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How Does Downstream Firms' Efficiency Affect Exclusive Supply Agreements?

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Abstract

We develop a bilateral monopoly model with a downstream entrant to examine anti-competitive exclusive supply contracts that prevent the upstream supplier from selling inputs to the downstream entrant. When the entrant is more efficient and needs a lesser amount of the input that is produced by the supplier than does the incumbent, the input demand may not increase significantly following the entry. Therefore, the socially efficient entry does not increase the supplier's profits significantly, which allows the downstream incumbent to deter socially efficient entry through an exclusive supply contract. This result holds even in the simplest framework, which is composed of a single seller, buyer, and entrant.

Keywords Antitrust policy · Entry deterrence · Exclusive supply contracts · Transformational technology · Input price discrimination

JEL Classification L12 · L41 · L42 · C72.

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1 Introduction

We often observe exclusive supply contracts between an input supplier and a final product producer in antitrust cases. For example, a large-scale pharmaceutical company enforced 10-year exclusive supply agreements for an essential ingredient.[1] In the relationship between a final good producer and retailers, an established toy retailer also prevented toy manufacturers from selling to warehouse clubs.[2] More recently, an online gaming company prohibited mobile game developers from providing their games through a rival online gaming company.[3]

Despite these observations, in the literature of anticompetitive exclusive dealing, many papers focus on exclusion in upstream markets. This study focuses on exclusion in downstream markets.

We construct a model of anticompetitive exclusive supply agreements in which a downstream incumbent prevents an upstream supplier from selling inputs to a potential downstream entrant whose efficiency is higher than the incumbent in terms of the amount of necessary inputs produced by the upstream supplier. We can interpret the efficiency difference as differences in the defect rate in the relationships between an input supplier and final product producers. The technology difference can also be explained by lower input use or lower wasted materials. The source of such efficiency differences can become a crucial issue for the upstream supplier because the efficiency of downstream firms can affect the demand for the input that is produced by the upstream supplier.

Under linear wholesale pricing (Iozzi & Valletti, 2014), we show that the downstream incumbent can deter socially efficient entry through exclusive supply contracts even in the simplest setting, where a single seller, buyer, and entrant exist. More specifically: When the entrant and incumbent have similar efficiency levels, we never have exclusion results; however, as the entrant's efficiency increases, exclusion can occur. The results imply that anticompetitive exclusive supply agreements are possible when the downstream entrant has a lower defect rate or other significant efficiency advantage vis-à-vis the downstream incumbent.

To understand our results, consider the impact of socially efficient entry: Socially efficient entry generates downstream competition and increases the final product output, which increases the demand for inputs that are produced by the upstream supplier and, consequently, its profit. However, as the entrant becomes more efficient, it demands a smaller quantity of the input that is produced by the upstream supplier. Therefore, the entry does not significantly increase the input demand. As a result, the upstream supplier cannot earn higher profits, which allows the

[1] *FTC v. Mylan Laboratories, Inc., Cambrex Corporation, Profarmaco S.r.l., and Gyma Laboratories of America, Inc*, No.X990015-1 (http://www.ftc.gov/os/caselist/x990015ddc.shtm).

[2] *Toys"R"Us, Inc., v. FTC* 0910082 (https://www.ftc.gov/enforcement/cases-proceedings/091-0082/toys-r-us-inc).

[3] See *Cease and Desist Order against DeNA Co., Ltd* (http://www.jftc.go.jp/en/pressreleases/yearly-2011/jun/individual-000427.html).

downstream incumbent to deter socially efficient entry by profitably compensating the upstream supplier.

The findings here provide the following important implication for anticompetitive exclusive dealing: When we consider entry deterrence in downstream markets, the source of differences in efficiency among downstream firms can be an important issue for upstream suppliers. Generally, upstream suppliers welcome the entry of efficient downstream firms because the efficiency of downstream firms usually increases input demand through lower downstream prices. However, if downstream entrants are more efficient in production technology so as to use fewer inputs that are produced by upstream suppliers, those upstream suppliers are less enthusiastic about the entrants' technological efficiency, which may lead to anticompetitive exclusive dealing.

We then extend our analysis by allowing input price discrimination and two-part tariffs to contribute to the literature of input price discrimination (Katz, 1987; DeGraba, 1990; Yoshida, 2000; Inderst & Shaffer, 2009). We show that input price discrimination and two-part tariffs reduce the possibility of exclusion because the upstream supplier can extract all of the industry profits. However, if input price discrimination is imperfect because of input arbitrage between the downstream firms, the exclusion result can be sustainable. Thus, anticompetitive exclusive supply agreements are more likely to arise when arbitrage is easy because of higher product storability or when a dominant downstream firm offers a price parity clause, which induces the supplier to use uniform pricing.

The structure of the paper is as follows: Sect. 2 presents a literature review on anticompetitive exclusive dealing. Section 3 contains the preliminaries. Section 4 provides the main results. Section 5 provides some discussion. Section 6 offers concluding remarks. Appendix 1 introduces the property of general demand. Appendix 2 presents the proofs of results.

2 Literature Review

This study is related to the literature on anticompetitive exclusive dealing.[4] Below, we explain the literature on exclusive dealing and our contribution to it.

In the literature on anticompetitive exclusive contracts, with the use of a simple setting with an upstream incumbent, an upstream entrant, and a downstream buyer, the Chicago School argument in the 1970s (Posner, 1976; Bork, 1978) points out that rational economic agents never sign exclusive contracts for anticompetitive reasons, if we consider all members' participation constraints in the contracting party.[5]

[4] Certain studies examine procompetitive exclusive dealing. See Marvel (1982), Besanko and Perry (1993), Segal and Whinston (2000a), de Meza and Selvaggi (2007), de Fontenay et al. (2010), and Chen and Sappington (2011).

[5] The aim of exclusive contracts is similar to strategic behavior to deter entry. For instance, Gilbert and Newbery (1982) consider the incumbent's entry deterrence through holding a patent and show that the incumbent acquires a patent to keep the monopoly if the monopoly profits are higher than the industry profits under the duopoly. The number of stakeholders in entry deterrence (1) is different from that in

The argument casts doubt about an intuitive view that exclusive contracts can deter efficient entrants,[6]

In rebuttal to the Chicago School argument, many papers find that rational economic agents agree with exclusive contracts for anticompetitive reasons in certain market environments. We categorize those papers into the following three: (1) increasing the number of downstream buyers from one; (2) changing the nature of upstream competition; (3) converting the vertical relations and focusing on downstream entry.[7] Our paper is closely related to the third category.

The papers in the first category add other downstream buyers to the Chicago School argument. Some of those papers focus on the presence of scale economies, wherein the upstream entrant needs a certain number of buyers to cover fixed costs (Rasmusen et al., 1991; Segal & Whinston, 2000b). Also, other papers consider downstream competition, wherein the upstream entry does not generate considerably high profits for downstream firms because downstream competition transfers most of the gain from entry to final consumers, who are third parties (Simpson & Wickelgren, 2007; Abito & Wright, 2008).[8]

The literature in the first category continues to evolve: In the original setting in the Chicago School argument (an ex-ante bilateral monopoly) with an inefficient outside retailer that can be an outside option for the efficient entrant, Kitamura et al. (2023a) show that excluding an upstream entry emerges if the efficiency of the upstream entrant is high. In addition, by extending the Chicago School setting to the case of durable goods, Kitamura et al. (2023b) show that exclusive contracts can be signed to deter upstream entry because such entry exacerbates the intertemporal competition between a downstream durable goods monopolist now and itself in the future.

