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WHICH IS BETTER FOR DURABLE GOODS PRODUCERS, EXCLUSIVE OR OPEN SUPPLY CHAIN?

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Abstract

We explore the supply chain problem of a downstream durable goods monopolist, who chooses one of the following trading modes: an exclusive supply chain with an incumbent supplier or an open supply chain, allowing the monopolist to trade with a new efficient entrant in the future. The predicted retail price reduction in the future dampens the profitability of the original firms. An efficient entrant's entry magnifies such a price reduction, causing a further reduction of original firms' joint profits. In equilibrium, the downstream monopolist chooses the exclusive supply chain to escape further price reductions, although it anticipates efficient entry.

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1 Introduction

We commonly observe an exclusive supply chain in many markets for durable goods, including industrial machinery/equipment and electronic and electric equipment (Heide, Dutta, and Bergen, 1998),[1] although the recent progress of information communication technology (ICT) helps firms find new trading partners worldwide, which affects the organizational formation of firms in various ways (Granot and Sošić, 2005; World Bank, 2009, Chapter 6; Bloom et al., 2014). The exclusive supply chain in the smartphone processor market is a typical example.[2] Apple, for instance, has selected an exclusive supply chain with Taiwan Semiconductor Manufacturing Company (TSMC) for Apple's processors.[3] The argument of supply chain openness is also related to the discussion on exclusive contracts in the context of competition policy (see the earlier discussions of Posner, 1976 and Bork, 1978). In reality, we have observed anticompetitive exclusive contracts in the market for durable goods such as aluminum (*the United States of America v. Aluminum Co. of America* in the US, 1945.), furniture (*Paramount Bed Case* in Japan, 1998), artificial teeth (*the United States of America. v. Dentsply International, INC.,* in the US, 2005), and CPUs (*Intel Case* in the US, 2005).[4] Despite these observations, previous studies on exclusive vertical chains and

[1] See also Mollgaard and Lorentzen (2004), who explore exclusive dealings in the Eastern European car component industry. Moreover, in the aviation industry, Boeing Company and Airbus sometimes award exclusivity to one or two jet engine makers over other makers. See "GE Unit Lands Exclusive Boeing Pact For Developing Commercial Jet Engine" *The Wall Street Journal,* July 8, 1999 (https://www.wsj.com/articles/SB931391538252682453), and "Airbus selects Rolls-Royce Trent 7000 as exclusive engine for the A330neo" *Rolls-Royce,* July 14, 2014 (https://www.rolls-royce.com/media/press-releases/yr-2014/140714-a330neo.aspx).

[2] For the case of Qualcomm's exclusive supply chain with Samsung, see "Samsung beats TSMC to win new Qualcomm order to make mobile chips" *The Korea Economic Daily,* October 6, 2020 (https://www.kedglobal.com/newsView/ked202010100034).

[3] See "Taiwan's TSMC to continue as Apple's exclusive A-series chip supplier: reports" *Taiwan News,* October 13, 2018 (https://www.taiwannews.com.tw/en/news/3551431).

[4] For each case, see the United States of America v. Aluminum Co. of America, 148 F.2d 416 (1945, https://law.justia.com/cases/federal/appellate-courts/F2/148/416/1503668/); Blair and Sokol (2015); United States of America. v. Dentsply International, INC., 399 F.3d (2005, https://www.

exclusive contracts investigate only perishable goods markets. In this study, to contribute to supply chain management and competition policy, we consider the problem of an exclusive supply chain in durable goods markets.

We consider a two-period durable goods market, as in Bulow (1986), Denicolò and Garella (1999), and Desai, Koenigsberg, and Purohit (2004), by introducing the entrant supplier in the second period. We explore the situation in which a downstream durable goods monopolist chooses one of two trading modes in the first period: (i) a two-period exclusive supply chain with an existing incumbent supplier, or (ii) an open supply chain, which causes competition between the incumbent and a potential supplier. We investigate whether the incumbent supplier and the downstream firm sign a two-period exclusive contract in the first period. To do it, we combine the model framework of durable goods markets (Bulow, 1986; Denicolò and Garella, 1999; Desai, Koenigsberg, and Purohit, 2004) with the scenario of entry deterrence through exclusive contracts in the Chicago School argument (Posner, 1976; Bork, 1978).

By introducing two-part tariffs as in Desai, Koenigsberg, and Purohit (2004), we show that exclusion is a unique equilibrium outcome in a general demand setting; in other words, the durability of products induces a downstream firm to choose an exclusive supply chain. As in the Chicago School framework, second-period entry generates upstream competition, which allows the downstream firm to procure inputs at a lower wholesale price in the second period. Thus, exclusion seems difficult. However, in durable goods markets, a retail price reduction through upstream competition in the second period makes some of final consumers refrain from purchasing in the first period, leading to a low retail price and low joint profits for the contracting party in the first period. That is, second-period upstream entry exacerbates the intertemporal pricing problem in the downstream market. Because exclusive contracts

leagle.com/decision/2005580399f3d1811565); Advanced Micro Devices, INC., a Delaware corporation, and AMD International Sales & Services, LTD., a Delaware corporation, v. Intel Corporation, a Delaware corporation, and Intel Kabushiki Kaisha, a Japanese corporation, Civil Action No. 05-441-JJF (2005, https://www.amd.com/system/files/amd-intel-full-complaint.pdf, respectively.

can mitigate such a pricing problem, the contracting party can enjoy higher joint profits in the first period. Therefore, the incumbent supplier can profitably make a two-period exclusive offer to the downstream firm in durable goods markets in the first period.

The exclusion mechanism in our study provides an important implication for competition policy. The Chicago School argument, which introduces the impossibility of exclusive contracts for anticompetitive reasons, does not necessarily apply to durable goods markets. Our study's exclusion mechanism arises from the nature of a durable goods monopolist, initially argued by Coase (1972).[5] Moreover, the exclusion outcomes in our study are derived under a general demand setting. The supplementary appendix also shows that exclusion outcomes are attainable in various extended settings under a linear demand system. Hence, we can apply the findings to diverse real-world exclusive supply chains in durable goods markets.

Because the exclusive contract in this study is a tool to deter the entry of efficient entrants in the future, this study is suitable for a situation where a local firm faces the threat of entry of highly efficient multinational firms.[6] For example, Vist, a Russian personal computer maker, develops exclusive distribution agreements with several key retailers as a survival strategy toward the entry of multinational firms such as Compaq, IBM, and Hewlett-Packard (Dawar and Frost, 1999). More importantly, multinational firms usually spend some time to actually enter the markets after the news of their entry (Bao and Chen, 2018). Such news in the media allows every economic agent to predict future entry and the incumbent firm to respond to the threat of future entry, both of which are necessary for this study's exclusion mechanism. Therefore, the exclusion mechanism can apply to such situations. In Section 5, we introduce the Intel case (2005) as an example of exclusive dealing in detail and consider the linkage with the results in this study.

[5] For a model analysis of Coase conjecture, see Stokey (1981), Bulow (1982), Gul, Sonnenschein, and Wilson (1986), and Hart and Tirole (1988).

[6] Note that multinational firms usually have high productivity, and they are more efficient than domestic firms (Helpman, Melitz, and Yeaple, 2004; Kimura and Kiyota, 2006).

The findings in this study also provide important predictions for information societies and the openness of supply chains. Recent developments in ICT seemingly facilitate the openness of supply chains because such progress allows downstream firms to find alternative trading partners more easily. However, our findings imply that such a view does not necessarily remain valid in durable goods markets; downstream durable goods producers may choose to develop an exclusive supply chain even when an efficient supplier appears in the future.[7]

The remainder of this paper is organized as follows. Section 2 provides the literature review. Section 3 constructs the model. Section 4 analyzes the existence of exclusion outcomes under two-part tariffs. Section 5 provides the extension analysis and discusses the linkage between this study and the Intel case (2005). Section 6 offers concluding remarks. Appendix A provides the proofs of the results.

2 Literature Review

This study is related to the literature on entry deterrence in durable goods markets.[8] By comparing selling with renting, Bucovetsky and Chilton (1986) show that a durable goods monopolist may choose selling to deter future entry. Bulow (1986) also shows that a durable goods monopolist has an incentive to increase durability to prevent future entry from the viewpoint of planned obsolescence. These studies focus on how vertically integrated durable goods monopolists influence the demand for future entrants. In contrast, this study discusses entry deterrence by an upstream firm that trades with a downstream durable goods monopolist by focusing on exclusive contracts.

The market environment in our model is also related to those in which consumers have

[7] Our focus is also related to the exclusiveness of *keiretsu* in the Japanese automobile industry (e.g., Aoki and Lennerfors, 2013) and channel coordination (e.g., Jeuland and Shugan, 1983; Coughlan, 1985; Gupta and Loulou, 1998; Gupta, 2008).

[8] Several studies analyze firms' strategies to deter future entry in the perishable goods market because of cost uncertainty (Milgrom and Roberts, 1982), quality uncertainty (Schmalensee, 1982), and switching costs (Klemperer, 1987).

multi-period opportunities to purchase final products. In those models, Besanko and Winston (1990) and Dudine, Hendel, and Lizzeri (2006) discuss storable goods markets, and Coase (1972), Bulow (1982, 1986), Denicolò and Garella (1999), Bruce, Desai, and Staelin (2006), Agrawal et al. (2012), and Gilbert, Randhawa, and Sun (2014) investigate durable goods markets. Our paper contributes to the research stream on those product markets with vertical supply chains (storable goods markets (Desai, Koenigsberg, and Purohit, 2010; Lin, Parlaktürk, Swaminathan, 2018; Kabul and Parlaktürk, 2019), leasing versus selling (Purohit, 1995; Desai and Purohit, 1999; Bhaskaran and Gilbert, 2009, 2015), and secondary markets (Shulman and Coughlan, 2007; Oraiopoulos, Ferguson, and Toktay, 2012)).

In particular, this study is related to the literature on anticompetitive exclusive contracts that deter the socially efficient entry of a potential entrant.[9] The literature on anticompetitive exclusive contracts starts from the Chicago School argument in the 1970s (Posner, 1976; Bork, 1978). Using a simple setting, they point out that rational economic agents never sign exclusive contracts for anticompetitive reasons if we consider all members' participation constraints in the contracting party.[10] In rebuttal to the Chicago School, post-Chicago economists find that rational economic agents agree with exclusive contracts for anticompetitive reasons in certain market environments. Some papers extend a single-buyer model in the Chicago School argument to a multiple-buyer model. For instance, the entrant needs a certain number of buyers to cover its fixed costs (Rasmusen, Ramseyer, and Wiley, 1991; Segal and Whinston, 2000), and buyers compete in downstream markets (Simpson and Wickelgren, 2007; Abito and Wright, 2008).[11] In these studies, negative externalities exist; signing

[9] Several studies focus on the fact that active firms may compete for exclusivity and explore the welfare effect (Mathewson and Winter, 1987; O'Brien and Shaffer, 1997; Bernheim and Whinston, 1998). Recently, Calzolari and Denicolò (2013, 2015) introduced asymmetric information in this literature.

[10] For the analysis of the impact of this argument on antitrust policies, see Motta (2004), Whinston (2006), and Fumagalli, Motta, and Calcagno (2018).

[11] In the literature on exclusion with downstream competition, Fumagalli and Motta (2006) show that the existence of participation fees to remain active in the downstream market plays a crucial role in exclusion if buyers are undifferentiated Bertrand competitors. See also Wright (2009), who reconsiders the result of

exclusive contracts reduces the possibility of entry under scale economies, and upstream entry reduces industry profits in the presence of downstream competition.[12] Furthermore, in the framework of a single downstream firm, several studies point out that the intensity of upstream competition plays a crucial role in the Chicago School argument.[13] They show that the exclusion result is attainable in the cases where the incumbent sets liquidated damages for the case of entry (Aghion and Bolton, 1987), where the entrant is capacity constrained (Yong, 1996), where upstream firms compete à la Cournot (Farrell, 2005), and where upstream firms can merge (Fumagalli, Motta, and Persson, 2009).[14] To the best of our knowledge, existing papers in this literature consider only perishable goods markets. Thus, we construct the model here to clarify that the exclusion mechanism in this study depends on the nature of durable goods markets; exclusion occurs because of the negative externality that future entry reduces current industry profits.

Furthermore, the model formulation of our paper has links to the models of durable goods markets concerning vertical channel coordination (Desai, Koenigsberg, and Purohit, 2004; Arya and Mittendorf, 2006; Su and Zhang, 2008; Bhaskaran and Gilbert, 2009, 2015; Yang, 2012; Gümüş, Ray, and Yin, 2013; Ramanan and Bhargava, 2014). Desai, Koenigsberg, and Purohit (2004) employ two-period durable goods monopoly models with a separate retail channel to discuss the effect of commitment on the vertical trading term. They show that the commitment to the vertical contract overcomes the Coase problem, leading to a higher

Fumagalli and Motta (2006) in the case of two-part tariffs.

[12] For the extended model of exclusion with scale economies, see Choi and Stefanadis (2018). By contrast, for extended models of exclusion with downstream competition, see Wright (2008), Argenton (2010), Kitamura (2010), and DeGraba (2013) who show the anticompetitiveness of the realized exclusive contracts. Gratz and Reisinger (2013) show procompetitive effects if downstream firms compete imperfectly and contract breaches are possible.

[13] For another mechanism of anticompetitive exclusive dealing, see Fumagalli, Motta, and Rønde (2012), who focus on the incumbent's relationship-specific investments. See also Kitamura, Matsushima, and Sato (2018), who focus on a complementary input supplier with market power.

[14] See also Kitamura, Matsushima, and Sato (2017), who show that anticompetitive exclusive dealing can occur if the downstream buyer bargains with suppliers sequentially.

profit for the monopoly manufacturer. Arya and Mittendorf (2006) consider a multi-period durable goods monopoly market. The monopolist determines if it separates its input sector to overcome the Coase problem. The trading term between the input and retail sectors is a linear wholesale price. They show the possibility that vertical separation by the monopolist occurs in equilibrium.[15] In line with the discussions by Desai, Koenigsberg, and Purohit (2004) and Arya and Mittendorf (2006), Su and Zhang (2008) investigate a newsvendor problem with demand uncertainty to discuss channel coordination. Bhaskaran and Gilbert (2009, 2015) follow Bulow (1982) to investigate the durability choice by a monopoly manufacturer under four scenarios ((i) centralized or decentralized channel and (ii) selling or leasing). Gümüş, Ray, and Yin (2013) discuss return policy under demand uncertainty in decentralized durable goods markets. The authors of those papers do not address the openness of the supply chain in durable goods markets, which is the primary topic of our article.

