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Abstract

This study constructs a model of a relationship-specific investment in a dynamic framework. Although such investment decreases operating costs and increases the current joint profits of firms in vertical relationships, its specificity reduces the ex-post flexibility to change a trading partner in the future. We demonstrate that whether the investment contract deters entry even in the absence of exclusionary terms depends on not only the specificity but also the efficiency of the investment. We also show that an increase in the investment efficiency does not necessarily improve the equilibrium social welfare.

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Keywords: Vertical Relation; Entry Deterrence; Relationship-Specific Investment; Switching Costs

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1 Introduction

In a number of vertical relationships, upstream firms make a relationship-specific investment in downstream firms. For example, some firms develop original systems or instruments and introduce them to downstream firms.[1] Similarly, some firms provide special training programs to the downstream firm's employees.[2] These types of investments seem to decrease the operating costs and increase the joint profits of firms in vertical relationships. In addition, they seem to increase industry output and generate a socially efficient effect. From a static viewpoint, these predictions are correct.

However, a relationship-specific investment usually generates specificity in vertical relationships. For example, through special training programs or the introduction of original systems, employees in downstream firms can establish specific routines (called "habitual routines") for their operations with a current trading partner. Owing to such specificity, when downstream firms change the trading partner, employees must usually unlearn these old routines before commencing operations with a new trading partner (Postrel and Rumelt, 1992). This generates switching costs such as temporary performance degradation or an increase in retraining costs for the ex-post change of the trading partner. Therefore, a relationship-specific investment may deter efficient future entry and lead to socially inefficient outcomes in a dynamic perspective.[3]

This study aims to theoretically explore the role of a relationship-specific investment as a barrier to efficient entry and its welfare implication based on a dynamic framework. It constructs a two-period model of entry deterrence with the relationship-specific investment. In the first period, one upstream incumbent exists but in the second period, a more efficient firm appears. The upstream incumbent offers the single downstream firm an investment contract with some fixed payments such as an introduction campaign for new systems or instruments for a limited time.

[1] For example, Ticketmaster, the leading ticket sales and distribution company in the United States, develops an original system for concert venues. See Whinston (2006). See also Holden and O'Toole's (2004) study, which explores the role of communication in determining the governance of manufacturer–retailer relationships.

[2] Ticketmaster also trains a venue's personnel in the use of its system.

[3] Postrel and Rumelt (1992) refer to the difficulty experienced by several companies such as Wedgwood and Nucor in changing employees' old habits. Further, in the psychological literature, Shiffrin and Schneider (1977) provide experimental evidence on this issue.

The key assumption in our model is that investment specificity generates switching costs when the downstream firm changes its trading partner. When specificity is high, the acceptance of such investment restricts trading partner choices of the downstream firm because it makes dealing with the entrant in the second period impossible. This exposes the downstream firm to the intertemporal trade-off that once it accepts the specific investment, it becomes efficient in the current period but cannot transact with an efficient entrant in the future. Therefore, for examining the existence of entry deterrence, we need to focus on the downstream firm's incentive to accept or reject the investment.

In this setting, we explore the existence of entry deterrence because of the relationship-specific investment and show that not only the investment specificity but also its efficiency is an important factor that makes entry deterrence possible. To understand the importance of investment efficiency in triggering entry deterrence, we begin by analyzing the case where the investment is not efficient: that is, the investment does not reduce operating costs. We show that the incumbent cannot then profitably design the investment contract to deter future entry even when the investment is considerably specific. When the downstream firm rejects the investment, the entrant offers a better wholesale price than the incumbent does in the second period. This leads to a higher level of rejection profits for the downstream firm, which the incumbent cannot profitably compensate under the investment contract.

In contrast, when the investment is efficient and reduces operating costs, the incumbent can profitably design the investment contract to deter future entry if the investment is sufficiently specific. In this case, the acceptance of investment increases the joint profits of the incumbent and the downstream firm in the first period. We point out that this allows the incumbent to profitably compensate the downstream firm's rejection profits.

Our results imply that an improvement in investment efficiency can trigger entry deterrence. This leads to an important welfare implication that an improvement in investment efficiency does not necessarily increase the equilibrium social welfare; that is, the relationship between the investment efficiency and equilibrium social welfare becomes non-monotonic. Hence, our results suggest that we should have a dynamic perspective when we discuss the welfare effect of relationship-specific investments. In a static view, such investment decreases the current operating costs of firms in vertical relationships and improves social welfare.

However, in a dynamic view, the investment efficiency might reduce social welfare because together with imposing switching costs, it can deter efficient future entry. Therefore, to evaluate the welfare effect of such investment, we need to consider these intertemporal effects. Otherwise, we might obtain misleading predictions.

On interpreting our findings differently, our analysis predicts that entry deterrence owing to an investment contract is more likely to be observed in an industry where downstream firms are small companies. Small companies usually have fewer internal reserves and assets because of difficulty in obtaining finance. Thus, upstream firms are more likely to need to incur investment costs to develop instruments and systems for downstream firms.

This study is related to the literature on entry deterrence with switching costs.[4] Klemperer (1987) shows that entry deterrence is possible when the incumbent firm uses switching costs in committing to a production capacity. In contrast, in the present study, entry deterrence arises because switching costs restrict trading partner choices of the downstream firm and the investment can increase the present joint profits of the firms in the vertical relationship.

This study is also related to the literature on entry deterrence through exclusive contracts. In the 1970s, the Chicago School (Posner, 1976; Bork, 1978) argued that if we consider downstream buyers' incentives to accept exclusive contracts, rational economic agents would not engage in exclusive dealing for anticompetitive reasons, and thus, entry deterrence is impossible by using exclusive contracts. In rebuttal of the Chicago School argument, post-Chicago economists show that entry deterrence is possible by using exclusive contracts in the presence of scale economies[5] (Rasmusen, Ramseyer, and Wiley, 1991; Segal and Whinston, 2000a) and downstream competition[6] (Simpson and Wickelgren, 2007; Abito and Wright,

[4]Entry deterrence is analyzed in a number of studies wherein it arises owing to excess capacity (Spence, 1977; Dixit, 1980), quality uncertainty (Schmalensee, 1982), and cost uncertainty (Milgrom and Roberts, 1982).

[5]Doganoglu and Wright (2010) explore exclusion in the presence of network externalities, which are an example of scale economies. Fumagalli and Motta (2006) explore an extended model of Rasmusen, Ramseyer, and Wiley (1991) and of Segal and Whinston (2000a), where buyers are not final consumers but competing firms. They show that intense downstream competition reduces the possibility of exclusion. However, Abito and Wright (2008) point out that this result depends on the assumption that buyers are undifferentiated Bertrand competitors who need to incur epsilon participation fees to stay active and show that if buyers are differentiated Bertrand competitors, then intense downstream competition enhances exclusion. Wright (2009) also points out that the equilibrium analysis of Fumagalli and Motta (2006) in the case of two-part tariffs contains some errors and shows that exclusion arises when scale economies are sufficiently large or the entrant's cost advantage is not too big.

[6]See also Wright (2008), Argenton (2010), Kitamura (2010, 2011), Johnson (2012), Gratz and Reisinger

2008). The present study has a similar motivation because we explore entry deterrence by considering downstream buyers' incentive to accept an investment contract. In contrast to earlier studies, however, this study shows that when a specific investment is made, the investment contract can deter efficient entry even in the absence of exclusionary terms, scale economies, and downstream competition.

Exclusion with non-exclusive contracts has recently been analyzed by many economists (Elhauge, 2009; Elhauge and Wickelgren, 2011, 2012a, and 2012b; Semenov and Wright, forthcoming). These studies consider the design of wholesale pricing to deter efficient entrants and show that exclusion is possible even in the absence of exclusionary terms. The present study shows another way of exclusion with non-exclusive contracts by using the investment contract.

Finally, this study is related to the literature on relationship-specific investments and exclusive dealing (Marvel, 1982; Segal and Whinston, 2000b; De Meza and Selvaggi, 2007; De Fontenay, Gans, and Groves, 2010). These studies examine the role of exclusive dealing in enhancing the level of relationship-specific investment and show that exclusive dealing may solve the hold-up problem and increase the level of investment in a specific market environment.[7] In contrast, the present study focuses on the specificity of relationship-specific investments as a barrier to future entry.

The reminder of this paper is organized as follows. Section 2 sets up the model. Section 3 analyzes the existence of entry deterrence because of the relationship-specific investment. Section 4 explores the welfare implications of the investment. Section 5 discusses the robustness of our results under linear wholesale pricing. Finally, Section 6 contains concluding remarks. Proofs of the results are provided in the Appendix.

(forthcoming), and Kitamura, Sato, and Arai (forthcoming).

[7] Recently, in an extension to Segal and Whinston (2000b), Fumagalli, Motta, and Rønde (2012) show that disregarding the interaction between investment promotion and market foreclosure may lead to misleading results. They show that the investment promotion effect of exclusive dealing enhances anticompetitive exclusive dealing.

2 The model

This section sets up the model. We first characterize upstream and downstream markets in 2.1. Then, we introduce the timing of the game in 2.2.

2.1 Upstream and downstream markets

In the upstream market, two upstream firms exist, an incumbent (denoted by I) and an entrant (denoted by E). They produce an identical product but differ in cost efficiency. While the incumbent has a marginal cost of production c_I, the entrant is more efficient and has a lower marginal cost; that is, $c_E < c_I$.

In the downstream market, a monopolistic downstream firm exists (denoted by D).[8] The downstream firm purchases inputs from the upstream firm to produce a final product. We assume that one unit of the final product requires one unit of the input and that the marginal cost of transformation or resale is c_D. We also assume that the demand for the final product Q is given by a simple linear function $Q(p) = 1 - p$ where p is the final product's price. We also assume that $c_I + c_D < 1$ such that selling to final consumers is at least profitable.

2.2 The timing of the game

The timing of the game follows that of Klemperer (1987) (see also Figure 1). The model contains two periods ($t = 1, 2$). At Period 1, only the incumbent exists in the upstream market. This may be because of a patent right, efficient marketing, or an industry protection policy. Period 1 consists of three stages. At Period 1.1, the incumbent offers the downstream firm an investment contract involving some fixed compensation $x \geq 0$. This offer is interpreted as an introduction campaign for new systems or instruments developed by the incumbent for a limited time.[9] The investment reduces the marginal cost of the downstream firm for the operation with the incumbent by $d \in [0, c_D)$. The level of d is interpreted as the degree

[8] In the literature on anticompetitive exclusive dealing, in the absence of multiple downstream buyers, an upstream incumbent cannot deter efficient entry. Therefore, our modeling strategy of assuming a downstream monopoly clarifies the role of investment as an entry barrier.

