Competition, Innovation and Vertical Integration

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Abstract

We investigate the effect of market competition on the choice of vertical integration and the intensity of innovation effort. Vertical integration has two effects on the profit of a firm: on one hand, it leads to more coordinated actions between the upstream firm and downstream firm; on the other hand, it leads to agency costs within the integrated firm. We show that the two effects result in a U-shaped relationship between competition and the benefit from vertical integration, which also leads to a non-monotone effect of competition on the intensity of innovation. The results highlight the role of organizational change on innovative activities when the market condition changes.

Key Words: Competition, Vertical Integration, Innovation, Input Specification, Moral Hazard

JEL Classification: D8, L1

1 Introduction

It has been a long-standing interest in economics to identify the determinants of vertical integration. Transaction cost economies and property rights theory have successfully generated a lot of insights (Bresnahan and Levin (2012) provides a useful survey), for which asset specificity and ex ante investment incentives play a central role. On the other hand, industrial economists have identified strategic reasons that lead to vertical integration (see Riordan (2008) for a survey in this direction). Much of the literature has focused on the firm boundary, and leave the internal operation of the integrated firm

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as a black-box, whereas another large literature has delivered fruitful results on how the internal incentives within a firm are affected by market conditions. We propose a simple model in this paper to bridge the gap between the two strands of literature, and study how market competition affects the choice of vertical integration, explicitly taking into consideration the internal incentive of an integrated firm.

We consider an upstream firm/entrepreneur and a downstream firm, and a downstream competitive fringe may enter with positive probability, which measures the competitiveness of the downstream market. The downstream sells a final product to consumers with an inelastic demand. The upstream entrepreneur makes two decisions: the degree of adaptation of input to the needs of the downstream firm, and the level of effort/investment which enables the production of inputs. The entrepreneur can make the input more adapted to the downstream firm, in which case it can supply the downstream firm at a lower cost, whereas it can only supply other downstream firms at a higher cost if the competitive fringe enters. We consider two organization forms: vertical separation and vertical integration. Under vertical separation, if the entrepreneur's investment is successful, it bargains with the downstream firm after observing whether a competitive downstream fringe has turned up or not. We assume that the bargaining is efficient. Under vertical integration (backward integration, to be precise), the downstream firm has the decision right over the degree of adaptation. The upstream entrepreneur now becomes a division of the integrated firm, and we assume that he works under an internal incentive contract. That is, the effort/investment is not observable, and a moral hazard problem arises in the integrated firm.

The choice between vertical integration and separation rests on two opposing forces. Under vertical separation, as the entrepreneur cannot capture the entire value of the investment, a hold-up problem arises which leads to little adaptation. Under vertical integration, the choice of adaptation is more efficient, but the cost of inducing effort becomes higher. We show that as the downstream market becomes more competitive, under vertical separation, the entrepreneur chooses a less adapted input, but also exerts more effort. This results in a U-shaped relationship between the benefit of vertical integration and downstream competition. We further show that depending on the costs of adaptation and exerting effort, vertical can be always profitable (low costs), profitable when competition is either very weak or very strong (intermediate costs), or profitable only when competition is weak (high costs). The result also means that with more inefficient investment technology or less asset specificity, we should see more vertical separation.

The results have interesting implications on how industries, especially innovation intensive industries, respond to intensified competition. For instance, while the traditional pharmaceutical industry turns to vertical separation with the entry of generic producers, the bio-pharmaceutical sectors resort to vertical integration. This could be due to both higher cost of discovery and lower level of asset specificity in the traditional sector. Similar vertical integration waves have also been observed in the high-tech (e.g. smart-phone) industry, where compatibility between software and hardware is essential.

2 Related Literature

Our model is similar to that of Aghion et al. (2006), who also obtain a U-shaped relationship between vertical integration and competition, in a framework of property rights with both upstream and downstream investments. Different from them, we consider only upstream investment, but take into consideration explicitly the degree of input adaptation and the internal organization of an integrated firm. This relates our paper to the large literature on incomplete contracts and firm organization, as surveyed by Legros and Newman (2014). Recent contributions such as McLaren (2000), Legros and Newman (2008, 2013), and Marin and Verdier (2008) have studied firm organization in a competitive equilibrium. Our multi-task setup is also related to the literature on delegation. For instance, in a simple Principal-Agent setup, Bester and Krähmer (2008) and Prendergast (2015) show that there is a genuine trade-off between delegation and incentives. Our paper goes one step further by showing how this trade-off is affected by market competition, and how this shapes the choice between integration and separation.

Our paper is also related to the literature on vertical integration and input specification. Choi and Yi (2000) studied the binary choice of generic and specific inputs, while Matsushima (2009), and Erkal (2007) studied product differentiation in a Hotelling framework. What is missing in these papers is an explicit treatment of incentives to invest, which is crucial in a lot of industries.[1]

[1] Erkal (2007) does consider investment, but she only considered a fixed cost-reduction investment with certain outcome.