3 Model

We explain the market environment. There is a common discount factor $\delta \in (0, 1)$ for all players who are active in two periods $t = 1, 2$. The final good is perfectly durable; that is, the final good produced and used in period 1 can be used in period 2, without depreciation. For simplicity, there is no resale market. We assume that all firms cannot commit to future prices and that there is no possibility of renting products.

The rest of this section is organized as follows. We first explain players' characteristics and the game's timing in Section 3.1. Section 3.2 then introduces the design of exclusive contracts.

[15] Yang (2012) extends Arya and Mittendorf (2006) to downstream oligopoly. Ramanan and Bhargava (2014) also employ the framework of Arya and Mittendorf (2006) to discuss consumers' uncertainty on their valuations of the product.

3.1 Basic environment

Consumers There are a number of consumers, each of whom buys at most one unit of the final good. For simplicity, we assume that the mass of consumers is normalized to one. We index consumers by $y \in [0, \bar{y}]$, whose distribution depends on $F(y)$, where $F'(y) > 0$ for all $y \in [0, \bar{y})$, $F(0) = 0$, and $F(\bar{y}) = 1$. The consumer type y's willingness to pay, which is stationary for all periods, is denoted by $v(y)$, where $v'(y) > 0$ for all $y \in [0, \bar{y})$. If a consumer y purchases a unit of the final good in period $t(= 1, 2)$, the consumer's gross lifetime discounted utility evaluated in period 1 becomes

$$u_t(y) = \delta^{t-1} v(y),$$

which implies that each consumer can use the final good for eternity.[16] In the supplementary appendix, we introduce the analysis under linear demand in which $F(y) = y$ and $v(y) = y$; that is, y is uniformly distributed and the consumer's willingness to pay is a linear function of y. This setting allows us to explore the existence of exclusion outcomes in various situations such as linear wholesale pricing and vertical product differentiation.

In period 2, a consumer type y, who does not purchase the final good in period 1, purchases the final good if and only if the consumer surplus is nonnegative, i.e., $v(y) - p_2 \geq 0$. By rationally predicting p_2, the consumer purchases the final good in period 1 if and only if $v(y) - p_1 \geq \delta(v(y) - p_2)$. The indifferent consumer type y_1 is defined by $v(y_1) - p_1 = \delta(v(y_1) - p_2)$. Let q_1 be the mass of consumers purchasing in period 1. By definition, we have $q_1 = 1 - F(y_1)$. Then, by using these two equations, we have the static inverse demand in period 1, which is a function of q_1 and p_2, as follows:

$$P_1(q_1, p_2) \equiv (1 - \delta) v(y(q_1)) + \delta p_2,$$

[16] Denicolò and Garella (1999) also use a similar formulation to discuss a durable goods market. Alternatively, we can consider the setting in which $\bar{v}(y)$ represents a value of per period use; the surplus of consumer type y is $(1 + \delta)\bar{v}(y) - p_1$ for the purchase in period 1, while it is $\bar{v}(y) - p_2$ for the purchase in period 2. In the supplementary appendix, we explore such a setting under linear demand and derive exclusion results.

where $y_1(q_1) \equiv F^{-1}(1-q_1)$. As $y_1'(q_1) = -1/F'(y_1) < 0$ always holds, $P_1(q_1, p_2)$ has the following properties:

$$\frac{\partial P_1(q_1,p_2)}{\partial q_1} = (1-\delta)v'(y_1)y_1'(q_1) < 0, \quad \frac{\partial P_1(q_1,p_2)}{\partial p_2} = \delta > 0.$$

The above properties imply that the static inverse demand in period 1 is downward sloping with respect to the current production level and becomes larger when consumers anticipate a higher future price.

Firms The upstream market consists of an incumbent supplier U_I and an entrant supplier U_E. U_I and U_E produce an identical input but differ in terms of cost efficiency. The constant marginal costs of U_I and U_E are $c_I(< v(\bar{y}))$ and $c_E \in [0, c_I)$, respectively. To guarantee that some consumers prefer to purchase the final good in period 1 ($q_1 > 0$), we assume that the difference in suppliers' marginal costs is not too large. In Section 4.3, we extend the model to the case in which the difference in the efficiency is too large and no consumer purchases the final good in period 1 when U_E's entry is anticipated. Each supplier offers a two-part tariff, which consists of a linear wholesale price w and an upfront fixed fee ψ to the downstream market if it is active.

The downstream market is composed of a downstream monopolist D. This modeling strategy clarifies the role of durable goods; namely, the prevention of efficient entry occurs even in the absence of scale economies and downstream competition, both of which require more than one downstream firm. D transforms one unit of the input into one unit of the final good, which is durable. To simplify the analysis, we assume that the cost of transformation is zero. Thus, if D faces a wholesale price w_t in period t, its per-unit production cost in period t becomes w_t. The assumption on the downstream monopolist follows that in Desai, Koenigsberg, and Purohit (2004).

Timing Following Bucovetsky and Chilton (1986) and Bulow (1986), in period 1, only U_I exists in the upstream market. This may be because of a patent right, superior technology, efficient marketing, or an industry protection policy. Period 1 consists of three stages. In period 1.1, U_I makes a two-period exclusive offer to D, with fixed compensation $x \geq 0$. This assumption simply follows the standard literature on naked exclusion. In Section 3.2, we show that for the existence of exclusion outcomes, it does not matter whether U_I or D makes exclusive offers. Following the standard literature on naked exclusion, we assume that the exclusive offer does not contain the term of wholesale prices.[17] After observing the exclusive offer, D decides whether to accept the offer. D immediately receives x if it accepts the offer. Let $\omega \in \{a, r\}$ be D's decision in period 1.1, where the superscript "a" ("r") indicates that the exclusive offer is accepted (rejected). In period 1.2, U_I offers a two-part tariff contract to D. In period 1.3, D orders the input and sells the final good to consumers.

At the beginning of period 2, U_E appears in the upstream market. Period 2 consists of three stages. In period 2.1, U_E decides whether to enter the market.[18] We assume that the fixed entry cost is sufficiently small such that U_E can earn positive profits. In period 2.2, active suppliers offer two-part tariff contracts to D. For the case of U_E's entry, U_I and U_E become homogeneous Bertrand competitors. We assume that if they charge the same input price, the efficient supplier, U_E, supplies its input to D. In period 2.3, D orders the input and sells the final good to consumers.

U_i's profit in period t when D's decision in period 1.1 is $\omega \in \{a, r\}$ is denoted by $\pi^{\omega}_{i|t}$, where $i \in \{I, E\}$. Likewise, D's profit in period t is denoted by $\pi^{\omega}_{D|t}$. We assume that U_I

[17] Rasmusen, Ramseyer, and Wiley (1991) and Segal and Whinston (2000) point out that price commitments are unlikely if the nature of the final good is not precisely described in advance. In the naked exclusion literature, it is known that if the incumbent can commit to wholesale prices, then the possibility of anticompetitive exclusive dealing is enhanced. See Yong (1999) and Appendix B of Fumagalli and Motta (2006).

[18] The result does not change if we consider the possibility that U_I makes exclusive offers in period 2 if its exclusive offer in period 1 is rejected. In such a case, the Chicago School argument can be applied; U_I cannot make exclusive offers to profitably compensate D in period 2.

and D maximize the present discounted value of their profits $\pi^{\omega}_{I|1} + \delta\pi^{\omega}_{I|2}$ and $\pi^{\omega}_{D|1} + \delta\pi^{\omega}_{D|2}$ respectively, while U_E maximizes the second-period profits $\pi^{\omega}_{E|2}$ for the case of entry.

3.2 Design of exclusive contracts

For an exclusion equilibrium to exist, the equilibrium transfer x^* must simultaneously satisfy the following two conditions.

First, the exclusive contract must satisfy individual rationality for D; that is, the amount of compensation x^* induces D to accept the exclusive offer:

$$\pi^a_{D|1} + x^* + \delta\pi^a_{D|2} \geq \pi^r_{D|1} + \delta\pi^r_{D|2} \quad \text{or} \quad x^* \geq \pi^r_{D|1} + \delta\pi^r_{D|2} - (\pi^a_{D|1} + \delta\pi^a_{D|2}). \tag{1}$$

Second, the exclusive contract must satisfy individual rationality for U_I; that is, U_I earns higher profits under exclusive dealing:

$$\pi^a_{I|1} + \delta\pi^a_{I|2} - x^* \geq \pi^r_{I|1} + \delta\pi^r_{I|2} \quad \text{or} \quad x^* \leq \pi^a_{I|1} + \delta\pi^a_{I|2} - (\pi^r_{I|1} + \delta\pi^r_{I|2}). \tag{2}$$

From the above conditions, it is evident that an exclusion equilibrium exists if and only if inequalities (1) and (2) simultaneously hold. This is equivalent to the following condition:

$$\pi^a_{I|1} + \delta\pi^a_{I|2} + \pi^a_{D|1} + \delta\pi^a_{D|2} \geq \pi^r_{I|1} + \delta\pi^r_{I|2} + \pi^r_{D|1} + \delta\pi^r_{D|2}. \tag{3}$$

Condition (3) implies that anticompetitive exclusive contracts are attained if exclusive contracts increase the overall joint profits of U_I and D. The condition also implies that whether U_I or D makes an exclusive offer does not affect the existence of exclusion outcomes.

4 Analysis

We characterize the properties of subgame perfect Nash equilibria by solving the game using backward induction. Starting from the game in period 2, we explore the equilibrium outcomes in the subgame after D's decision in period 1.1. We then explore the contractual decision in period 1.1 to examine the existence of exclusion outcomes.

4.1 Period 2

Let y_2 denote the indifferent consumer in period 2, which satisfies $v(y_2) - p_2 = 0$. By defining q_2 as the mass of consumers purchasing in period 2, the sum of the production level in both periods becomes $q_1 + q_2 = 1 - F(y_2)$. From these two equations, we obtain the residual inverse demand function in period 2 given q_1:

$$P_2(q_2|q_1) \equiv v(y_2(q_2|q_1)),$$

where $y_2(q_2|q_1) \equiv F^{-1}(1 - q_1 - q_2)$. Note that $P_2(q_2|q_1)$ has the following property:

$$\frac{\partial P_2(q_2|q_1)}{\partial q_1} = \frac{\partial P_2(q_2|q_1)}{\partial q_2} = -\frac{v'(y_2(q_2|q_1))}{F'(y_2(q_2|q_1))} < 0. \tag{4}$$

For notational convenience, we define $q_2^*(q_1, z)$, $P_2^*(q_1, z)$, and $\Pi_2^*(q_1, z)$ as follows:

$$\begin{aligned} q_2^*(q_1, z) &\equiv \underset{q_2 \geq 0}{\operatorname{argmax}}\ (P_2(q_2|q_1) - z)q_2, \\ P_2^*(q_1, z) &\equiv P_2(q_2^*(q_1, z)|q_1), \\ \Pi_2^*(q_1, z) &\equiv (P_2^*(q_1, z) - z)q_2^*(q_1, z), \end{aligned} \tag{5}$$

where $0 \leq z < P_2(0|q_1)$.

In period 2.3, given the two-part tariff contract (w_2, ψ_2), D chooses $q_2^*(q_1, w_2)$ to maximize its second-period profit, which leads to the equilibrium price $P_2^*(q_1, w_2)$. D earns

$$\pi_{D|2}(q_1, w_2) = \Pi_2^*(q_1, w_2) - \psi_2.$$

The following lemma summarizes the properties of $q_2^*(q_1, w_2)$, $P_2^*(q_1, w_2)$, and $\Pi_2^*(q_1, w_2)$.

Lemma 1. *$q_2^*(q_1, w_2)$, $P_2^*(q_1, w_2)$, and $\Pi_2^*(q_1, w_2)$ have the following properties:*

$$\frac{\partial q_2^*(q_1, w_2)}{\partial w_2} < 0, \quad \frac{\partial P_2^*(q_1, w_2)}{\partial w_2} > 0, \quad \frac{\partial \Pi_2^*(q_1, w_2)}{\partial q_1} < 0.$$

Proof. See Appendix A.1. □

In period 2.2, the supplier(s) consider the profit maximization problem(s), given q_1. First, we discuss the case in which the exclusive offer is accepted in period 1.1. Second, we explore the case in which the exclusive offer is rejected in period 1.1. Finally, we compare both cases.

Exclusive supply chain When the exclusive supply chain is chosen, only U_I exists in the upstream market in period 2. In period 2.2, U_I offers the trading term, $(w^a_{2|I}, \psi^a_{2|I}) = (c_I, \psi^a_2)$, such that $\Pi^*_2(q_1, w_2) - \psi^a_2 = 0$. D accepts this trading term, and the resulting profits of U_I and D are given by

$$\pi^a_{I|2} = \Pi^*_2(q_1, c_I), \quad \pi^a_{D|2} = 0.$$

The realized price in period 2 is $p^a_2 = P^*_2(q_1, c_I)$.

Open supply chain When the open supply chain is chosen, U_E enters the upstream market in period 2.1. In period 2.2, the upstream competition between U_I and U_E induces U_I to offer the best trading term, $(w^r_{2|I}, \psi^r_{2|I}) = (c_I, 0)$, which allows D to earn $\Pi^*_2(q_1, c_I)$. Anticipating this trading term by U_I, U_E sets $(w^r_{2|E}, \psi^r_{2|E}) = (c_E, \psi^r_{2|E})$ such that $\Pi^*_2(q_1, c_E) - \psi^r_{2|E} = \Pi^*_2(q_1, c_I)$. D accepts this trading term, and the resulting profits of D, U_I, and U_E are

$$\pi^r_{D|2} = \Pi^*_2(q_1, c_I), \quad \pi^r_{I|2} = 0, \quad \pi^r_{E|2} = \Pi^*_2(q_1, c_E) - \Pi^*_2(q_1, c_I).$$

The realized price in period 2 is $p^r_2 = P^*_2(q_1, c_E)$.