[9] As stated earlier, if downstream firms in an industry are small companies, they usually have limited internal reserves and assets because they cannot obtain finance easily. Thus, upstream firms are more likely to incur investment costs and offer a specific investment to downstream firms.

of investment efficiency. To simplify the analysis, we assume that the investment cost is zero.[10] The downstream firm decides to accept or reject this offer. We denote the decision by $\theta \in \{a, r\}$, where $\theta = a$ (r) indicates the acceptance (rejection). We assume that when the downstream firm is indifferent between accepting and rejecting the investment contract, it accepts the contract.[11]

At Period 1.2, the incumbent offers wholesale contracts consisting of two-part tariffs $(w_{I|t=1}, F_{I|t=1}) \in \mathbb{R}^2_+$. In Section 5, we briefly discuss the case of linear wholesale pricing.[12] At Period 1.3, the downstream firm sells to final consumers. Note that because the incumbent uses two-part tariffs, it optimally sets its per-unit wholesale price to equal its marginal cost to remove the double marginalization problem; that is, $w_{I|t=1} = c_I$. Therefore, if the downstream firm has accepted the investment contract at Period 1.1, then it operates at $c_I + c_D - d$. However, if it has rejected the investment contract, then it operates at $c_I + c_D$ (see also Table 1).

At Period 2, the entrant appears in the upstream market. Period 2 consists of four stages. At Period 2.1, the entrant decides whether to enter the upstream market. We denote the entrant's decision by $\lambda \in \{in, out\}$, where $\lambda = in$ (out) indicates that the entrant enters (stays out of) the market. We assume that the fixed cost of entry is negligible. Therefore, the entrant always enters the market if its post-entry profits (gross of entry costs) are positive. At Period 2.2, all active upstream firms offer wholesale contracts consisting of two-part tariffs $(w_{i|t=2}, F_{i|t=2})$, where $i \in \{I, E\}$, to the downstream firm. As in Period 1, active upstream firms optimally set the per-unit wholesale prices to equal their marginal costs; that is, $w_{i|t=2} = c_i$ for $i \in \{I, E\}$.

At Period 2.3, given the wholesale contracts offered by the upstream firm(s), the downstream firm decides on a trading partner. If the downstream firm deals with the incumbent and has accepted the investment contract at Period 1, then the downstream firm operates at

[10] Introducing a positive investment cost does not alter our main results qualitatively.

[11] If we assume that the downstream firm rejects the investment when it is indifferent, some of the arguments in this study must be modified slightly. However, the essence of our results is still valid. See footnotes 18 and 23 for details.

[12] Two-part tariffs allow us to illustrate our main results in a simpler way. As discussed in Section 5, although we find almost the same results under linear wholesale pricing, the welfare analysis becomes considerably complicated.

$c_I + c_D - d$. If the downstream firm deals with the incumbent but has rejected the investment contract at Period 1, then the incumbent makes the investment offer again without fixed compensation x and the downstream firm accepts the investment offer.[13] As a result, the downstream firm operates at $c_I + c_D - d$. On the other hand, if the downstream firm decides to deal with the entrant, then the downstream firm operates at $c_E + c_D$.[14] However, if the downstream firm has accepted the investment contract at Period 1, then it needs to incur switching costs $K > 0$. The level of switching costs is interpreted as the degree of investment specificity. For example, in the context of "habitual routines," these switching costs include a temporary performance degradation or an increase in the costs of familiarizing employees with a new routine.[15] We adopt the tie-break rule that when the downstream firm is indifferent between dealing with the incumbent or the entrant, it continues to deal with the incumbent. At Period 2.4, the downstream firm orders the product produced by upstream firms and sells to final consumers.

The incumbent's and the downstream firm's operating profits at Period 1 when the downstream firm's investment decision at Period 1 is $\theta \in \{a, r\}$ are denoted by $\Pi^{\theta}_{I|t=1}$ and $\pi^{\theta}_{D|t=1}$, respectively. Similarly, the incumbent's, the downstream firm's, and the entrant's operating profits at Period 2 when the downstream firm's decision at Period 1 is $\theta \in \{a, r\}$ and the entrant's decision at Period 2 is $\lambda \in \{in, out\}$ are denoted by $\Pi^{\theta(\lambda)}_{I|t=2}$, $\pi^{\theta(\lambda)}_{D|t=2}$, and $\Pi^{\theta(\lambda)}_{E|t=2}$, respectively. We assume no discounting between Period 1 and Period 2, for simplicity.[16]

Finally, in the analysis below, we assume that the following inequalities are satisfied:

[13] This is because the investment (at least) does not harm the downstream firm's profits at Period 2.

[14] We do not explicitly consider the investment between the entrant and the downstream firm. If the entrant could offer the investment contract at Period 2, the downstream firm that decides to deal with the entrant always accepts the offer and this reduces the downstream firm's operating costs to less than $c_E + c_D$. This does not alter our main results qualitatively.

[15] In this study, we assume that there is no switching cost when the downstream firm rejects the investment contract at Period 1. Of course, there can be a positive switching cost to change the trading partner even when the investment is not made. However, in the context of "habitual routines," the ex-post change of trading partner can be more costly when employees have established specific routines with the old partner than when they have not. Therefore, our setting can be interpreted as one in which the general switching cost that does not depend on whether the investment is made is normalized to zero; we only focus on the switching cost owing to the investment specificity.

[16] Introducing a discount rate $\beta \in (0, 1)$ between Period 1 and Period 2 does not change our results qualitatively.

Assumption 1.

$$0 \leq d < c_I - c_E \leq c_D. \tag{1}$$

The second inequality guarantees that entry occurs at Period 2 as long as the investment contract is rejected at Period 1. If the second inequality does not hold, the downstream firm never deals with the entrant and entry never occurs at Period 2. The third inequality implies that investment efficiency d is in fact bounded by $c_I - c_E$ and not by c_D. This assumption simplifies the analysis below.

3 Relationship-specific investment and entry deterrence

In this section, we analyze the existence of entry deterrence owing to the relationship-specific investment. In 3.1, we describe the conditions to be satisfied so that the incumbent can deter entry using an investment contract. In 3.2 and 3.3, we explore when these conditions are actually satisfied. To understand easily the role of investment as an entry barrier, in 3.2, we analyze the case where the investment is not efficient ($d = 0$) and in 3.3, we analyze the case where the investment is efficient ($d > 0$).

3.1 Conditions for entry deterrence with a relationship-specific investment

In this subsection, we describe the conditions to be satisfied for the incumbent to profitably deter entry by using an investment contract. In brief, for the existence of entry deterrence owing to a relationship-specific investment, the following two conditions must be satisfied simultaneously:

Condition (i) Entry must be unprofitable for the entrant when the investment is undertaken at Period 1.1,

Condition (ii) Entering into an investment contract at Period 1.1 must be profitable for both the incumbent and the downstream firm.

In what follows, we describe these two conditions more formally.

3.1.1 Profitability of entry for the entrant

First, we examine Condition (i) and derive the condition that entry at Period 2.1 becomes unprofitable for the entrant if the investment contract is made at Period 1.1. If the entrant enters the market, the incumbent and the entrant compete for the downstream firm at Period 2.2. If the investment has been undertaken at Period 1.1, the downstream firm must incur certain switching costs to change its trading partner. In this case, to attract the downstream firm, the entrant must cover such switching costs in addition to guaranteeing the profits likely to result for the downstream firm from the incumbent's best offer. Therefore, we have the following lemma that summarizes the condition under which entry at Period 2.1 becomes unprofitable and the entrant does not enter the market:

Lemma 1. *Suppose that the investment contract is made at Period 1.1. Then, the entrant does not enter the market at Period 2.1 if and only if the investment is sufficiently specific or efficient; that is, a pair of* (K, d) *satisfies* $K \geq \hat{K}(d)$ *and* $d \geq 0$ *simultaneously, where*

$$\hat{K}(d) = \frac{(c_I - c_E - d)((1 - (c_I + c_D - d)) + (1 - (c_E + c_D)))}{4}, \tag{2}$$

and where $\hat{K}'(d) < 0$ *and* $\lim_{d \to c_I - c_E} \hat{K}(d) = 0$.

Whether $K \geq \hat{K}(d)$ holds depends on the degrees of investment specificity K, investment efficiency d, and entrant's efficiency c_E. Note that while the left-hand side of $K \geq \hat{K}(d)$ is increasing in K, the right-hand side is decreasing in both d and c_E. As the investment becomes more specific (as K increases), the downstream firm must incur larger switching costs to change its trading partner at Period 2. Then, the entrant must offer a better wholesale contract to induce the downstream firm to change its trading partner. Similarly, as the investment becomes more efficient (as d increases), the entrant needs to offer a better wholesale contract to the downstream firm. In these cases, it tends to be unprofitable for the entrant to enter the market at Period 2.1. By contrast, as the entrant becomes more efficient (as c_E decreases), it can yield higher profits since the joint profits of the entrant and the downstream firm increase. Therefore, market entry at Period 2.1 is more likely to be profitable for the entrant. Hence, when the investment is highly specific but efficient and the entrant is not so efficient, $K \geq \hat{K}(d)$ is more likely to hold and the entrant tends to not enter the market at Period 2.1.

3.1.2 Investment contract design

Next, supposing that $K \geq \hat{K}(d)$ is satisfied, we examine Condition (ii) and derive the condition that an investment contract deterring the efficient entrant needs to satisfy. Given the equilibrium entry behavior of the entrant at Period 2.1, the equilibrium profits of the incumbent, entrant, and downstream firm in the subgames after Period 1.1 are summarized in Table 2.[17] For the investment contract to be accepted at Period 1.1, it needs to satisfy the following two conditions simultaneously.

First, the investment contract must satisfy financial feasibility for the incumbent: the investment contract must enable the incumbent to yield higher profits, that is,

$$\Pi^{a}_{I|t=1} + \Pi^{a(out)}_{I|t=2} - x \geq \Pi^{r}_{I|t=1} + \Pi^{r}_{I|t=2}. \tag{3}$$

Second, the investment contract must satisfy individual rationality for the downstream firm: namely, the amount of x must induce the downstream firm to accept the investment contract, that is,

$$\pi^{a}_{D|t=1} + \pi^{a(out)}_{D|t=2} + x \geq \pi^{r}_{D|t=1} + \pi^{r}_{D|t=2}. \tag{4}$$

From inequalities (3) and (4), we have the following inequality:

$$\Pi^{a}_{I|t=1} + \Pi^{a(out)}_{I|t=2} + \pi^{a}_{D|t=1} + \pi^{a(out)}_{D|t=2} \geq \Pi^{r}_{I|t=1} + \Pi^{r}_{I|t=2} + \pi^{r}_{D|t=1} + \pi^{r}_{D|t=2}. \tag{5}$$

Inequality (5) implies that for the investment contract to be profitable for both the incumbent and the downstream firm, this contract is required to at least increase the two-period joint profits of contracting parties.

3.2 Benchmark: When investment is not efficient

From the discussion in 3.1, it is easy to see that the relationship-specific investment deters the entrant if and only if inequalities $K \geq \hat{K}(d)$ and (5) hold simultaneously. Now, we explore when these conditions are actually satisfied. To understand easily the role of investment as an entry barrier, in this subsection, we analyze the case where the investment is not efficient ($d = 0$). In the next subsection, we analyze the case where the investment is efficient ($d > 0$).

