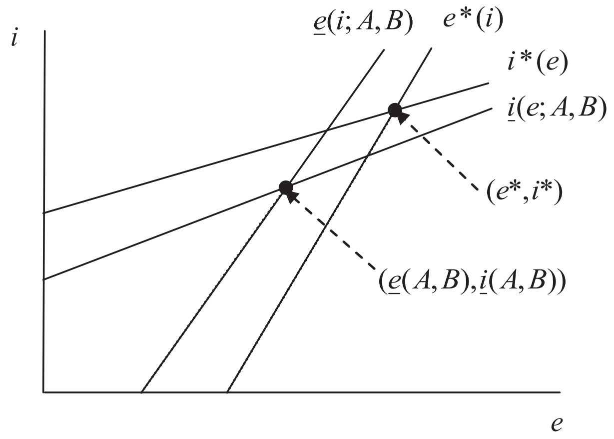

Figure 2: Equilibrium Investment Pairs under Simultaneous Investment

function of i with respect to e under the first best; $e^*(i)$ is the response function of e with respect to i under the first best; $\underline{i}(e; A, B)$ is the response function of i with respect to e under the simultaneous investment with ownership structure (A, B); $\underline{e}(i; A, B)$ is the response function of e with respect to i under the simultaneous investment with ownership structure (A, B).

Following the notation of Hart (1995), the equilibrium investment pairs under simultaneous investment $(\underline{i}(A, B), \underline{e}(A, B))$ is denoted by $(\underline{i}_0, \underline{e}_0)$, $(\underline{i}_1, \underline{e}_1)$, and $(\underline{i}_2, \underline{e}_2)$ for non-integration, type 1 integration, and type 2 integration respectively. In Hart (1995), relationship-specific investments are "selfish". Therefore, he has the following results: compared with non-integration, type 1 integration raises $M1$'s investment, but lowers $M2$'s investment; compared with non-integration, type 2 integration raises $M2$'s investment, but lowers $M1$'s investment.[14]

In contrast, since relationship-specific investments are complementary in our model, we do not have a clear picture of investment level if the organizational form shifts from

[14]See page 42 in Hart (1995): $\underline{i}_1 \geq \underline{i}_0 \geq \underline{i}_2$; $\underline{e}_2 \geq \underline{e}_0 \geq \underline{e}_1$.

one type of ownership structure to another. To illustrate, Figure 3 depicts the response functions and the equilibrium investment pairs under simultaneous investment with non-integration.[15]

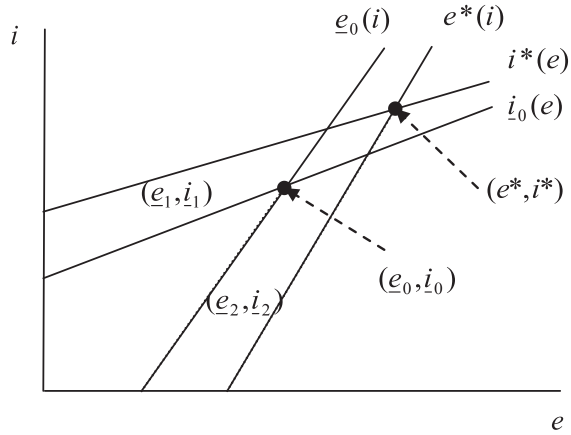

Figure 3: Equilibrium Investment Pairs under Simultaneous Investment with Various Types of Ownership Structure

If the organizational form shifts from non-integration to type 1 integration, the equilibrium investment pairs will reach some point in the shaded area to the "upper left" of $(\underline{e}_0, \underline{i}_0)$, which is bounded below by $\underline{i}_0(e)$ and right by $\underline{e}_0(i)$. Therefore, compared with non-integration, type 1 integration does not necessarily raise $M1$'s investment while lower $M2$'s investment. Similarly, if the organizational form shifts from non-integration to type 2 integration, the equilibrium investment pairs will reach some point in the shaded area to the "lower right" of $(\underline{e}_0, \underline{i}_0)$, which is bounded above by $\underline{i}_0(e)$ and left by $\underline{e}_0(i)$. Therefore, compared with non-integration, type 2 integration does not necessarily raise $M2$'s investment while lower $M1$'s investment.

2.3 Sequential Investment

Suppose $M2$ can observe the investment i from $M1$ before his investment. Given the ownership structure (A, B) agreed at date 1, $M1$ chooses i at date 1.1. After observing $M1$'s investment, $M2$ chooses e at date 1.2. From equation 1, they maximize their own payoffs, net of investment costs.

With backward induction, at date 1.2, $M2$ chooses e given $M1$'s choice i at date 1.1.

$$\max_e \pi_2(i, e; A, B) - C_2(e) = r_2(e; B) + (1 - \alpha)[R(i, e) - (r_1(i; A) + r_2(e; B))] - C_2(e)$$
$$\text{s.t.} \quad i \quad \text{is some given constant}$$

[15]Here, $\underline{i}_0(e) \equiv \underline{i}(e; \{a1\}, \{a2\})$; $\underline{e}_0(i) \equiv \underline{e}(i; \{a1\}, \{a2\})$.

The first order condition is

$$(1-\alpha)\frac{\partial R(i,e)}{\partial e}+\alpha\frac{dr_2(e;B)}{de}=C_2'(e) \tag{2}$$

From the first order condition above, we get the response function of $M2$ under ownership structure (A,B).

$$e=e(i;A,B)$$

At date 1.1, $M1$ chooses i given the response function of $M2$ above.

$$\max_i \ \pi_1(i,e;A,B)-C_1(i)=r_1(i;A)+\alpha[R(i,e)-(r_1(i;A)+r_2(e;B))]-C_1(i)$$
$$\text{s.t.} \quad e=e(i;A,B)$$

The first order condition is

$$\alpha\frac{\partial R(i,e)}{\partial i}+(1-\alpha)\frac{dr_1(i;A)}{di}+\alpha\left[\frac{\partial R(i,e)}{\partial e}-\frac{dr_2(e;B)}{de}\right]\frac{de}{di}=C_1'(i) \tag{3}$$

Let $(\bar{i}(A,B),\bar{e}(A,B))$ denote the solution of the optimization problem above under ownership structure (A,B).

The following proposition shows that under sequential investment, underinvestment of the relationship-specific investment is alleviated. Simply because relationship-specific investments are complementary, the first mover has incentive to invest more to encourage the follower to catch up.