The papers in the second category, which focus on the nature of upstream competition, point out that exclusion is attainable when: the incumbent supplier can set liquidated damages in the event of entry (Aghion & Bolton, 1987); the entrant is capacity constrained (Yong, 1996); suppliers compete à la Cournot (Farrell, 2005); suppliers can merge (Fumagalli et al., 2009); the incumbent supplier makes

Footnote 5 (continued)
exclusive contracts (more than 1), which leads to the difference in the difficulties of achieving monopoly positions in the cases of entry deterrence and exclusive contracts.

[6] There are other types of contracts that involve vertical restraints: loyalty rebates; slotting fees; resale price maintenance; quantity fixing; and so on (see, for example, Rey and Tirole, 1986; Rey and Vergé 2010, Asker and Bar-Isaac 2014).

[7] Bernheim and Whinston (1998), for instance, explore market circumstances under which an exclusive contract excludes rival incumbents.

[8] In the literature on exclusion with downstream competition, Fumagalli and Motta (2006) show that participation fees to remain active in the downstream market play a crucial role in exclusion if buyers are undifferentiated Bertrand competitors. See also Wright (2009), who further discusses the result of Fumagalli and Motta (2006) in the case of two-part tariffs. For an extension of these studies, see Wright (2008), Argenton (2010), Kitamura (2010), DeGraba (2013), and Gratz and Reisinger (2013).

relationship-specific investments (Fumagalli et al., 2012); or there exists a complementary input supplier with market power (Kitamura et al., 2018a).[9]

The papers in the third category discuss downstream entrants.[10] Comanor and Rey (2000) consider a market with an incumbent supplier, a downstream incumbent having external suppliers, and a downstream entrant. The existence of external suppliers limits the downstream incumbent's purchase price offered to the incumbent supplier, inducing the efficient downstream entrant to offer a low purchase price in response to the incumbent's offer. Therefore, the upstream supplier cannot earn higher profits even when efficient entry occurs, which induces the upstream supplier to engage in anticompetitive exclusive dealing. Oki and Yanagawa (2011) also show an exclusion outcome in a market with two upstream suppliers.

By contrast, the present study considers neither the outside option of the downstream incumbent nor upstream competition but explores how the difference between the downstream firms' production technologies affects anticompetitive exclusive supply agreements.

3 Preliminaries

This section develops the basic environment of the model. For convenience, we consider the relationship between input suppliers and final product producers, although we can also apply this model to the relationship between final good producers and retailers.

3.1 Upstream and Downstream Markets

The downstream market is composed of an incumbent D_I and an entrant D_E. Each downstream firm produces a homogeneous final product; the firms use only an input that is monopolistically produced by an upstream supplier U. For this supplier, the marginal cost is $c \geq 0$, and w is the wholesale price offered by it.

The downstream firms differ in production technology. D_I produces one unit of the final product using one unit of input. The per-unit production cost of D_I, c_I, becomes

$$c_I = w. \tag{1}$$

By contrast, D_E produces one unit of the final product using $k \in (0, 1)$ units of input. The per-unit production cost of D_E, c_E, becomes

[9] Kitamura et al. (2017) also show that anticompetitive exclusive dealing can occur if the downstream buyer bargains with suppliers sequentially.

[10] In the literature on international technology transfer, Lin and Saggi (2007) consider downstream entry attaining an exclusive supply chain with local suppliers in a successive Cournot model.

$$c_E = kw. \tag{2}$$

Equation (2) implies that D_E becomes increasingly more efficient than D_I as k decreases.

We can interpret the production-technology assumption in two ways: First, between an input supplier and final product producers, entrant producer D_E has the efficient technology that allows it to reduce input use: e.g., the number of defective products. Second, between a final product producer U and retailers, entrant retailer D_E is better at supply-chain management than the incumbent in that it needs fewer products that are produced by the final product producer U.

3.2 Timing of the Game

The model consists of four stages (Fig. 1). In Stage 1, D_I offers an exclusive supply contract to U.[11] This contract involves some fixed compensation of $x \geq 0$. U decides whether to accept this offer. We use the scripts a and r to indicate the cases in which U accepts or rejects the offer, respectively. In Stage 2, after observing U's decision, D_E decides whether to enter the downstream market. We assume that the fixed cost of entry $f(> 0)$ is sufficiently small, such that if D_E is active, it could earn positive profits.

In Stage 3, U offers a common linear wholesale price of the input, w, to the active downstream firm(s). In case a, U offers input price w^a only to D_I. In case r, U offers input price w^r to all active downstream firms. In Sect. 5, we discuss the case where input price discrimination is possible. In Stage 4, active downstream firms order inputs, produce final products, and sell them to final consumers. In case r, D_I and D_E compete. D_I's profit when U accepts (rejects) the exclusive offer is denoted by π_I^a (π_I^r), and U's profit when it accepts (rejects) the exclusive offer is denoted by π_U^a (π_U^r).

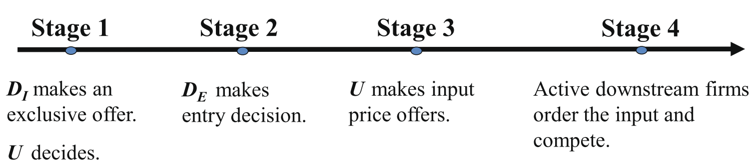

Fig. 1 Time line

[11] The assumption on the first-mover advantage of D_I follows the Chicago School argument. Some studies show that exclusion results arise even in the absence of a first-mover advantage. See Choi and Stefanadis (2018), who extend the model of exclusion with scale economies. Recently, Kitamura et al. (2018b) show that exclusive-offer competition leads to anticompetitive exclusive dealing even in the framework of the Chicago School argument. According to their results, if D_E is able to make exclusive offers in the model here, D_E excludes D_I in the equilibrium, and such exclusion is still socially inefficient.

3.3 Design of Exclusive Supply Contracts

Given the equilibrium outcomes in the subgame following Stage 1, we derive the essential conditions for an exclusive supply contract. For an exclusion equilibrium, the equilibrium transfer x^* must satisfy the following two conditions simultaneously:

First, it must satisfy the individual rationality condition for D_I: D_I must earn higher operating profits under exclusive dealing:

$$\pi_I^a - x^* \geq \pi_I^r \ \ or \ \ x^* \leq \pi_I^a - \pi_I^r. \tag{3}$$

Second, it must satisfy the individual rationality for U: The compensation amount x^* must induce U to accept the exclusive supply offer:

$$x^* + \pi_U^a \geq \pi_U^r \ \ or \ \ x^* \geq \pi_U^r - \pi_U^a. \tag{4}$$

The inequalities (3) and (4) imply

$$\pi_I^a + \pi_U^a \geq \pi_I^r + \pi_U^r. \tag{5}$$

Condition (5) implies that for the existence of anticompetitive exclusive supply contracts, we must examine whether exclusive supply agreements increase the joint profits of D_I and U. Therefore, the existence of exclusion equilibria does not depend on who makes the offer: The results do not change even if we allow U to make the exclusive supply offer.