[17] For the detailed derivation of the equilibrium offer and profit of each firm, see Appendix A.

Assume that the relationship-specific investment is not efficient; that is, $d = 0$. If investment specificity K is sufficiently low such that $K < K(0)$, then the downstream firm can change the trading partner at Period 2 even when it accepts the investment at Period 1. Then, the downstream firm tries to accept the investment at Period 1 and to deal with the entrant at Period 2. Therefore, the incumbent cannot deter the entrant by using the investment contract.[18]

By contrast, if the investment is sufficiently specific such that $K \geq \hat{K}(0)$ holds, then the acceptance of an investment contract induces the downstream firm to lose its best option of accepting the investment contract at Period 1 but dealing with the entrant at Period 2. In such a market environment, the downstream firm may strategically decide to reject the investment offer so that it can deal with the entrant at Period 2. By considering the downstream firm's incentive to accept or reject the investment offer, the following proposition shows that when the investment is not efficient, exclusion never occurs:

Proposition 1. *Suppose that the relationship-specific investment is not efficient: $d = 0$. Then, the incumbent cannot deter the efficient entrant even when the investment is sufficiently specific (even when $K \geq \hat{K}(0)$ holds).*

The intuitive logic for the result under $K \geq \hat{K}(0)$ is as follows (see also Figure 2). When the downstream firm accepts the investment contract at Period 1, the entrant does not enter the upstream market at Period 2 and only the incumbent offers wholesale contracts at both Period 1 and Period 2. At each period, the joint profits of the incumbent and the downstream firm coincide with monopoly profits for marginal costs $c_I + c_D$.

However, when the downstream firm rejects the investment contract at Period 1, the entrant enters the upstream market, and the incumbent and the entrant compete for the downstream firm at Period 2. In the equilibrium, the downstream firm buys from the entrant under a wholesale contract that leaves the downstream firm with slightly higher profits than the monopoly profits for marginal costs $c_I + c_D$. This implies that the acceptance of investment

[18] In this case, the incumbent accepts the investment owing to the assumption that if the downstream firm is indifferent between accepting and rejecting the investment contract, it accepts the contract. If instead we assume that the downstream firm rejects the investment when it is indifferent, it is easy to see that the investment is rejected and the incumbent cannot deter the entrant.

reduces the two-period joint profits of the incumbent and the downstream firm; that is, inequality (5) does not hold. Therefore, the incumbent cannot profitably compensate the downstream firm for the rejection profits; that is, if the incumbent increases x to satisfy inequality (4), then inequality (3) does not hold.

3.3 When investment is efficient

We now assume that the relationship-specific investment is efficient; that is, $d > 0$. If investment specificity K is sufficiently low such that $K < \hat{K}(d)$, the downstream firm can choose its best option of accepting the investment contract at Period 1 but dealing with the entrant at Period 2. Therefore, while the investment is always accepted, the incumbent cannot deter the entrant with the investment contract.[19]

By contrast, if the investment is sufficiently specific such that $K \geq \hat{K}(d)$, the incumbent can deter the efficient entrant unlike in the case where $d = 0$:

Proposition 2. *The incumbent can deter the efficient entrant if and only if the investment is not only specific but also efficient. More precisely, entry deterrence is possible for a pair of* (K, d) *which satisfies* $K \geq \hat{K}(d)$ *and* $d > 0$ *simultaneously.*

Figure 3 summarizes Proposition 2. To understand easily the results here, we provide the intuitive logic by dividing the degree of investment specificity into two domains, $K \geq \hat{K}(0)$ and $K < \hat{K}(0)$. First, Figure 3 implies that when the investment specificity is sufficiently high such that $K \geq \hat{K}(0)$, entry deterrence is possible in the presence of even small investment efficiency $d > 0$. In this case, the crucial difference from the previous subsection arises in the subgame after the downstream firm accepts the investment contract at Period 1 (see also Figure 4). Unlike the case where the investment has no efficiency ($d = 0$), here, if the downstream firm accepts the investment contract at Period 1, then the investment increases the joint profits of the incumbent and the downstream firm at Period 1 to the monopoly profits for marginal costs $c_I + c_D - d$. An increase in the joint profits at Period 1 leads to an increase

[19] In this case, regardless of whether the investment contract is accepted at Period 1, the entrant always enters the market at Period 2. This implies that while investing improves the joint profits of the incumbent and the downstream firm at Period 1, it does not affect their joint profits at Period 2 (see Table 2). Therefore, the downstream firm (strictly) prefers to accept the contract at Period 1 but to deal with the entrant at Period 2.

in the left-hand side of inequality (5) for all $d > 0$. This allows the incumbent to profitably compensate the downstream firm for the rejection profits at Period 2.

Second, Figure 3 implies that when the investment specificity is sufficiently low such that $K < \hat{K}(0)$, entry deterrence requires the higher investment efficiency d. In this case, the investment is always accepted regardless of the level of investment efficiency d. As discussed in the interpretation of Lemma 1, an increase in investment efficiency d forces the entrant to offer better wholesale prices, which reduces the entrant's post-entry profit. Therefore, for the sufficiently efficient investment, entry is not profitable for the entrant when the investment contract is accepted at Period 1. Since inequality (5) is satisfied for all $d > 0$, the incumbent can deter the efficient entrant for the sufficiently higher investment efficiency d that satisfies $K \geq \hat{K}(d)$.

Combining the results of Propositions 1 and 2, we obtain important insights into entry deterrence under relationship-specific investment. The incumbent cannot exclude rivals only with a specific investment: for exclusion, the investment needs to be not only specific but also efficient.

Finally, note that our result in this section that entry deterrence can occur in the presence of even small investment efficiency $d > 0$ is due largely to the assumption of two-part tariff contracts. In Section 5, we show that entry deterrence requires sufficiently higher efficiency under linear wholesale pricing.

4 Relationship-specific investment and social welfare

In this section, we explore the welfare implications of the relationship-specific investment. In 4.1, we analyze when the relationship-specific investment should be made from a social welfare perspective by comparing the level of social welfare in the cases when the investment is and is not made. In 4.2, we explore the relationship between the equilibrium social welfare and investment efficiency.

4.1 Social desirability of the investment

In the previous section, we observed that in the equilibrium, the investment contract is always accepted at Period 1 except when (K, d) satisfies $K \geq \hat{K}(0)$ and $d = 0$ simultaneously, as summarized in Figure 3. In this subsection, by comparing the level of social welfare in the cases when the investment is and is not made, we explore the conditions under which making the relationship-specific investment is socially desirable (or undesirable).[20] We analyze the two types of investment separately, depending on whether the investment deters entry at Period 2. In 4.1.1, we analyze the case where the investment deters entry. In 4.1.2, we analyze the case where the investment does not deter entry.

4.1.1 When investment deters entry

We first assume that the investment is sufficiently specific that it deters the efficient entrant at Period 2 (i.e., $K \geq \hat{K}(d)$ holds). In this case, the investment is accepted in the equilibrium if and only if it is efficient. Therefore, here, we restrict our attention to the case of $d > 0$. Let W^{INE} denote the equilibrium level of social welfare (the superscript INE stands for "investment and no entry"), which is defined as follows:

$$W^{INE} = \frac{3[1-(c_I + c_D - d)]^2}{8} + \frac{3[1-(c_I + c_D - d)]^2}{8}. \tag{6}$$

The first and second terms of the right-hand side of the above equation represent the equilibrium level of social welfare at Period 1 and Period 2, respectively. In the equilibrium, investing at Period 1 reduces the downstream firm's marginal cost by d. However, such investment also leads to entry deterrence and the downstream firm deals with the incumbent at Period 2.

We compare this with the case where the investment is not made at Period 1. In the latter case, although the downstream firm's marginal cost is not reduced at Period 1, the efficient entrant enters the upstream market and the downstream firm deals with the entrant at Period

[20]In this subsection, we explore the investment's social desirability under the assumption that trading partner choices of the downstream firm at Period 2 are determined by the firms' private incentives (i.e., whether $K \geq \hat{K}(d)$ holds). Instead, if we assume that a social planner or the government could force the downstream firm to deal with the entrant at Period 2, the evaluation of the investment's social desirability could be different from that in this subsection. Details are available from the authors upon request.

2. Let W^{NIE} denote the levels of social welfare in this case (the superscript NIE stands for "no investment and entry"), which is defined as follows:

$$W^{NIE} = \frac{3[1-(c_I+c_D)]^2}{8} + \frac{3[1-(c_E+c_D)]^2}{8}. \tag{7}$$

By comparing equations (6) and (7), we obtain the following proposition:

Proposition 3. *Suppose that the relationship-specific investment is sufficiently specific such that it leads to entry deterrence ($K \geq \hat{K}(d)$). Then, investing is socially desirable if and only if this investment is sufficiently efficient; that is, $W^{INE} \gtreqless W^{NIE}$ if and only if $d \gtreqless \overline{d}$, where*

$$\overline{d} = \sqrt{\frac{[1-(c_I+c_D)]^2 + [1-(c_E+c_D)]^2}{2}} - (1-(c_I+c_D)) < c_I - c_E. \tag{8}$$

The relationship-specific investment generates two contrary effects on social welfare. First, the investment improves the efficiency of the vertical relationship between the incumbent and the downstream firm. Because this effect increases social welfare at Period 1, it can be interpreted as the current benefit on investing. From equations (6) and (7), the current benefit CB can be derived as the difference between the first terms of the right-hand sides of equations (6) and (7), that is:

$$CB(d|K \geq \hat{K}(d)) = \frac{3[1-(c_I+c_D-d)]^2}{8} - \frac{3[1-(c_I+c_D)]^2}{8}. \tag{9}$$

Second, on the contrary, the investment deters the efficient entrant and this decreases social welfare at Period 2. This effect can be regarded as the future loss on investing. The future loss FL can be calculated as the difference between the second terms of the right-hand sides of equations (6) and (7):

$$FL(d|K \geq \hat{K}(d)) = \frac{3[1-(c_E+c_D)]^2}{8} - \frac{3[1-(c_I+c_D-d)]^2}{8}. \tag{10}$$

By comparing equations (9) and (10), an increase in investment efficiency d leads to different effects. On the one hand, the current benefit is increasing in d because the efficient investment increases the social welfare at Period 1. On the other hand, the future loss is decreasing in d because welfare loss at Period 2 decreases for the efficient investment. Therefore, if the investment is sufficiently efficient ($d > \overline{d}$), then the current benefit dominates the future loss and the investment becomes socially desirable.