Comparison Finally, we compare the above outcomes in period 2 given q_1. For the pair of U_I and D, their joint profit under the exclusive supply chain is the same as that under the open supply chain. The difference between these two cases appears in the realized prices in period 2. Using the results in Lemma 1, we have the following property:

Lemma 2. *Given q_1, the realized price under the exclusive supply chain is higher than that under the open supply chain: $P^*_2(q_1, c_I) > P^*_2(q_1, c_E)$ always holds.*

The lower realized price in period 2 under the open supply chain follows from the efficiency of U_E; namely, entry of the efficient upstream entrant leads to the lower market price. In the following analysis, we show that this property plays an important role in choosing an exclusive or open supply chain.

4.2 Period 1

Anticipating the outcome in period 2, D determines q_1 given the trading term (w_1, ψ_1) in period 1.3. For expositional simplicity, we use $P_1(q_1|c_I) \equiv P_1(q_1, P_2^*(q_1, c_I))$ and $P_1(q_1|c_E) \equiv P_1(q_1, P_2^*(q_1, c_E))$ to express the static inverse demand functions under the exclusive supply chain and the open supply chain in period 1, respectively. The difference in these two inverse demand functions arises from the difference in the realized prices in period 2. Using the properties of $\partial P_1(q_1, p_2)/\partial p_2 > 0$ and $P_2^*(q_1, c_I) > P_2^*(q_1, c_E)$, the two inverse demands in period 1 have the following property:

Lemma 3. *The static inverse demand in period 1 under the exclusive supply chain is always strictly larger than that under the open supply chain; i.e.,* $P_1(q_1|c_I) > P_1(q_1|c_E)$ *holds for any* q_1.

The result in Lemma 3 implies that the exclusive supply chain allows D to face larger consumer demand than the open supply chain, which can be explained by the intertemporal external effect of entry in period 2. Under the open supply chain, the entry of U_E occurs in period 2, allowing consumers to purchase the final good at a low price in period 2. Such a low price in period 2 induces some consumers to refrain from purchasing in period 1. Hence, the consumer demand in period 1 under the open supply chain becomes smaller than that under the exclusive supply chain. In other words, the contracting party suffers from the small consumer demand in period 1 under the open supply chain.

In the rest of this subsection, we derive the equilibrium outcomes. Because firms' profit maximization problems depend greatly on the contractual decision in period 1.1, we explore the profit maximization problem in periods 1.2 and 1.3 for the cases of the exclusive supply chain and the open supply chain, separately.

Exclusive supply chain We derive the equilibrium outcome starting from D's profit maximization problem in period 1.3. When the exclusive supply chain is chosen in period

1.1, D anticipates that it earns zero profit in period 2; namely, $\pi^a_{D|2} = 0$. Then, given the two-part tariff contract (w_2, ψ_2), which is offered by U_I in period 1.2, D chooses the production level $q^a_1(w_1)$ to maximize its overall profits in period 1.3:

$$q^a_1(w_1) \equiv \underset{q_1 \geq 0}{\text{argmax}}\ (P_1(q_1|c_I) - w_1)q_1 - \psi_1. \tag{6}$$

The first-order condition of the maximization problem in (6) is

$$P_1(q^a_1(w_1)|c_I) - w_1 + \frac{\partial P_1(q^a_1(w_1)|c_I)}{\partial q_1} q^a_1(w_1) = 0. \tag{7}$$

We now consider U_I's profit maximization problem in period 1.2. By anticipating $\pi^a_{I|2} = \Pi^*_2(q^a_1(w_1), c_I)$, U_I's overall profits become

$$(w^a_1, \psi^a_1) \equiv \underset{w_1, \psi_1}{\text{argmax}}\ (w_1 - c_I)q^a_1(w_1) + \psi_1 + \delta\Pi^*_2(q^a_1(w_1), c_I).$$

U_I determines the highest ψ_1 such that D prefers accepting (w_1, ψ_1) to declining it; that is, $\psi_1 = (P_1(q^a_1(w_1)|c_I) - w_1)q^a_1(w_1)$. Under this two-part tariff contract, D's overall profits are zero; $\pi^a_{D|1} + \delta\pi^a_{D|2} = 0$. Then, U_I's profit maximization problem is rewritten as

$$w^a_1 \equiv \underset{w_1}{\text{argmax}}\ (P_1(q^a_1(w_1)|c_I) - c_I)q^a_1(w_1) + \delta\Pi^*_2(q^a_1(w_1), c_I). \tag{8}$$

The first-order condition of the maximization problem in (8) is

$$\left\{(P_1(q^a_1(w^a_1)|c_I) - c_I) + \frac{\partial P_1(q^a_1(w^a_1)|c_I)}{\partial q_1} q^a_1(w^a_1) + \delta \frac{\partial \Pi^*_2(q^a_1(w^a_1), c_I)}{\partial q_1}\right\} q^{a\prime}_1(w^a_1) = 0. \tag{9}$$

Using the first-order conditions in (7) and (9), we obtain the following:

$$w^a_1 = c_I - \delta \frac{\partial \Pi^*_2(q^a_1(w^a_1), c_I)}{\partial q_1}.$$

From Lemma 1, we have $\partial\Pi^*_2(q^a_1(w^a_1), c_I)/\partial q_1 < 0$, which implies that $w^a_1 > c_I$ holds. The following proposition summarizes the discussion.

Proposition 1. *When an exclusive supply chain is chosen for both periods, the equilibrium wholesale price in period 1 is strictly higher than the marginal cost of U_I; that is, $w^a_1 > c_I$.*

Proof. The above discussion is based on $q_1^{a\prime}(w_1^a) < 0$. The proof of $q_1^{a\prime}(w_1^a) < 0$ is provided in Appendix A.2. □

This proposition is a generalization of Desai, Koenigsberg, and Purohit (2004) in that the demand system in our paper is a general form. Under the exclusive supply chain, D chooses the first period production level without considering the profit in period 2 because it anticipates that it earns nothing in period 2. To control D's pricing behavior in period 1, U_I sets $w_1^a > c_I$ to fulfill the overall joint profit maximization of U_I and D.

Note that the realized production level in period 1, $q_1^a(w_1^a)$, is the same as q_1^*, which is the solution of the following maximization problem:

$$q_1^* \equiv \underset{q_1 \geq 0}{\operatorname{argmax}} \ (P_1(q_1|c_I) - c_I)q_1 + \delta\Pi_2^*(q_1, c_I).$$

This means that U_I indirectly controls q_1 through its wholesale price, w_1, to maximize the overall joint profits of U_I and D. As a result, the overall joint profits of U_I and D become

$$\pi_{I|1}^a + \delta\pi_{I|2}^a + \pi_{D|1}^a + \delta\pi_{D|2}^a = (P_1(q_1^*|c_I) - c_I)q_1^* + \delta\Pi_2^*(q_1^*, c_I). \tag{10}$$

Open supply chain When the open supply chain is chosen in period 1.1, D anticipates it earns $\pi_{D|2}^r = \Pi_2^*(q_1, c_I)$ in period 2. Then, given the two-part tariff contract (w_2, ψ_2), which is offered by U_I in period 1.2, D chooses the production level $q_1^r(w_1)$ to maximize its overall profits in period 1.3:

$$q_1^r(w_1) \equiv \underset{q_1 \geq 0}{\operatorname{argmax}} \ (P_1(q_1|c_E) - w_1)q_1 - \psi_1 + \delta\Pi_2^*(q_1, c_I). \tag{11}$$

The first-order condition of the maximization problem in (11) is

$$P_1(q_1^r(w_1)|c_E) - w_1 + \frac{\partial P_1(q_1^r(w_1)|c_E)}{\partial q_1} q_1^r(w_1) + \delta \frac{\partial \Pi_2^*(q_1^r(w_1), c_I)}{\partial q_1} = 0. \tag{12}$$

By anticipating this reaction, U_I's profit maximization problem in period 1.2 becomes

$$(w_1^r, \psi_1^r) \equiv \underset{w_1, \psi_1}{\operatorname{argmax}} \ (w_1 - c_I)q_1^r(w_1) + \psi_1$$

Note that under the open supply chain, D can earn $\delta\Pi_2^*(0, c_I)$ in period 2 through the competition between U_I and U_E if it rejects the two-part tariff contract (w_1, ψ_1). U_I determines the highest ψ_1 such that D prefers accepting (w_1, ψ_1) to declining it; the optimal level of upfront fixed payment satisfies $\psi_1 = (P_1(q_1^r(w_1)|c_I) - w_1)q_1^r(w_1) + \delta\Pi_2^*(q_1, c_I) - \delta\Pi_2^*(0, c_I)$. Under this two-part tariff contract, U_I cannot extract all the overall joint profits of U_I and D; unlike the exclusive supply chain, D earns positive overall profits, $\pi_{D|1}^r + \delta\pi_{D|2}^r = \delta\Pi_2^*(0, c_I)$. Then, U_I's profit maximization problem is rewritten as

$$w_1^r \equiv \underset{w_1}{\operatorname{argmax}}\ (P_1(q_1^r(w_1)|c_E) - c_I)q_1^r(w_1) + \delta\Pi_2^*(q_1^r(w_1), c_I) - \delta\Pi_2^*(0, c_I). \tag{13}$$

The first-order condition of the maximization problem in (13) is

$$\left\{(P_1(q_1^r(w_1^r)|c_E) - c_I) + \frac{\partial P_1(q_1^r(w_1^r)|c_E)}{\partial q_1} q_1^r(w_1^r) + \delta \frac{\partial \Pi_2^*(q_1^r(w_1^r), c_I)}{\partial q_1}\right\} q_1^{r\prime}(w_1^r) = 0. \tag{14}$$

Using the first-order conditions in (12) and (14), we obtain the following:

$$w_1^r = c_I.$$

The following proposition summarizes the discussion.

Proposition 2. *When U_E enters the upstream market in period 2, the equilibrium linear wholesale price in period 1 equals the marginal cost of U_I; that is, $w_1^r = c_I$.*

Proof. The above discussion is based on $q_1^{r\prime}(w_1^r) < 0$. The precise proof of $q_1^{r\prime}(w_1^r) < 0$ is provided in Appendix A.3. □

Under the open supply chain, from (12) and (14), we find that D's maximization problem aligns with U_I's if and only if U_I sets $w_1^r = c_I$ as in the standard two-part tariff pricing.

Note that the realized production level in period 1, $q_1^r(w_1^r)$, is the same as q_1^{**}, which is the solution of the following maximization problem:

$$q_1^{**} \equiv \underset{q_1 \geq 0}{\operatorname{argmax}}\ (P_1(q_1|c_E) - c_I)q_1 + \delta\Pi_2^*(q_1, c_I).$$

Thus, the overall joint profits of U_I and D become

$$\pi^r_{I|1} + \delta\pi^r_{I|2} + \pi^r_{D|1} + \delta\pi^r_{D|2} = (P_1(q_1^{**}|c_E) - c_I)q_1^{**} + \delta\Pi^*_2(q_1^{**}, c_I). \tag{15}$$

Comparison We finally examine the contractual decision in period 1.1. We compare equations (10) and (15): the overall joint profits in the two trading modes. For q_1, the overall joint profits in period 1 under the exclusive supply chain are

$$\Pi^a(q_1^*) \equiv (P_1(q_1|c_I) - c_I)q_1 + \delta\Pi^*_2(q_1, c_I), \tag{16}$$

while those under the open supply chain are

$$\Pi^r(q_1) \equiv (P_1(q_1|c_E) - c_I)q_1 + \delta\Pi^*_2(q_1, c_I). \tag{17}$$

The only difference between $\Pi^a(q_1)$ and $\Pi^r(q_1)$ is in the static inverse demand in period 1, $P_1(q_1|\cdot)$. From Lemma 3, we have $P_1(q_1|c_I) > P_1(q_1|c_E)$ for any q_1, which implies that $\Pi^a(q_1) > \Pi^r(q_1)$ holds for all q_1. Recall that, under the two modes, U_I indirectly controls q_1 through its wholesale price, w_1. Therefore, under the exclusive supply chain, by setting $w_1 = w_1^a$, U_I achieves the overall joint profits, $\Pi^a(q_1^*)$, which are strictly higher than those under the open supply chain, $\Pi^r(q_1^{**})$; that is, condition (3) always holds.

Theorem 1. *In durable goods markets, U_I and D choose an exclusive supply chain for any c_I, c_E, and δ if D produces the positive production level in period 1 when consumers predict U_E's entry in period 2.*

Theorem 1 implies that if at least some consumers purchase final goods in period 1 under the open supply chain, the two-period exclusive supply chain, which deters the entry of an efficient entrant in period 2, is always established in durable goods markets. This result can be explained by the intertemporal negative externality in durable goods markets. In durable goods markets, future entry intertemporally affects the current market outcome. Efficient entry in period 2 discourages final consumers from purchasing final goods in period 1 because they predict that entry leads to a future price reduction. Such a property prevents the contracting party from choosing the optimal pair of prices (p_1, p_2) to maximize overall joint profits under the open supply chain. In other words, using the two-part tariff contract, U_I can indirectly control the pair of prices to achieve overall joint profit maximization under the exclusive supply chain, whereas it cannot control the prices in period 2 because of the entry of U_E under the open supply chain. Therefore, although consumers benefit from future entry, such entry is harmful to the contracting party; namely, in durable goods markets, rational economic agents choose the exclusive supply chain, which deters efficient future entry.

In addition, from the viewpoint of competition policy, the findings here provide a new insight for anticompetitive exclusive contracts. If we modify our model to the case of perishable goods markets, the modified model coincides with the framework of the Chicago School argument; exclusive contracts cannot deter the entry of an efficient entrant. Theorem 1 implies that the Chicago School argument cannot be applied to durable goods markets; the nature of durable goods markets allows the inefficient incumbent supplier to deter efficient future entry thorough anticompetitive exclusive contracts.[19]

4.3 Highly efficient entrant

Thus far, we explore the case in which at least some consumers purchase final goods in period 1. However, if U_E is sufficiently efficient, the inverse demand in period 1, $P_1(q_1|c_E)$, becomes so small that no consumer purchases final goods in period 1 under the open supply chain; that is, $q_1^r = 0$. In this case, the overall joint profits in period 1 under the open supply chain are $\Pi^r(0) = \delta\Pi_2^*(0, c_I)$. From (16) and (17), we have

$$\Pi^a(q_1^*) > \Pi^a(0) = \Pi^r(0),$$

[19] In the supplementary appendix, we compare the social surpluses under the exclusive supply chain and the open supply chain, by introducing linear demand. We show that the exclusive supply chain to deter the efficient entrant is always undesirable from the viewpoint of social surplus.

which implies that the exclusive supply chain leads to higher overall joint profits of U_I and D than the open supply chain even when U_E is highly efficient.