Another strand of literature studies how market competition affect the internal incentives of firms, taking as given the firm boundary. Early contributions such as Raith (2003) and Schmidt (1997) showed that competition may affect incentives in a non-monotone way. Recent works, for instance Etro and Cella (2013), Chalioti (2015) and Chalioti and Serfes (2016) consider explicitly the incentive to innovation with risk-averse managers. Baggs and de Bettignies (2007) and Bloom et al. (2010) provides empirical evidence along this line.

3 The Setup

We build our analysis on the simple model of Aghion et al. (2006) with one upstream firm U and one downstream firm D. The upstream firm provides an essential input to the downstream firm, which then transform it into a final product on a one-to-one basis. There is a unit mass of homogeneous consumers, whose value for a unit of the final product is v. Each consumer is willing to purchase one unit of the final product as long as its price does not exceed v.

Upstream Firm/Technology The upstream firm U makes two decisions: how much to adapt its input to the needs of the downstream firm, and how much effort to exert/invest in the relevant technology. Concerning the latter decision, we assume that by incurring a cost of

$$c_e(e) = \frac{1}{2}ke^2,$$

the upstream firm U successfully develops the relevant technology with probability e, which allows it to supply the input to downstream firm(s). Concerning the first decision, U can choose a degree of adaptation δ. In case of successful investment, this allows it to supply the downstream firm D at a cost of $c - \delta$, and to supply other potential downstream entrants at a cost of $c + \delta$.[2] A degree of adaption δ comes at a cost of

$$c_d(\delta) = \frac{1}{2}\gamma\delta^2.$$

That is, if U chooses no adaptation, it supplies all downstream firms at the same cost c, which we assume to be smaller than v. If it positively adapts to the needs of the

[2] More generally, one could consider a cost structure of $c - \lambda\delta$ for the dedicated downstream firm, and $c + \lambda\delta$ for other downstream firms. But this is equivalent to our model by substituting γ with γ/λ.

downstream firm, it can supply D at a lower cost, but other downstream firms at a higher cost. Thus, δ measures the depth of input specification. Different from, for instance, Choi and Yi (2000) and Avenel (2008) who also study vertical integration with input specification, where the degree of input specification is fixed, we assume the degree is a choice variable for the upstream firm. Several papers have also examined how vertical integration affects the degree of input specification, e.g. Matsushima (2004, 2009) and Erkal (2007). While these papers take upstream firms' production technology as given, we also explicitly study the upstream firm's investment incentives, and how it interacts with input specification and vertical integration.

We assume in the following analysis that

Assumption 1. $k \cdot \gamma > 1$.

This guarantees that the equilibrium degree of input specification is positive and is smaller than $v - c$, i.e. the added value of input specification is no greater than the basic value of the product.[3]

Downstream Firm/Market The downstream firm D transforms the input into final product at no additional cost. As consumers have an inelastic demand with a reservation price v, it is clear that if D is the only firm that serves the downstream market, it will charge a price of $p = v$ for the final product. As in Aghion et al. (2006), we assume that a downstream competitive fringe is present, i.e. downstream entry occurs with probability ρ. With probability $1 - \rho$, D is the only firm in the downstream market. The parameter ρ measures the competitiveness of the downstream market. We adopt this rather stark assumption on downstream competitiveness to underline the main economic insights, which focuses on the trade-off between the incentives in the market and the incentives within an integrated firm. This comes at the cost that we cannot analyze how market competition affects the incentives within a firm, as studied, for instance, by Raith (2003) and Schmidt (1997).

Bargaining/Vertical Separation Under vertical separation, the payoffs to firms are determined through bargaining. Specifically, for a given degree of input specification δ, when entry does not occur, U and D share the industry profit $v - c + \delta$ equally. When

[3] As what becomes clear later, the comparison between vertical separation and vertical integration depends on the value of $k\gamma$, we assume other parameters v, c, k, and γ are such that the equilibrium is interior.

entry occurs, we assume that U and D bargain with outside options. As there is no alternative input suppliers, the outside option of D is zero. The outside option of U is to sell through one fringe downstream firm,[4] which yields a profit to U of $v - c - \delta$. Thus, the bargaining outcome with downstream entry is a profit of

$$\pi^U = v - c - \delta + \frac{1}{2}[(v - c + \delta) - (v - c - \delta)] = v - c$$

for the upstream firm, and a profit of

$$\pi^D = \frac{1}{2}[(v - c + \delta) - (v - c - \delta)] = \delta$$

for the downstream firm. Summing up, the expected profit for U under vertical separation is

$$\begin{aligned} \pi^U_{VS} = &\quad \rho(v - c) + (1 - \rho)\tfrac{1}{2}(v - c + \delta), \\ \pi^D_{VS} = &\qquad \rho\delta + (1 - \rho)\tfrac{1}{2}(v - c + \delta). \end{aligned}$$