4 Main Results

We consider the existence of anticompetitive exclusive dealing to deter the socially efficient entry of D_E when the downstream firms engage in homogeneous good price competition with a well-behaved general demand $Q(p)$, where p is the retail price. $Q(p)$ is continuous, and $Q'(p) < 0$. The quantity that consumers demand for D_i is $Q(p_i)$ when $p_i < p_j$ and is 0 when $p_i > p_j$, where $i,j \in \{I, E\}$ and $j \neq i$. When $p_i = p_j$, the downstream firm with the lower per-unit production cost supplies the entire quantity $Q(p_i)$. We define $p^*(z)$ and $\Pi^*(z)$ for $z \geq 0$ as follows:

$$p^*(z) \equiv \underset{p}{\text{argmax}}\ (p - z)Q(p), \ \ \Pi^*(z) \equiv (p^*(z) - z)Q(p^*(z)).$$

We assume that the demand function satisfies the following conditions:

Assumption 1 The demand function has the following properties: (i) For all $p > z$, $(p - z)Q(p)$ is strictly and globally concave in p: $2Q'(p) + (p - z)Q''(p) < 0$; (ii) $Q(p)$ is log-concave: $-d(Q(p^*(z))/Q'(p^*(z)))/dz \leq 0$.

Assumption 1 (i) is the standard second-order condition, and (ii) secures that the pass-through rate—$p^{*\prime}(z)$—is less than 1. The upper bound of the pass-through rate is a key to obtaining the main result (Proposition 1), and the curvature of the demand function (the elasticity of demand) in itself is not a key factor in obtaining this result.

We assume that $p^*(z)$ has the following properties:

Assumption 2 The level of c is not too high:

$$p^*(0) > c. \tag{6}$$

In the following, we solve the game with the use of backward induction; we start from Stage 4.

4.1 *U* Accepts the Exclusive Supply Offer in Stage 1 (Case *a*)

We first consider the case where U accepts the exclusive offer in Stage 1. In this case, it can supply only to D_I. Given input price w^a, D_I optimally chooses $p_I^a(w^a) = p^*(w^a)$ in Stage 4. By anticipating this pricing, U sets the input price for D_I to maximize its profit in Stage 3.

$$w^a = \underset{w}{\operatorname{argmax}}\ (w - c)Q(p^*(w)). \tag{7}$$

To have a unique solution, we assume that $(w - c)Q(p^*(w))$ is strictly and globally concave in w.

Because we have $w^a > c$ in the equilibrium, the equilibrium price level $p^*(w^a)$ does not maximize the joint profits of D_I and U; that is, the double marginalization problem occurs.

$$\pi_I^a + \pi_U^a = (p^*(w^a) - c)Q(p^*(w^a)) < \Pi^*(c). \tag{8}$$

Although entry deterrence allows D_I to earn higher operating profits, D_I and U cannot maximize their joint profits because of the double marginalization problem.

4.2 *U* Rejects the Exclusive Supply Offer in Stage 1 (Case *r*)

We next consider the case where U rejects the exclusive supply offer in Stage 1. In this case, D_E enters the downstream market in Stage 2.

In Stage 4, given the input price w^r, the downstream firms compete in price. D_I earns zero profits in this subgame: $\pi_I^r = 0$ for all $0 < k < 1$. In addition, downstream competition leads to two types of equilibria in Stage 4.

Case (i) D_I offers $p_I^{r(i)} = w^r$ and D_E offers $p_E^{r(i)} = w^r$ if $p^*(kw^r) \geq w^r$.

Case (ii) D_I offers $p_I^{r(ii)} = w^r$ and D_E offers $p_E^{r(ii)} = p^*(kw^r)$ if $p^*(kw^r) \leq w^r$.

In Case (i) (if $p^*(kw^r) \geq w^r$), the marginal cost pricing of D_I binds the pricing of D_E, which leads to $p_E^{r(i)} = w^r$. In Case (ii) (if $p^*(kw^r) \leq w^r$), the marginal cost pricing of D_I does not bind the pricing of D_E, which leads to $p_E^{r(ii)} = p^*(kw^r)$.[12]

By anticipating this pricing in Stage 4, U optimally chooses its input price in Stage 3. Note that for each case, we have a unique interior solution: We have $w^{r(i)} \in [c, \infty)$ and $w^{r(ii)} \in [c, \infty)$. Each interior solution must satisfy the constraints ($w^{r(i)} \in [c, p^*(kw^r(k))]$ and $w^{r(ii)} \in [p^*(kw^r(k)), \infty)$), where $w^r(k)$ is the input price such that

$$p^*(kw^r(k)) \equiv w^r(k),$$

for each k. $w^r(k)$ is the threshold value at which the mode in Stage 4 changes from Case (i) to Case (ii). Under Assumption 1, we can show that $w^r(k)$ is unique for each k (see Appendix 1).

In the rest of this subsection, we first characterize the properties of each interior solution in the full domain $[c, \infty)$ in Lemmas 1 and 2. We then consider the constraints of each interior solution in Lemma 3 and characterize the properties of U's profit in Lemma 4. Finally, in the next subsection, we explore the existence of an exclusion equilibrium.

From this point forward, we characterize each interior solution in the full domain $[c, \infty)$.

First, in Case (i), U faces its input demand

$$q_E^{r(i)} = kQ(p_E^{r(i)}) = kQ(w^r). \tag{9}$$

Given this input demand, U optimally chooses input price $w^{r(i)} \equiv \operatorname{argmax}_{w^r} k(w^r - c)Q(w^r)$ in Stage 3. With the maximization problem, the profit of U is as follows:

$$\pi_U^{r(i)} = \max_{w^r} k(w^r - c)Q(w^r) = k\Pi^*(c). \tag{10}$$

From Eqs (8) and (10), we identify the following properties.

Lemma 1 *Under the interior solution* $w^{r(i)} \in [c, \infty)$, $\pi_U^{r(i)}$ *has the following properties*:

1. $\pi_U^{r(i)}$ *is strictly increasing in k but decreasing in c.*
2. *As* $k \to 1$, $\pi_U^{r(i)} \to \Pi^*(c)$, *which is strictly larger than* $\pi_I^a + \pi_U^a$.
3. *As* $k \to 0$, $\pi_U^{r(i)} \to 0$.

The notable feature in Case (i) is that U earns lower profits as D_E becomes more efficient. Such a counterintuitive result can be explained by the relationship between D_E's efficiency and its input demand. In Case (i), the equilibrium retail

[12] The properties of cases (i) and (ii) are similar to the Arrow's terminology of non-drastic and drastic innovation.

price becomes $p^{r(i)} = w^r$; D_E's efficiency does not affect the retail price. Because of this property, the production level of final products is unchanged even when D_E becomes more efficient. Thus, as in Eq. (9), D_E's input demand becomes smaller as D_E becomes efficient, which induces U to earn a lower profit.