Proposition 2 *Sequential investment alleviates the underinvestment caused by the hold-up problem, i.e.* $\bar{i}(A,B)\geq \underline{i}(A,B)$ *and* $\bar{e}(A,B)\geq \underline{e}(A,B)$, $\forall(A,B)$.

Proof. See the Appendix. ■

The response functions and the equilibrium investment pairs under sequential investment, under simultaneous investment, and at the first best are illustrated in Figure 4. Here, $\bar{i}(e;A,B)$ is the response function of i with respect to e under the sequential investment with ownership structure (A,B); $\bar{e}(i;A,B)$ is the response function of e with respect to i under the sequential investment with ownership structure (A,B). With sequential investment, $M2$'s response function remains unchanged, while $M1$'s response function is shifting up. Therefore, the equilibrium investment pairs will reach some point on $M2$'s response function curve and above $(\underline{e}(A,B),\underline{i}(A,B))$ (the bold portion of $e(i;A,B)$ in Figure 4). Clearly, both investment levels will increase with sequential investment. But there are possibilities of overinvestment for both i and e.

Following the notation of Hart (1995), the equilibrium investment pairs under sequential investment $(\bar{i}(A,B),\bar{e}(A,B))$ is denoted by $(\bar{i}_0,\bar{e}_0)$, $(\bar{i}_1,\bar{e}_1)$, and $(\bar{i}_2,\bar{e}_2)$ for

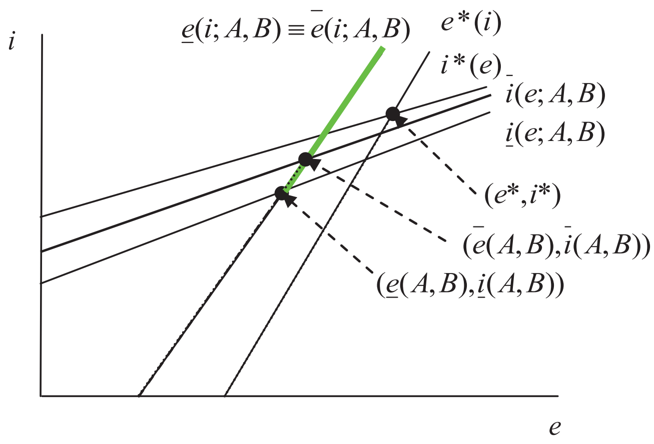

Figure 4: Equilibrium Investment Pairs under Sequential Investment

non-integration, type 1 integration, and type 2 integration respectively. Similar to the result in the case of simultaneous investment, since relationship-specific investments are complementary in our model, we do not have a clear picture of investment level if the organizational form shifts from one type of ownership structure to another. To illustrate, Figure 5 depicts the response functions and the equilibrium investment pairs under sequential investment with non-integration.[16]

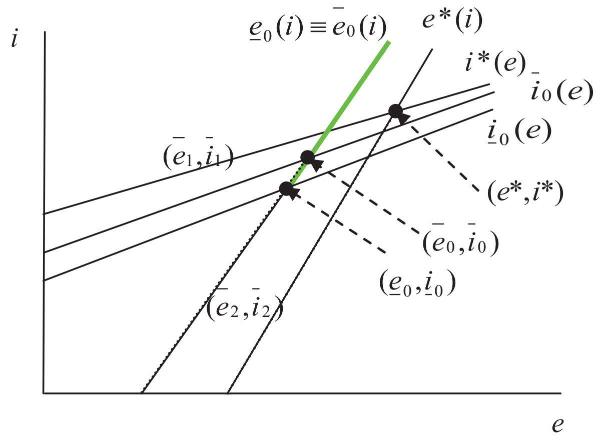

Figure 5: Equilibrium Investment Pairs under Sequential Investment with Various Types of Ownership Structure

If the organizational form shifts from non-integration to type 1 integration, the equilibrium investment pairs will reach some point in the shaded area to the "upper left" of $(\bar{e}_0, \bar{i}_0)$, which is bounded below by $\bar{i}_0(e)$ and right by $\bar{e}_0(i)$. Therefore,

[16]Here, $\bar{i}_0(e) \equiv \bar{i}(e; \{a1\}, \{a2\})$; $\bar{e}_0(i) \equiv \bar{e}(i; \{a1\}, \{a2\})$.

compared with non-integration, type 1 integration does not necessarily raise $M1$'s investment while lower $M2$'s investment. Similarly, if the organizational form shifts from non-integration to type 2 integration, the equilibrium investment pairs will reach some point in the shaded area to the "lower right" of $(\overline{e}_0, \overline{i}_0)$, which is bounded above by $\overline{i}_0(e)$ and left by $\overline{e}_0(i)$. Therefore, compared with non-integration, type 2 integration does not necessarily raise $M2$'s investment while lower $M1$'s investment.[17]

2.4 Welfare Analysis

In proposition 2, we show that due to the encouragement effect there will be more investments under sequential investment given any ownership structure (A, B). The further question is whether more investments are better, or if the ex ante surplus $S(i,e) = R(i,e) - C_1(i) - C_2(e)$ is increasing as i and e increase under sequential investment.

Let $\overline{S}_0 = R(\overline{i}_0, \overline{e}_0) - C_1(\overline{i}_0) - C_2(\overline{e}_0)$; $\overline{S}_1 = R(\overline{i}_1, \overline{e}_1) - C_1(\overline{i}_1) - C_2(\overline{e}_1)$; $\overline{S}_2 = R(\overline{i}_2, \overline{e}_2) - C_1(\overline{i}_2) - C_2(\overline{e}_2)$. And $\underline{S}_0 = R(\underline{i}_0, \underline{e}_0) - C_1(\underline{i}_0) - C_2(\underline{e}_0)$; $\underline{S}_1 = R(\underline{i}_1, \underline{e}_1) - C_1(\underline{i}_1) - C_2(\underline{e}_1)$; $\underline{S}_2 = R(\underline{i}_2, \underline{e}_2) - C_1(\underline{i}_2) - C_2(\underline{e}_2)$. In addition, the ex ante surplus $S(i,e)$ under the first best $S^* = R(i^*, e^*) - C_1(i^*) - C_2(e^*)$.

As in Figure 4, i and e will increase with sequential investment. But there are possibilities of overinvestment for both i and e. We say i is ***conditionally underinvested*** given e, if $\frac{\partial R(i,e)}{\partial i} > C_1'(i)$; i is ***conditionally optimally invested*** given e, if $\frac{\partial R(i,e)}{\partial i} = C_1'(i)$; i is ***conditionally overinvested*** given e, if $\frac{\partial R(i,e)}{\partial i} < C_1'(i)$. Similarly, e is conditionally underinvested given i, if $\frac{\partial R(i,e)}{\partial e} > C_2'(e)$; e is conditionally optimally invested given i, if $\frac{\partial R(i,e)}{\partial e} = C_2'(e)$; e is conditionally overinvested given i, if $\frac{\partial R(i,e)}{\partial e} < C_2'(e)$.