Vertical Integration We consider backward integration, i.e. the downstream firm D acquires the upstream firm U.[5] Different from Aghion et al. (2006) where U and D still bargain over the profit shares under vertical integration, or Matsushima (2009) and Avenel (2008) where D has full control over the upstream firm after integration, I assume that with backward integration, the input choice and effort are governed by internal contracts. Specifically, the degree of input specification δ is observable and verifiable, and thus can be contracted upon. However, the level of effort/investment is not observable, thus the downstream firm faces a moral hazard problem under vertical integration. The internal contract can be written as a 3-tuple of (δ, w, b): δ is the contracted degree of input specification, w is the basis wage, b is a bonus when U succeeds in investment. In addition, we assume that U is protected by limited liability, and thus we must have $w \geq c_d(\delta)$. Standard incentive theory (e.g. Laffont and Martimort (2009)) immediately implies that in the optimal contract $w = c_d(\delta)$, and the incentive to exert effort/invest is totally provided by the bonus.

The Game Under vertical separation, the game proceeds as follows:

[4] This is because downstream firms are non-differentiated.

[5] Forward integration is straightforward and always profitable, as it results in efficient choices of input specification and effort.

1. The upstream firm U chooses δ and e; If the investment fails, the game ends; If the investment succeeds, the game proceeds to Stage 2;

2. It is observed whether a competitive fringe enters or not;

3. The two firms U and D bargain over the share of profits as above;

4. The downstream firm sells to consumers.[6]

Under vertical integration, the game is as follows:

1. A contract $(\delta, c_d(\delta), b)$ is offered to the upstream firm U. If the contract is rejected, the game ends.

2. If the contract is accepted, U makes an effort/investment. If the investment fails, the game ends;

3. If the investment succeeds, the downstream firm sells to consumers.

4 Two Benchmarks

Before analyzing the full model, we first describe two benchmarks, whiles lies out the basic economic mechanism and intuition for our main results.

4.1 Benchmark 1: No Effort/Investment

The first benchmark assumes there is no effort/investment, i.e. the upstream firm U is ready to serve the downstream firm, and it only chooses the degree of input specification. We start with vertical separation. The problem of U is

$$\max_{\delta} \pi^U = \rho(v-c) + (1-\rho)\frac{1}{2}(v-c+\delta) - \frac{1}{2}\gamma\delta^2.$$

The first order condition yields

$$\delta_{vs}^1 = \frac{1-\rho}{2\gamma}.$$

Under vertical integration, since δ is contractible, the integrated firm simply solves

$$\max_{\delta} \pi_{VI} = v - c + \delta - \frac{1}{2}\gamma\delta^2,$$

[6]Since the bargaining is efficient, the more efficient downstream firm D always serves the downstream market for any $\delta > 0$, which is satisfied in equilibrium.

which yields

$$\delta_{vi}^1 = \frac{1}{\gamma}.$$

It is clear that a vertically integrated upstream firm chooses a more adapted input for the downstream firm, i.e. $\delta_{vi}^1 - \delta_{vs}^1 > 0$, and the difference is larger when the downstream market is more competitive, i.e. when ρ becomes larger. This leads to the following result:

Lemma 1. *When the upstream firm only chooses the degree of input specification, vertical integration is always profitable, and the benefit from vertical integration is increasing with the competitiveness of the downstream market.*

Proof. Consider the joint profit of U and D, under both vertical separation and vertical integration, it is given by

$$\pi(\delta) = v - c + \delta - \frac{1}{2}\gamma\delta^2.$$

The joint profit is maximized at $\delta = 1/\gamma = \delta_{vi}^1$, combined with $\delta_{vi}^1 > \delta_{vs}^1$, this means that the joint profit is always higher under vertical integration.

In addition, since δ_{vs}^1 is decreasing in ρ, the profit difference $\pi(\delta_{vi}^1) - \pi(\delta_{vs}^1)$ is increasing in ρ. $\square$

The fact that vertical integration leads to more adaptation is no surprise, which has been identified in a number of works such as Choi and Yi (2000), Avenel (2008), and Matsushima (2009). By taking the degree of adaptation as a continuous variable, we also show that the adaptation is greater when downstream competition if fiercer. This is rather intuitive as when downstream entry is more likely, the value of investing in the outside option is higher for the vertically separated upstream firm, which leads to less adaptation. The result thus implies that we should see more vertical integration when downstream market becomes more competitive.