Second, in Case (ii), U faces its input demand $q_E^{r(ii)} = kQ(p^*(kw^r))$. Given this input demand, U sets an input price to maximize its profit in Stage 3:

$$\pi_U^{r(ii)} = \max_{w^r} (w^r - c)kQ(p^*(kw^r)) = \max_{w} (w - kc)Q(p^*(w)). \tag{11}$$

From Eqs (7) and (11), we identify the following properties:

Lemma 2 *Under the interior solution* $w^{r(ii)} \in [c, \infty)$, $\pi_U^{r(ii)}$ *has the following properties*:

1. $\pi_U^{r(ii)}$ *is strictly decreasing in* k *and* c.
2. *As* $k \to 1$, $\pi_U^{r(ii)} \to \pi_U^a$.
3. *For any* $c \geq 0$, *as* $k \to 0$, $\pi_U^{r(ii)} \to \pi_U^a|_{c=0}$.
4. *For* $c = 0$, $\pi_U^{r(ii)} = \pi_U^a|_{c=0}$,

where $\pi_U^a|_{c=0}$ is U's profit level under the standard double marginalization problem when $c = 0$ (see Eq. (7)).

The notable feature in Case (ii) differs from Case (i) in that U earns higher profits as D_E becomes more efficient. In Case (ii), U and D_E face the double marginalization problem. The equilibrium retail price becomes $p^{(ii)} = p^*(kw^r)$; in contrast to Case (i), as D_E becomes more efficient, it sets a lower retail price, and increases the output level of final products and the input demand. Thus, U and D_E earn higher profits as D_E's efficiency increases.

We now characterize these two equilibria on two domains: $[c, w^r(k)]$ and $[w^r(k), \infty)$.

Lemma 3 *For Cases* (*i*) *and* (*ii*), *at least one of the following holds*, $w^{r(i)} \in [c, w^r(k)]$ *or* $w^{r(ii)} \in [w^r(k), \infty)$.

Proof See Appendix 2.1. □

Because $\pi_U^{r(i)} = \pi_U^{r(ii)}$ for $w^{r(i)} = w^{r(ii)} = w^r(k)$, one of the above-mentioned interior solutions becomes U's optimal solution in equilibrium. Therefore, exclusion is possible regardless of equilibrium type if we have

$$\pi_I^a + \pi_U^a \geq \max\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}. \tag{12}$$

The following lemma characterizes the properties of $\max\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ (see Fig. 2):

Lemma 4 $\max\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ *has the following properties*:

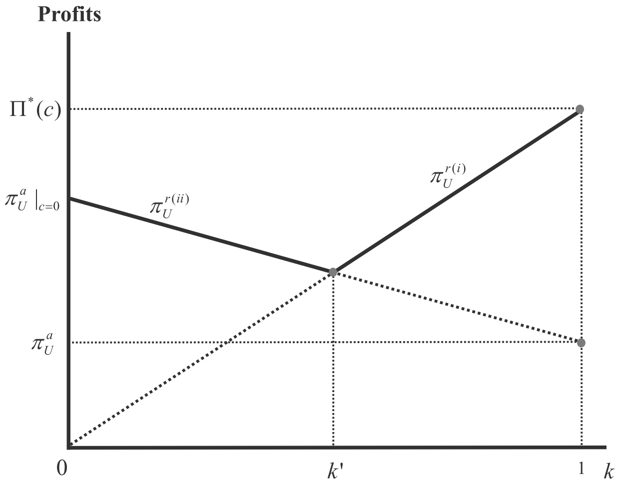

Fig. 2 Properties of max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$

1. *It is strictly decreasing in c.*
2. *Its functional form is V-shaped with respect to k. More precisely*, *we have*

$$\max\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\} = \begin{cases} \pi_U^{r(ii)} & \text{if } 0 < k \le k', \\ \pi_U^{r(i)} & \text{if } k' < k < 1. \end{cases}$$

Proof See Appendix 2.2. □

The characteristic of max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ in Lemma 4 comes from the first items in Lemmas 1 and 2: This value depends on k. However, the joint profit of D_I and U under exclusion, $\pi_I^a + \pi_U^a$, does not depend on k (see Eq. (8)) because D_E is inactive. From these conditions, exclusion is possible if condition (12) holds for $k = k'$, at which max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ takes the lowest value.

4.3 The Existence of an Exclusion Equilibrium

By combining the arguments in Sects. 4.1 and 4.2, we finally explore the existence of an exclusion equilibrium by focusing on c.

We start from the simplest case of $c = 0$. The properties of max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ and $\pi_I^a + \pi_U^a$ for $c = 0$ is summarized in the left side of Fig. 3.

By checking condition (12), we have $\pi_I^a + \pi_U^a > \pi_U^{r(ii)}$ for $0 < k \le k'$ and $\pi_I^a + \pi_U^a > \pi_U^{r(i)}$ for $k' \le k \le k^*$, where

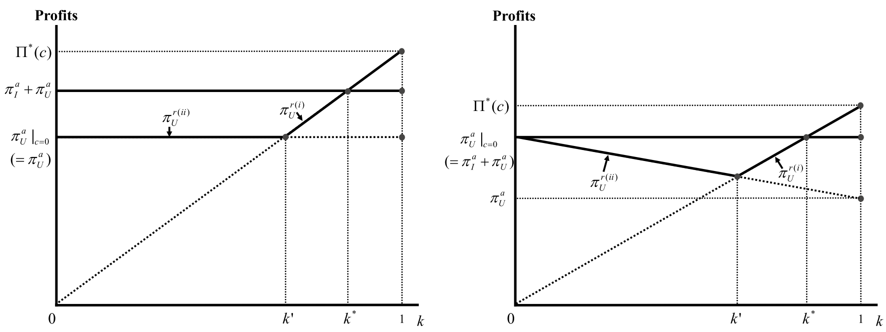

Fig. 3 Properties of max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ and $\pi_I^a + \pi_U^a$ for $c \leq \tilde{c}$ Note: $c = 0$ (left) and $c = \tilde{c}$ (right)

$$k^* \equiv \frac{\pi_I^a + \pi_U^a}{\Pi^*(c)}.$$

Thus, when $c = 0$, exclusion is an equilibrium for $0 < k \leq k^*$.

As c increases from $c = 0$, $\max\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ and $\pi_I^a + \pi_U^a$ decrease, while $\pi_U^a\Big|_{c=0}$ is unchanged. There exists a unique threshold value $\tilde{c}$ such that $\pi_U^a\Big|_{c=0} = \pi_I^a + \pi_U^a$ (see the right-hand side of Fig. 3). When $0 < c \leq \tilde{c}$, we have $\pi_I^a + \pi_U^a \geq \pi_U^a\Big|_{c=0} > \pi_U^{r(ii)}$ for $0 < k \leq k'$ and $\pi_I^a + \pi_U^a \geq \pi_U^{r(i)}$ for $k' \leq k \leq k^*$, which implies that condition (12) always holds in Case (ii). Thus, by combining the result for $c = 0$, we conclude that when $0 \leq c \leq \tilde{c}$, exclusion is an equilibrium outcome for $0 < k \leq k^*$.