From the first order conditions under simultaneous investment in section 2.2 and the first order conditions under sequential investment in section 2.3, we know that e is either conditionally underinvested given i or conditionally optimally invested given i under both simultaneous and sequential investment. Similarly, under simultaneous investment, i is either conditionally underinvested given e or conditionally optimally invested given e. But under sequential investment, i could be conditionally overinvested given e, if $\frac{\partial R(i,e)}{\partial i} < C_1'(i)$.

The following lemma shows that if i is conditionally underinvested given e or conditionally optimally invested given e, $S(i,e)$ increases as i and e increase. Even if i is conditionally overinvested given e, $S(i,e)$ still increases as i and e increase provided that the encouragement effect is sufficiently large; only if encouragement

[17] Under sequential investment the equilibrium investment pairs in type 1 integration is not bounded above by $i^*(e)$, whereas under simultaneous investment the equilibrium investment pairs in type 1 integration is bounded above by $i^*(e)$.

effect is small enough, does $S(i,e)$ decrease as i and e increase.

Lemma 1 i) *If* $\frac{\partial R(i,e)}{\partial i} \geq C_1'(i)$, $S(i,e)$ *increases as* i *and* e *increase.*

ii) *If* $\frac{\partial R(i,e)}{\partial i} < C_1'(i)$ *and* $\frac{de}{di} \geq -\frac{\frac{\partial R(i,e)}{\partial i} - C_1'(i)}{\frac{\partial R(i,e)}{\partial e} - C_2'(e)}$, $S(i,e)$ *increases as* i *and* e *increase.*

iii) *If* $\frac{\partial R(i,e)}{\partial i} < C_1'(i)$ *and* $\frac{de}{di} < -\frac{\frac{\partial R(i,e)}{\partial i} - C_1'(i)}{\frac{\partial R(i,e)}{\partial e} - C_2'(e)}$, $S(i,e)$ *decreases as* i *and* e *increase.*

Proof. See the Appendix. ■

From Lemma 1 and the first order conditions under sequential investment in section 2.3, the following proposition shows that sequential investment will be better than simultaneous investment in terms of larger ex ante surplus $S(i,e)$.

Proposition 3

$$\overline{S}_0 \geq \underline{S}_0, \overline{S}_1 \geq \underline{S}_1, \overline{S}_2 \geq \underline{S}_2$$

Proof. See the Appendix. ■

Intuitively, under sequential investment, since the relationship-specific investments are complementary, $M1$ has incentive to invest more to elicit more investment from the follower $M2$. Therefore, i could be conditionally overinvested given e. But $M1$ can only capture partial of the benefit from his own investment i. In addition, e is either conditionally underinvested given i or conditionally optimally invested given i. Consequently, the overinvestment effect, if it exists, is dominated by the encouragement effect.

3 Choices of Ownership Structure

Now, we turn to determine which ownership structure is optimal. The logic is that at date 1, before investing the relationship-specific investments, $M1$ and $M2$ negotiate the ownership structure. They will choose the one maximizing the ex ante surplus $S(i,e) = R(i,e) - C_1(i) - C_2(e)$ given that lump-sum transfers are possible at date 1. Under simultaneous investment, $M1$ and $M2$ choose the ownership structure that $\max\{\underline{S}_0, \underline{S}_1, \underline{S}_2\}$; under sequential investment, $M1$ and $M2$ choose the ownership structure that $\max\{\overline{S}_0, \overline{S}_1, \overline{S}_2\}$.

From proposition 3, since the encouragement effect dominates the overinvestment effect, firms are always better off shifting from simultaneous investment to sequential investment. That is, $\max\{\overline{S}_0, \overline{S}_1, \overline{S}_2\} \geq \max\{\underline{S}_0, \underline{S}_1, \underline{S}_2\}$. The question now is which ownership structure is the best under simultaneous investment and sequential investment respectively.[18]

Similar to Hart (1995), we introduce the following definitions.

Definition 1 *$M1$'s investment decision is said to be* **inelastic** *if $M1$ chooses the same level of i, say $\widehat{i}$, in any ownership structure; $M2$'s investment decision is said to be inelastic if $M2$ chooses the same level of e, say $\widehat{e}$, in any ownership structure.*

Definition 2 *$M1$'s investment is said to become* **relatively unproductive** *if $R(i,e)$ is replaced with $\theta R(i,e) + (1-\theta)C_1(i) + (1-\theta)R(i,e)|_{i=0}$, and $r_1(i;A)$ is replaced with $\theta r_1(i;A) + (1-\theta)C_1(i)$, where $\theta > 0$ is small; $M2$'s investment is said to become* **relatively unproductive** *if $R(i,e)$ is replaced with $\theta R(i,e) + (1-\theta)C_2(e) + (1-\theta)R(i,e)|_{e=0}$, and $r_2(e;B)$ is replaced with $\theta r_2(e;B) + (1-\theta)C_2(e)$, where $\theta > 0$ is small.*

Definition 3 *Assets $a1$ and $a2$ are* **independent** *if $\frac{dr_1(i;\{a1,a2\})}{di} \equiv \frac{dr_1(i;\{a1\})}{di}$ and $\frac{dr_2(e;\{a1,a2\})}{de} \equiv \frac{dr_2(e;\{a2\})}{de}$.*

Definition 4 *Assets $a1$ and $a2$ are* **strictly complementary** *if either $\frac{dr_1(i;\{a1\})}{di} \equiv \frac{dr_1(i;\emptyset)}{di}$ or $\frac{dr_2(e;\{a2\})}{de} \equiv \frac{dr_2(e;\emptyset)}{de}$.*

Definition 5 *$M1$'s investment i is* **essential** *if $\frac{dr_2(e;\{a1,a2\})}{de} \equiv \frac{dr_1(i;\{a1\})}{di} \equiv \frac{dr_2(e;\emptyset)}{de}$; $M2$'s investment e is essential if $\frac{dr_1(i;\{a1,a2\})}{di} \equiv \frac{dr_2(e;\{a2\})}{de} \equiv \frac{dr_1(i;\emptyset)}{di}$.*[19]

The following proposition employs the definitions above.