4.1.2 When investment does not deter entry

We next assume that the investment is not so specific and that it allows entry by an efficient entrant at Period 2 (that is, $K < \hat{K}(d)$ holds). In the equilibrium for this market environment, the investment contract with $d \geq 0$ is always accepted at Period 1 but the efficient entrant enters the upstream market and the downstream firm deals with the entrant at Period 2. Let W^{IE} denote the equilibrium levels of social welfare in this case (the superscript IE stands for "investment and entry"), which is defined as follows:

$$W^{IE} = \frac{3[1-(c_I + c_D - d)]^2}{8} + \left[\frac{3[1-(c_E + c_D)]^2}{8} - K\right]. \tag{11}$$

One of the important features of W^{IE} is represented in the brackets of the right-hand side of equation (11). Although the entry occurs at Period 2, the downstream firm needs to incur switching cost K, which constitutes the social cost, to deal with the entrant.[21] This implies that the investment may be socially undesirable even when it does not lead to entry deterrence at Period 2.

As in 4.1.1, we compare this with the case where the investment is not made at Period 1. In the latter case, although the downstream firm's marginal cost is not reduced at Period 1, the entrant enters the upstream market and the downstream firm deals with the entrant without switching costs at Period 2. Therefore, the level of social welfare in this case coincides with W^{NIE}, represented by equation (7). By comparing equations (7) and (11), we obtain the following proposition, which shows when the investment that does not lead to entry deterrence becomes socially desirable:

Proposition 4. *Suppose that the relationship-specific investment is not so specific and that it allows entry at Period 2 ($K < \hat{K}(d)$). Then, investing is socially desirable if and only if this investment is not so specific or is sufficiently efficient. More precisely,*

1. *When the investment is sufficiently efficient (for $d > \overline{d}$) or within an intermediate range of efficiency (for $\underline{d} < d \leq \overline{d}$), investing is always socially desirable; that is, $W^{IE} > W^{NIE}$*

[21] In this model, switching cost K could be interpreted as damages for breach of contract. However, in that case, K is just a monetary transfer between firms and does not affect the social welfare. Alternatively, in this study, we consider K as, for example, a temporary performance degradation, which harms social welfare.

always holds, where

$$\underline{d} = \sqrt{\frac{3[1-(c_I+c_D)]^2+2[1-(c_E+c_D)]^2}{5}} - (1-(c_I+c_D)), \qquad (12)$$

and

2. *When the investment is not too efficient (for $d \leq \underline{d}$), investing is socially desirable if and only if the investment specificity is sufficiently low; that is, $W^{NIE} \gtreqless W^{IE}$ if and only if $K \gtreqless \tilde{K}(d)$, where:*

$$\tilde{K}(d) = \frac{3d((1-(c_I+c_D-d))+(1-(c_I+c_D)))}{8}. \qquad (13)$$

As in the case of the investment that leads to entry deterrence in 4.1.1, the investment that does not deter entry also has two contrary effects on social welfare: a current benefit and a future loss. First, the investment improves the vertical relationship's efficiency and increases social welfare at Period 1. From the first terms of the right-hand sides of equations (7) and (11), this current benefit on investing is the same as that in 4.1.1:

$$CB(d|K < \hat{K}(d)) = \frac{3[1-(c_I+c_D-d)]^2}{8} - \frac{3[1-(c_I+c_D)]^2}{8}. \qquad (14)$$

Second, on the contrary, the investment generates a future loss that is different from the future loss in 4.1.1. In contrast to 4.1.1, here, investing does not lead to entry deterrence. However, it requires the downstream firm to incur switching cost K to deal with the entrant at Period 2. This becomes the future loss to make the investment that does not deter entry:

$$FL(d|K < \hat{K}(d)) = K. \qquad (15)$$

The comparison between equations (14) and (15) implies that the current benefit is increasing in investment efficiency d but the future loss is not. It also implies that the current benefit does not depend on investment specificity K but that the future loss is increasing in K. Therefore, if the investment efficiency is sufficiently high or the switching cost is not too high, then the current benefit is predominant and such investing improves social welfare.

The results of Propositions 3 and 4 are summarized in Figure 5. Note that the curve $K = \hat{K}(d)$, which we derived in Lemma 1, represents the critical values of K above which

Proposition 3 applies and below which Proposition 4 applies. From Figure 5, it can be seen that overall, a relationship-specific investment is socially desirable when its efficiency is sufficiently high. This implies that a high-efficiency investment is more likely to improve social welfare than a low-efficiency one. However, as we explain below, a close look at Figure 5 reveals that this argument does not always hold.

Figure 5 shows that for an intermediate level of investment specificity (i.e., for $K \in (\hat{K}(\overline{d}), \hat{K}(\underline{d}))$), there is a non-monotonic relationship between the investment's social desirability and its degree of efficiency. More precisely, as the investment becomes more efficient, the welfare property of the investment shifts from socially undesirable to desirable, then back to undesirable, and, finally, to desirable.

This result reflects the property of the future loss on investing; the future loss discontinuously changes according to investment efficiency d. In contrast to the current benefit, the future loss differs in the cases when the investment deters and does not deter entry. In the former case, the future loss is derived from the failure of efficient entry owing to the existence of a switching cost (equation (10)). By contrast, when the investment does not deter entry, the future loss is derived from the switching cost itself (equation (15)).

Figure 6 illustrates the property of future loss for an intermediate level of specificity. Figure 6 shows that if investment efficiency d increases above the threshold value d_2, then the future loss increases discontinuously. At this increase of d, the equilibrium outcome at Period 2 moves from entry to entry deterrence. Because entry deterrence leads to higher market prices and to a smaller level of consumer surplus, the change of equilibrium outcome reduces the social welfare at Period 2. This leads to a discontinuous change in future loss.

By comparing the future loss and the current benefit in Figure 6, an increase in the investment efficiency (for $d \in [d_1, d_2)$) first makes the investment socially desirable as the current benefit increases and dominates the future loss. However, a further increase in efficiency (for $d \in [d_2, \overline{d})$) enables the investment to deter entry at Period 2 and this raises the future loss discontinuously, thereby making the investment socially undesirable. Finally, as the investment becomes sufficiently efficient (for $d \geq \overline{d}$), the current benefit on investing dominates the future loss again. Therefore, investing becomes socially desirable.

4.2 Social welfare and investment efficiency

In this subsection, for a given degree of specificity K, we explore how a change in investment efficiency $d \geq 0$ affects the equilibrium social welfare. Intuitively, an improvement in investment efficiency decreases the operating costs and thus increases the equilibrium social welfare. This view seems correct because it is easy to see that W^{INE} and W^{IE} are increasing in d from equations (6) and (11).[22]

However, the following proposition shows that the possibility of entry deterrence triggered by the investment efficiency leads to a non-monotonic relationship between the investment efficiency and equilibrium social welfare:

Proposition 5. *For a given degree of specificity K, the equilibrium social welfare is increasing in investment efficiency d except where it discontinuously decreases by triggering entry deterrence. More precisely, a slight improvement in investment efficiency d around $\hat{d}(K)$ reduces the equilibrium social welfare, where*

$$\hat{d}(K) = \begin{cases} 0 & for\ K \geq \hat{K}(0), \\ \sqrt{(1-(c_E+c_D))^2 - 4K} - (1-(c_I+c_D)) & for\ K < \hat{K}(0). \end{cases} \tag{16}$$

Note that $\hat{d}(K)$ for $K < \hat{K}(0)$ is the inverse function of $\hat{K}(d)$ (see equation (2)). When $K \geq \hat{K}(0)$, the investment contract is rejected and entry occurs under $d = 0$. However, the presence of (even small) investment efficiency enables the contract to be accepted and entry deterrence occurs. Therefore, as the investment efficiency increases from zero to positive, the equilibrium social welfare changes from W^{NIE} to W^{INE}.

By contrast, when $K < \hat{K}(0)$, the investment contract is accepted for any $d \geq 0$. However, whether entry deterrence occurs still depends on the investment efficiency. In this case, by making entry less profitable for the entrant, the higher investment efficiency leads to entry deterrence. Therefore, as the investment efficiency increases above $\hat{d}(K)$, the equilibrium social welfare changes from W^{IE} to W^{INE}.[23] These discontinuous changes for both $K \geq \hat{K}(0)$

[22]From equation (7), it is easy to see that W^{NIE} is independent of investment efficiency d.

[23]If we assume that the downstream firm rejects an investment contract when it is indifferent, the investment is accepted only for $d > 0$ also under $K < \hat{K}(0)$. Therefore, the equilibrium social welfare under $K < \hat{K}(0)$ discontinuously changes not only around $d = \hat{d}(K)$ but also around $d = 0$. In the latter case, as the investment efficiency slightly increases from zero to positive, the equilibrium social welfare under $K < \hat{K}(0)$ changes from W^{NIE} to W^{IE}. Proposition 4 implies that this discontinuous change reduces the equilibrium social welfare.

and $K < \hat{K}(0)$ reduce the equilibrium social welfare.

The results in this section clarify the importance of a dynamic perspective for the discussion of relationship-specific investments. In a static view, the investment efficiency decreases operating costs among vertical relations and has a welfare improving effect. However, in a dynamic view, the investment specificity generates a switching cost to change the trading partner and has a welfare reducing effect regardless of whether the investment deters future entry. In addition, from a dynamic perspective, an improvement in investment efficiency does not necessarily increase social welfare, because it can trigger entry deterrence. Therefore, to consider the welfare effect of the investment, we need to consider these intertemporal effects of the investment. Otherwise, we may obtain misleading predictions.

5 Linear wholesale pricing

In this section, we briefly discuss the case when the upstream firms can use only linear wholesale pricing. For analysis, we make an additional assumption as follows:

Assumption 2.

$$c_I - d < \frac{1 - c_D + c_E}{2}. \tag{17}$$

Note that the right-hand side of this inequality represents a monopoly wholesale price by the entrant. It is easy to see that this inequality is more likely to hold when c_I is small or c_E is large. This assumption implies that the entrant's cost advantage is so small that it cannot set the monopoly price in wholesale competition with the incumbent.[24] Combining Assumptions 1 and 2, under linear wholesale pricing, we restrict our attention to investment efficiency d, which satisfies the following inequality:

$$\max\left\{\frac{(c_I - c_E) - (1 - (c_D + c_I))}{2}, 0\right\} < d < c_I - c_E. \tag{18}$$

In the case of linear wholesale pricing, as the next proposition shows, we have qualitatively the same results as under two-part tariffs but the investment efficiency becomes more important to trigger entry deterrence.

[24] A similar assumption is often made in the exclusive dealing literature (e.g., Fumagalli and Motta, 2006; Abito and Wright, 2008; Kitamura, 2010). Entry deterrence can still occur without this assumption, but the analysis becomes more complicated.

Proposition 6. *Suppose that the upstream firms can only use linear wholesale contracts. Then, the incumbent can deter the efficient entrant through the investment contract if and only if the investment is sufficiently specific and efficient; that is, a pair of* (K, d) *satisfies* $K \geq \hat{K}(d)$ *and* $d > \tilde{d}$ *simultaneously, where*

$$\tilde{d} = \frac{\sqrt{6}-2}{2}(1-(c_D+c_I)) > 0, \tag{19}$$

and where $(\sqrt{6}-2)/2 \approx 0.2247$.