Theorem 2. *In durable goods markets, U_I and D choose an exclusive supply chain for any c_I, c_E, and δ even if D does not produce the positive production level in period 1 when consumers expect U_E's entry in period 2.*

The results in Theorems 1 and 2 imply that in durable goods markets, the exclusive supply chain is always established regardless of the difference in cost efficiency. Note that the results in this study depend on the assumption that upstream suppliers can adopt two-part tariffs. In the supplementary appendix, we extend the model of linear demand to the case of linear wholesale pricing. We show that in contrast to the case of two-part tariffs, linear wholesale pricing does not lead to exclusion outcomes for a high discount factor. The major difference between the two types of wholesale pricing is the existence of a double marginalization problem, which is often observed for the case of linear wholesale pricing. When the exclusive supply chain is chosen, the double marginalization problem occurs for both periods, which reduces the overall joint profits of U_I and D under the exclusive supply chain. By contrast, when the open supply chain is chosen, efficient entry in period 2 can mitigate such a problem; D can earn considerably high profits in period 2. If the discount factor is high, this effect becomes dominant and thus, the open supply chain is chosen in the equilibrium.

5 Intel Case

In this section, we briefly consider the linkage between exclusive dealing in this study and the Intel case (2005). In the CPU market, Intel's rival firms develop competitive products such as "Crusoe" developed by Transmeta in the early 2000s and "Ryzen" developed by AMD and "M1" developed by Apple based on ARM architecture around 2020. Hence, although Intel maintains a dominant position in the CPU market, it commonly faces the threat of competitive products developed by rival firms. More importantly, Ryzen and ARM-based processors have been adopted recently by several personal computer makers because of their high performance.[20] Because of these adoptions, for example, AMD's market share for notebook CPUs grows from 11.4% in 2019 to 20.1% in 2020.[21] Against the market environment change, Intel would currently have an incentive to exclude these rivals through exclusive contracts if such contracts were lawful. Thus, considering the linkage between the exclusion mechanism in this study and the Intel case (2005) allows us to predict the feasibility of the exclusive dealing in the current and future CPU markets.

In the Intel case (2005), a competitive product also existed.[22] Intel had a dominant position in the market for the 32-bit version of x86 microprocessors to run on the Microsoft Windows and Linux families of operating systems. However, in 2003, AMD achieved technological leadership for the 64-bit version of the x86 microprocessors, which are expected to become the next-generation standard.[23] The US District Court for the District of Delaware pointed out that "*Bested in a technology duel over which it long claimed leadership, Intel increased exploitation of its market power to pressure customers to refrain from migrating to AMD's superior, lower-cost microprocessors.*"[24] As one of the countermeasures against

[20] See "Apple unleashes M1" *Apple,* November 10, 2020 (`https://www.apple.com/newsroom/2020/11/apple-unleashes-m1/`), "Lenovo brings AMD to its gaming laptops" *CNET,* July 16, 2020 (`https://www.cnet.com/news/lenovo-brings-amd-to-its-gaming-laptops/`), and "HP Envy x360 13 (2020) review: This small 2-in-1 is more premium than its price" *CNET,* September 23, 2020 (`https://www.cnet.com/reviews/hp-envy-x360-13-2020-review/`).

[21] See "Global Notebook Computer Shipment Expected to Reach 217 Million Units in 2021, with Chromebooks Accounting for 18.5% of Total Shipment, Says TrendFoce" *TrendForce,* January 6, 2021 (`https://www.trendforce.com/presscenter/news/20210106-10633.html`).

[22] See also "Intel and AMD: A long history in court" *CNET,* July 8, 2005 (`https://www.cnet.com/news/intel-and-amd-a-long-history-in-court/`).

[23] In fact, 64-bit microprocessors started to become mainstream in CPU markets after Intel launched Core 2 processors, its first 64-bit microprocessors for general consumers, on July 27, 2006 (`https://www.intel.com/pressroom/archive/releases/2006/20060727comp.htm`).

[24] See page 3 of the report on Advanced Micro Devices, Inc., a Delaware corporation, and AMD Inter-

AMD, "*Intel had forced major customers into exclusive-or near exclusive deals.*"[25] From the above evidence, Intel's exclusive dealings can be interpreted as its strategy to protect its dominant position in the CPU market in the future, which corresponds to this study's assumption in which the incumbent supplier, a currently dominant firm, is inferior to the entrant supplier in the future. In addition, compared with other industries, firms and consumers can easily access information on the perspective on the change of upstream markets in computing industries, which implies that all economic agents are more likely to anticipate the market structure in the future, which is also required in the exclusion mechanism in this study. Therefore, the exclusive mechanism in this study is more likely to work effectively in the CPU market; namely, using exclusive contracts, a dominant CPU supplier can exclude a rival CPU supplier, which has efficient technology regarded as the next-generation standard.

In addition, Intel's conduct as described above benefits not only Intel but also personal computer manufacturers because these manufacturers obtain a large amount from the awarding of rebates and various other payments. For example, in a single quarter in 2007, conditional rebates and payments from Intel amounted to 76% of Dell's operating profit (Gans, 2013).[26] From the viewpoint of downstream personal computer manufacturers, this kind of offer from Intel is very attractive. It is an adequate incentive for downstream firms to choose exclusive trading.

Finally, we note that in the analysis of the previous section, input suppliers differ in terms of cost efficiency. Considering the Intel case (2005), it is more suitable to construct a model in which inputs produced by suppliers are vertically differentiated. In the supplementary appendix, we extend the model of linear demand to the case in which input suppliers produce

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national Sales & Services, Ltd., a Delaware corporation, v. Intel corporation, a Delaware corporation, and Intel Kabushiki Kaisha, a Japanese corporation, Civil Action No. 05-441-JJF, 2005 (`https://www.amd.com/system/files/amd-intel-full-complaint.pdf`).

[25] See page 2 of the report.

[26] See also Japan Fair Trade Commission (2005): `http://www.jftc.go.jp/eacpf/cases/intel.pdf`, and the European Commission (2009): `http://ec.europa.eu/competition/sectors/ICT/intel.html`.

vertically differentiated inputs, following Argenton (2010). We show that the exclusion mechanism in this study remains valid; namely, inferior input suppliers can deter superior input suppliers through exclusive contracts in durable goods markets.

6 Conclusion

This study has explored a supply chain problem in durable goods markets. We consider the situation in which a downstream durable goods monopolist chooses one of the two trading modes: (i) an exclusive supply chain with an existing incumbent supplier, or (ii) an open supply chain, which causes competition between the existing incumbent supplier and a potential supplier in the future. The problem is also related to the discussion of anticompetitive exclusive contracts. Therefore, this study contributes to the literature in terms of both supply chain management and competition policy. Extending the static framework of the Chicago School argument to a two-period durable goods model without price commitment, we show that the downstream durable goods monopolist chooses the exclusive supply chain by signing long-term exclusive contracts; the potential entrant cannot enter the upstream market even when it is efficient. This study's exclusion mechanism is explained by the time-inconsistency problem (Coase, 1972).

Our result has new policy implications for antitrust agencies; the Chicago School argument, which is based on static perishable goods markets, is not necessarily applicable to durable goods markets. Because of the nature of durable goods, rational economic agents can engage in anticompetitive exclusive contracts to exclude the efficient entrant in the future even under the simplest setting in which exclusion never occurs in static perishable goods markets. When we discuss the anticompetitiveness of exclusive contracts, we need to consider the durability of final goods in the market in which exclusion occurs. Otherwise, we may overestimate the Chicago School argument, which may lead to misleading predictions.

The results here could explain why some vertical relations are too stable, which results in inefficiency. In the literature on business and management, long-standing organization ties cause lower incentives for opportunistic behavior (Williamson, 1975), information search (Uzzi, 1997), and necessary restructuring (Ernst and Bamford, 2005). Such organizations are less likely to search for new partners and capabilities and pursue existing business practices, which result in a decrease in benefits within interorganizational ties or a negative impact on organization performance (Uzzi, 1997; Goerzen, 2007; Poppo, Zhou, and Zenger, 2008).[27] In our model, the downstream firm has an incentive to sign a two-period contract with the incumbent supplier, even by anticipating the appearance of a new efficient supplier in the near future. The resulting outcome leads to inefficiency of the vertical chain. Thus, although the advancement of informatization and globalization seemingly expands the open supply chain, these business environment changes may have a smaller impact on the openness of vertical relations in durable goods markets.

Despite these contributions, there remain some issues requiring future research. First, we predict that the exclusion results are more likely to be observed if we introduce product durability into the other models of anticompetitive exclusive dealing based on perishable goods in the literature. Second, for the analysis in this study, we restrict our attention to a particular industry structure—a single potential entrant supplier—for clarity, but we can certainly assume multiple entrant suppliers. As in Kitamura (2010), if we assume multiple entrants, the competition between entrants induces the downstream firm to earn higher profits under the open supply chain, which enables us to predict that the exclusive supply chain may not be chosen if multiple entrants are sufficiently efficient. Thus, extensions and applications of our model can help researchers and policy makers address similar real-world issues.

[27] In addition, as those organizations accumulate relationship-specific experiences, such organizational inertia becomes stronger, and the partners share relationship-specific routines (Kim, Oh, and Swaminathan, 2006). Moreover, the specificity and efficiency of a relationship-specific investment may discourage the downstream firm from switching to a new trading partner (Kitamura, Miyaoka, and Sato, 2016).

A Proofs of the results

A.1 Proof of Lemma 1

In this proof, we often use $q_2^* \equiv q_2^*(q_1, w_2)$ for notational simplicity. We first explore the property of $\partial q_2^*(q_1, w_2)/\partial w_2$. For $z = w_2$, the first-order condition of D's profit maximization problem (5) becomes

$$P_2(q_2^*|q_1) - w_2 + \frac{\partial P_2(q_2^*|q_1)}{\partial q_2} q_2^* = 0. \tag{18}$$

The second-order condition of the maximization problem in (5) leads to

$$2\frac{\partial P_2(q_2^*|q_1)}{\partial q_2} + \frac{\partial^2 P_2(q_2^*|q_1)}{\partial q_2^2} q_2^* < 0.$$

Then, using (18), the implicit function theorem shows that

$$\frac{dq_2^*}{dw_2} = \frac{1}{2\frac{\partial P_2(q_2^*|q_1)}{\partial q_2} + \frac{\partial^2 P_2(q_2^*|q_1)}{\partial q_2^2} q_2^*} < 0. \tag{19}$$

Hence, we have $\partial q_2^*(q_1, w_2)/\partial w_2 < 0$. We next consider the property of $\partial P_2^*(q_1, w_2)/\partial w_2$. Using (4) and (19), partial differentiation leads to

$$\frac{\partial P_2^*(q_1, w_2)}{\partial w_2} = \frac{\partial P_2(q_2^*(q_1, w_2)|q_1)}{\partial w_2} = \frac{\partial P(q_2^*|q_1)}{\partial q_2} \frac{\partial q_2^*(q_1, w_2)}{\partial w_2} > 0.$$

Finally, we examine the property of $\Pi_2^*(q_1, w_2)$. Using (4) and (18), we have

$$\frac{\partial \Pi_2^*(q_1, w_2)}{\partial q_1} = \frac{\partial P_2(q_2^*|q_1)}{\partial q_1} q_2^* < 0.$$

Q.E.D.

A.2 Proof of Proposition 1

We only show that $q_1^{a\prime}(w_1) < 0$ holds. The second-order condition of D's profit maximization problem (6) leads to

$$2\frac{\partial P_1(q_1^a(w_1)|c_I)}{\partial q_1} + \frac{\partial^2 P_1(q_1^a(w_1)|c_I)}{\partial q_1^2} q_1^a(w_1) < 0.$$

Using (7), the implicit function theorem shows that

$$\frac{dq_1^a}{dw_1} = \frac{1}{2\frac{\partial P_1(q_1^a(w_1)|c_I)}{\partial q_1} + \frac{\partial^2 P_1(q_1^a(w_1)|c_I)}{\partial q_1^2} q_1^a(w_1)} < 0.$$

Q.E.D.

A.3 Proof of Proposition 2

We only show that $q_1^{r\prime}(w_1) < 0$ holds. The second-order condition of the maximization problem in (11) leads to

$$2\frac{\partial P_1(q_1^r(w_1)|c_E)}{\partial q_1} + \frac{\partial^2 P_1(q_1^r(w_1)|c_E)}{\partial q_1^2} q_1^r(w_1) + \delta \frac{\partial^2 \Pi_2^*(q_1^r(w_1), c_I)}{\partial q_1^2} < 0.$$

Using (12), the implicit function theorem shows that

$$\frac{dq_1^r}{dw_1} = \frac{1}{2\frac{\partial P_1(q_1^r(w_1)|c_I)}{\partial q_1} + \frac{\partial^2 P_1(q_1^r(w_1)|c_I)}{\partial q_1^2} q_1^r(w_1) + \delta \frac{\partial^2 \Pi_2^*(q_1^r(w_1), c_I)}{\partial q_1^2}} < 0.$$

Q.E.D.

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Online Appendix for Which is Better for Durable Goods Producers: Exclusive or Open Supply Chain?

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Abstract

In this Appendix, we introduce a linear demand system to show a wide range of extensions to the analyses of Kitamura, Matsushima, and Sato (2021). Section 1 constructs a model. Section 2 explores the case of two-part tariffs as a benchmark analysis. Section 3 examines the case of a highly efficient entrant. Section 4 provides the analysis under linear wholesale pricing. Section 5 considers the case in which suppliers produce vertically differentiated inputs. Section 6 investigates the case of a foreign supplier's entry. Finally, Section 7 extends the analysis by introducing another formulation of consumers' utility.

JEL classification codes: L12, L41, L42.
Keywords: Antitrust policy; Durable goods; Exclusive supply chain; Vertical relation.

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1 Model

The basic model structure in this appendix coincides with that in Kitamura, Matsushima, and Sato (2021). Thus, we briefly explain the model under linear demand.