Proposition 4 *Table 1 characterizes the optimal ownership structures under simultaneous investment and sequential investment respectively.*

Proof. See the Appendix. ■

The proposition above is intuitive. Part (i) says that there is no way to assign ownership to the party whose investment decision is not responsive to incentives. Part (ii) says that there is no way to assign ownership to the party whose investment is unimportant. And these apply to both the simultaneous and sequential investment cases.

[18] We say that some ownership structure is optimal if it weakly dominates all other ownership structures with the largest ex ante surplus.

[19] If either i or e is essential, then from definition 4, $a1$ and $a2$ are strictly complementary. If both i and e are essential, then from definition 3, $a1$ and $a2$ are independent.

Table 1: Optimal Choice of Ownership Structures

		Simultaneous Investment	**Sequential Investment**
(i)	If i is inelastic	type 2 integration	type 2 integration
	If e is inelastic	type 1 integration	type 1 integration
(ii)	If i is relatively unproductive	type 2 integration	type 2 integration
	If e is relatively unproductive	type 1 integration	type 1 integration
(iii)	If assets $a1$ and $a2$ are independent	non-integration	***non-integration or type 1 integration***
(iv)	If assets $a1$ and $a2$ are strictly complementary	type 1 integration or type 2 integration	***non-integration could be optimal***
(v)	If i is essential	type 1 integration	type 1 integration
	If e is essential	type 2 integration	***all ownership structures could be optimal***
	If both i and e are essential	all ownership structures are equally good	all ownership structures are equally good
(vi)	If α is close to 0	type 1 integration	type 1 integration
	If α is close to 1	type 2 integration	type 2 integration

Part (iii) says that under simultaneous investment, if access to $a1$ does not increase $M2$'s marginal return from e given he already has access to $a2$, then $S(i, e)$ will decrease as the organizational form shifts from non-integration to type 2 integration. The reason is that while the transfer of control over $a1$ from $M1$ to $M2$ has no effect on $M2$'s marginal investment return from e, it may have a significantly negative effect on $M1$'s marginal investment return from i. Similarly, if access to $a2$ does not increase $M1$'s marginal return from i given he already has access to $a1$, then $S(i, e)$ will decrease as the organizational form shifts from non-integration to type 1 integration. Therefore, under simultaneous investment when assets are independent, both forms of integration are dominated by non-integration.

Under sequential investment, the argument above also applies when the organizational form shifts from non-integration to type 2 integration, as there is neither change of $M2$'s marginal investment return from e nor the encouragement effect. However, when the organizational form shifts from non-integration to type 1 integration, $M2$'s marginal investment return from e decreases. Meanwhile, instead of remaining unchanged under simultaneous investment, $M1$'s marginal return from i

could increase due to the encouragement effect, even if access to $a2$ does not increase $M1$'s marginal return from i given he already has access to $a1$. Therefore, we can not say that non-integration dominates type 1 integration. That is, both non-integration and type 1 integration could be optimal under sequential investment when assets are independent.

Part (iv) says that under simultaneous investment, if access to $a2$ alone has no effect on $M2$'s marginal return from e ($M2$ needs $a1$ as well), then $S(i, e)$ will increase as the organizational form shifts from non-integration to type 1 integration. The reason is that while the transfer of control over $a2$ from $M2$ to $M1$ increases $M1$'s marginal investment return from i, it has no effect on $M2$'s marginal investment return from e. Similarly, if access to $a1$ alone has no effect on $M1$'s marginal return from i ($M1$ needs $a2$ as well), then $S(i, e)$ will increase as the organizational form shifts from non-integration to type 2 integration. Therefore, under simultaneous investment when the assets are strictly complementary, non-integration is dominated either by type 1 or type 2 integration.

Under sequential investment, if access to $a2$ alone has no effect on $M2$'s marginal return from e ($M2$ needs $a1$ as well), the argument above also applies when the organizational form shifts from non-integration to type 1 integration, as there is neither change of $M2$'s marginal investment return from e, nor the encouragement effect. However, if access to $a1$ alone has no effect on $M1$'s marginal return from i ($M1$ needs $a2$ as well), when the organizational form shifts from non-integration to type 2 integration, $M2$'s marginal investment return from e will increase. Meanwhile, instead of remaining unchanged under simultaneous investment, $M1$'s marginal return from i could decrease due to the encouragement effect, even if access to $a1$ alone has no effect on $M1$'s marginal return from i. Therefore, we can not say that non-integration is dominated by type 2 integration. That is, strictly complementary assets could be owned separately.

Part (v) says that under simultaneous investment, if $M2$'s marginal return from e is not enhanced by the presence of $a1$ and $a2$ in the absence of i, the asset transfer from $M2$ to $M1$ has no effect on $M2$'s investment incentive. But $M1$'s investment incentive increases. Therefore, it is better to give all the control rights to $M1$. Similarly, if $M1$'s marginal return from i is not enhanced by the presence of $a1$ and $a2$ in the absence of e, it is better to give all the control rights to $M2$.

Under sequential investment, if $M2$'s marginal return from e is not enhanced by the presence of $a1$ and $a2$ in the absence of i, the argument above also applies when the organizational form shifts to type 1 integration, as there is neither change of $M2$'s marginal investment return from e, nor the encouragement effect. However, if $M1$'s marginal return from i is not enhanced by the presence of $a1$ and $a2$ in the absence of e, when the organizational form shifts to type 2 integration, $M2$'s marginal investment return from e will increase. Meanwhile, instead of remaining unchanged under simultaneous investment, $M1$'s marginal return from i could decrease due to the encouragement effect. Therefore, we can not say that non-integration or type 1 integration is dominated by type 2 integration. That is, all ownership structures could be optimal under sequential investment even if e is essential.

If both i and e are essential, $M1$'s marginal return from i and $M2$'s marginal return from e will remain the same for all ownership structures. It is straightforward that all ownership structures are equally good for both the simultaneous and sequential investment cases.

Part (vi) says that if $M1$ has a larger share of the ex post bargaining power, it is better to let $M2$ have all the control rights. The reason is that in this case $M1$'s investment is close to conditionally optimal level. What we need to do is to maximize the investment elicited from $M2$. Therefore, to balance the ex post bargaining power, $M2$ should have all the control rights. Similarly, if $M2$ has a larger share of the ex post bargaining power, $M1$ should have all the control rights. And these apply to both the simultaneous and sequential investment cases.[20]

3.1 Some Empirical Implications to Outsourcing

From proposition 4, we have the following empirical implications to outsourcing: a final good producer outsources its intermediate products to some supplier. Relationship specific investments occur sequentially. For instance, the final good producer initiates the design and development, followed by the supplier's effort in acquiring raw materials. Therefore, the final good producer is $M1$ and the supplier is $M2$ in our theoretic model.