4.2 Benchmark 2: No Adaptation

Now assume that U only chooses how much effort to exert, taken as given the input specification δ. The upstream firm then solves

$$\max_e \pi^U = e[\rho(v-c) + (1-\rho)\frac{1}{2}(v - c + \delta)] - \frac{1}{2}ke^2.$$

The first order condition yields

$$e_{vs}^1 = \frac{v - c + \delta + \rho(v - c - \delta)}{2k}.$$

Under Vertical integration, the internal contract simply specifies a bonus b, and will be accepted by U.[7] Thus, U chooses its effort to maximize

$$\max_e \pi_{vi}^U = e \cdot b - \frac{1}{2}ke^2,$$

which yields $e_{vi}^1 = b/k$. The downstream firm then chooses the bonus b to solve

$$\max_b \pi_{vi}^D = \frac{b}{k}(v - c + \delta) - \frac{b}{k} \cdot b.$$

The solution is given by $b^* = \frac{v-c+\delta}{2}$, which corresponds to $e_{vi}^1 = \frac{v-c+\delta}{2k}$. Apparently, we have $e_{vs}^1 - e_{vi}^1 > 0$ and the difference is increasing in ρ. This gives us the following result:

Lemma 2. *When the upstream firm only chooses the level of effort, vertical integration is unprofitable, and the loss from vertical integration is increasing with the competitiveness of the downstream market.*

Proof. The joint profit of U and D is given by

$$\pi(e) = e(v - c + \delta) - \frac{1}{2}ke^2,$$

which is maximized at $e^* = \frac{v-c+\delta}{k}$. Simple algebra yields $e_{vi}^1 < e_{vs}^1 < e^*$, together with the fact that e_{vs}^1 is increasing in ρ, this means that the joint profit is always higher under vertical separation, and the difference is increasing in the downstream competitiveness ρ. □

Vertical integration affects the investment incentive in two ways. First, it internalizes all benefit from the successful investment (it changes from $\rho(v-c) + \frac{1}{2}\rho(v-c+\delta)$), which tends to increase the level of investment. Second, the moral hazard problem associated with vertical integration raises the cost of inducing effort/investment. Specifically, the cost of inducing an effort level of e is ke^2 for the integrated firm, instead of $ke^2/2$ for the independent upstream firm. This reduces the level of investment. In total, with our

[7] Since effort is not observable, for any positive b, the upstream firm U earns a rent, i.e. the individual rationality constraint is satisfied. In addition, due to limited liability, the downstream firm D can do no better than offering $w = 0$.

linear-quadratic setup, the second effect dominates and the integrated firm invests less. The effect of downstream competition on an independent upstream firm's investment incentive is straightforward: when there is more competition, it gets a larger share of the industry profit and thus invests more. This result thus implies that we should see less vertical integration when downstream market becomes more competitive.

Lemma 1 and 2 highlights the two channels that vertical integration changes the incentives of the upstream firm. On one hand, it leads to more adapted input, which is beneficial; on the other hand, it dampens the incentives to invest, which is detrimental. When both forces are at work, competition in the downstream market typically affects the incentives to integrate vertically in a non-monotone way, which we turn on to in the following section.

5 Combining Incentives and Adaptation

Now we turn to our main model with both investment incentives and input specification. We start with vertically separated firms.

5.1 Vertical Separation

The independent upstream firm chooses both the degree of adaptation δ and the level of effort/investment e to

$$\max_{\delta,e} \pi^U = e[\rho(v-c) + (1-\rho)\frac{1}{2}(v-c+\delta)] - \frac{1}{2}\gamma\delta^2 - \frac{1}{2}ke^2. \tag{1}$$

The optimal choice is characterized by:

Proposition 1. *Under vertical separation, the degree of adaptation and the level of investment are*

$$\begin{aligned} \delta_{vs} &= \frac{(1-\rho^2)(v-c)}{4k\gamma-(1-\rho)^2}, \\ e_{vs} &= \frac{2\gamma(1+\rho)(v-c)}{4k\gamma-(1-\rho)^2}. \end{aligned}$$

Moreover, δ_{vs} is decreasing in ρ and e_{vs} is increasing in ρ under Assumption 1.

Proof. From Equation (1), the first order conditions are

$$\begin{aligned} \frac{\partial \pi^U}{\partial \delta} &= \frac{e}{2}(1-\rho) - \gamma\delta, \\ \frac{\partial \pi^U}{\partial e} &= \frac{v-c+\delta}{2} + \rho\frac{v-c-\delta}{2} - ke. \end{aligned}$$

Solving the two equations together gives us the values (δ_{vs}, e_{vs}) as in Proposition 1. Differentiating δ_{vs} with respect to ρ yields

$$\frac{d\delta_{vs}}{d\rho} = -\frac{2(v-c)[4k\gamma\rho + (1-\rho)^2]}{[4k\gamma - (1-\rho)^2]^2},$$

which is negative for any $\rho \in [0,1]$ with $k\gamma > 1$. Similarly,

$$\frac{de_{vs}}{d\rho} = \frac{2\gamma(v-c)[4(k\gamma-1) + (1+\rho)^2]}{[4k\gamma - (1-\rho)^2]^2},$$

which is positive for any $\rho \in [0,1]$ with $k\gamma > 1$. □

Proposition 1 confirms that the qualitative property of the degree of adaptation in Lemma 1 and the level of investment in Lemma 2 is preserved when both are present. Particularly, as downstream market becomes more competitive, the independent upstream firm chooses a less adapted input but exerts higher effort in developing the relevant technology. The effect of ρ on δ_{vs} is straightforward: as ρ increases, it becomes more valuable to invest in the outside option, which results in a lower adaptation. The effect of ρ on e_{vs} is two-fold: there is a positive direct effect as U gets a larger share of the industry profit when ρ increases, and there is a negative indirect effect as δ is lower, which reduces the overall industry profit. The proposition indicates that the direct effect dominates.