1.1 Basic environment

Consumers There is a mass of consumers for every period. Each consumer has a different preference for a final good. Let v be the consumer type in terms of willingness to pay, which is stationary for all periods and uniformly distributed on the interval $[0, 1]$.[1] For simplicity, we assume that the mass of consumers is normalized to one. In durable goods markets, each consumer purchases a final good once by considering the final good price in both periods, p_1 and p_2. To clarify the exclusion mechanism in a simple way, we assume that each consumer can use the final good for eternity; a consumer type v always enjoys $v - p_t$ by purchasing the final good in period t.[2] In period 2, a consumer type v, who does not purchase the final good in period 1, purchases the final good if and only if the consumer surplus is nonnegative, i.e., $v - p_2 \geq 0$. By rationally predicting p_2, the consumer purchases the final good in period 1 if and only if $v - p_1 \geq \delta(v - p_2)$. By defining the indifferent consumer's willingness to pay v_1 as $v_1 - p_1 = \delta(v_1 - p_2)$, we have

$$v_1 = \frac{p_1 - \delta p_2}{1 - \delta}. \tag{1.1}$$

Then, the willingness to pay of consumers who purchase the final good in period 1 is distributed in $v \in [v_1, 1]$; thus, the demand for the final good at each period Q_t becomes

$$Q_1 = 1 - v_1, \quad Q_2 = v_1 - p_2.$$

[1] In the model, we assume that $F(y) = y$ and $v(y) = y$ as in Kitamura, Matsushima, and Sato (2021).

[2] Alternatively, we can consider the setting in which v represents a value of per period use; the surplus of consumer type v is $(1 + \delta)v - p_1$ for the purchase in period 1, while it is $v - p_2$ for the purchase in period 2. In Section 7, we explore such a case and derive exclusion results.

Firms The upstream market consists of the incumbent supplier U_I and the entrant supplier U_E. U_I and U_E produce an identical input but differ in terms of cost efficiency; that is, U_E is more efficient than U_I, with constant marginal cost $c_E \in [0, c_I)$, as opposed to U_I's constant marginal cost $c_I < 1$. We explore the case in which suppliers' inputs are vertically differentiated in Section 5. Following Abito and Wright (2008) and Kitamura (2010), we measure U_E's cost advantage by η, where $c_I = \eta p^m(c_E) + (1-\eta)c_E$ and $p^m(c_E)$ is the monopoly price for the industry when the marginal cost is c_E and the market demand is $Q = 1 - p$: $p^m(c_E) = (1 + c_E)/2$. $\eta = 0$ implies that U_E has no cost advantage. As η increases, U_E becomes efficient. We assume that $\eta \in (0, 2)$.[3] From the definition of η, the marginal cost of U_E can be expressed as a function of η and c_I as follows:

$$c_E = \frac{2c_I - \eta}{2 - \eta}.$$

The downstream market is composed of a downstream monopolist D. D transforms one unit of the input into one unit of the final good, which is durable. To simplify the analysis, we assume that the cost of transformation is zero.

Timing The timing of the game coincides with that of Kitamura, Matsushima, and Sato (2021).

1.2 Design of exclusive contracts

From Kitamura, Matsushima, and Sato (2021), an exclusion equilibrium exists if and only if the following condition holds:

$$\pi^a_{I|1} + \delta\pi^a_{I|2} + \pi^a_{D|1} + \delta\pi^a_{D|2} \geq \pi^r_{I|1} + \delta\pi^r_{I|2} + \pi^r_{D|1} + \delta\pi^r_{D|2}. \tag{1.2}$$

[3] When $c_E = 0$, we have $c_I = \eta/2$. In this case, as $\eta \to 0$, $c_I \to 0$ and as $\eta \to 2$, $c_I \to 1$. We impose the restriction $\eta \in (0, 1)$ for the case of linear wholesale pricing in Section 4.

2 Two-part tariffs

This section considers the case of two-part tariffs, which consist of a linear wholesale price w and an upfront fixed fee ψ. A two-part tariff offered by U_i in period t when D's decision is $\omega \in \{a, r\}$ is denoted by $(w^{\omega}_{i|t}, \psi^{\omega}_{i|t})$.

To guarantee that at least some consumers purchase the final goods in period 1, we assume the following condition:

Assumption 1. $v_1 < 1$ *holds for the case in which the open supply chain is chosen in period 1.1; i.e.,*

$$0 < \delta < \hat{\delta}(\eta) \equiv \frac{2(2-\eta)}{4-\eta}, \tag{2.1}$$

where $\hat{\delta}'(\eta) < 0$ *for all* $\eta \in (0, 2)$ *and where as* $\eta \to 0$, $\hat{\delta}(\eta) \to 1$ *and as* $\eta \to 2$, $\hat{\delta}(\eta) \to 0$.

If condition (2.1) does not hold, all consumers are attracted to the purchase in period 2, when the entry of U_E is predicted. In Section 3, we explore the case in which condition (2.1) does not hold.

In the rest of this section, we solve the game using backward induction, starting from period 2.3. In Section 2.1, we first explore the equilibrium outcomes in the subgame following D's decision in period 1.1. Section 2.2 then explores the contractual decision in period 1.1.

2.1 Equilibrium outcomes after period 1.1

We characterize the properties of the subgame perfect Nash equilibria after the subgame in period 1.1 from the perspective of joint profit maximization between each supplier and D. This approach simplifies the analysis. In the last part of this subsection, we show that the overall joint profit maximization is achieved under two-part tariff contracts in the equilibrium, derived in Appendix A.1.

We first consider the game in period 2. For notational convenience, we define $p^*_2(z, v_1)$

and $\Pi_2^*(z, v_1)$ as follows:

$$p_2^*(z, v_1) \equiv \underset{p_2 \geq z}{\text{argmax}}(p_2 - z)(v_1 - p_2), \tag{2.2}$$

$$\Pi_2^*(z, v_1) \equiv (p_2^*(z, v_1) - z)(v_1 - p_2^*(z, v_1)).$$

By solving the joint profit maximization problem (2.2), we have

$$p_2^*(z, v_1) = \frac{v_1 + z}{2}, \quad \Pi_2^*(z, v_1) = \frac{(v_1 - z)^2}{4}.$$

Note that $\Pi_2^*(z, v_1)$ is the jointly maximized profit of U_I and D in period 2 when the supplier has a marginal cost equal to $z \geq 0$. When the exclusive supply chain is chosen in period 1.1, U_I becomes the equilibrium supplier in period 2; that is, the joint profit of U_I and D becomes $\Pi_2^*(c_I, v_1)$ and the equilibrium price of the final good is $p_2^*(c_I, v_1)$ under exclusive dealing. By contrast, when the open supply chain is chosen, U_I and U_E compete in period 2. U_I makes its best offer $(c_I, 0)$ to D. U_E offers $(c_E, \Pi_2^*(c_E, v_1) - \Pi_2^*(c_I, v_1))$ and it becomes the equilibrium supplier in period 2. In the equilibrium, D chooses $p_2^*(c_E, v_1)$. As a result, D earns $\Pi_2^*(c_I, v_1)$ and U_I earns nothing, which implies that the joint profit of U_I and D becomes $\Pi_2^*(c_I, v_1)$ for the case of entry. Therefore, the joint profit of U_I and D in period 2 can be expressed by $\Pi_2^*(c_I, v_1)$ regardless of D's decision in period 1.1. However, the value of the indifferent consumer's willingness to pay v_1 depends on D's decision in period 1.1 because the equilibrium final good price depends on the efficiency of the equilibrium supplier. By substituting the equilibrium price in period 2 into equation (1.1), we have

$$v_1(p_1, z) = \frac{2p_1 - \delta z}{2 - \delta}, \tag{2.3}$$

where $z = c_I$ (c_E) when the exclusive (open) supply chain is chosen in period 1.1. Equation (2.3) shows that in durable goods markets, the equilibrium outcome in period 2 intertemporally affects the indifferent consumer's willingness to pay, which cannot be observed in the perishable goods market. Equation (2.3) implies that the price reduction due to entry in period 2 increases $v_1(p_1, z)$; therefore, the contracting party needs to reduce the final good price to maintain the same output level in period 1 when entry in period 2 is predicted; namely, in durable goods markets, the possibility of future entry reduces current consumer demand.

We next consider the game in period 1. Using equation (2.3), we define $p_1^*(z)$, $\Pi_1^*(z)$, and $\Pi_J^*(z)$ as follows:

$$p_1^*(z) \equiv \underset{p_1}{\operatorname{argmax}}(p_1 - c_I)(1 - v_1(p_1, z)) + \delta\Pi_2^*(c_I, v_1(p_1, z)), \tag{2.4}$$

$$\Pi_1^*(z) \equiv (p_1^*(z) - c_I)(1 - v_1(p_1^*(z), z)), \quad \Pi_J^*(z) \equiv \Pi_1^*(z) + \delta\Pi_2^*(c_I, v_1(p_1^*(z), z)).$$

Note that $\Pi_J^*(z)$ is the jointly maximized overall profits of D and U_I when the marginal cost of an equilibrium supplier in period 2 is z. By solving the joint profit maximization problem (2.4), we have the following joint profit maximizing prices in the equilibrium:

$$p_1^*(z) = \frac{(2-\delta)^2(1+c_I) + 2\delta(1-\delta)z}{2(4-3\delta)}, \quad p_2^*(z, v_1(p_1^*(z), z)) = \frac{(2-\delta)(1+c_I) + 4(1-\delta)z}{2(4-3\delta)}. \tag{2.5}$$

Under these prices, the equilibrium overall joint profit of U_I and D becomes

$$\Pi_1^*(z) = \frac{\{(2-\delta)^2 - (4-2\delta-\delta^2)c_I + 2\delta(1-\delta)z\}\Big\{(2-\delta)(1-c_I) - \delta(1-z)\Big\}}{2(4-3\delta)^2},$$

$$\Pi_2^*(c_I, v_1(p_1^*(z), z)) = \frac{\big((2-\delta)(1-c_I) + \delta(c_I - z)\big)^2}{4(4-3\delta)^2},$$

$$\Pi_J^*(z) = \frac{(2-\delta)^2(1-c_I)^2 - \delta(c_I - z)\big(4(1-\delta)(1-c_I) - \delta(c_I - z)\big)}{4(4-3\delta)}. \tag{2.6}$$

The following lemma shows that the joint profit maximization prices (2.5) are obtained as the subgame perfect Nash equilibrium outcomes.

Lemma 2.1. *Suppose that suppliers adopt two-part tariffs and condition (2.1) holds. In the subgames after period 1.1, the pair of final goods prices becomes* $(p_1^*(c_I), p_2^*(c_I, v_1(p_1^*(c_I), c_I)))$ *when the exclusive supply chain is chosen and* $(p_1^*(c_E), p_2^*(c_E, v_1(p_1^*(c_E), c_E)))$ *when the open supply chain is chosen.*

Proof. See Appendix B.1. □

2.2 Choice of supply chain

By using the above results, we now consider the game in period 1.1. By definition, we have $\Pi_J^*(c_I) = \pi_{I|1}^a + \delta\pi_{I|2}^a + \pi_{D|1}^a + \delta\pi_{D|2}^a$ and $\Pi_J^*(c_E) = \pi_{I|1}^r + \delta\pi_{I|2}^r + \pi_{D|1}^r + \delta\pi_{D|2}^r$. Thus, we examine whether $\Pi_J^*(c_I) \geq \Pi_J^*(c_E)$ holds. From equation (2.6), this condition is equivalent to $4(1-\delta)(1-c_I) \geq \delta(c_I - c_E)$. By solving this condition with respect to δ, we have

$$0 < \delta \leq \overline{\delta}(c_E) \equiv \frac{4(1-c_I)}{4-3c_I-c_E},$$

where $\overline{\delta}(c_E) \in (0,1)$, $\overline{\delta}'(c_E) > 0$, and $\overline{\delta}(c_E) \to 1$ as $c_E \to c_I$. Therefore, the exclusion supply chain is chosen for a sufficiently small discount factor. The following proposition shows that the exclusive supply chain is always chosen as long as condition (2.1) holds:

Proposition 2.1. *Suppose that condition (2.1) holds. If suppliers adopt two-part tariffs in durable goods markets, U_I and D choose an exclusive supply chain for all $(\eta, \delta) \in (0,2) \times (0, \hat{\delta}(\eta)]$.*

Proof. See Appendix B.2. □

3 Highly efficient entrant

In the previous section, we considered the case in which at least some consumers purchase final goods by assuming condition (2.1) holds. However, if all players are sufficiently patient and U_E is sufficiently efficient, condition (2.1) does not hold; U_I cannot earn positive profits when the open supply chain is chosen in period 1.1. Although such a situation seemingly induces U_I and D to choose the open supply chain, the following proposition shows that U_I and D choose the exclusive supply chain, which deters socially efficient entry:

Proposition 3.1. *Suppose that condition (2.1) does not hold. If suppliers adopt two-part tariffs in durable goods markets, U_I and D choose an exclusive supply chain for all* $(\eta, \delta) \in (0,2) \times (\hat{\delta}(\eta), 1]$.

Proof. See Appendix B.3. □

4 Linear wholesale pricing

In this section, we extend the case of a two-part tariff to that of linear wholesale pricing; U_i offers $(w^{\omega}_{i|t}, 0)$ in period t when D's decision is $\omega \in \{a, r\}$. In this subsection, we assume that $\eta \in (0,1)$ under which the equilibrium wholesale price in period 2 always becomes the marginal cost of U_I for the case of entry; that is, $w^r_{I|2} = w^r_{E|2} = c_I$.[4] The equilibrium outcomes in the subgame after D's decision in period 1.1 are provided in Appendix A.2. The following proposition shows that in the case of linear wholesale pricing, the exclusive supply chain is chosen under certain conditions.

Proposition 4.1. *Suppose that suppliers offer linear wholesale pricing and* $\eta \in (0,1)$*. In durable goods markets, U_I and D choose the exclusive supply chain for* $\delta \leq \tilde{\delta} \simeq 0.79537$.

Proof. See Appendix B.4. □

The intuitive explanation for the above result is provided in Section 4 of Kitamura, Matsushima, and Sato (2021).