Recall that under two-part tariffs, entry deterrence under the investment contract occurs if and only if $K \geq \hat{K}(d)$ and $d > 0$ (Proposition 2). Unlike under two-part tariffs, entry deterrence under linear wholesale pricing requires a *sufficiently* higher efficiency; that is, $d > \tilde{d} > 0$.[25] Figure 7 illustrates the result of Proposition 6 when $\tilde{d}$ falls within the range of inequality (18).[26]

In the case of linear wholesale pricing, the major difference from the case of two-part tariffs is the presence of a double marginalization problem. Under $K \geq \hat{K}(d)$, when the investment contract is accepted, the incumbent maintains a monopoly throughout both periods and the double marginalization problem reduces the joint profits of the incumbent and the downstream firm in both periods. By contrast, when the investment contract is rejected, that problem reduces the joint profits of the incumbent and the downstream firm only at Period 1 because the wholesale price competition between the incumbent and the entrant eliminates the problem at Period 2. This means that the left-hand side of inequality (5) decreases more significantly than the right-hand side. Therefore, under linear wholesale pricing, condition (5) becomes tighter and the investment needs to be still more efficient than the one under two-part tariffs.

In relation to the welfare implications of the investment under linear wholesale pricing, various cases arise depending on the parameter values and the analysis becomes considerably

[25] $\tilde{d}$ falls within the range of inequality (18) if and only if $\sqrt{6}/2 < (1-(c_D+c_E))/(1-(c_D+c_I)) < \sqrt{6}$. When $(1-(c_D+c_E))/(1-(c_D+c_I)) \leq \sqrt{6}/2$, we have $\tilde{d} \geq c_I - c_E$ and the incumbent can never deter the entrant with the investment contract that satisfies inequality (18). By contrast, when $(1-(c_D+c_E))/(1-(c_D+c_I)) \geq \sqrt{6}$, we have $\tilde{d} \leq [(c_I - c_E) - (1-(c_D+c_I))]/2$ and the incumbent can always deter the entrant under inequality (18).

[26] As Figure 7 shows, under $K < \hat{K}(d)$, the investment contract is accepted but entry occurs regardless of the value of d. This is for the same reason as under two-part tariffs. See footnote 19.

complicated. However, when $\tilde{d}$ falls within the range of inequality (18), we obtain results similar to those under two-part tariffs: first, investing tends to be socially desirable when the investment is not so specific but highly efficient; second, the equilibrium social welfare discontinuously decreases as d exceeds the threshold value $\tilde{d}$.

6 Concluding remarks

This study explored the role of relationship-specific investment as a barrier to efficient entry. The investment generates switching costs to change the trading partner, thereby reducing the downstream firm's ex-post flexibility to deal with the efficient entrant in the future. However, the investment also increases the current joint profits of the incumbent and the downstream firm. We showed that because of *both* the switching costs and an increase in current joint profits, the incumbent could deter the efficient entrant in the future by using an investment contract. We also showed that the investment's welfare effect depends on both its specificity and efficiency and that an increase in the investment efficiency can reduce the equilibrium social welfare.

These results provide an important policy implication. When we discuss the welfare effect of a relationship-specific investment, we need to have a dynamic perspective. From a static perspective, the investment reduces current operating costs among vertical relationships and it seems to be efficient. From a dynamic perspective, however, the investment efficiency itself enables the investment contract to be accepted even when it generates switching costs to change a trading partner in the future. Therefore, the seemingly efficient investment can also be the cause of inefficiency. To evaluate the relationship-specific investment correctly, we need to pay attention to both of these opposing effects on social welfare.

By interpreting our results differently, we obtain an important policy implication that an inefficient firm may survive for a long time because of relationship-specific investments. In the international trade literature, a number of economists argue that vertical relationships within Japanese companies, known as *keiretsu*, play the role of a structural trade barrier (e.g., Lawrence, 1991, 1993a, and 1993b; Spencer and Qiu, 2001).[27] One important feature of

[27] In the Structural Impediments Initiative (SII) between Japan and the United States during 1989–1990, particular attention was paid to the role of *keiretsu*. The U.S. government argued that *keiretsu* linkages made

keiretsu is that relationship-specific investments are common among its members, for example, as in the auto industry. Our results might be one possible explanation of why foreign firms cannot easily enter the Japanese market in the presence of relationship-specific investments within *keiretsu* groups.

Several outstanding issues require future research. First, there is a concern about the generality of our results. Although our analysis is in terms of a parametric example, the results may extend to more general settings. Second, a concern about the role of strategic interaction between downstream firms exists. In our model, a downstream firm is a monopolist in its final product market. However, the competition between downstream firms is an important research topic. We predict that, as discussed by Simpson and Wickelgren (2007) and Abito and Wright (2008) in their studies on anticompetitive exclusive dealing, competition between downstream firms enables the upstream incumbent to deter efficient entry under the relationship-specific investment more easily.

Finally, a concern about the incumbent's strategic behavior exists. According to our results, the incumbent may have an incentive to control the investment specificity. For example, its investment may be too specific. We trust that this study will assist future researchers in addressing these issues.

A Equilibria in the subgame following Period 1.1

In this Appendix, we analyze the equilibrium in each of the possible subgames after Period 1.1. Especially, we explore the wholesale contracts offered by upstream firms, realized profit of each firm, and entry behavior of the entrant in the equilibrium of each subgame.

foreign entry into the Japanese market difficult. At the end of the SII talks, the Japanese government agreed to strengthen monitoring by its Fair Trade Commission of transactions among *keiretsu* firms and to take the necessary steps toward eliminating any restraints on competition that might arise from their business practices (Lawrence, 1993b).

A.1 When the downstream firm accepts the investment contract at Period 1.1

First, suppose that the downstream firm accepts the relationship-specific investment at Period 1.1. At Period 1.2, to solve the double marginalization problem, the incumbent sets its per-unit wholesale price to equal its marginal cost and extracts all of the downstream firm's profit through the fixed fee; that is, the incumbent offers the following wholesale contract:

$$(w_{I|t=1}, F_{I|t=1}) = \left(c_I, \frac{[1-(c_I+c_D-d)]^2}{4}\right). \tag{20}$$

Therefore, the incumbent and the downstream firm respectively yield the following operating profits at Period 1.3:

$$\begin{aligned} \Pi^a_{I|t=1} &= \frac{[1-(c_I+c_D-d)]^2}{4}, \\ \pi^a_{D|t=1} &= 0. \end{aligned} \tag{21}$$

At Period 2.1, the entrant decides whether to enter the upstream market. If the entrant does not enter the upstream market, the incumbent monopolizes the market and offers the same wholesale contract as at Period 1. Therefore, the equilibrium operating profits for the incumbent, the entrant, and the downstream firm respectively become

$$\begin{aligned} \Pi^{a(out)}_{I|t=2} &= \frac{[1-(c_I+c_D-d)]^2}{4}, \\ \Pi^{a(out)}_{E|t=2} &= 0, \\ \pi^{a(out)}_{D|t=2} &= 0. \end{aligned} \tag{22}$$

By contrast, when the entrant enters the upstream market, the incumbent and the entrant compete for the downstream firm at Period 2.2. While the incumbent's best offer $(w_{I|t=2}, F_{I|t=2}) = (c_I, 0)$ leaves the downstream firm with $[1-(c_I+c_D-d)]^2/4$, the entrant's best offer $(w_{E|t=2}, F_{E|t=2}) = (c_E, 0)$ leaves the downstream firm with $[1-(c_E+c_D)]^2/4 - K$.[28] Therefore, which upstream firm profitably captures the downstream firm depends on the specificity and efficiency of the investment. First, if $[1-(c_I+c_D-d)]^2/4 \geq [1-(c_E+c_D)]^2/4 - K$, which is equivalent to

[28]Note that since the downstream firm has accepted the investment contract at Period 1.1, it must incur switching costs to change the trading partner to the entrant at Period 2.

$K \geq \hat{K}(d)$, the downstream firm's switching costs are so high that the incumbent can profitably attract the downstream firm.[29] Anticipating that the post-entry profit is zero, the entrant does not enter the market in the equilibrium (owing to negligible entry costs). Therefore, in this case, the equilibrium profit of each firm at Period 2 is given by equation (22).

Second, if $[1-(c_I+c_D-d)]^2/4 < [1-(c_E+c_D)]^2/4-K$, which is equivalent to $K < \hat{K}(d)$, the level of switching costs is low enough for the entrant to profitably attract the downstream firm. In this case, the incumbent and the entrant offer the following wholesale contracts:

$$\begin{aligned} (w_{I|t=2}, F_{I|t=2}) &= (c_I, 0), \\ (w_{E|t=2}, F_{E|t=2}) &= \left(c_E, \frac{[1-(c_E+c_D)]^2}{4} - \left[\frac{[1-(c_I+c_D-d)]^2}{4} + K + \varepsilon\right]\right), \end{aligned} \tag{23}$$

where ε is some infinitesimally small number.[30] At Period 2.3, the downstream firm chooses the entrant as the trading partner. At Period 2.4, each firm yields the following operating profits:

$$\begin{aligned} \Pi^{a(in)}_{I|t=2} &= 0, \\ \Pi^{a(in)}_{E|t=2} &= \frac{[1-(c_E+c_D)]^2}{4} - \left[\frac{[1-(c_I+c_D-d)]^2}{4} + K + \varepsilon\right], \\ \pi^{a(in)}_{D|t=2} &= \frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon. \end{aligned} \tag{24}$$

Therefore, anticipating that the post-entry profit is strictly positive, the entrant enters the market at Period 2.1 in the equilibrium.

A.2 When the downstream firm rejects the investment contract at Period 1.1

Next, suppose that the downstream firm rejects the relationship-specific investment at Period 1.1. At Period 1.2, the incumbent offers the following wholesale contract:

$$(w_{I|t=1}, F_{I|t=1}) = \left(c_I, \frac{[1-(c_I+c_D)]^2}{4}\right). \tag{25}$$

[29]The incumbent can do this by offering $w_{I|t=2} = c_I$ and choosing the fixed fee that makes the downstream firm indifferent between its offer and the entrant's: $F_{I|t=2} = [1-(c_I+c_D-d)]^2/4 - \left[[1-(c_E+c_D)]^2/4 - K\right]$.

[30]The entrant sets the per-unit wholesale price at the marginal cost level and chooses the fixed fee that leaves the downstream firm with slightly more profit than the incumbent's best offer.