We next consider the case of $c > \tilde{c}$. For a slight increase in c from $\tilde{c}$, there exists a threshold value $k'' \in (0, k^*]$ such that $\pi_U^{r(ii)} = \pi_I^a + \pi_U^a$ in Case (ii) (see the left-hand side of Fig. 4) because D_E with sufficiently small k significantly contributes to the reduction of U's real marginal cost, kc, (see (11)), in particular when c is high. As k becomes small, U can set a sufficiently high wholesale price and earn a large profit from the trade with D_E. Thus, exclusion is impossible when k is sufficiently small ($0 < k < k''$), whereas it is possible when k is not too small ($k'' \leq k \leq k^*$); that is, condition (12) does not always hold in Case (ii).

By contrast, for sufficiently large c, $k^* < k' < k''$ may hold as in the right-hand side of Fig. 4.[13] In this case, condition (12) does not hold even for $k = k'$: Entry is an equilibrium outcome for all $0 < k < 1$. Moreover, from the above discussion, we can conclude that if $k^* < k < 1$, exclusion never occurs for any c. Proposition 1 summarizes the discussion:

Proposition 1 *Suppose that the downstream firms are undifferentiated Bertrand competitors. The possibility of exclusion depends on the marginal cost of U— c— and the efficiency of* D_E*: k.*

[13] This is observed in the case of linear demand.

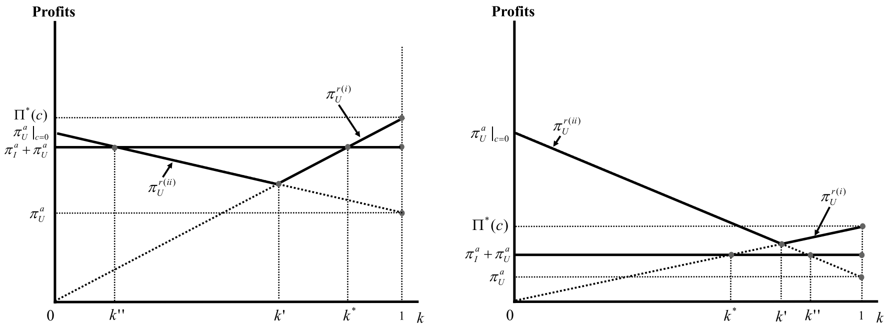

Fig. 4 Properties of max $\left\{\pi_U^{r(i)}, \pi_U^{r(ii)}\right\}$ and $\pi_I^a + \pi_U^a$ for $c > \tilde{c}$. Note: not sufficiently large c (left) and sufficiently large c (right)

1. *When the marginal cost of U is sufficiently low—$0 \le c \le \tilde{c}$—exclusion is possible if $0 < k \le k^*$.*
2. *When c is not too low—$\tilde{c} < c < \tilde{c}'$ where $\tilde{c}'$ satisfies $\pi_I^a + \pi_U^a = \pi_U^{r(i)}|_{k=k'} = \pi_U^{r(ii)}|_{k=k'}$ —exclusion is possible if $k'' \le k \le k^*$.*
3. *For any level of c, entry is a unique equilibrium outcome if $k^* < k < 1$.*

Note that condition (12) is a sufficient condition. Therefore, there may exist an exclusion equilibrium even when condition (12) does not hold. We provide the necessary and sufficient conditions for the exclusion equilibrium, by introducing linear demand:

Remark 1 Suppose that $Q(p) = (\alpha - p)/\beta$, where $\alpha > c$ and $\beta > 0$. Exclusion is a unique equilibrium outcome if and only if $0 < k \le 3/4$ and $0 \le c \le \hat{C}(k)$, where $\hat{C}(k) = \left(\sqrt{6} - 2\right)\alpha/(\sqrt{6} - 2k)$; otherwise, entry is a unique equilibrium outcome. Note that $\partial\hat{C}(k)/\partial k > 0$, $\hat{C}(k) \to (3 - \sqrt{6})\alpha/3 \simeq 0.1835\alpha$ as $k \to 0$, and $\hat{C}(k) \to 2(6 - \sqrt{6})\alpha/15 \simeq 0.4734\alpha$ as $k \to 3/4$.

Under linear demand, we have $k^* = 3/4$; $k'' = (2\alpha - (\alpha - c)\sqrt{6})/2c$; $\tilde{c} = (3 - \sqrt{6})\alpha/3 \simeq 0.1835\alpha$; and $\tilde{c}' = 2(6 - \sqrt{6})\alpha/15 \simeq 0.4734\alpha$. For $0 < k \le 1/2$, we have equilibrium in Case (ii) when entry occurs. Conversely, for $1/2 < k < 1$, we have the equilibrium in Case (i) (Case (ii)) if $c \le \acute{C}(k)$ ($c > \acute{C}(k)$), where $\acute{C}(k) = \alpha(k - \sqrt{2k}(1 - k))/k(2 - k)$.[14] Fig. 5 summarizes the result in Remark 1 for $\alpha = 1$. Note that we can obtain a similar result under a demand system with constant elasticity of demand: $Q = \alpha p^{-\varepsilon}$, where $\varepsilon > 1$.[15]

[14] Under linear demand, $\pi_U^a < \pi_U^r$ holds for all $(c, k) \in [0, \alpha) \times (0, 1)$, which implies that U always welcomes D_E's entry if it rejects the exclusive offer. Thus, the fixed transfer—x—is crucial to attaining exclusive dealing.

[15] If we consider perfectly inelastic consumer demand ($Q(p) = q(> 0)$ if $p \le \bar{p}(> 0)$, otherwise, $Q(p) = 0$), the exclusion does not occur because the shrinkage of input demand through entry is com-

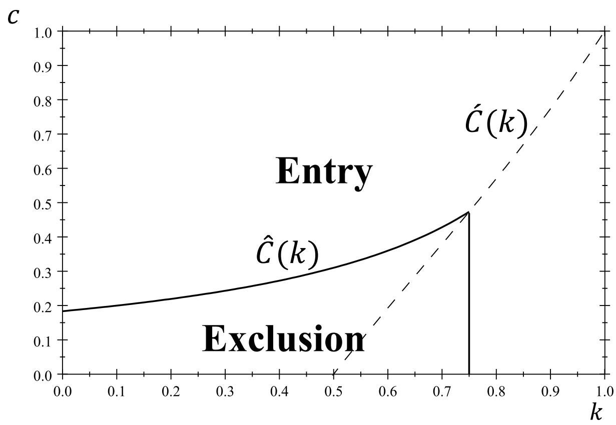

Fig. 5 Results of Remark 1 ($\alpha = 1$)

We explain the features of Proposition 1 (Remark 1), by classifying the situation into the three cases: (i) $c > \tilde{c}'$, (ii) $c \leq \tilde{c}'$ and $k > k^*$, and (iii) $c \leq \tilde{c}'$ and $k \leq k^*$. Suppose that the marginal cost of U is high enough ($c > \tilde{c}'$). The double marginalization problem is significant under exclusion (see $\pi_I^a + \pi_U^a$ in the righthand side of Fig. 4). In Case (i) ($k > k'(> k^*)$), rejecting an exclusive contract enhances downstream competition, which mitigates the double marginalization problem as in the Chicago School argument. In Case (ii) ($k < k'$), downstream entry improves the downstream efficiency: $w^a - kw^r$ is large. Thus, downstream entry induces U to earn a high profit, which makes exclusion impossible.