5.2 Vertical Integration

When D backward integrates with U, it offers U a contract (δ, w, b). As we have argued earlier, under limited liability and moral hazard, the optimal fixed wage $w = c_d(\delta)$. Thus, similar as in Section 4.2, given such a contract, the upstream manager U simply chooses an effort of $e(b) = b/k$. In other words, the expected cost of inducing an effort level/success probability of e for the downstream firm is $e * ke = ke^2$. Thus, we can write the problem for the manager of the integrated firm as

$$\max_{\delta,e} \pi^D = e(v - c + \delta) - ke^2 - \frac{1}{2}\gamma\delta^2. \tag{2}$$

It follows that

Proposition 2. *Under vertical integration, the degree of adaptation and the level of investment are*

$$\begin{aligned} \delta_{vi} &= \frac{v-c}{2k\gamma - 1}, \\ e_{vi} &= \frac{\gamma(v-c)}{2k\gamma - 1}. \end{aligned}$$

In addition, $\delta_{vi} > \delta_{vs}$ for any $\rho \in [0,1]$. There exists a $\hat{\rho}$ such that $e_{vi} < e_{vs}$ if $\rho > \hat{\rho}$, and $e_{vi} > e_{vs}$ if $\rho < \hat{\rho}$.

Proof. From Equation (3), the first order conditions are

$$\begin{aligned} \frac{d\pi^D}{d\delta} &= e - \gamma\delta, \\ \frac{d\pi^D}{de} &= v - c + \delta - 2ke. \end{aligned}$$

Solving the two equations together yields the expression for (δ_{vi}, e_{vi}) in Proposition 2. Together with Proposition 1, we have

$$\delta_{vi} - \delta_{vs} = \frac{2(v-c)[k\gamma(1+\rho^2) + \rho(1-\rho)]}{(2k\gamma - 1)(4k\gamma - (1-\rho)^2)},$$

which is always positive for any $\rho in [0,1]$. In addition,

$$e_{vi} - e_{vs} = \frac{\gamma(v-c)[4k\gamma\rho - (1+4\rho-\rho^2)]}{(2k\gamma - 1)(4k\gamma - (1-\rho)^2)}.$$

Notice that $1 + 4\rho - \rho^2$ is concave for $\rho \in [0,1]$. Moreover, under Assumption 1, $4k\gamma\rho < 1 + 4\rho - \rho^2$ at $\rho = 0$, while $4k\gamma\rho > 1 + 4\rho - \rho^2$ at $\rho = 1$. Hence, there exists a $\hat{\rho}$, defined by $4k\gamma\hat{\rho} = 1 + 4\hat{\rho} - \hat{\rho}^2$, such that $e_{vi} > e_{vs}$ if $\rho < \hat{\rho}$ and $e_{vi} < e_{vs}$ if $\rho > \hat{\rho}$. □

Thus, a vertical integrated firm always implements more input adaptation, as the outside option becomes irrelevant. However, since it becomes harder to motivate the upstream manager to invest, the integrated firm may optimally induce less investment than a vertically separated upstream firm, when downstream competition is sufficiently competitive.

5.3 The Incentive to Integrate

Vertical integration is profitable if the joint profit of U and D is higher under vertical integration. Define $\pi(\delta, e)$ as follows:

$$\pi(\delta, e) = e(v - c + \delta) - \frac{1}{2}\gamma\delta^2 - \frac{1}{2}ke^2.$$

It is straightforward to check that the joint profits under vertical separation and vertical integration are given by[8]

$$\Pi_{vs} = \pi(\delta_{vs}, e_{vs}), \Pi_{vi} = \pi(\delta_{vi}, e_{vi}).$$

The following proposition characterizes our main result:

[8]Notice that, under vertical integration, the upstream manager earns a rent of $ke_{vi}^2/2$.

Proposition 3. *There exists* $1 < t_1 < t_2$ *such that*

a If $1 < k\gamma < t_1$*,* $\Pi_{vi} > \Pi_{vs}$ *for all* $\rho \in [0, 1]$*;*

b If $t_1 < k\gamma < t_2$*,* $\Pi_{vi} > \Pi_{vs}$ *for* $\rho \in [0, \rho_1) \cup (\rho_2, 1]$*, where* $0 < \rho_1 < \rho_2 < 1$*;*

c If $t_2 < k\gamma$*,* $\Pi_{vi} > \Pi_{vs}$ *for* $\rho \in [0, \rho_3)$*, where* $0 < \rho_3 < 1$*.*

All ρ_1, ρ_2, ρ_3 *depend only on* $k\gamma$*.*

Proof. See Appendix A. □

The benefit of vertical integration compared to vertical separation depends on $k\gamma$, which measures how responsive are effort and adaption to incentives. With high level of responsiveness ($k\gamma$ is low), vertical integration is always profitable. With intermediate responsiveness, vertical integration is profitable when downstream competition is either very strong or very weak. With low level of responsiveness, vertical integration is profitable only when the market is not very competitive. Particularly, for relatively weak downstream competition (ρ close to zero), vertical integration is always profitable. This is due to the fact that vertical integration eliminates the hold-up problem, which leads to more efficient adaptation ($\delta_{vi} > \delta_{vs}$) and more investment ($e_{vi} > e_{vs}$).