Therefore, at Period 1.3, the incumbent and the downstream firm respectively yield:

$$\begin{aligned}\Pi^r_{I|t=1} &= \frac{[1-(c_I+c_D)]^2}{4},\\ \pi^r_{D|t=1} &= 0.\end{aligned} \tag{26}$$

At Period 2.1, the entrant decides whether to enter the market. If the entrant enters the upstream market, the incumbent and the entrant compete for the downstream firm at Period 2.2. While the incumbent's best offer leaves the downstream firm with $[1-(c_I+c_D-d)]^2/4$, the entrant's best offer leaves the downstream firm with $[1-(c_E+c_D)]^2/4$.[31] Therefore, the entrant can profitably capture the downstream firm. In the equilibrium, the incumbent and the entrant respectively offer the following wholesale contracts:

$$\begin{aligned}(w_{I|t=2}, F_{I|t=2}) &= (c_I, 0),\\ (w_{E|t=2}, F_{E|t=2}) &= \left(c_E, \frac{[1-(c_E+c_D)]^2}{4} - \left[\frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon\right]\right).\end{aligned} \tag{27}$$

Then, the downstream firm decides to deal with the entrant and each firm yields the following operating profits:

$$\begin{aligned}\Pi^r_{I|t=2} &= 0,\\ \Pi^r_{E|t=2} &= \frac{[1-(c_E+c_D)]^2}{4} - \left[\frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon\right],\\ \pi^r_{D|t=2} &= \frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon.\end{aligned} \tag{28}$$

Therefore, anticipating the positive post-entry profit, the entrant enters the market at Period 2.1 in the equilibrium.

B Proofs

Proof of Lemma 1

Note that since we assume negligibly small entry costs, the entrant does not enter the market if and only if its post-entry profit is less than or equal to zero. If the entrant enters the market, the incumbent and the entrant compete for the downstream firm at Period 2.2. While the

[31] Since the downstream firm has rejected the investment contract at Period 1.1, there are no switching costs for the downstream firm to change its trading partner.

incumbent's best offer leaves the downstream firm with $[1-(c_I+c_D-d)]^2/4$, the entrant's best offer leaves the downstream firm with $[1-(c_E+c_D)]^2/4-K$. Therefore, if

$$\frac{[1-(c_I+c_D-d)]^2}{4} \geq \frac{[1-(c_E+c_D)]^2}{4} - K \tag{29}$$

holds, the incumbent profitably attracts the downstream firm and the entrant's post-entry profit becomes zero. By solving this inequality with respect to K, we have $K \geq \hat{K}(d)$.

Q.E.D.

Proof of Proposition 1

See the proof of Proposition 2.

Q.E.D.

Proof of Proposition 2

Recall that the relationship-specific investment deters the entrant if and only if both of inequalities $K \geq \hat{K}(d)$ and (5) hold. Substituting equilibrium profits (see Table 2 or Appendix A) into inequality (5), it can be rewritten as follows:

$$2\left(\frac{[1-(c_I+c_D-d)]^2}{4}\right) \geq \frac{[1-(c_I+c_D)]^2}{4} + \frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon. \tag{30}$$

It is easy to see that this inequality holds if and only if $d > 0$. Therefore, when $d = 0$, inequality (30) does not hold and incumbent cannot profitably induce the downstream firm to accept the investment contract, even if $K \geq \hat{K}(d)$ under $d = 0$ is satisfied (Proposition 1). On the other hand, when $d > 0$, inequality (30) always holds and the incumbent can deter the efficient entrant if and only if $K \geq \hat{K}(d)$ is satisfied (Proposition 2).

Q.E.D.

Proof of Proposition 3

From equations (6) and (7), we have

$$\begin{aligned} W^{INE} \gtreqless W^{NIE} &\Leftrightarrow \frac{3[1-(c_I+c_D-d)]^2}{4} \gtreqless \frac{3[1-(c_I+c_D)]^2}{8} + \frac{3[1-(c_E+c_D)]^2}{8} \\ &\Leftrightarrow d \gtreqless \sqrt{\frac{[1-(c_I+c_D)]^2+[1-(c_E+c_D)]^2}{2}} - (1-(c_I+c_D)). \end{aligned} \tag{31}$$

Let $\overline{d}$ denote the right-hand side of last inequality. Then, we have $W^{INE} \gtreqless W^{NIE}$ if and only if $d \gtreqless \overline{d}$.

Q.E.D.

Proof of Proposition 4

From equations (7) and (11), we have

$$\begin{aligned} W^{NIE} \gtreqless W^{IE} &\Leftrightarrow \frac{3[1-(c_I+c_D)]^2}{8} \gtreqless \frac{3[1-(c_I+c_D-d)]^2}{8} - K \\ &\Leftrightarrow K \gtreqless \frac{3d((1-(c_I+c_D-d))+(1-(c_I+c_D)))}{8}. \end{aligned} \tag{32}$$

Let $\tilde{K}(d)$ denote the right-hand side of last inequality. It is easy to see that $\partial\tilde{K}(d)/\partial d > 0$ and $\tilde{K}(0) = 0$. Recall that we now consider the case of $K < \hat{K}(d)$. From the properties of $\hat{K}(d)$ and $\tilde{K}(d)$, there exists $\underline{d} \in (0, c_I - c_E)$ such that $\hat{K}(\underline{d}) = \tilde{K}(\underline{d})$. Then, $\underline{d}$ can be obtained as equation (12) and it is easy to see that $\underline{d} < \overline{d}$. When $d > \underline{d}$, we have $K < \hat{K}(d) < \tilde{K}(d)$. Therefore, $W^{NIE} < W^{IE}$ always holds. On the other hand, when $d \leq \underline{d}$, we have $\hat{K}(d) \geq \tilde{K}(d)$. Therefore, we have $W^{NIE} \gtreqless W^{IE}$ if and only if $K \gtreqless \tilde{K}(d)$.

Q.E.D.

Proof of Proposition 5

We show that a slight improvement in investment efficiency d around $\hat{d}(K)$ discontinuously reduces the equilibrium social welfare. Since the reasons behind this result differ depending on $K \geq \hat{K}(0)$ and $K < \hat{K}(0)$, we explore these two cases separately. To indicate the dependence on investment efficiency d, we denote welfare levels when the investment is made at Period 1 as $W^{INE}(d)$ and $W^{IE}(d)$.

First, we show that the equilibrium social welfare under $K \geq \hat{K}(0)$ discontinuously dicreases at $d = \hat{d}(K) = 0$. Note that the equilibrium social welfare in this case is equal to W^{NIE} for $d = 0$ and $W^{INE}(d)$ for $d \in (0, c_I - c_E)$. Since Proposition 3 shows $W^{NIE} > W^{INE}(d)$ for a sufficiently small $d > 0$, it can be seen that a slight improvement in investment efficiency from $d = 0$ reduces social welfare in the equilibrium.

Next, we show that the equilibrium social welfare under $K < \hat{K}(0)$ discontinuously dicreases at $d = \hat{d}(K) = \sqrt{(1-(c_E+c_D))^2 - 4K} - (1-(c_I+c_D))$. Note that the equilibrium social welfare in this case is equal to $W^{IE}(d)$ for $d \in [0, \hat{d}(K))$ and $W^{INE}(d)$ for $d \in [\hat{d}(K), c_I - c_E)$. From equations (6) and (11), we have

$$\begin{aligned} \lim_{d \to \hat{d}(K)-0} W^{IE}(d) &= \frac{3(1-(c_E+c_D))^2}{4} - \frac{5}{2}K, \\ W^{INE}(\hat{d}(K)) &= \frac{3(1-(c_E+c_D))^2}{4} - 3K, \end{aligned} \tag{33}$$

and it is easy to see that $\lim_{d \to \hat{d}(K)-0} W^{IE}(d) > W^{INE}(\hat{d}(K))$. Therefore, the equilibrium social welfare discontinuously decreases when d exceeds or even equals $\hat{d}(K)$.

Q.E.D.

Proof of Proposition 6

As in the case of two-part tariffs, for the existence of entry deterrence under linear wholesale pricing, the two conditions mentioned in Subsection 3.1 must be satisfied simultaneously.

First, entry at Period 2.1 must be unprofitable for the entrant if the investment contract is accepted at Period 1.1. Note that the entrant does not enter the market if and only if its post-entry profit is less than or equal to zero. If the entrant enters the market, the incumbent and the entrant compete for the downstream firm at Period 2.2. While the incumbent's best offer $w_{I|t=2} = c_I$ leaves the downstream firm with $[1-(c_I+c_D-d)]^2/4$, the entrant's best offer $w_{E|t=2} = c_E$ leaves the downstream firm with $[1-(c_E+c_D)]^2/4 - K$. Therefore, if

$$\frac{[1-(c_I+c_D-d)]^2}{4} \geq \frac{[1-(c_E+c_D)]^2}{4} - K \tag{34}$$

holds, the incumbent profitably attracts the downstream firm and the entrant's post-entry profit becomes zero. By solving this inequality with respect to K, we have $K \geq \hat{K}(d)$.

Next, supposing that $K \geq \hat{K}(d)$ is satisfied, an investment contract which deters the efficient entrant must be profitable for both the incumbent and the downstream firm, that is, inequality (5) must be satisfied. Below, we derive the equilibrium profit of each firm in the possible subgames after Period 1.1.

First, suppose that the downstream firm accepts the investment contract at Period 1.1. At Period 1.2, as an upstream monopolist, the incumbent offers $w_{I|t=1} = (1 - (c_D - d) + c_I)/2$. Therefore, the incumbent and the downstream firm respectively yield the following operating profits at Period 1.3:

$$\begin{aligned} \Pi^a_{I|t=1} &= \frac{[1 - (c_I + c_D - d)]^2}{8}, \\ \pi^a_{D|t=1} &= \frac{[1 - (c_I + c_D - d)]^2}{16}. \end{aligned} \tag{35}$$

At Period 2.1, assuming $K \geq \hat{K}(d)$ holds, the entrant does not enter the upstream market. In this case, the incumbent offers the same wholesale price as at Period 1, and the equilibrium operating profits for the incumbent, the entrant, and the downstream firm respectively become

$$\begin{aligned} \Pi^{a(out)}_{I|t=2} &= \frac{[1 - (c_I + c_D - d)]^2}{8}, \\ \Pi^{a(out)}_{E|t=2} &= 0, \\ \pi^{a(out)}_{D|t=2} &= \frac{[1 - (c_I + c_D - d)]^2}{16}. \end{aligned} \tag{36}$$

Suppose next that the downstream firm rejects the investment contract at Period 1.1. At Period 1.2, the incumbent offers $w_{I|t=1} = (1 - c_D + c_I)/2$. Therefore, at Period 1.3, the incumbent and the downstream firm respectively yield:

$$\begin{aligned} \Pi^r_{I|t=1} &= \frac{[1 - (c_I + c_D)]^2}{8}, \\ \pi^r_{D|t=1} &= \frac{[1 - (c_I + c_D)]^2}{16}. \end{aligned} \tag{37}$$

At Period 2.1, the entrant makes the entry decision. When it enters the upstream market, the incumbent and the entrant compete for the downstream firm at Period 2.2. While the incumbent's best offer $w_{I|t=2} = c_I$ leaves the downstream firm with $[1 - (c_I + c_D - d)]^2/4$, the entrant's best offer $w_{E|t=2} = c_E$ leaves the downstream firm with $[1 - (c_E + c_D)]^2/4$. From Assumption 1, it is easy to see that the entrant can profitably capture the downstream firm. Therefore, in equilibrium, the entrant always enters the market and the entrant's wholesale price becomes $w_{E|t=2} = c_I - d - \varepsilon$, where ε is some infinitesimally small number, from

Assumption 2. Then, each firm yields the following operating profits:

$$\begin{aligned}
\Pi^r_{I|t=2} &= 0, \\
\Pi^r_{E|t=2} &= \frac{(c_I - c_E - d)(1 - (c_I + c_D - d))}{2}, \\
\pi^r_{D|t=2} &= \frac{[1 - (c_I + c_D - d)]^2}{4} + \varepsilon.
\end{aligned} \tag{38}$$

By substituting above equilibrium profits in each case into inequality (5), it can be rewritten as follows:

$$2\left(\frac{3[1 - (c_I + c_D - d)]^2}{16}\right) \geq \frac{3[1 - (c_I + c_D)]^2}{16} + \frac{[1 - (c_I + c_D - d)]^2}{4} + \varepsilon. \tag{39}$$

By rearranging this inequality, we have inequality (19). Therefore, under linear wholesale pricing, the incumbent can deter the efficient entrant if and only if inequalities $K \geq \hat{K}(d)$ and (19) are both satisfied.