5 Vertically differentiated inputs

In this subsection, we extend Section 2's analysis to the case in which input suppliers produce vertically differentiated inputs. The basic model structure here follows Argenton (2010), who examines the existence of anticompetitive exclusive contracts when upstream suppliers'

[4] This assumption implies that U_E's monopoly price is higher than c_I. The exclusive supply chain can still be chosen even when U_E is more efficient, while the analysis becomes more complicated.

products are vertically differentiated. Although Argenton (2010) explores the case in which two downstream firms exist in the perishable goods market, we explore the case in which a single downstream firm exists in durable goods markets. The quality of the final product with the input supplied by U_i is denoted by μ_i, where $i \in \{I, E\}$. Following Argenton (2010), we assume that U_E produces a higher quality input, $\mu_E > \mu_I$, and that for simplicity, all firms' marginal costs are zero; that is, $c_I = c_E = c_D = 0$. Consumer preferences follow the standard in the literature on vertical product differentiation. There is a unit mass of consumers, indexed by θ, which is uniformly distributed on the interval $[0, 1]$. Consumers decide whether to purchase one unit of final goods. To purchase one unit of the final good with quality μ_i in period t, a consumer of type θ pays $p_{i|t}$ and enjoys consumer surplus $\theta\mu_i - p_{i|t}$.[5] As in the previous section, each consumer purchases the final good once by considering the prices of available final goods in both periods $p_{I|1}$ and $p_{i|2}$. In period 2, a consumer type θ, who does not purchase the final good in period 1, purchases the final good if and only if $\theta\mu_I - p^a_{I|2} \geq 0$ when the exclusive supply chain is chosen ($\max\{\theta\mu_I - p^r_{I|2}, \theta\mu_E - p^r_{E|2}\} \geq 0$ when the open supply chain is chosen). By rationally predicting $p_{i|2}$, the consumer purchases the final good with the input supplied by U_I in period 1 if and only if $\theta\mu_I - p^a_{I|1} \geq \delta(\theta\mu_I - p^a_{I|2})$ when the exclusive supply chain is chosen ($\theta\mu_I - p^r_{I|1} \geq \max\{\delta(\theta\mu_I - p^r_{I|2}), \delta(\theta\mu_E - p^r_{E|2})\}$ when the open supply chain is chosen). We define the indifferent consumer's type θ^a_1 and θ^r_1 as $\theta^a_1\mu_I - p^a_{I|1} = \delta(\theta^a_1\mu_I - p^a_{I|2})$ and $\theta^r_1\mu_I - p^r_{I|1} = \delta(\theta^r_1\mu_E - p^r_{E|2})$, respectively. To obtain interior solutions, we assume the following condition:

Assumption 5.1.

$$\frac{\mu_E}{\mu_I} < \psi(\delta) \equiv \frac{2-\delta}{\delta}, \tag{5.1}$$

where $\psi'(\delta) < 0$ for all $\delta \in (0, 1)$ and where $\delta \to 0$, $\psi(\delta) \to \infty$ and as $\delta \to 1$, $\psi(\delta) \to 1$.

If condition (5.1) holds, the second-order condition and $0 < \theta^r_1 < 1$ simultaneously hold.[6]

[5] Consumer preferences here coincide with those in the previous section for $\mu_I = \mu_E = 1$.

[6] This condition is derived from $\theta^r_1 < 1$. The other conditions always hold if this condition holds. More

The equilibrium outcomes in the subgame after D's decision in period 1.1 are provided in Appendix A.3. The following proposition shows that the exclusive supply chain is always chosen.

Proposition 5.1. *Suppose that suppliers adopt two-part tariffs and condition (5.1) holds. In durable goods markets, the incumbent supplier with the low quality input can achieve an exclusive supply chain, which excludes the future entrant supplier with the high quality input.*

Proof. See Appendix B.5. □

6 Entry of a foreign firm

Thus far, we have assumed that U_E is a domestic firm. In this subsection, we extend Section 2's analysis to the case in which U_E is a foreign firm. In reality, a domestic incumbent supplier may use exclusive contracts to deter the entry of a foreign firm with high efficiency. For example, Vist, a Russian personal computer manufacturer, develops exclusive distribution agreements with several key retailers as a survival strategy toward the entry of foreign firms such as Compaq, IBM, and Hewlett-Packard (Dawar and Frost, 1999), which is described in the introduction of Kitamura, Matsushima, and Sato (2021).

Note that condition (1.2) implies that the possibility of exclusion depends only on the overall joint profit of U_I and D; the nationality of U_E does not affect the possibility of exclusion. Hence, we only focus on the social inefficiency of the exclusive supply chain, which deters entry of a foreign firm, by comparing the social surpluses. The following proposition shows that the exclusive supply chain to deter the foreign firm, which is more efficient than U_I, is always undesirable from a viewpoint of social surplus in the domestic market.

Proposition 6.1. *Suppose that U_E is a foreign supplier and suppliers adopt two-part tariffs. Then, the exclusive supply chain to deter the entry of U_E is always socially inefficient.*

importantly, as in Proposition 3.1, the exclusive supply chain is chosen even when condition (5.1) does not hold.

Proof. See Appendix B.6. □

Note that if U_E is a domestic supplier, U_E's profit is also contained in the social surplus for the case of entry. Therefore, we have the following proposition:

Proposition 6.2. *Suppose that U_E is a domestic supplier and suppliers adopt two-part tariffs. Then, the exclusive supply chain to deter the entry of U_E is always socially inefficient.*

7 When v represents the value of per period use

In this section, we extend Section 2's analysis to the case in which v is the per period use value. In this setting, the consumer purchases the final good in period 1 if and only if $(1+\delta)v - p_1 \geq \delta(v - p_2)$, which is the only difference from the model introduced in Section 1. The indifferent consumer's willingness to pay becomes

$$v_1 = p_1 - \delta p_2.$$

Compared with equation (1.1), the model setting here leads to a lower value of v_1; namely, consumers are more attracted to the purchase in period 1 when they enjoy v for per period use. Thus, the demand for the final good in period 2 may be too small to obtain positive sales for the higher value of c_I. To avoid this problem, we make the following assumption:

Assumption 7.1. *$v_1 > c_I$ holds; i.e.,*

$$0 < c_I < \overline{c}(\delta) \equiv \frac{2+\delta}{2+3\delta}, \tag{7.1}$$

where $\overline{c}'(\delta) < 0$ for all $\delta \in (0,1)$ and where $\delta \to 0$, $\overline{c}(\delta) \to 1$ and $\delta \to 1$, $\overline{c}(\delta) \to 3/5$.

Under condition (7.1), at least some consumers purchase the final good in period 2 regardless of the acceptance decision of exclusive contracts in period 1.1.

When suppliers adopt two-part tariffs, the joint profit maximization problems in period 2 and period 1 in this appendix coincides with joint profit maximization problems (2.2) and (2.4).[7] By solving these joint profit maximization problems, we obtain the joint profit maximizing prices in the equilibrium:

$$p_1^*(z) = \frac{(2+\delta)\big(2+\delta+(2-\delta)c_I\big)+2\delta z}{2(4+\delta)}, \quad p_2^*(z, v_1(p_1^*(z), z)) = \frac{2+\delta+(2-\delta)c_I+4z}{2(4+\delta)}.$$

Under these prices, the equilibrium production levels of final goods are given by

$$Q_1^*(z) = \frac{2(1-c_I)+\delta(c_I+z)}{4+\delta}, \quad Q_2^*(z) = \frac{2(1+c_I)+\delta(1-c_I)-2(2+\delta)z}{2(4+\delta)},$$

which implies that even when the open supply chain is chosen, at least some consumers purchase the final good in period 1 for all $0 \leq c_E < c_I < \overline{c}(\delta)$. Then, the equilibrium overall joint profit of U_I and D becomes

$$\Pi_1^*(z) = \frac{\big(2(1-c_I)+\delta(c_I+z)\big)\big(4(1-c_I)-(2+\delta)c_I+\delta+2z\big)}{2(4+\delta)^2},$$

$$\Pi_2^*(c_I, v_1(p_1^*(z), z)) = \frac{\big(2(1-(1+\delta)c_I)+\delta(1-z)\big)^2}{4(4+\delta)^2},$$

$$\Pi_J^*(z) = \frac{4+4\delta+\delta^2-2(4+2\delta+\delta^2)c_I+2(2+\delta^2)c_I^2+\big(4(1-c_I)+\delta(2c_I+z)\big)\delta z}{4(4+\delta)}. \quad (7.2)$$

We now examine the contractual decision in period 1.1. From equation (7.2), we have

$$\Pi_J^*(c_I) - \Pi_J^*(c_E) = \frac{\delta\big(4(1-c_I)+\delta(3c_I+c_E)\big)(c_I-c_E)}{4(4+\delta)} > 0,$$

for all $(\delta, c_E) \in (0,1) \times [0, c_I)$, which implies that condition (1.2) always holds. Thus, we have the following proposition.

Proposition 7.1. *Suppose that v represents the value of per period use and condition (7.1) holds. If suppliers adopt two-part tariffs in durable goods markets, U_I and D choose an exclusive supply chain for all $(\delta, c_E) \in (0,1) \times [0, c_I)$.*

[7] Like in Section 2, we can show that overall joint profit maximization is achieved under two-part tariff contracts. The calculation results are available upon request.

A Equilibrium outcomes in subgames after period 1.1

We derive the equilibrium outcomes after the game in period 1.1 using backward induction. Appendix A.1 introduces the equilibrium outcomes under two-part tariffs. Appendix A.2 provides the equilibrium outcomes under linear wholesale pricing. Finally, Appendix A.3 derives the equilibrium outcomes when inputs are vertically differentiated.

A.1 Two-part tariffs

We first consider the case where the exclusive supply chain is chosen (equivalently, the exclusive offer is accepted) in period 1.1. In this case, U_I becomes an upstream monopolist in both periods. As discussed in Section 2, in period 2.2, U_I offers $(c_I, \Pi_2^*(c_I, v_1))$ to D. In period 2.3, D chooses $p_2^*(c_I, v_1)$. U_I earns $\Pi_2^*(c_I, v_1)$ and D earns nothing. By substituting $z = c_I$ into (2.3), we have $v_1(p_1, c_I)$. By anticipating these reaction functions and given $(w_{I|1}, \psi_{I|1})$, in period 1.3, D chooses the final good price to maximize its overall profits:

$$p_1^a(w_{I|1}) = \underset{p_1 \geq w_{I|1}}{\text{argmax}}(p_1 - w_{I|1})(1 - v_1(p_1, c_I)) - \psi_{I|1}.$$

Because U_I can extract all D's profit by setting $\psi_{I|1}^a = (p_1^a(w_{I|1}) - w_{I|1})(1 - v_1(p_1^a(w_{I|1}), c_I))$, U_I's profit maximization problem in period 1.2 becomes

$$w_{I|1}^a = \underset{w_{I|1}}{\text{argmax}}(p_1^a(w_{I|1}) - c_I)(1 - v_1(p_1^a(w_{I|1}), c_I)) + \delta\Pi_2^*(c_I, v_1(p_1^a(w_{I|1}), c_I)).$$

In the equilibrium, we have

$$w_{I|1}^a = \frac{\delta(2-\delta) + (8(1-\delta) + \delta^2)c_I}{2(4-3\delta)} > c_I,$$

which leads to (2.5) with $z = c_I$. The firms' equilibrium profits, excluding the fixed compensation x, are

$$\pi_{I|1}^a + \delta\pi_{I|2}^a = \frac{(2-\delta)^2(1-c_I)^2}{4(4-3\delta)}, \quad \pi_{E|2}^a = 0, \quad \pi_{D|1}^a + \delta\pi_{D|2}^a = 0. \tag{A.1}$$

Second, we consider the case in which the open supply chain is chosen in period 1.1. In this case, U_I is an upstream monopolist in period 1 but it needs to compete with U_E in period 2 because socially efficient entry occurs. Given v_1, in period 2.2, U_I makes its best offer $(c_I, 0)$ and earns nothing. In contrast, U_E offers $(c_E, \Pi_2^*(c_E, v_1) - \Pi_2^*(c_I, v_1))$, which induces D to earn $\Pi_2^*(c_I, v_1)$ in period 2. Because U_E is the equilibrium supplier, the indifferent consumer's willingness to pay becomes $v_1(p_1, c_E)$. By anticipating these reaction functions and given $(w_{I|1}, \psi_{I|1})$, in period 1.3, D chooses the final good price to maximize its overall profits:

$$p_1^r(w_{I|1}) = \underset{p_1}{\text{argmax}}(p_1 - w_{I|1})(1 - v_1(p_1, c_E)) + \delta\Pi_2^*(c_I, v_1(p_1, c_E)) - \psi_{I|1}.$$

If D rejects U_I's two-part tariffs in period 1.2, D earns nothing in period 1 but $(1 - c_I)^2/4$ in period 2 because of the competition between U_I and U_E. By anticipating this outside profit, in period 1.2, U_I sets two-part tariffs that induce D to earn $\delta(1 - c_I)^2/4$ by setting $\psi_{I|1}^r = (p_1^r(w_{I|1}) - w_{I|1})(1 - v_1(p_1^r(w_{I|1}), c_I)) + \delta\Pi_2^*(c_I, v_1(p_1^r(w_{I|1}), c_I)) - \delta(1 - c_I)^2/4$. U_I's profit maximization problem in period 1.2 becomes

$$w_{I|1}^r = \underset{w_{I|1}}{\text{argmax}}(p_1^r(w_{I|1}) - c_I)(1 - v_1(p_1^r(w_{I|1}), c_E)) + \delta\Pi_2^*(c_I, v_1(p_1^r(w_{I|1}), c_E)) - \frac{\delta(1 - c_I)^2}{4}.$$

In the equilibrium, we have $w_{I|1}^r = c_I$, which leads to (2.5) with $z = c_E$. The resulting firms' profits are

$$\begin{aligned} &\pi_{I|1}^r + \delta\pi_{I|2}^r = \frac{(4(1-\delta) - \eta(2-\delta))(1-c_I)^2}{4(2-\eta)^2(4-3\delta)}, \quad \pi_{E|2}^r = \frac{\eta(4(2-\delta) + \eta\delta)(1-c_I)^2}{4(2-\eta)^2(4-3\delta)}, \\ &\pi_{D|1}^r + \delta\pi_{D|2}^r = \frac{\delta(1-c_I)^2}{4}. \end{aligned} \tag{A.2}$$