The result is qualitatively different from Aghion et al. (2006), which predicts that the benefit of vertical integration is either increasing, decreasing, or U-shape in the competitiveness of downstream market, and firms are indifferent between integration or not if $\rho = 0$. Hence, without any fixed cost (or fixed cost saving), we should either always observe vertical integration, or only observe it when competition is very intense. In our simple setup, the relationship between competition and vertical integration is genuinely non-monotone, and we could observe vertical at either end of the competition spectrum without any fixed cost considerations.

The following corollary immediately follows from Proposition 3:

Corollary 1. *For a given* $t = k\gamma$*, let* $\mathbb{L} = \{\rho | \Pi_{vi}(\rho, t) > \Pi_{vs}(\rho, t)\}$ *be the range of parameter* ρ *such that vertical integration is profitable, then* $\|\mathbb{L}\|$ *is decreasing in* t*.*

That is, as either the cost of investment/exerting effort or the cost of input adaptation becomes higher, we should observe less vertical integration. Simply speaking, as the costs get higher, both incentives (investment and adaptation) become less responsive, and thus it becomes increasingly harder to motivate the upstream manager within an integrated firm. Hence, firms resort to the market which provides stronger incentives.

The two parameters k and γ also have interesting implications. k is the cost coefficient of investment, Corollary 1 says that as the investment technology becomes less efficient, we should see less vertical integration. The pharmaceutical sector provides a potential example. As the cost of discovering molecules becomes increasingly high, a trend has emerged that big pharmaceutical companies outsource their research activities in the traditional pipelines. (This is accompanied with the entry of generic producers in the downstream firms, which also implies more vertical separation.) On the other hand, γ can be interpreted as the degree of asset specificity, higher γ means that it is more costly to adapt an input to the special use of one downstream firm, which corresponds to lower asset specificity. Corollary 1 then indicates that when there is more asset specificity (lower γ), we should observe more vertical integration. The bio-pharmaceutical industry and the high-tech industry are potential examples in this direction. As bio-pharmaceuticals feature much higher asset specificity (and also the cost of discovery is lower) than traditional pharmaceuticals, merger waves have been observed in this sector. Similar trend has been observed in the high-tech (e.g. smart-phones) market, where compatibility between software and hardware is crucial.

5.4 Effect of Competition on Innovation and Welfare

We use the value of effort/investment to measure the innovation intensity. We have seen that under vertical integration, innovation is independent from downstream competition; whereas under vertical separation, innovation is increasing with downstream competition. Proposition 2 says that innovation intensity is higher under vertical integration if downstream market is not very competitive, i.e. $\rho < \hat{\rho}$. Moreover, under this condition, vertical integration is also more profitable than vertical separation. To see this, notice that the choice of adaptation δ is efficient (maximize the joint profit) under vertical integration; hence, if the investment incentive is also higher under vertical integration (which is insufficient from the perspective of maximizing the joint profit), the joint profit must be higher under vertical integration.[9] Put in a different way, if vertical

[9]Specifically, in this case, we have $\Pi_{vi} = \pi(\delta_{vi}, e_{vi}) > \pi(\delta^{vi}(e_{vs}), e_{vs}) > \pi(\delta_{vs}, e_{vs}) = \Pi_{vs}$, where $\delta^{vi}(e_{vs})$ is the efficient choice of δ for a given investment e_{vs}.

separation is the better organization form, it must induce a higher innovation intensity. Since competition affects the organization of firms in a non-monotone way, it is natural that it affects innovation in a non-monotone way.

Corollary 2. *If $k\gamma > t_2$, innovation intensity is (weakly) increasing with downstream competition; If $t_1 < k\gamma < t_2$, innovation intensity is the highest at $\rho = \rho_2$; If $k\gamma < t_1$, innovation intensity is constant.*

This follows directly from Proposition 3: for intermediate value of responsiveness, vertical separation occurs for intermediate intensity of downstream competition. Hence, innovation intensity first increases and then drops back to the level under vertical integration. The non-monotone relationship is a consequence of organizational change induced by downstream competition. Other papers have also derived such a non-monotone relationship. For instance, Aghion et al. (2005) obtains an inverted-U shape between competition and innovation in a step-by-step innovation model; Etro and Cella (2013) obtains such a relationship embedding incentive contracts in a competitive labor market.[10]

The welfare consequence of downstream competition also immediately follows from Proposition 3. Since consumers have an inelastic demand, total welfare corresponds to total profit.