Q.E.D.

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	When *D* accepts the investment at Period 1.1	**When *D* rejects the investment at Period 1.1**
Period 1	$c_I + c_D - d$	$c_I + c_D$
Period 2	**When *D* deals with *I*:** $c_I + c_D - d$ **When *D* deals with *E*:** $c_E + c_D$ (*D* must incur the switching costs K)	**When *D* deals with *I*:** $c_I + c_D - d$ **When *D* deals with *E*:** $c_E + c_D$ (There is no switching cost for *D*)

Table 1: Downstream firm's total marginal cost at each period in each subgame

	When *D* accepts the investment at Period 1.1	**When *D* rejects the investment at Period 1.1**
Period 1	$\Pi^{a}_{I\|t=1} = \frac{[1-(c_I+c_D-d)]^2}{4}$, $\pi^{a}_{D\|t=1} = 0$	$\Pi^{r}_{I\|t=1} = \frac{[1-(c_I+c_D)]^2}{4}$, $\pi^{r}_{D\|t=1} = 0$
Period 2	**If** $K \geq \widehat{K}(d)$, ***E* does not enter the market:** $\Pi^{a(out)}_{I\|t=2} = \frac{[1-(c_I+c_D-d\ )]^2}{4}$ $\Pi^{a(out)}_{E\|t=2} = 0$ $\pi^{a(out)}_{D\|t=2} = 0$	***E* always enters the market:** $\Pi^{r}_{I\|t=2} = 0$ $\Pi^{r}_{E\|t=2} = \frac{[1-(c_E+c_D)]^2}{4} - \pi^{r}_{D\|t=2}$ $\pi^{r}_{D\|t=2} = \frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon$
	If $K < \widehat{K}(d)$, ***E* enters the market:** $\Pi^{a(in)}_{I\|t=2} = 0$ $\Pi^{a(in)}_{E\|t=2} = \frac{[1-(c_E+c_D)]^2}{4} - \pi^{a(in)}_{D\|t=2} - K$ $\pi^{a(in)}_{D\|t=2} = \frac{[1-(c_I+c_D-d)]^2}{4} + \varepsilon$	

Table 2: Equilibrium profits and equilibrium entry behavior in the subgames after Period 1.1
Note: ε is some infinitesimally small number.

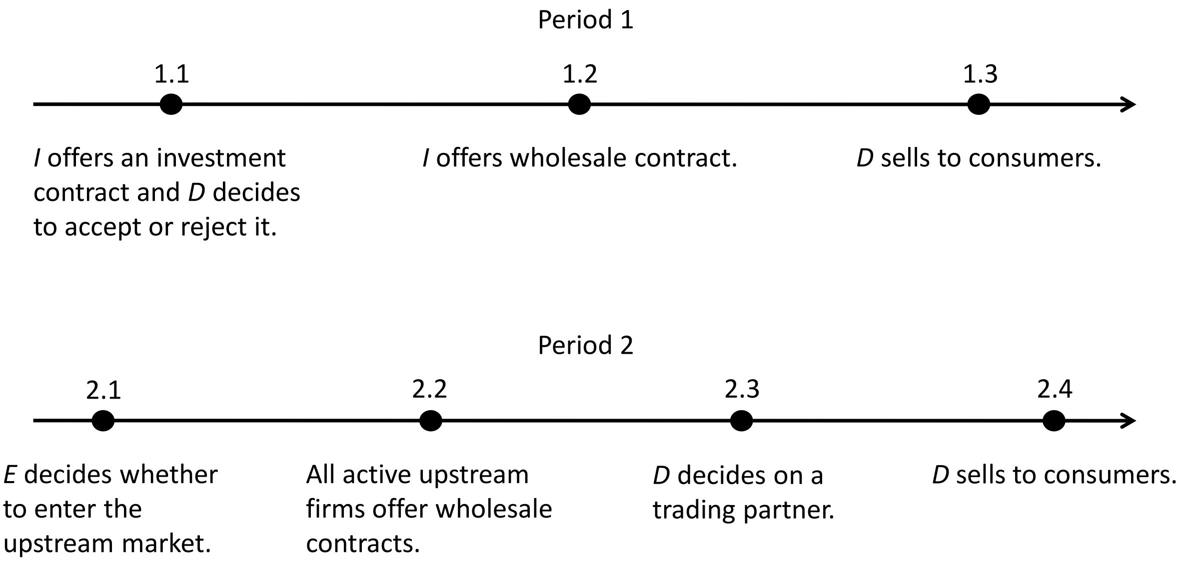

Figure 1: Timeline

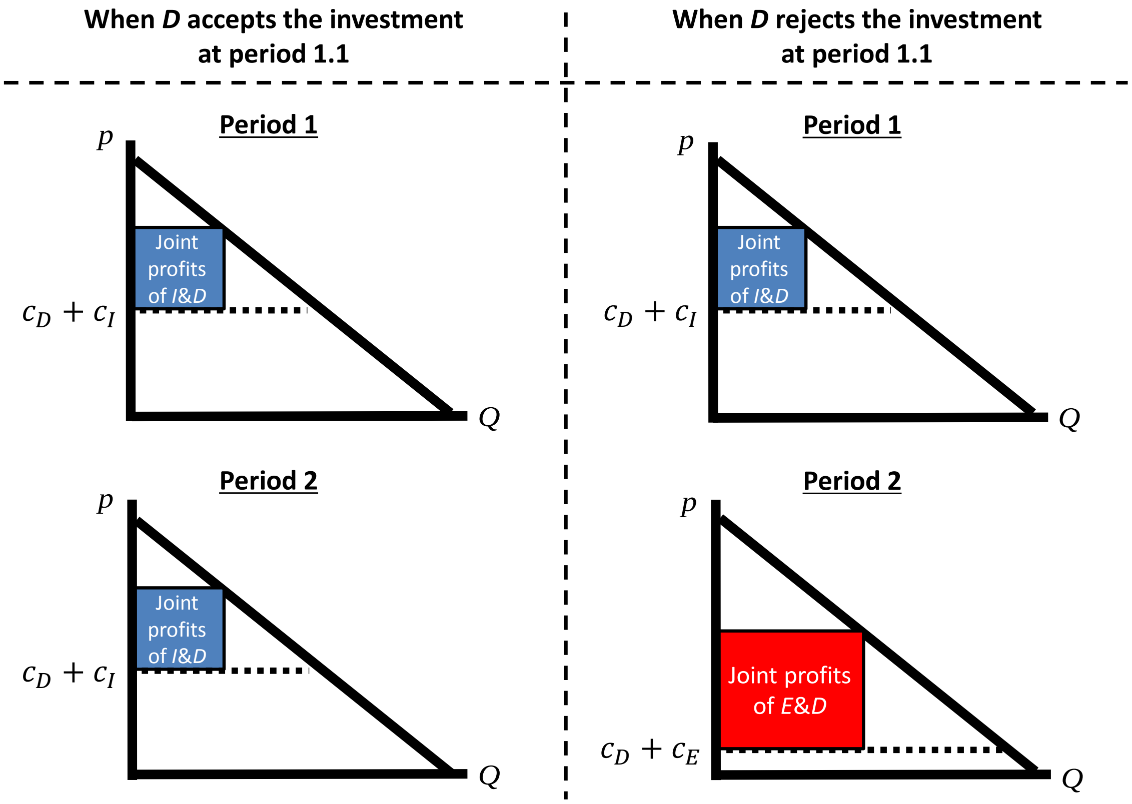

Figure 2: Joint profits of upstream and downstream firms
when investment is not efficient