When the marginal cost of U is not high enough ($c \leq \tilde{c}'$), the gain from the downstream competition still leads to a large amount of input demand expansion as long as D_E demands a large amount of input for k ($(k' <)k^* < k < 1$) in Case (i); exclusion never occurs if $k > k^*$, otherwise ($k < k^*$), it can occur depending on U's cost, c. The equilibrium property contrasts with the results in the literature on anticompetitive exclusive dealing, which indicates that firms are unlikely to engage in anticompetitive exclusive dealing as the entrant becomes more efficient. Hence, an exclusive contract in this study works like the Luddites (e.g., Hobsbawm, 1952; Mokyr, 1992) and resistance to technological change (e.g., Parente and Prescott, 1994, 1999; Desmet, Greig, and Parente, 2020).

Finally, we consider the interaction between the values of c and k for $c \leq \tilde{c}'$ and $k \leq k'$ in Case (ii). D_E's efficiency improvement has two effects on the input demand: One is the demand shrinkage effect in which D_E's efficiency improvement directly reduces the input demand $kQ(p^r)$. The other is the demand expansion effect in which

Footnote 15 (continued)
pletely offset by the higher input price, which exceeds the consumers' willingness to pay, $\bar{p}$. The result is available upon request.

D_E's efficiency improvement indirectly expands the input demand by reducing D_E's marginal cost kw and the retail price.

As the marginal cost of U becomes higher (higher c within $c \le \tilde{c}'$), the demand expansion effect becomes stronger because the reduction of D_E's marginal cost is larger. By contrast, the demand shrinkage effect becomes weaker because higher c leads to smaller input demand and the amount of input demand shrinkage is smaller: As the marginal cost of U becomes higher, the gain from the higher efficiency of D_E becomes larger, and the loss from the higher efficiency of D_E becomes smaller. Therefore, the threshold value of k—k''—becomes larger as c increases.

We discuss D_E's efficiency management because we show that exclusion is more likely to occur if k is *small*. One may consider how D_E increases k to avoid exclusion by D_I. We discuss two scenarios: First, D_E could offer U a per-unit "kickback" of $k^* - k + \varepsilon$, which benefits U and increases the effective marginal cost of D_E to $k^* + \varepsilon$. To implement the kickback, D_E needs to commit to it *before* D_I offers U an exclusive supply contract. The scenario does not seem to match the timeline in Fig. 1. Second, D_E could simply buy larger quantities of the input than it actually needs to use—and destroys enough, so that the effective $k(> k^*)$. D_E needs to commit credibly to procuring excessive quantities *before* D_I's exclusive offer.

We think that our exclusion mechanism implies that D_E needs to choose not a radical but a moderately efficient technology when it decides on entry and announces its entry decision *before* Stage 1: A too-advanced technology diminishes the importance of U, which induces it to sign an inefficient exclusive supply contract with D_I.

4.4 Robustness of the Results

Finally, we check the robustness of these results.[16] We first examine the existence of anticompetitive exclusive dealing under quantity competition with $P(Q) = \alpha - \beta Q$. There can be an exclusion equilibrium for $k \le \hat{k} \simeq 0.92(> 3/4)$ under quantity competition, which implies that the possibility of anticompetitive exclusion under Cournot competition is higher. This result follows from the difference in the degree of demand expansion between the two types of competition. Compared with undifferentiated Bertrand competition, D_E's entry under Cournot competition leads to a smaller demand expansion. Therefore, D_E's entry leads to a smaller increase in U's profit; exclusion outcomes are more likely to be observed.

We also examine the case of price competition with differentiated products. The demand for D_i's product is $q_i = (\alpha' - p_i + \gamma p_j)/(1 - \gamma^2)$ ($i,j \in \{I, E\}$, $j \ne i$, $\alpha' > c$, $\gamma \in [0, 1)$) (Singh and Vives, 1984). We find that an exclusion equilibrium exists for a smaller k whose threshold value increases with the degree of product substitution γ and converges to 3/4 when $\gamma \to 1$: Product differentiation decreases the possibility of exclusion. As downstream firms' products are differentiated, input demand expansion becomes larger, which makes D_I's compensation to U more difficult.

[16] The detailed analyses in those extended settings are available upon request.

As another extension, we introduce an inefficient upstream supplier U_O with marginal cost $c + c_o$ ($c_o > 0$) to the main model. We assume that $c/k < c + c_o < \alpha/2$ under which upstream competition binds U's pricing and the entry of D_E occurs only when it can trade with U. Using linear demand, we find that D_I can achieve exclusive dealing even for $k > 3/4$: The existence of an inefficient supplier facilitates downstream exclusion. When upstream competition exists, the entry of D_E triggers both upstream and downstream competition, which gives most of the gain from entry to final consumers (third parties); this reduces D_I and U's joint profits, as in upstream exclusion with downstream competition (Simpson & Wickelgren, 2007; Abito & Wright, 2008). Thus, exclusion is more likely to be observed.

5 Discussion

This section briefly introduces the discussion of different pricing policies and exclusive dealing in toy retailing markets.

5.1 Wholesale Pricing

This section briefly discusses the wholesale pricing of the input. Thus far, we have assumed that U charges downstream firms a uniform price w^r when D_E enters the downstream market. We consider how the results in Sect. 4 change if U is able to (i) charge different input prices; and (ii) adopt two-part tariffs. The two discussions clarify the effect of input price discrimination on the market structure, and thus contribute to the literature on input price discrimination.

We first explore the case of input price discrimination. When U chooses input prices w_i^r for D_i, where $i \in \{I, E\}$, the per unit costs of D_I and D_E are denoted by w_I^r and kw_E^r. To clarify the difference from uniform pricing, we focus on the case where U rejects the exclusive supply offer in Stage 1 and D_E enters the downstream market in Stage 2. In Stage 4, given the input prices that are set in Stage 3, undifferentiated Bertrand competition occurs, which leads to monopolization by the downstream firm with a lower per unit cost. In equilibrium, U optimally chooses a pair of input prices (w_I^r, w_E^r), such that $w_I^r = kw_E^r = p^*(kc)$ in Stage 3, and earns $\pi_U^r = (w_E^r - c)kQ(w_I^r) = (p^*(kc) - kc)Q(p^*(kc)) = \Pi^*(kc) < \pi_I^a + \pi_U^a$; thus, exclusion is not achievable.

The impossibility of exclusion under price discrimination follows U's control ability of downstream competition. Under a uniform price, U cannot control the downstream competition for the case of entry, which prevents U from achieving the joint profit maximization with D_E, which plays a key role in an exclusion outcome. By contrast, when price discrimination is possible, U can control the downstream competition. When undifferentiated Bertrand competition D_I and D_E occurs, U can jointly maximize profit with D_E, and more importantly, it can earn all of the profits.[17] Thus there is no room for an exclusion equilibrium.