Corollary 3. *If $k\gamma < t_1$, total welfare is constant; if $k\gamma > t_1$, total welfare is hump-shaped, i.e. it attains a maximum at an intermediate level of downstream competition.*

6 Conclusion

We consider the impact of vertical integration on innovation and the resulting implications on market structure and welfare. When deciding whether to integrate or not, the firms face the trade-off between more coordination within the integrated entity, in terms of more customized input specification, and costlier incentive provision within the integrated entity, as opposed to incentives generated in a competitive market. We demonstrate that this trade-off leads to a U-shaped relationship between vertical integration and competi-

[10]In our model, the non-monotonicity has a form of discontinuous drop at ρ_2. In a more general model with continuum of upstream-downstream pairs, which have different fixed costs associated with integration/separation, a more continuous reduction in innovation can be easily obtained.

tion, which results in non-monotone relationship between competition and innovation as well as welfare.

References

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005). Competition and innovation: An inverted-u relationship. *Quarterly Journal of Economics 120*(2), 701–728.

Aghion, P., R. Griffith, and P. Howitt (2006). Vertical integration and competition. *American Economic Review: Papers & Proceedings 96*(2), 97–102.

Avenel, E. (2008). Strategic vertical integration without foreclosure. *Journal of Industrial Economics 56*(2), 247–262.

Baggs, J. and J.-E. de Bettignies (2007). Product market competition and agency costs. *Journal of Industrial Economics 55*(2), 289–323.

Bester, H. and D. Krähmer (2008). Delegation and incentives. *RAND Journal of Economics 39*(3), 664–682.

Bloom, N., R. Sadun, and J. van Reenen (2010). Does product market competition lead firms to decentralize? *American Economic Review: Papers & Proceedings 100*(2), 434–438.

Bresnahan, T. and J. Levin (2012). Vertical integration and market structure. In R. Gibbons and J. Roberts (Eds.), *Handbook of Organizational Economics*. Princeton University Press.

Chalioti, E. (2015). Incentive contracts under product market competition and r&d spillovers. *Economic Theory 58*, 305–328.

Chalioti, E. and K. Serfes (2016). Stratetic incentives for innovations and market competition. *International Journal of Industrial Organization, forthcoming*.

Choi, J. P. and S.-S. Yi (2000). Vertical foreclosure with the choice of input specifications. *RAND Journal of Economics 31*(4), 717–743.

Erkal, N. (2007). Buyer-supplier interaction, asset specificity, and product choice. *International Journal of Industrial Organization 25*, 988–1010.

Etro, F. and M. Cella (2013). Equilibrium principal-agent contracts: Competition and r&d incentives. *Journal of Economics & Management Strategy 22*(3), 488–512.

Laffont, J.-J. and D. Martimort (2009). *The theory of incentives: the principal-agent model*. Princeton university press.

Legros, P. and A. Newman (2008). Competing for ownership. *Journal of the European Economic Association 6*(6), 1273–1308.

Legros, P. and A. Newman (2013). A price theory of vertical and lateral integration. *Quarterly Journal of Economics 128*(2), 727–770.

Legros, P. and A. Newman (2014). Contracts, ownerships, and industrial organization: Past and future. *Journal of Law, Economics and Organization 30*(1), 82–117.

Marin, D. and T. Verdier (2008). Power inside the firm and the market: A general equilibrium approach. *Journal of the European Economic Association 6*(4), 752–788.

Matsushima, N. (2004). Technology of upstream firms and equilibrium product differentiation. *International Journal of Industrial Organization 22*, 1091–1114.

Matsushima, N. (2009). Vertical mergers and product differentiation. *Journal of Industrial Economics 57*(4), 812–834.

McLaren, J. (2000). "Globalization" and vertical structure. *American Economic Review 90*(5), 1239–1254.

Prendergast, C. (2015). The economics of wild goose chases. *RAND Journal of Economics 46*(1), 146–164.

Raith, M. (2003). Competition, risk, and managerial incentives. *American Economic Review 93*(4), 1425–1436.

Riordan, M. (2008). Competitive effects of vertical integration. In P. Buccirossi (Ed.), *Handbook of Antitrust Economics*. MIT Press.

Schmidt, K. (1997). Managerial incentives and product market competition. *Review of Economic Studies 64*(2), 191–213.