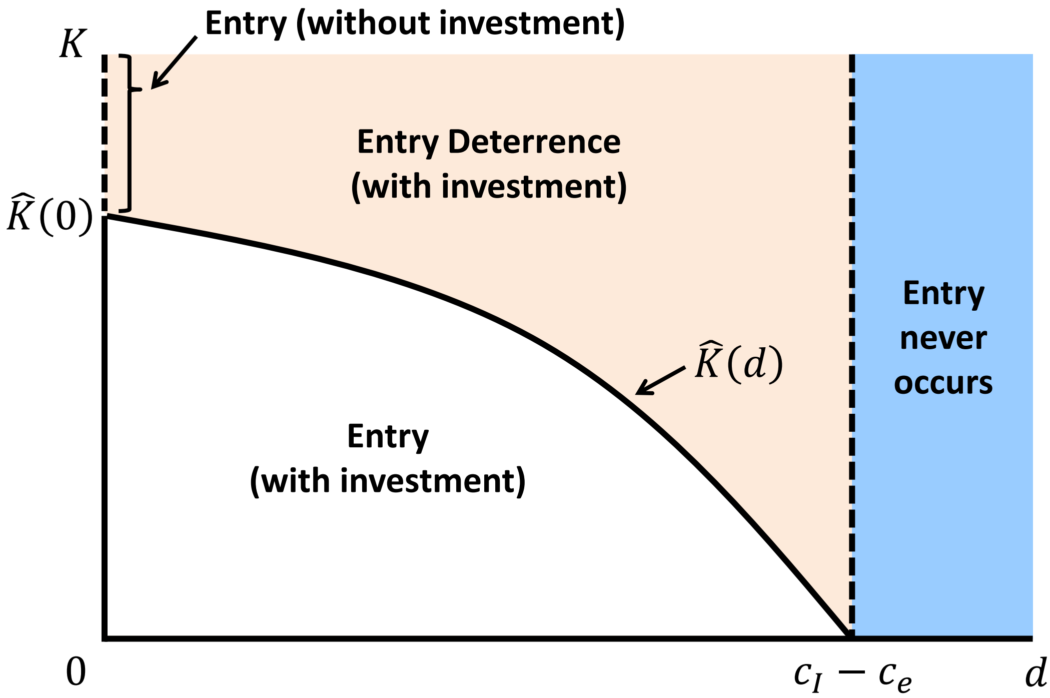

Figure 3: Area of entry deterrence

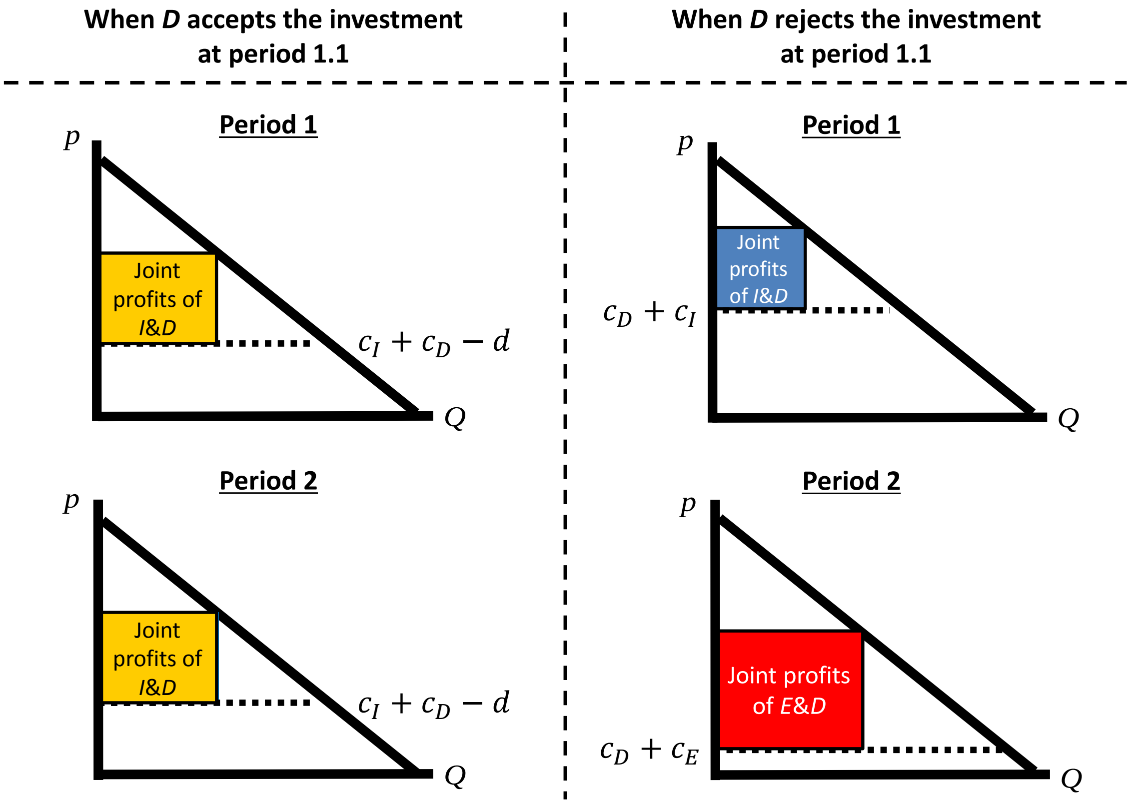

Figure 4: Joint profits of upstream and downstream firms
when investment is efficient

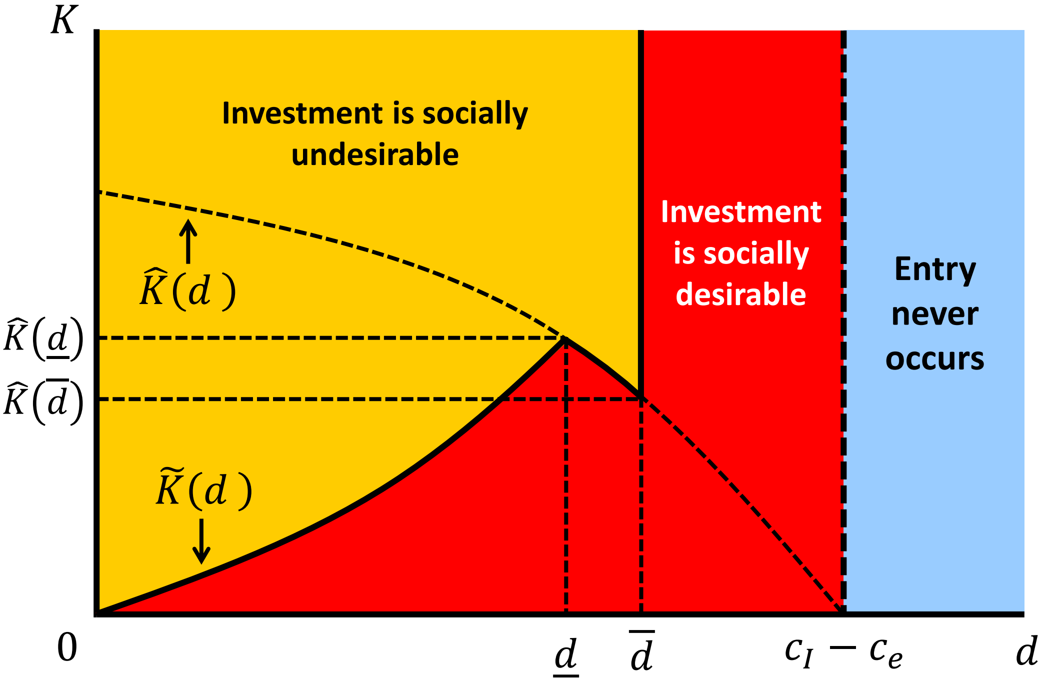

Figure 5: Social desirability of the relationship-specific investment

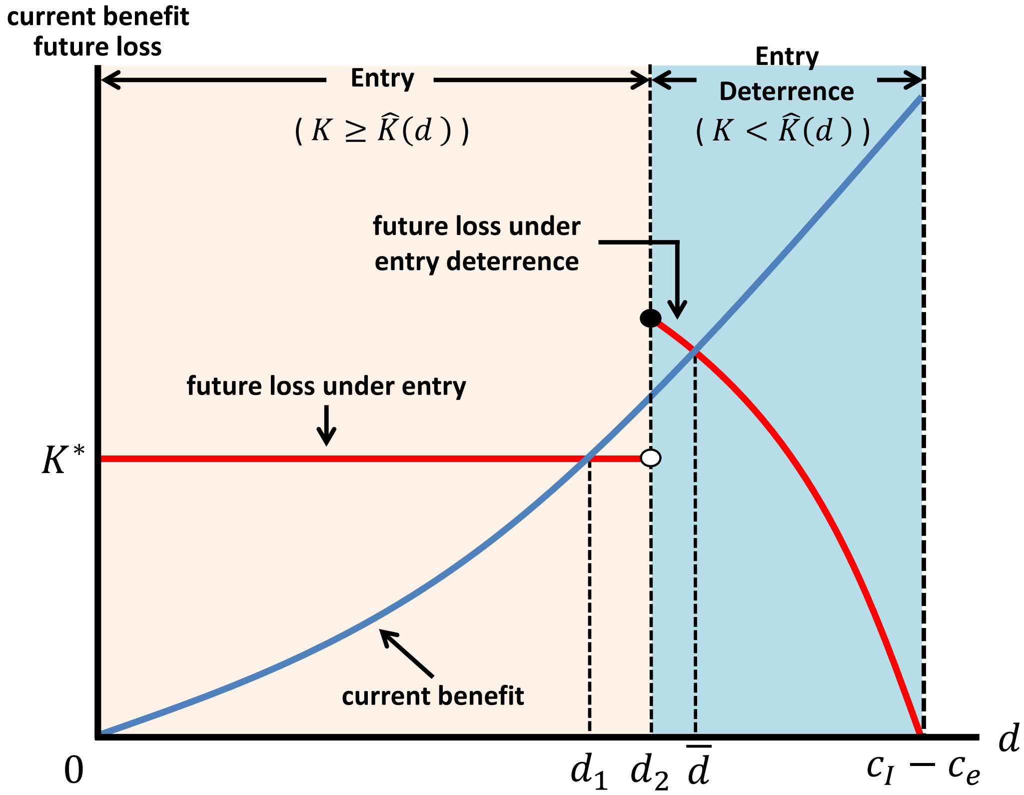

Figure 6: Current benefit and future loss

for an intermediate level of the specificity $K^* \in \left(\widehat{K}(\overline{d}), \widehat{K}(\underline{d})\right)$

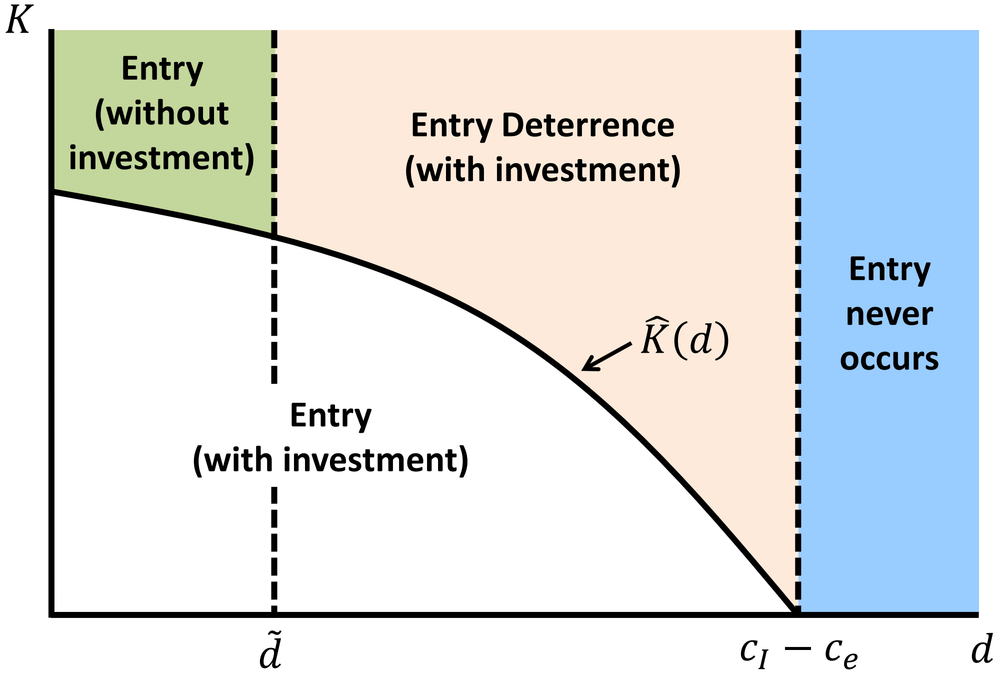

Figure 7: Area of entry deterrence under linear wholesale pricing