Corollary 1 *Type 1 integration could be the optimal ownership structure, even if the assets are independent.*

Corollary 1 is based on part (iii) of proposition 4, which might help explain that the final good producer may have incentive to acquire "irrelevant" assets from the supplier when outsourcing.

Corollary 2 *Non-integration could be the optimal ownership structure, even if the assets are strictly complementary for the final good producer.*

Corollary 2 is based on part (iv) of proposition 4, which might help explain that strictly complementary assets could be owned separately when outsourcing.

Corollary 3 *Type 2 integration may NOT be the optimal ownership structure, even if the investment from the supplier is essential.*

[20] Schmitz (2013) uses the generalized Nash bargaining solution and gets the similar result.

Corollary 3 is based on part (v) of proposition 4, which might help explain that the final good producer may have incentive to control some assets even if the supplier's investment is "critical" when outsourcing.

Corollary 4 *If one party has a larger share of the ex post bargaining power, it is better to let the other party have all the control rights.*

Corollary 4 is based on part (vi) of proposition 4, which might help explain that the "weaker" party during the renegotiation stage may be better to assign all the control rights at the negotiation stage.

4 Concluding Remarks

Our sequential investment model provides a new scope to understand individual firmsstrategic choices of organizational forms involving in the growing international division of labor and specialization. With sequential investment, the final good producer may have incentive to invest more to elicit more investment from the supplier. And thus, it may be even better to give the final good producer more residual rights of control. The empirical implication is that when outsourcing, non-integration might be a better arrangement, even if the assets are strictly complementary.

Appendix

Proof of Proposition 1 Let $x = (i, e)$. Similar to the proof of proposition 1 in Hart and Moore (1990), define $g(x) = R(i, e) - C_1(i) - C_2(e)$ and $h(x; A, B)$ such that

$$\nabla g(x) = \begin{pmatrix} \frac{\partial R(i,e)}{\partial i} - C_1'(i) \\ \frac{\partial R(i,e)}{\partial e} - C_2'(e) \end{pmatrix}$$

$$\nabla h(x; A, B) = \begin{pmatrix} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) \end{pmatrix}$$

From the first order conditions in section 2.1 and 2.2, we have

$$\nabla g(x)\big|_{x=(i^*,e^*)} = 0$$

$$\nabla h(x; A, B)\big|_{x=(\underline{i}(A,B),\underline{e}(A,B))} = 0$$

From assumption 3, we have $\nabla g(x) \geq \nabla h(x; A, B)$ for any ownership structure (A, B) and investments i, e. Define $f(x, \lambda) = \lambda g(x) + (1 - \lambda)h(x; A, B)$. Also define $x(\lambda) = (i(\lambda), e(\lambda))$ to solve $\nabla f(x, \lambda) = 0$. Total differentiating, we obtain

$$H(x, \lambda)dx(\lambda) = -[\nabla g(x) - \nabla h(x; A, B)]d\lambda$$

where $H(x,\lambda)$ is the Hessian of $f(x,\lambda)$ with respect to x. From assumption 1 and 4, $H(x,\lambda)$ is negative definite. Also, from assumption 4, the off-diagonal elements of $H(x,\lambda)$ are non-negative. From Takayama (1985), p.393, theorem 4.D.3 [III"] and [IV"], $H(x,\lambda)^{-1}$ is nonpositive. Therefore, $dx(\lambda)/d\lambda \geq 0$, and $x(1) \geq x(0)$, which implies $\underline{i}(A,B) \leq i^*$ and $\underline{e}(A,B) \leq e^*$. ■

Proof of Proposition 2 With backward induction, at date 1.2, $M2$ maximizes his own payoffs, net of investment costs, by choosing e given $M1$'s choice i at date 1.1. Total differentiating the first order condition (equation 2), we obtain

$$(1-\alpha)\frac{\partial^2 R(i,e)}{\partial e^2}de + (1-\alpha)\frac{\partial^2 R(i,e)}{\partial e \partial i}di + \alpha\frac{d^2 r_2(e;B)}{de^2}de = C_2''(e)de$$

Rearranging and from assumption 1 and 4, we have

$$\frac{de}{di} = \frac{(1-\alpha)\frac{\partial^2 R(i,e)}{\partial e \partial i}}{C_2''(e) - (1-\alpha)\frac{\partial^2 R(i,e)}{\partial e^2} - \alpha\frac{d^2 r_2(e;B)}{de^2}} \geq 0$$

Similar to the proof of proposition 1, let $x = (i,e)$. From equation 2 and 3, define $h(x;A,B)$ and $l(x;A,B)$ such that

$$\nabla h(x;A,B) = \begin{pmatrix} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) \end{pmatrix}$$

$$\nabla l(x;A,B) = \begin{pmatrix} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right]\frac{de}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) \end{pmatrix}$$

From the first order conditions in section 2.2 and 2.3, we have

$$\nabla h(x;A,B)\big|_{x=(\underline{i}(A,B),\underline{e}(A,B))} = 0$$
$$\nabla l(x;A,B)\big|_{x=(\bar{i}(A,B),\bar{e}(A,B))} = 0$$

From assumption 3 and $\frac{de(i;A,B)}{di} \geq 0$, we have $\nabla l(x;A,B) \geq \nabla h(x;A,B)$ for any ownership structure (A,B) and investments i,e. Define $f(x,\lambda) = \lambda h(x;A,B) + (1-\lambda)l(x;A,B)$. Also define $x(\lambda) = (i(\lambda), e(\lambda))$ to solve $\nabla f(x,\lambda) = 0$. Total differentiating, we obtain

$$H(x,\lambda)dx(\lambda) = -[\nabla h(x;A,B) - \nabla l(x;A,B)]d\lambda$$

where $H(x,\lambda)$ is the Hessian of $f(x,\lambda)$ with respect to x. From assumption 1 and 4, $H(x,\lambda)$ is negative definite. Also, from assumption 4, the off-diagonal elements of $H(x,\lambda)$ are non-negative. From Takayama (1985), p.393, theorem 4.D.3 [III"] and [IV"], $H(x,\lambda)^{-1}$ is nonpositive. Therefore, $dx(\lambda)/d\lambda \geq 0$, and $x(1) \geq x(0)$, which implies $\bar{i}(A,B) \geq \underline{i}(A,B)$ and $\bar{e}(A,B) \geq \underline{e}(A,B)$. ■

Proof of Lemma 1 From proposition 2, given any ownership structure (A, B) there will be more investments under sequential investment. Total differentiating the ex ante surplus $S(i,e) = R(i,e) - C_1(i) - C_2(e)$,

$$dS(i,e) = \left[\frac{\partial R(i,e)}{\partial i} - C_1'(i)\right] di + \left[\frac{\partial R(i,e)}{\partial e} - C_2'(e)\right] de$$

We know e is either conditionally underinvested given i or conditionally optimally invested given i, $\frac{\partial R(i,e)}{\partial e} \geq C_2'(e)$. Clearly, from the equation above, if i is also conditionally underinvested or conditionally optimally invested, $\frac{\partial R(i,e)}{\partial i} \geq C_1'(i)$, then $S(i,e)$ will increase as i and e increase.