Next, we consider the case in which U adopts two-part tariffs, which are publicly observable, and makes take-it-or-leave-it offers.[18] Two-part tariffs consist of a linear wholesale price—w—and an upfront fixed fee: F. The two-part tariff offered by U to D_i when U accepts (rejects) the exclusive supply offer is denoted by (w_i^a, F_i^a) and $((w_i^r, F_i^r))$, where $i \in \{I, E\}$. When U accepts the exclusive supply offer, it sets $(w_I^a, F_I^a) = (c, \Pi^*(c))$, which allows U and D_I jointly to earn $\pi_I^a + \pi_U^a = \Pi^*(c)$. By contrast, when U rejects the exclusive supply offer, it sets $(w_i^r, F_i^r) = (c, \Pi^*(kc))$. In the equilibrium, we have $\pi_U^r = \Pi^*(kc)$, which implies that as in discrimination under linear pricing, condition (5) never holds. Thus, exclusive supply contracts are not attainable.

When U can adopt two-part tariffs, it can avoid the double marginalization problem, which benefits U. As in price discrimination under linear pricing at the beginning of this subsection, two-part tariffs allow U to maximize profits jointly with D_E and to earn all of the profits. Because D_E is more efficient than D_I, the joint profit of U and D_E is higher than that of U and D_I. Thus, D_I cannot achieve exclusion.

We introduce two remarks on the above results. First, we should emphasize that in each case, downstream firms earn zero operating profits when U rejects the exclusive supply offer. Anticipating this outcome, D_E does not enter the downstream market in Stage 2 even when U rejects the exclusive supply offer in Stage 1. Therefore, when U charges different input prices and adopts two-part tariffs, there is a price commitment problem: U is unable to commit initially to an input price offer that allows D_E to cover the fixed cost $f(> 0)$.[19]

Second, introducing input arbitrage between D_I and D_E, we can combine the two polar cases discussed above: (i) U cannot price discriminate; or (ii) U can price discriminate. Each downstream firm can sell its purchased input to its rival by incurring a per-unit arbitrage cost t. U sets its prices for D_I and D_E while anticipating the possibility of input arbitrage. Using linear demand, we find that D_I successfully excludes D_E through an exclusive supply contract if t is not large enough and k is small: If there is a chance of input arbitrage, an exclusive supply contract between D_I and U is attainable even when U can price discriminate.[20] t would be low under low transport costs relative to the values of those products (or high values of products relative to transport costs). Pharmaceuticals are such a prominent example of potential arbitrage.[21]

[17] When the downstream firms compete in quantity, joint profit maximization is impossible, and D_E earns a positive profit, which is lower than when U employs a uniform price.

[18] Under private offers, U cannot maximize joint profits because of opportunistic behavior as posited by Hart and Tirole (1990). See also O'Brien and Shaffer (1992), McAfee and Schwartz (1994), and Rey and Vergé (2004).

[19] The commitment problem is mitigated if we consider imperfect downstream market competition such as differentiated Bertrand competition and quantity competition or general bargaining with two-part tariffs.

[20] The results are available upon request.

[21] We thank the General Editor for pointing out the scenario.

From the above discussions, we can conclude that this study is most suitable for a discussion of the anticompetitiveness of exclusive supply agreements in industries where input price discrimination is less implementable. Such cases are more likely to be observed when dominant downstream firms impose a price parity clause or when arbitrage is easy because of higher product storability. Therefore, anticompetitive exclusive supply agreements are more likely to occur when D_I offers price parity clauses or when product storability is high.[22]

5.2 Exclusive Dealing in Toy Retailing Markets

We briefly consider the link between exclusive supply agreements in this study and the case of Toys "R" Us (TRU), which was the largest toy retailer in the US in the late twentieth century.[23] In the early 1990s, TRU faced a competitive threat from warehouse clubs, such as Costco and Sam's Club. To avoid competition from warehouse clubs, TRU approached toy suppliers, and *"Suppliers agreed not to sell to the clubs the same toys that TRU carried."*[24]

This case is related to our study in the following aspects: The first aspect is the efficiency difference between TRU and warehouse clubs. TRU sold a large variety of toy products; it stored 16000 stock-keeping units in the early 1990s.[25] Such large stock-keeping units were usually costly in terms of supply chain management. Conversely, warehouse clubs had lower operating costs by increasing inventory turnover ratios, contributing to a low risk of obsolescence—which is similar to lower defect rates.[26] Therefore, warehouse clubs were more efficient.

The second aspect is the possibility of price discrimination.[27] Toy products are usually storable goods, which implies that arbitrage among retailers is not very difficult. From the discussion in Sect. 5.1, suppliers seemed to have difficulty in adopting price discrimination with no arbitrage when they sold toy products to not only TRU, but also to warehouse clubs.

Note that both aspects play an essential role in achieving exclusive dealing in this study. Moreover, a similar case is observed in the exclusive supply agreements by Belk Stores, a department store chain in the US. Belk Stores induced Jantzen sportswear to stop selling to Garment District, a discount retailer in the US.[28] Therefore, our

[22] Recently, several papers discuss price parity clauses (e.g., Johnson, 2017 and references therein).

[23] See Federal Trade Commission (1997), available at https://www.ftc.gov/sites/default/files/documents/cases/1997/09/toysrus_0.pdf. See also Comanor and Rey (2000) and Scherer (2009).

[24] See page 1 of Federal Trade Commission (1997).

[25] See page 3 of Federal Trade Commission (1997).

[26] See page 6 of Federal Trade Commission (1997). Moreover, Costco is famous for efficient supply chain management because of higher inventory turnover ratios (lower risk of obsolescence) than other retailers. See, for example, "What Costco's Inventory Turnover Says About Its Moat" *The Motley Fool* August 22, 2016 (https://www.fool.com/investing/2016/08/22/what-costcos-inventory-turnover-says-about-its-moa.aspx).

[27] Scherer (2009, pp.445–453) summarizes the key issues in the case of TRU.

[28] See *The Garment District, Inc., v. Belk Stores Service, Inc., Mathews-Belk Company, Jantzen, Inc*, 799 F.2d 905. (https://law.justia.com/cases/federal/appellate-courts/F2/799/905/117747/). See also Comanor and Rey (2000) for detailed discussions.

exclusion mechanism can apply to the situation in which a specialty retailer makes an exclusive supply offer to manufacturers to exclude large discount retailers.

6 Concluding Remarks

This study examined anticompetitive exclusive supply agreements; we focus on the necessary amount of inputs to produce one unit of final product. Previous studies have not differentiated between the incumbent and entrants with regard to the necessary amount of inputs, because they mainly analyzed entry deterrence in upstream markets. However, our study suggests that when we focus on entry deterrence in downstream markets by considering exclusive supply contracts, the difference in the necessary amount of inputs can be an important market element.

We find that when the incumbent and entrant differ in the necessary amount of inputs, the inefficient downstream incumbent and the supplier may sign exclusive supply contracts to deter socially efficient entry—even in the three-player model with a single seller, buyer, and entrant. In addition, the difference in the necessary amount of inputs changes the relationship between the entrant's efficiency and the possibility of exclusion: Anticompetitive exclusive supply agreements are more likely to arise if the entrant's superior efficiency is at an intermediate level.

These results provide new implications for antitrust agencies: It may be useful to focus on the efficiency measure when discussing the anticompetitiveness of exclusive supply agreements. It may be possible to measure downstream firms' efficiency by checking the defect rate in relationships between an input supplier and final good producers.

We also find that exclusive supply agreements based on the difference in the necessary amount of inputs are more likely to arise when upstream firms have difficulty adopting input price discrimination. Although perfect price discrimination, where no input arbitrage exists, reduces the possibility of anticompetitive exclusive supply agreements, exclusion results are achievable if there is a chance of input arbitrage.