A Proof of Proposition 3

Let $t = k\gamma$. Substituting (δ_{vs}, e_{vs}) into $\pi(\delta, e)$ yields

$$\Pi_{vs} = \frac{1}{2}\gamma(v-c)^2 \underbrace{\frac{4t(1+\rho)(3-\rho) + 8\rho(1-\rho^2) - (1-\rho^2)^2}{(4t-(1-\rho)^2)^2}}_{f(t,\rho)};$$

Similarly, substituting $\delta = \delta_{vi}$ and $e = e_{vi}$ yields

$$\Pi_{vi} = \frac{1}{2}\gamma(v-c)^2 \underbrace{\frac{3t-1}{(2t-1)^2}}_{g(t)}.$$

First, notice that Π_{vi} is independent of ρ. For Π_{vs}, we have

$$\frac{\partial f(t,\rho)}{\partial \rho}|_{\rho=0} = \frac{4(8t^2-6t-1)}{(4t-1)^3}, \tag{3}$$

which is positive for all $t > 1$;

$$\frac{\partial f(t,\rho)}{\partial \rho}|_{\rho=1} = -\frac{1}{t^2}, \tag{4}$$

which is negative for all $t > 1$. Moreover,

$$\frac{\partial^2 f(t,\rho)}{\partial \rho^2} = -\frac{8\Delta(\rho,t)}{(4t-(1-\rho)^2)^4},$$

where $\Delta(\rho,t) = [A(\rho) + B(\rho)t) + C(\rho)t^2 + t(4t-1)^2 - 6]$ with

$$\begin{aligned} A(\rho) &= 3\rho^5 + 6\rho^4 - 30\rho^3 + 24\rho^2 + 3\rho, \\ B(\rho) &= 9\rho^4 + 60\rho^3 - 50\rho^2 - 20\rho, \\ C(\rho) &= 56\rho^2 + 32\rho. \end{aligned}$$

It is then straightforward to check that $\forall \rho \in [0,1]$:

$$\Delta(\rho,1) > 0; \frac{\partial \Delta(\rho,t)}{\partial t}|_{t=1} > 0; \frac{\partial^2 \Delta(\rho,t)}{\partial t^2} > 0, \forall t > 1.$$

Thus, $\Delta(\rho,t) > 0$ for any $\rho \in [0,1]$ and $t > 1$, which means $\frac{\partial^2 f(t,\rho)}{\partial \rho^2} < 0$ for any $\rho \in [0,1]$ and $t > 1$. Together with Equation (3) and (4), this indicates that $f(\rho,t)$ is inverted-U shape in ρ for any $t > 1$.

For the comparison between Π_{vs} and Π_{vi}, let $R(\rho,t) = \dfrac{\Pi_{vs}}{\Pi_{vi}}$. We have

$$R(0,t) = \frac{(12t-1)(2t-1)^2}{(3t-1)(4t-1)^2},$$

which is smaller than 1 for any $t > 1$, and

$$R(1,t) = \frac{(2t-1)^2}{t(3t-1)},$$

which is greater than 1 if $t > \frac{3+\sqrt{5}}{2}$ and smaller than 1 if $1 < t < \frac{3+\sqrt{5}}{2}$. Thus, for large enough t, i.e. for $t > t_2 \triangleq \frac{3+\sqrt{5}}{2}$, there exists a ρ_3 such that $\Pi_{vi} > \Pi_{vs}$ if $\rho < \rho_3$ and $\Pi_{vi} < \Pi_{vs}$ if $\rho > \rho_3$.

On the other hand, if t is sufficiently small, it is easy to show that

$$R(\rho,1) < 1, \forall \rho \in [0,1]. \tag{5}$$

That is, for relatively small t, vertical integration is always profitable. Moreover,

$$\frac{\partial R(\rho,t)}{\partial t} = \frac{(2t-1)(\rho+1)S(\rho,t)}{(4t-(1-\rho)^2)^3(3t-1)^2},$$

where $S(\rho,t) = D(\rho) + E(\rho)t + F(\rho)t^2$, with

$$\begin{aligned} D(\rho) = &\quad -\rho^5 - 5\rho^4 + 34\rho^3 + 10\rho^2 - 33\rho - 5, \\ E(\rho) = &\quad 6\rho^5 + 30\rho^4 - 192\rho^3 + 24\rho^2 + 106\rho - 6, \\ F(\rho) = &\quad 72\rho^3 - 72x^2 + 56x + 72. \end{aligned}$$

It is readily to show that $\forall \rho \in [0,1]$,

$$S(\rho,1) > 0; \frac{\partial S(\rho,t)}{\partial t}|_{t=1} > 0; \text{ and } \frac{\partial^2 S(\rho,t)}{\partial t^2} > 0, \forall t > 1.$$

Therefore, $S(\rho,t) > 0$ for all $\rho \in [0,1]$ and $t > 1$, and hence $\dfrac{\partial R(\rho,t)}{\partial t} > 0$ for all $\rho \in [0,1]$ and $t > 1$. Together with Equation 5, this means that there exists a t_1, defined by $\max_\rho R(\rho,t_1) = 1$, such that if $t < t_1$, $\Pi_{vi} > \Pi_{vs}$ for all $\rho \in [0,1]$.

For intermediate value of t such that $t_1 < t < t_2$, we have $R(0,t) < 1$, $R(1,t) < 1$, and $\max_\rho R(\rho,t) > 1$. Hence, there exists ρ_1 and ρ_2 such that $\Pi_{vi} < \Pi_{vs}$ for $\rho \in (\rho_1,\rho_2)$.