Instead, if i is conditionally overinvested, i.e. $\frac{\partial R(i,e)}{\partial i} < C_1'(i)$, to let $S(i,e)$ increase as i and e increase, from the equation above, we must have

$$\frac{de}{di} \geq -\frac{\frac{\partial R(i,e)}{\partial i} - C_1'(i)}{\frac{\partial R(i,e)}{\partial e} - C_2'(e)}$$

■

Proof of Proposition 3 From the first order conditions under sequential investment in section 2.3, rearrange equation 2

$$\alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right] = \frac{\partial R(i,e)}{\partial e} - C_2'(e)$$

Plug into equation 3 and rearrange.

$$\frac{de}{di} = -\frac{\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} - C_1'(i)}{\alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right]} \geq -\frac{\frac{\partial R(i,e)}{\partial i} - C_1'(i)}{\frac{\partial R(i,e)}{\partial e} - C_2'(e)}$$

where $\frac{\partial R(i,e)}{\partial i} \geq \frac{dr_1(i;A)}{di}$ from assumption 3.

According to proposition 2 and lemma 1, we have $\overline{i}(A,B) \geq \underline{i}(A,B)$ and $\overline{e}(A,B) \geq \underline{e}(A,B)$ for all (A,B), which implies $\overline{S}_0 \geq \underline{S}_0$, $\overline{S}_1 \geq \underline{S}_1$, and $\overline{S}_2 \geq \underline{S}_2$. ■

Proof of Proposition 4

(i) Suppose $M1$'s investment decision is inelastic. $M1$ sets $i = \widehat{i}$ for all ownership structures. Under simultaneous investment, from the first order conditions in section 2.2 and assumption 3, clearly to elicit more investment from $M2$, it is better to give all the control rights to $M2$. Conversely, if $M2$'s investment decision is inelastic, it is better to give all the control rights to $M1$. Under sequential investment, the argument above also applies.

(ii) Suppose $M1$'s investment is relatively unproductive. Under simultaneous investment, $M2$'s first order condition becomes:

$$\alpha\left[\theta\frac{\partial R(i,e)}{\partial i} + (1-\theta)C_1'(i)\right] + (1-\alpha)\left[\theta\frac{dr_1(i;A)}{di} + (1-\theta)C_1'(i)\right] = C_2'(e)$$

which simplifies to

$$\alpha \frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} = C_1^{'}(i)$$

In other words, $M1$'s investment i and θ are independent. However, ex ante surplus

$$\begin{aligned} S(i,e) &= \theta R(i,e) + (1-\theta)C_1(i) + (1-\theta)R(i,e)|_{i=0} - C_1(i) - C_2(e) \\ &\to R(i,e)|_{i=0} - C_2(e) \quad as \quad \theta \to 0 \end{aligned}$$

Therefore, for θ small, what matters is $M2$'s investment decision. It is optimal to give all the control rights to $M2$. The same argument shows that if $M2$'s investment is relatively unproductive, $M1$ should have all the control rights.

Under sequential investment, the argument above also applies if $M2$'s investment is relatively unproductive.

However, under sequential investment, the story changes a little if $M1$'s investment is relatively unproductive due to the encouragement effect. In this case, $M1$'s first order condition becomes:

$$\begin{aligned} &\alpha\left[\theta\frac{\partial R(i,e)}{\partial i} + (1-\theta)C_1^{'}(i)\right] + (1-\alpha)\left[\theta\frac{dr_1(e;A)}{de} + (1-\theta)C_1^{'}(i)\right] + \\ &\alpha\left[\theta\frac{\partial R(i,e)}{\partial e} + (1-\theta)\left(\frac{\partial R(i,e)}{\partial e}\Big|_{i=0}\right) - \frac{dr_2(e;B)}{de}\right]\frac{de}{di} = C_1^{'}(i) \end{aligned}$$

$M2$'s first order condition becomes:

$$(1-\alpha)\left[\theta\frac{\partial R(i,e)}{\partial e} + (1-\theta)\left(\frac{\partial R(i,e)}{\partial e}\Big|_{i=0}\right)\right] + \alpha\frac{dr_2(e;B)}{de} = C_2^{'}(e)$$

Rearrange and we have

$$\theta\frac{\partial R(i,e)}{\partial e} + (1-\theta)\left(\frac{\partial R(i,e)}{\partial e}\Big|_{i=0}\right) - \frac{dr_2(e;B)}{de} = \frac{1}{1-\alpha}\left[C_2^{'}(e) - \frac{dr_2(e;B)}{de}\right]$$

Total differentiating $M2$'s first order condition, we obtain

$$(1-\alpha)\theta\frac{\partial^2 R(i,e)}{\partial e^2}de + (1-\alpha)\theta\frac{\partial^2 R(i,e)}{\partial e \partial i}di + (1-\alpha)(1-\theta)\left(\frac{\partial^2 R(i,e)}{\partial e^2}\Big|_{i=0}\right)de + \alpha\frac{d^2 r_2(e;B)}{de^2}de = C_2^{''}(e)de$$

Rearrange and we have

$$\frac{de}{di} = \frac{(1-\alpha)\theta\frac{\partial^2 R(i,e)}{\partial e \partial i}}{C_2^{''}(e) - (1-\alpha)\theta\frac{\partial^2 R(i,e)}{\partial e^2} - (1-\alpha)(1-\theta)\left(\frac{\partial^2 R(i,e)}{\partial e^2}\Big|_{i=0}\right) - \alpha\frac{d^2 r_2(e;B)}{de^2}}$$

Plug into $M1$'s first order condition and rearrange.

$$\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} + \frac{\alpha\left[C_2^{'}(e) - \frac{dr_2(e;B)}{de}\right]\frac{\partial^2 R(i,e)}{\partial e \partial i}}{C_2^{''}(e) - (1-\alpha)\theta\frac{\partial^2 R(i,e)}{\partial e^2} - (1-\alpha)(1-\theta)\left(\frac{\partial^2 R(i,e)}{\partial e^2}\Big|_{i=0}\right) - \alpha\frac{d^2 r_2(e;B)}{de^2}} = C_1^{'}(i)$$

In this case, $M1$'s investment i and θ are not independent and i is greater than the level under simultaneous investment case. However, as $\theta \to 0$, ex ante surplus

$$\begin{aligned} S(i,e) &= \theta R(i,e) + (1-\theta)C_1(i) + (1-\theta)R(i,e)|_{i=0} - C_1(i) - C_2(e) \\ &\to R(i,e)|_{i=0} - C_2(e) \quad as \quad \theta \to 0 \end{aligned}$$

Therefore, for θ small, what matters is $M2$'s investment decision. It is optimal to give all the control rights to $M2$.