These results provide the following implications: First, exclusive supply agreements are more likely to be observed when the product is storable, which makes input arbitrage easier. Second, the analysis here can be applied when the dominant downstream firm offers price parity clauses, which induces the upstream supplier to use uniform pricing.

As further research, we could incorporate a more sophisticated bargaining procedure into the main model because this study is related to the literature on buyer power in the sense that buyers can unilaterally offer exclusive contracts to suppliers as in Miklós-Thal et al. (2011). We hope this study facilitates researchers in addressing the issue.

Appendix 1: Property of Demand Function

By definition, $p^*(z)$ satisfies the first-order condition $Q(p^*(z)) + (p^*(z) - z)Q'(p^*(z)) = 0$, following Fabinger and Weyl (2012), which can be rewritten as

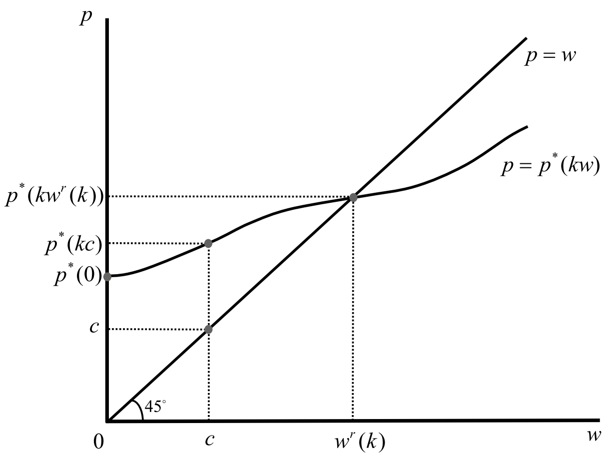

Fig. 6 Properties of $p^*(kw)$

$$p^*(z) - z = -\frac{Q(p^*(z))}{Q'(p^*(z))} \equiv \mu(p^*(z)).$$

When $Q(p)$ is log-concave, we have

$$\mu'(p^*(z)) \le 0. \tag{13}$$

By totally differentiating the first-order condition, we obtain the pass-through rate

$$p^{*\prime}(z) = \frac{Q'(p^*(z))}{2Q'(p^*(z)) + (p^*(z) - z)Q''(p^*(z)))} = \frac{1}{1 - \mu'(p^*(z))}. \tag{14}$$

Under condition (13), $0 < p^{*\prime}(z) \le 1$ always holds.

We now check the existence and uniqueness of $w^r(k)$. Because $dp^*(kw)/dw = kp^{*\prime}(w) \le k$ holds under condition (13), $p^*(kw)$ is strictly increasing in w and its pass-through rate is smaller than or equal to $k(< 1)$, which is smaller than the increase in w (see also Fig. 6). In addition, we have $p^*(kc) > c$ for all $0 < k < 1$ when condition (6) holds. Therefore, there exists a unique $w^r(k)$ for each k.

Appendix 2: Proofs of Results

Proof of Lemma 3

We show that at least one interior solution exists in the profit maximization problems in Cases (i) and (ii) when the exclusive offer is rejected in Stage 1. For expositional simplicity, we replace $w^r(k)$ with $w(k)$, which satisfies (see the last paragraph before Lemma 3)

$$p^*(kw(k)) = w(k). \tag{15}$$

The profit maximization problems of U in the two cases are given as

$$\text{Case (i)}\ \max_w\ (w-c)kQ(w)\ \ s.t.\ \ w \in [c, w(k)],$$
$$\text{Case (ii)}\ \max_w\ (w-c)kQ(p^*(kw))\ \ s.t.\ \ w \in [w(k), \infty).$$

The first-order conditions are given as

$$\text{Case (i)}\ H^{(i)}(w) \equiv Q(w) + (w-c)Q'(w),$$
$$\text{Case (ii)}\ H^{(ii)}(w) \equiv Q(p^*(kw)) + (w-c)kQ'(p^*(kw))p^{*\prime}(kw).$$

Note that each maximization problem has a unique interior solution on domain $[c, \infty)$. However, there exists a possibility of a corner solution, where the problem in Case (i) has an interior solution on domain $[w(k), \infty)$ and the problem in Case (ii) has an interior solution on domain $[c,\ w(k)]$. In such cases, U's profit is maximized at the corner, $w = w(k)$.

We explore whether the corner solution problem arises. Note that $w(k)$ is the optimal input price if and only if $H^{(i)}(w(k)) > 0$ and $H^{(ii)}(w(k)) < 0$. We show that the two inequalities do not simultaneously hold. More precisely, we show that $H^{(ii)}(w(k)) > 0$ if $H^{(i)}(w(k)) > 0$.

Suppose that $H^{(i)}(w(k)) > 0$:

$$H^{(i)}(w(k)) = Q(w(k)) + (w(k) - c)Q'(w(k)) > 0. \tag{16}$$

Using equation (15), $H^{(ii)}(w(k))$ can be rewritten as

$$H^{(ii)}(w(k)) = Q(w(k)) + (w(k) - c)kQ'(w(k))p^{*\prime}(kw(k)). \tag{17}$$

Using equations (16) and (17), we have the following relationship:

$$\begin{aligned} H^{(ii)}(w(k)) &> H^{(ii)}(w(k)) - H^{(i)}(w(k)) \\ &= (w(k) - c)Q'(w(k))[kp^{*\prime}(kw(k)) - 1] > 0, \end{aligned}$$

The last inequality holds because $Q'(p) < 0,\ 0 < k < 1,$ and $0 < p^{*\prime}(kw(k)) \le 1$ always hold under condition (13).

From the above discussion, we have $H^{(ii)}(w(k)) > 0$ if $H^{(i)}(w(k)) > 0$. This implies that in Case (ii), an interior solution always exists on domain $(w(k), \infty)$ if in Case (i), the interior solution does not exist on domain $[c,\ w(k)]$ and the corner solution appears: We always have $w^{r(ii)} \in (w(k), \infty)$ if $w^{r(i)} = w(k)$.

This also implies that at least one interior solution exists and there are three possibilities with respect to the optimal input price for U:

1. An interior solution exists only on domain $(c,\ w(k))$ in Case (i).
2. An interior solution exists only on domain $(w(k), \infty)$ in Case (ii).
3. Interior solutions exist on domain $(c,\ w(k))$ in Case (i) and $(w(k), \infty)$ in Case (ii).

In the first and second cases, we have unique interior solutions. Therefore, the statements in Lemma 3 hold.

Q.E.D.

Proof of Lemma 4

By Lemmas 1 and 2, the first statement in Lemma 4 holds. We now prove the second statement. For a sufficiently small k (as $k \to 0$), we have $\pi_U^{r(i)} < \pi_U^{r(ii)}$. However, for $k = 1$, we have $\pi_U^{r(i)} > \pi_U^{r(ii)}$. Because $\pi_U^{r(ii)}$ is strictly decreasing in k but $\pi_U^{r(i)}$ is strictly increasing in k, there exists $k' \in (0, 1)$ such that $\pi_U^{r(i)} = \pi_U^{r(ii)}$.

Q.E.D.

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