A.2 Linear wholesale pricing

We first consider the case where the exclusive supply chain is chosen in period 1.1. In this case, U_I becomes an upstream monopolist in both periods. In period 2.3, D's profit maximization problem given $w_{I|2}$ and v_1 is given by

$$p_2^a(w_{I|2}, v_1) = \underset{p_2 \geq w_{I|2}}{\text{argmax}}(p_2 - w_{I|2})(v_1 - p_2).$$

By solving this problem, we have $p_2^a(w_{I|2}, v_1) = (w_{I|2} + v_1)/2$. By anticipating D's reaction function, U_I's profit maximization problem in period 2.2 becomes

$$w_{I|2}^a(v_1) = \underset{w_{I|2} \geq c_I}{\operatorname{argmax}} (w_{I|2} - c_I)(v_1 - p_2^a(w_{I|2}, v_1)).$$

By solving this problem, we have $w_{I|2}^a(v_1) = (v_1 + c_I)/2$. The final good price of given v_1 in period 2 becomes

$$p_2^a(v_1) = \frac{3v_1 + c_I}{4}. \tag{A.3}$$

Period 2 profits given v_1 are given by $\pi_{I|2}^a(v_1) = (v_1 - c_I)^2/8$ and $\pi_{D|2}^a(v_1) = (v_1 - c_I)^2/16$. By substituting (A.3) into (1.1), we have

$$v_1^a(p_1) = \frac{4p_1 - \delta c_I}{4 - \delta}.$$

By anticipating these reaction functions and given $w_{I|1}$, in period 1.3, D chooses the final good price to maximize its overall profits:

$$p_1^a(w_{I|1}) = \underset{p_1 \geq w_{I|1}}{\operatorname{argmax}} (p_1 - w_{I|1})(1 - v_1^a(p_1)) + \delta \frac{(v_1^a(p_1) - c_I)^2}{16}.$$

By anticipating this reaction, in period 1.2, U_I chooses the input price

$$w_{I|1}^a = \underset{w_1 \geq c_I}{\operatorname{argmax}} (w_{I|1} - c_I)(1 - v_1^a(p_1^a(w_{I|1}))) + \delta \frac{(v_1^a(p_1^a(w_{I|1})) - c_I)^2}{8}.$$

The equilibrium prices and indifferent consumer's willingness to pay are

$$\begin{aligned}
w_{I|1}^a &= \frac{128 - 72\delta + 11\delta^2 + (128 - 24\delta - 11\delta^2)c_I}{32(8 - 3\delta)}, \quad w_{I|2}^a = \frac{24 - 7\delta - (40 - 17\delta)c_I}{8(8 - 3\delta)}, \\
p_1^a &= \frac{(4 - \delta)(24 - 7\delta) + (32 + 4\delta - 7\delta^2)c_I}{16(8 - 3\delta)}, \quad p_2^a = \frac{3(24 - 7\delta) + (56 - 27\delta)c_I}{16(8 - 3\delta)}, \\
v_1^a &= \frac{24 - 7\delta + (8 - 5\delta)c_I}{4(8 - 3\delta)}.
\end{aligned}$$

The firms' equilibrium profits, excluding the fixed compensation x, are

$$\begin{aligned}
\pi_{I|1}^a + \delta \pi_{I|2}^a &= \frac{(8 - \delta)(1 - c_I)^2}{64(8 - 3\delta)}, \quad \pi_{E|2}^a = 0, \\
\pi_{D|1}^a + \delta \pi_{D|2}^a &= \frac{(1024 - 576\delta + 32\delta^2 + 19\delta^3)(1 - c_I)^2}{256(8 - 3\delta)^2}.
\end{aligned} \tag{A.4}$$

Second, we consider the case where the open supply chain is chosen in period 1.1. In this case, U_I is an upstream monopolist in period 1 but it needs to compete with U_E in period 2. Given v_1, the competition between U_I and U_E in period 2.2 leads to $w^r_{E|2} = c_I$. Given this input pricing, D's maximization problem in period 2.3 becomes

$$p^r_2(v_1) = \underset{p_2 \geq c_I}{\text{argmax}}(p_2 - c_I)(v_1 - p_2).$$

The solution of this problem is

$$p^r_2(v_1) = \frac{v_1 + c_I}{2}. \tag{A.5}$$

Period 2 profits given v_1 are given by $\pi^r_{I|2}(v_1) = 0$ and $\pi^r_{D|2}(v_1) = (v_1 - c_I)^2/4$. By substituting (A.5) into (1.1), we have

$$v^r_1(p_1) = \frac{2p_1 - \delta c_I}{2 - \delta}.$$

By anticipating these reaction functions and given $w_{I|1}$, in period 1.3, D chooses the final good price to maximize its overall profits:

$$p^r_1(w_{I|1}) = \underset{p_1 \geq w_{I|1}}{\text{argmax}}(p_1 - w_{I|1})(1 - v^r_1(p_1)) + \delta \frac{(v^r_1(p_1) - c_I)^2}{4}.$$

By anticipating $p^r_1(w_{I|1})$, in period 1.2, U_I optimally chooses the input price:

$$w^r_{I|1} = \underset{w_{I|1} \geq c_I}{\text{argmax}}(w_{I|1} - c_I)(1 - v^r_1(p^r_1(w_{I|1}))).$$

By solving these problems, the equilibrium prices and indifferent consumer's willingness to pay are

$$w^r_{I|1} = \frac{1 - \delta + (1 + \delta)c_I}{2}, \quad w^r_{E|2} = c_I, \quad p^r_1 = \frac{(2 - \delta)(3 - 2\delta) + (2(1 - \delta^2) + \delta)c_I}{2(4 - 3\delta)},$$
$$p^r_2 = \frac{3 - 2\delta + (5 - 4\delta)c_I}{2(4 - 3\delta)}, \quad v^r_1 = \frac{3 - 2\delta + (1 - \delta)c_I}{4 - 3\delta}.$$

The firms' equilibrium profits are

$$\begin{aligned} \pi^r_{I|1} + \delta\pi^r_{I|2} &= \frac{(1 - \delta)^2(1 - c_I)^2}{2(4 - 3\delta)}, \quad \pi^r_{E|2} = \frac{(1 - \delta)(c_I - c_E)(1 - c_I)}{2(4 - 3\delta)}, \\ \pi^r_{D|1} + \delta\pi^r_{D|2} &= \frac{(1 + 2\delta(1 - \delta))(1 - c_I)^2}{4(4 - 3\delta)}. \end{aligned} \tag{A.6}$$

A.3 Vertical product differentiation

For the sake of convenience, we derive the outcomes when U_i monopolizes the upstream market in period 2 and D's decision in period 1.1 is $\omega \in \{a, r\}$. The type of consumer who is indifferent between purchasing the final good with U_i's input and not in period 2 satisfies $\theta_2\mu_i - p_{i|2} = 0$. From this condition, the demand for the final good with U_i's input in period 2 given θ_1^ω becomes

$$Q^\omega_{i|2}(p_{i|2}, \theta^\omega_1) = \theta^\omega_1 - \frac{p_{i|2}}{\mu_i}.$$

In period 2.3, D's profit maximization problem given $(w_{i|2}, \psi_{i|2})$ is given by

$$p^\omega_{i|2}(w_{i|2}, \theta^\omega_1) = \underset{p_{i|2} \geq w_{i|2}}{\text{argmax}} (p_{i|2} - w_{i|2}) Q^\omega_{I|2}(p_{i|2}, \theta^\omega_1) - \psi_{i|2}. \tag{A.7}$$

By solving this problem, we have $p^\omega_{i|2}(w_{i|2}, \theta^\omega_1) = (w_{i|2} + \theta^\omega_1\mu_i)/2$. In period 2.2, U_i extracts D's profits by setting $\psi^\omega_{i|2} = (p_{i|2}(w_{i|2}, \theta^\omega_1) - w_{i|2})Q_{i|2}(p_{i|2}(w_{i|2}, \theta^\omega_1), \theta^\omega_1) - k^\omega_{i|2}$, where $k^\omega_{i|2}$ is D's outside profits. Then, U_i's profit maximization problem in period 2.2 becomes

$$w^\omega_{i|2}(\theta^\omega_1) = \underset{w_{i|2}}{\text{argmax}}\, p^\omega_{i|2}(w_{i|2}, \theta^\omega_1) Q^\omega_{i|2}(p_{i|2}(w_{i|2}, \theta^\omega_1), \theta^\omega_1) - k^\omega_{i|2}. \tag{A.8}$$

In the equilibrium, $w^\omega_{I|2}(\theta^\omega_1) = 0$, which leads to the following final good price with U_i's input given θ^ω_1 in period 2:

$$p^\omega_{i|2}(\theta^\omega_1) = \frac{\theta^\omega_1\mu_i}{2}. \tag{A.9}$$

The rest of this appendix is organized as follows. Appendix A.3.1 explores the case where the exclusive supply chain is chosen in period 1.1. Appendix A.3.2 introduces the case where the open supply chain is chosen in period 1.1.

A.3.1 Exclusive supply chain

When the exclusive supply chain is chosen in period 1.1, U_I becomes an upstream monopolist in both periods. We first consider period 2. D and U_I's profit maximization problems are given by (A.7) and (A.8) with $i = I$, $\omega = a$, and $k^{\omega}_{i|2} = 0$. Period 2 profits given θ^a_1 are

$$\pi^a_{I|2}(\theta^a_1) = \frac{(\theta^a_1)^2 \mu_I}{4}, \quad \pi^a_{D|2}(\theta^a_1) = 0.$$

We next consider period 1. By substituting (A.9) into $\theta^a_1 \mu_I - p_{I|1} = \delta(\theta^a_1 \mu_I - p^a_{I|2})$, we have

$$\theta^a_1(p_{I|1}) = \frac{2p_{I|1}}{(2-\delta)\mu_I}.$$

Then, the demand for the final goods in period 1 becomes

$$Q^a_{I|1}(p_{I|1}) = 1 - \frac{2p_{I|1}}{(2-\delta)\mu_I}.$$

Given $(w_{I|1}, \psi_{I|1})$, in period 1.3, D chooses the final good price to maximize its profits:

$$p^a_{I|1}(w_{I|1}) = \underset{p_{I|1} \geq w_{I|1}}{\operatorname{argmax}} (p_{I|1} - w_{I|1}) Q^a_{I|1}(p_{I|1}) - \psi_{I|1}.$$

By solving this problem, we have $p^a_{I|1}(w_{I|1}) = (2w_{I|1} + (2-\delta)\mu_I)/4$. In period 1.2, U_I can extract all of D's overall profits by setting $\psi^a_{I|1} = (p^a_{I|1}(w_{I|1}) - w_{I|1}) Q^a_{I|1}(p^a_{I|1}(w_{I|1}))$. Then, U_I's profit maximization problem in period 1.2 becomes

$$w^a_{I|1} = \underset{w_{I|1}}{\operatorname{argmax}}\, p^a_{I|1}(w_{I|1}) Q^a_{I|1}(p^a_{I|1}(w_{I|1})) + \delta \pi^a_{I|2}(\theta^a_1(p^a_{I|1}(w_{I|1}))).$$

The equilibrium prices are

$$w^a_{I|1} = \frac{\delta(2-\delta)\mu_I}{2(4-3\delta)}, \quad w^a_{I|2} = 0, \quad p^a_{I|1} = \frac{(2-\delta)^2 \mu_I}{2(4-3\delta)}, \quad p^a_{I|2} = \frac{(2-\delta)\mu_I}{2(4-3\delta)}.$$

The firms' equilibrium profits, excluding the fixed compensation x, are

$$\pi^a_{I|1} + \delta \pi^a_{I|2} = \frac{(2-\delta)^2 \mu_I}{4(4-3\delta)}, \quad \pi^a_{E|2} = 0, \quad \pi^a_{D|1} + \delta \pi^a_{D|2} = 0. \tag{A.10}$$

A.3.2 Open supply chain

When the open supply chain is chosen in period 1.1, U_I is an upstream monopolist in period 1, while it needs to compete with U_E in period 2.

We first consider period 2. By considering the possibility of upstream monopoly and duopoly, we derive the equilibrium outcomes in period 2. Assuming the monopoly outcome in period 2, we consider the case where D purchases only U_E's input. D and U_E's profit maximization problems are given by (A.7) and (A.8) with $i = E$ and $\omega = r$. In this case, U_E offers $w_{E|2}^{r(m)} = 0$. The joint profits between U_E and D under upstream monopoly become

$$\pi_E^{r(m)}(\theta_1^r) + \pi_D^{r(m)}(\theta_1^r) = \frac{(\theta_1^r)^2 \mu_E}{4}. \tag{A.11}$$

By contrast, assuming the duopoly outcome in period 2, we can derive the following demand for the final good with each supplier. The type of consumer who is indifferent between purchasing the final good with U_I's input and purchasing nothing in period 2, denoted by $\hat{\theta}^r$, satisfies $\hat{\theta}^r \mu_I - p_{I|2} = 0$. In addition, the type of consumer who is indifferent between purchasing the final good with U_E's input and purchasing the final good with U_I's input, denoted by $\tilde{\theta}^r$, satisfies $\tilde{\theta}^r \mu_E - p_{E|2} = \tilde{\theta}^r \mu_I - p_{I|2}$. By solving these equations, we have $\hat{\theta}^r = p_{I|2}/\mu_I$ and $\tilde{\theta}^r = (p_{E|2} - p_{I|2})/(\mu_E - \mu_I)$. Assuming $\hat{\theta}^r \leq \tilde{\theta}^r \leq \theta_1^r$, the demand for the final good with U_i's input is given by

$$Q_{E|2}^{r(d)}(p_{I|2}, p_{E|2}, \theta_1^r) = \theta_1^r - \frac{p_{E|2} - p_{I|2}}{\mu_E - \mu_I}, \quad Q_{I|2}^{r(d)}(p_{I|2}, p_{E|2}, \theta_1^r) = \frac{p_{E|2} - p_{I|2}}{\mu_E - \mu_I} - \frac{p_{I|2}}{\mu_I}.$$

In period 2.3, given $(w_{i|2}, \psi_{i|2})$, D optimally chooses the prices of the final goods:

$$(p_{I|2}^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r), p_{E|2}^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r)) = \underset{p_{i|2}^r}{\operatorname{argmax}} \sum_{i \in \{I,E\}} \left\{ (p_{i|2} - w_{i|2}) Q_{i|2}^{r(d)}(p_{I|2}, p_{E|2}, \theta_1^r) - \psi_{i|2} \right\}.$$

By solving this problem, we have

$$p_{I|2}^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r) = \frac{w_{I|2} + \theta_1^r \mu_I}{2}, \quad p_{E|2}^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r) = \frac{w_{E|2} + \theta_1^r \mu_E}{2}, \tag{A.12}$$

which leads to the following demand for each input:

$$q_I^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r) = \frac{\mu_I w_{E|2} - \mu_E w_{I|2}}{2(\mu_E - \mu_I)}, \quad q_E^{r(d)}(w_{I|2}, w_{E|2}, \theta_1^r) = \frac{w_{I|2} - w_{E|2} + \theta_1^r(\mu_E - \mu_I)}{2(\mu_E - \mu_I)}. \tag{A.13}$$

By comparing upstream monopoly and duopoly, we now show that D never purchases U_I's input. When U_E offers $w^r_{E|2} = 0$, the first equation in (A.13) implies that U_I's input is never purchased for $w_I > 0$. By contrast, when U_I offers $w^r_{I|2} \leq 0$, the joint profits between U_I and D when D purchases both U_E's and U_I's inputs by substituting (A.12) and (A.13) become

$$\pi_I^{r(d)}(w_{I|2}, w_{E|2}, \psi_{I|2}, \theta_1^r) + \pi_D^{r(d)}(w_{I|2}, w_{E|2}, \psi_{I|2}, \psi_{E|2}, \theta_1^r) = \frac{(\theta_1^r)^2 \mu_E}{4} - \frac{\mu_E w_{I|2}^2}{4\mu_I(\mu_E - \mu_I)} - \psi_{E|2},$$

for $w_{E|2} = 0$. The joint profits between U_I and D are maximized at $w_{I|2} = 0$, under which D's demand for U_I's input is zero. The comparison with (A.11) implies that U_I cannot increase the industry profits; namely, D never purchases U_I's input on the equilibrium path.