(iii) Suppose assets $a1$ and $a2$ are independent. Under simultaneous investment, consider the organizational form shifts from non-integration to type 2 integration. From assumption 3, we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} - C_1^{'}(i) \geq \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\emptyset)}{di} - C_1^{'}(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2^{'}(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a1,a2\})}{de} - C_2^{'}(e) \end{cases}$$

Similar to the proof of proposition 1 and 2, we have $\underline{i}_0 \geq \underline{i}_2, \underline{e}_0 \geq \underline{e}_2$. That is, non-integration dominates type 2 integration. The same argument shows that non-integration dominates type 1 integration.

Under sequential investment, consider the organizational form shifts from non-integration to type 2 integration. From assumption 3, we have[21]

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a2\})}{de}\right]\frac{de}{di} - C_1^{'}(i) \geq \\ \qquad \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\emptyset)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a2\})}{de}\right]\frac{de}{di} - C_1^{'}(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2^{'}(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a1,a2\})}{de} - C_2^{'}(e) \end{cases}$$

Similar to the proof of proposition 1 and 2, we have $\bar{i}_0 \geq \bar{i}_2, \bar{e}_0 \geq \bar{e}_2$. That is, non-integration dominates type 2 integration.

However, the story changes as we consider the organizational form shifts from non-integration to type 1 integration. From assumption 3, from $M2$'s first order condition, we have

$$(1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2^{'}(e) \geq (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\emptyset)}{de} - C_2^{'}(e)$$

But from $M1$'s first order condition, it could be

$$\begin{aligned} &\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a2\})}{de}\right]\frac{de}{di} - C_1^{'}(i) < \\ &\quad \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1,a2\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\emptyset)}{de}\right]\frac{de}{di} - C_1^{'}(i) \end{aligned}$$

Therefore, we can not say that non-integration dominates type 1 integration. That is, both non-integration and type 1 integration could be optimal under sequential investment.

[21] In this case, $M2$'s first order condition does not change when the organizational form shifts from non-integration to type 2 integration. And therefore $\frac{de}{di}$ does not change either.

(iv) Suppose assets $a1$ and $a2$ are strictly complementary: either $\frac{dr_1(i;\{a1\})}{di} \equiv \frac{dr_1(i;\emptyset)}{di}$ or $\frac{dr_2(e;\{a2\})}{de} \equiv \frac{dr_2(e;\emptyset)}{de}$. Under simultaneous investment, start with non-integration. From assumption 3, either the organizational form shifts to type 1 integration we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} - C_1'(i) \leq \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1,a2\})}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2'(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\emptyset)}{de} - C_2'(e) \end{cases}$$

or the organizational form shifts to type 2 integration we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} - C_1'(i) = \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\emptyset)}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2'(e) \leq (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a1,a2\})}{de} - C_2'(e) \end{cases}$$

Similar to the proof of proposition 1 and 2, we have either $\underline{i}_0 \leq \underline{i}_1, \underline{e}_0 \leq \underline{e}_1$, or $\underline{i}_0 \leq \underline{i}_2, \underline{e}_0 \leq \underline{e}_2$. That is, non-integration is dominated either by type 1 or type 2 integration.

Under sequential investment, start with non-integration. From assumption 3, if $\frac{dr_2(e;\{a2\})}{de} \equiv \frac{dr_2(e;\emptyset)}{de}$, the organizational form shifts to type 1 integration we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a2\})}{de}\right]\frac{de}{di} - C_1'(i) \leq \\ \qquad \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1,a2\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\emptyset)}{de}\right]\frac{de}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2'(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\emptyset)}{de} - C_2'(e) \end{cases}$$

Similar to the proof of proposition 1 and 2, we have $\underline{i}_0 \leq \underline{i}_1, \underline{e}_0 \leq \underline{e}_1$. That is, non-integration is dominated by type 1 integration.

However, the story changes if $\frac{dr_1(i;\{a1\})}{di} \equiv \frac{dr_1(i;\emptyset)}{di}$. From assumption 3, from $M2$'s first order condition, the organizational form shifts to type 2 integration we have

$$(1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a2\})}{de} - C_2'(e) \leq (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a1,a2\})}{de} - C_2'(e)$$

But from $M1$'s first order condition, it could be

$$\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a2\})}{de}\right]\frac{de}{di} - C_1'(i) >$$
$$\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\emptyset)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a1,a2\})}{de}\right]\frac{de}{di} - C_1'(i)$$

Therefore, we can not say that non-integration is dominated by type 2 integration. That is, strictly complementary assets could be owned separately under sequential investment.

(v) Suppose i is essential. Under simultaneous investment, consider the organizational form shifts from type 2 integration or non-integration to type 1 integration. From assumption 3, we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} - C_1'(i) \leq \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1,a2\})}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\emptyset)}{de} - C_2'(e) \end{cases}$$

where $(A, B) \in \{(\{a1\}, \{a2\}); (\emptyset, \{a1, a2\})\}$. Similar to the proof of proposition 1 and 2, we have $\underline{i}_1 \geq \max\{\underline{i}_0, \underline{i}_2\}, \underline{e}_1 \geq \max\{\underline{e}_0, \underline{e}_2\}$. That is, type 1 integration dominates non-integration and type 2 integration. The same argument shows that type 2 integration dominates non-integration and type 1 integration if e is essential.

Under sequential investment, if i is essential, consider the organizational form shifts from type 2 integration or non-integration to type 1 integration. From assumption 3, we have

$$\begin{cases} \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right]\frac{de}{di} - C_1'(i) \leq \\ \qquad\qquad \alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\{a1,a2\})}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\emptyset)}{de}\right]\frac{de}{di} - C_1'(i) \\ (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) = (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\emptyset)}{de} - C_2'(e) \end{cases}$$

where $(A, B) \in \{(\{a1\}, \{a2\}); (\emptyset, \{a1, a2\})\}$. Similar to the proof of proposition 1 and 2, we have $\overline{i}_1 \geq \max\{\overline{i}_0, \overline{i}_2\}, \overline{e}_1 \geq \max\{\overline{e}_0, \overline{e}_2\}$. That is, type 1 integration dominates non-integration and type 2 integration.

However, the story changes if e is essential. Consider the organizational form shifts from type 1 integration or non-integration to type 2 integration. From assumption 3, from $M2$'s first order condition, we have

$$(1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;B)}{de} - C_2'(e) \leq (1-\alpha)\frac{\partial R(i,e)}{\partial e} + \alpha\frac{dr_2(e;\{a1,a2\})}{de} - C_2'(e)$$

But from $M1$'s first order condition, it could be

$$\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;A)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right]\frac{de}{di} - C_1'(i) >$$
$$\alpha\frac{\partial R(i,e)}{\partial i} + (1-\alpha)\frac{dr_1(i;\emptyset)}{di} + \alpha\left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;\{a1,a2\})}{de}\right]\frac{de}{di} - C_1'(i)$$

where $(A, B) \in \{(\{a1\}, \{a2\}); (\{a1, a2\}, \emptyset)\}$. Therefore, we can not say that non-integration or type 1 integration is dominated by type 2 integration. That is, all ownership structures could be optimal under sequential investment even if e is essential.

If both i and e are essential, $M1$'s marginal return from i and $M2$'s marginal return from e will remain the same for all ownership structures. Therefore, under simultaneous investment $\underline{i}_0 = \underline{i}_1 = \underline{i}_2, \underline{e}_0 = \underline{e}_1 = \underline{e}_2$; under sequential investment $\overline{i}_0 = \overline{i}_1 = \overline{i}_2, \overline{e}_0 = \overline{e}_1 = \overline{e}_2$.

(vi) If $\alpha \to 0$, under simultaneous investment, the first order conditions become

$$\begin{cases} \frac{dr_1(i;A)}{di} = C_1'(i) \\ \frac{\partial R(i,e)}{\partial e} = C_2'(e) \end{cases}$$

Clearly, it is better to give all the control rights to $M1$ to maximize the investment elicited from $M1$, since e and ownership structures are independent. The same argument shows that if $\alpha \to 1$, $M2$ should have all the control rights.

Under sequential investment, if $\alpha \to 0$, the argument above also applies and $M1$ should have all the control rights. The story changes a little if $\alpha \to 1$, due to the encouragement effect. In this case, the first order conditions become

$$\begin{cases} \frac{\partial R(i,e)}{\partial i} + \left[\frac{\partial R(i,e)}{\partial e} - \frac{dr_2(e;B)}{de}\right]\frac{de}{di} = C_1'(i) \\ \frac{dr_2(e;B)}{de} = C_2'(e) \end{cases}$$

Note, here $\frac{de}{di} = 0$. Therefore, i and ownership structures are independent. $M2$ should have all the control rights. ■

References

[1] Cai, Hongbin. 2003. "A Theory of Joint Asset Ownership." *Rand Journal of Economics*, 34: 62-76.

[2] Che, Yeon-Koo. 2000. "Can a Contract Solve Hold-up When Investments Have Externalities? A Comment on De Fraja (1999)." *Games and Economic Behavior*, 33: 195-205.

[3] Che, Yeon-Koo, and Donald B. Hausch. 1999. "Cooperative Investments and the Value of Contracting." *American Economic Review*, 89: 125-147.

[4] Che, Yeon-Koo, and József Sákovics. 2004. "A Dynamic Theory of Holdup." *Econometrica*, 72(4): 1063-1103.

[5] Che, Yeon-Koo, and József Sákovics. 2007. "Contractual Remedies to the Hold-up Problem: A Dynamic Perspective." *American Law & Economics Association Annual Meetings*, bepress.

[6] Che, Yeon-Koo, and József Sákovics. 2008. "Hold-up Problem." *The New Palgrave Dictionary of Economics*, 2nd edition.

[7] De Fraja, Gianni. 1999. "After You Sir. Hold-up, Direct Externalities, and Sequential Investment." *Games and Economic Behavior*, 26: 22-39.

[8] Grossman, Sanford J., and Oliver D. Hart. 1986. "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *Journal of Political Economy*, 94(4): 691-719.

[9] Hart, Oliver D. 1995. *Firms Contracts and Financial Structure*. Oxford, U.K.: Clarendon Press.

[10] Hart, Oliver D., and John Moore. 1990. "Property Rights and the Nature of the Firm." *Journal of Political Economy*, 98(6): 1119-1158.

[11] Helpman, Elhanan. 2006. "Trade, FDI, and the Organization of Firms." *Journal of Economic Literature*, 44: 589-630.

[12] Laffont, Jean-Jacques, and David Martimort. 2002. *The Theory of Incentives: the Principal-Agent Model*. Princeton University Press.

[13] Mai, Maxim, Vladimir Smirnov and Andrew Wait. 2014. "Ownership, Access, and Sequential Investment." *Canadian Journal of Economics*, 47(1): 203-231.

[14] Maskin, Eric, and Jean Tirole. 1999. "Unforeseen Contingencies and Incomplete Contracts." *Review of Economic Studies*, 66: 83-114.

[15] Nöldeke, Georg, and Klaus M. Schmidt. 1998. "Sequential Investments and Options to Own." *Rand Journal Of Economics*, 29(4): 633-653.

[16] Schmitz, Patrick W. 2013. "Bargaining Position, Bargaining Power, and the Property Rights Approach." *Economics Letters*, 119(1): 28-31.

[17] Smirnov, Vladimir, and Andrew Wait. 2004. "Hold-up and Sequential Specific Investments." *Rand Journal Of Economics*, 35(2): 386-400.

[18] Takayama, Akira. 1985. *Mathematical Economics*. 2d ed. Hinsdale, Ill.: Dryden.

[19] Yeats, Alexander J. 2001. "Just How Big Is Global Production Sharing?" In *Fragmentation: New Production Patterns in the World Economy,* ed. Sven W. Arndt and Henryk Kierzkowski. Oxford and New York: Oxford University Press.

[20] Yi, Kei-Mu. 2003. "Can Vertical Specialization Explain The Growth Of World Trade." *Journal of Political Economy*, 111(1): 52-102.

[21] Zhou, Junjie, and Ying-Ju Chen. 2013. "The benefit of sequentiality in social networks." Mimeo.