The equilibrium outcomes in period 2 are summarized as follows. In period 2.2, U_I offers $(w^r_{I|2}, \psi^r_{I|2}) = (0, 0)$ and earns nothing. In contrast, U_E offers $(0, \psi^r_{E|2})$, which induces D to earn the outside profit when it sells the final good with U_I's input; that is, $k^r_{E|2} = (\theta_1^r)^2 \mu_I / 4$.[8] This leads to $\psi^r_{E|2} = (\theta_1^r)^2(\mu_E - \mu_I)/4$. Under these offers, the equilibrium price of the final good with U_E's input becomes

$$p^r_{E|2}(\theta_1^r) = \frac{\theta_1^r \mu_E}{2}. \tag{A.14}$$

As a result, period 2 profits given θ_1^r are

$$\pi^r_{I|2}(\theta_1^r) = 0, \quad \pi^r_{E|2}(\theta_1^r) = \frac{(\theta_1^r)^2(\mu_E - \mu_I)}{4}, \quad \pi^r_{D|2}(\theta_1^r) = \frac{(\theta_1^r)^2 \mu_I}{4}.$$

We next consider period 1. By substituting (A.14) into $\theta_1^r \mu_I - p_{I|1} = \delta(\theta_1^r \mu_E - p^r_{E|2})$, we have

$$\theta_1^r(p_{I|1}) = \frac{2p_{I|1}}{2\mu_I - \delta\mu_E}.$$

Then, the demand for the final good with U_I's input in period 1 becomes

$$Q^r_{I|1}(p_{I|1}) = 1 - \frac{2p_{I|1}}{2\mu_I - \delta\mu_E}.$$

[8] The profit maximization problem of D in such a case corresponds with the maximization problem (A.7) by substituting $(w_{i|2}, \psi_{i|2}) = (0, 0)$ and $\theta_1^\omega = 1$.

Given $(w^r_{I|1}, \psi^r_{I|1})$, in period 1.3, D optimally chooses the final good price with U_I's input to maximize its overall profits:

$$p^r_{I|1}(w_{I|1}) = \underset{p_{I|1}}{\text{argmax}}(p_{I|1} - w_{I|1})Q^r_{I|1}(p_{I|1}) + \delta\pi^r_{D|2}(\theta^r_1(p_{I|1})) - \psi^r_{I|1}.$$

By solving this problem, we have

$$p^r_{I|1}(w_{I|1}) = \frac{(2\mu_I - \delta\mu_E)(2(w_{I|1} + \mu_I) - \delta\mu_E)}{2((4-\delta)\mu_I - 2\delta\mu_E)}.$$

If D rejects U_I's two-part tariffs in period 1.2, D earns nothing in period 1 but $\mu_I/4$ in period 2 because of the competition between U_I and U_E. By anticipating this outside profit, in period 1.2, U_I sets two-part tariffs that induce D to earn $\delta\mu_I/4$ by setting $\psi^r_{I|1} = (p_{I|1}(w_{I|1}) - w_{I|1})Q^r_{I|1}(p_{I|1}(w_{I|1})) + \delta(\theta^r_1(p_{I|1}(w_{I|1})))^2\mu_I/4 - \delta\mu_I/4$. Then, U_I's profit maximization problem in period 1.2 becomes

$$w^r_{I|1} = \underset{w_{I|1}}{\text{argmax}}\, p^r_{I|1}(w_{I|1})Q^r_{I|1}(p^r_{I|1}(w_{I|1})) + \frac{\delta\left\{\theta^r_{I|1}(p^r_{I|1}(w_{I|1}))\right\}^2\mu_I}{4} - \frac{\delta\mu_I}{4}.$$

In the equilibrium, we have $w^r_{I|1} = 0$. The firms' overall profits in the equilibrium are

$$\begin{aligned} &\pi^r_{I|1} + \delta\pi^r_{I|2} = \frac{((2-\delta)\mu_I - \delta\mu_E)^2}{4((4-\delta)\mu_I - 2\delta\mu_E)}, \quad \pi^r_{E|2} = \frac{\delta(\mu_E - \mu_I)(2\mu_E - \delta\mu_I)^2}{4((4-\delta)\mu_I - 2\delta\mu_E)^2}, \\ &\pi^r_{D|1} + \delta\pi^r_{D|2} = \frac{\delta\mu_I}{4}. \end{aligned} \tag{A.15}$$

B Proofs of the results

B.1 Proof of Lemma 2.1

See the results in Appendix A.1.

Q.E.D.

B.2 Proof of Proposition 2.1

Substituting $z(\eta) = (2c_I - \eta)/(2-\eta)$ into $\Pi^*_J(z)$, we have

$$\Pi^*_J(z(\eta)) = \frac{(8 - \eta^2\delta^2 + 2\eta^2 + 2\eta\delta^2 + 4\eta\delta - 8\eta + 2\delta^2 - 8\delta)(1-c_I)^2}{2(2-\eta)^2(4-3\delta)}.$$

By differentiating $\Pi_J^*(\eta)$ with respect to η, we have

$$\frac{\partial \Pi_J(z(\eta))}{\partial \eta} = -\frac{\delta(2(2-\eta)-(4-\eta)\delta)(1-c_I)^2}{(2-\eta)^3(4-3\delta)} < 0,$$

for all $(\eta, \delta) \in (0,2) \times (0, \hat{\delta}(\eta))$. Hence, $\Pi_J^*(c_I) > \Pi_J^*(c_E)$ holds for $c_E < c_I$, which implies that condition (1.2) holds.

Q.E.D.

B.3 Proof of Proposition 3.1

If condition (2.1) does not hold, U_I and D cannot earn positive profits in period 1 for the case in which the open supply chain is chosen in period 1.1; that is, $\pi_{I|1}^r = \pi_{D|1}^r = 0$. In period 2, U_I and D earn $\pi_{I|2}^r = 0$, $\pi_{D|2}^r = (1-c_I)^2/4$. By substituting these equations and (A.1), we find that

$$\pi_{I|1}^a + \delta\pi_{I|2}^a + \pi_{D|1}^a + \delta\pi_{D|2}^a - (\pi_{I|1}^r + \delta\pi_{I|2}^r + \pi_{D|1}^r + \delta\pi_{D|2}^r) = \frac{(1-\delta)^2(1-c_I)^2}{4-3\delta} > 0,$$

which implies that condition (1.2) always holds.

Q.E.D.

B.4 Proof of Proposition 4.1

By substituting (A.4) and (A.6), we find that

$$\pi_{I|1}^a + \delta\pi_{I|2}^a + \pi_{D|1}^a + \delta\pi_{D|2}^a - (\pi_{I|1}^r + \delta\pi_{I|2}^r + \pi_{D|1}^r + \delta\pi_{D|2}^r) = \frac{\delta(768 - 1280\delta + 412\delta^2 - 21\delta^3)(1-c_I)^2}{256(4-3\delta)(8-3\delta)^2}.$$

Condition (1.2) holds for $\delta \leq \tilde{\delta}$.

Q.E.D.

B.5 Proof of Proposition 5.1

By substituting (A.10) and (A.15), we find that

$$\pi^a_{I|1}+\delta\pi^a_{I|2}+\pi^a_{D|1}+\delta\pi^a_{D|2}-(\pi^r_{I|1}+\delta\pi^r_{I|2}+\pi^r_{D|1}+\delta\pi^r_{D|2}) = \frac{\delta(\mu_E-\mu_I)((8(1-\delta)+\delta^2)\mu_E+\delta(4-3\delta)\mu_I)}{4(4-3\delta)((4-\delta)\mu_I-2\delta\mu_E)}.$$

Condition (1.2) holds if and only if $\mu_E/\mu_I \leq \hat{\psi}(\delta) \equiv (8(1-\delta)+\delta^2)/\delta(4-3\delta)$. As $\hat{\psi}(\delta)-\psi(\delta) = 2(1-\delta)/(4-3\delta) > 0$ for all $\delta \in (0,1)$, exclusion always becomes a unique equilibrium outcome as long as condition (5.1) holds.

B.6 Proof of Proposition 6.2

We first derive the social surplus when the exclusive supply chain is chosen. The consumer surplus in this case becomes

$$\begin{aligned} CS^a(\delta) &= \int_0^{Q_1^a}(1-x-p_1^a)dx + \delta\int_0^{Q_2^a}(v_1^a-x-p_2^a)dx \\ &= \frac{(4-3\delta^2)(1-c_I)^2}{8(4-3\delta)}. \end{aligned}$$

The producer surplus in the domestic market becomes $\Pi_J(c_I)$. By summing these surpluses, the social surplus under the exclusive supply chain becomes

$$W^a(\delta) = \frac{(12-8\delta-\delta^2)(1-c_I)^2}{8(4-3\delta)}.$$

Second, we derive the social surplus when the open supply chain is chosen for $\delta < \hat{\delta}(\eta)$. The consumer surplus becomes

$$\begin{aligned} CS^r(\eta,\delta|\delta<\hat{\delta}(\eta)) &= \int_0^{Q_1^r}(1-x-p_1^r)dx + \delta\int_0^{Q_2^r}(v_1^r-x-p_2^r)dx \\ &= \frac{(16-16\eta+4\eta^2-12\delta^2+\eta^2\delta^2+16\eta\delta-4\eta\delta^2-4\eta^2\delta)(1-c_I)^2}{8(2-\eta)^2(4-3\delta)}. \end{aligned}$$

Domestic firms earn $\Pi_J(c_E)$ in this case. By summing these surpluses, the social surplus under the open supply chain for $\delta < \hat{\delta}(\eta)$ becomes

$$W^r(\eta,\delta|\delta<\hat{\delta}(\eta)) = \frac{(48-48\eta-32\delta+12\eta^2-4\delta^2+32\eta\delta-4\eta^2\delta+4\eta\delta^2-3\eta^2\delta^2)(1-c_I)^2}{8(2-\eta)^2(4-3\delta)}.$$

Third, we derive the social surplus when the open supply chain is chosen for $\delta \geq \hat{\delta}(\eta)$. The consumer surplus becomes

$$CS_1^r(\eta, \delta | \delta \geq \hat{\delta}(\eta)) + \delta CS_2^r(\eta, \delta | \delta \geq \hat{\delta}(\eta)) = 0 + \delta \int_0^{Q_2^r} (v_1^r - x - p_2^r) dx$$
$$= \frac{\delta (1 - c_E)^2}{8}.$$

Domestic firms' two-period joint profit becomes $\delta(1 - c_I)^2/4$. By summing these surpluses, the social surplus under the open supply chain for $\delta \geq \hat{\delta}(\eta)$ becomes

$$W^r(\eta, \delta | \delta \geq \hat{\delta}(\eta)) = \frac{\delta(6 - 4\eta + \eta^2)(1 - c_I)^2}{4(2 - \eta)}.$$

We now consider the social inefficiency of the exclusive supply chain. First, we explore the case of $\delta < \hat{\delta}(\eta)$. In this case, we have

$$W^r(\eta, \delta | \delta < \hat{\delta}(\eta)) - W^a(\delta) = \frac{\eta^2 \delta (2 - \delta)(1 - c_I)^2}{4(2 - \eta)^2 (4 - 3\delta)} > 0,$$

for all $(\eta, \delta) \in (0, 2) \times (0, \hat{\delta}(\eta))$. Second, we explore the case of $\delta \geq \hat{\delta}(\eta)$. We define $\Gamma(\eta, \delta)$ as

$$\Gamma(\eta, \delta) \equiv W^r(\eta, \delta | \delta \geq \hat{\delta}(\eta)) - W^a(\delta)$$
$$= \frac{(-48 + 48\eta - +80\delta - 12\eta^2 - 32\delta^2 - 64\eta\delta + 16\eta^2\delta + 20\eta\delta^2 - 5\eta^2\delta^2)(1 - c_I)^2}{8(2 - \eta)^2(4 - 3\delta)}.$$

Note that $\Gamma(\eta, \delta)$ has the following two properties

$$\frac{\partial \Gamma(\eta, \delta)}{\partial \eta} = \frac{\delta (1 - c_I)^2}{(2 - \eta)^3} > 0,$$

$$\Gamma(\eta, \hat{\delta}(\eta)) = \frac{\eta^2 (1 - c_I)^2}{(4 - \eta)(4 - \eta^2)} > 0,$$

for all $\eta \in (0, 2)$, which implies that we have $\Gamma(\eta, \delta) > 0$ for all $(\eta, \delta) \in (0, 2) \times [\hat{\delta}(\eta), 1)$. Thus, exclusion of U_E is always anticompetitive even when U_E is a foreign firm.

Q.E.D.

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