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Integration vs. Separation under Two-part Tariff with Network Compatibility Effects *

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Abstract This paper examines the interplay between the strength of network externalities with both degrees of compatibility and product substitutability in a vertical structure. As alternative solutions to double marginalization, we compare the efficiency between integration case and vertical separation in centralized Nash bargaining with a two-part tariff under Cournot and Bertrand competition. In contrast to conventional wisdom, the equivalence between vertical separation under a two-part tariff and vertical integration never holds in network market with compatibility. Consequently, we show that regardless of the strength of network externalities with both degrees of compatibility and product substitutability, industrial profits, social welfare and consumer surplus are always higher under vertical separation in centralized Nash bargaining than under integration case. Thus, under Cournot and Bertrand competition, double marginalization is necessary to implement the efficient outcomes, except for the case of full compatibility.

Keywords Network Externalities, Compatibility, Two-part Tariff, Integration

JEL Classification D43, L13, L14

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1. INTRODUCTION

Pricing distortion in a vertically related market is the result of double marginalization. There are several alternative solutions to such distortion in a monopolistic market. The first is vertical integration between upstream and retailer. The second is Nash bargaining contract between them. The third includes vertical restraints, such as fixed fee with exclusive territories and resale price maintenance, royalty, and so on. Most important thing is that all equilibria of alternative solutions are equivalent in market without network externalities. In this paper, we revisit vertically related market to check the equivalence between vertical separation in centralized Nash bargaining with a two-part tariff and vertical integration in the presence of network externalities with compatibility under Cournot and Bertrand competition[1].

Recently, information and technology (i.e., IT) industry rapidly progressed with the proliferation of internet and personal computers. Many products in IT industry have the special feature of positive consumption externalities. In other words, a consumer's utility from consuming a product increases with the number of other consumers consuming it. On the theoretical side, a substantial literature also focuses on network externalities since network effects arise in many industries. Many studies, including Katz and Shapiro (1985), Economides (1996), Shyippe (2001) and Hoernig (2012), have investigated an industry with network externalities. In this study, focusing on the role of consumer expectations, we check the robustness of the results on vertically related market which is observed in equilibrium in a network industry.

For the compatible and incompatible networks, we can think of several examples for which our analysis could be used. For example, we can think of Skype[2] "Traditional fixed telephony typically has compatible network. Skype is a software program that allows users to make telephone calls over the internet. When this service was launched, users of Skype could only make calls within their community. After its launch, the program also allowed its users to place calls to landlines or cell phone. Compatibility became only partial as users can call within community free of change but outside the community for a fee[3]."

[1] For Nash bargaining model without network externalities with compatibility, see Lopez and Naylor (2004), Lopez (2007), Alipranti *et al.* (2014), Basak and Wang (2016), Basak (2017), and so on.

[2] We borrow Skype example from Belleflamme and Peitz (2015).

[3] The empirical phenomenon is exemplified by the market for e-books. Amazon has chosen application compatibility by making it possible for Apple iPad users to view e-books purchased from its Amazon Kindle Store. In contrast, Apple has chosen application incompatibility, meaning

As for vertically related market of example, Qualcomm, the representative upstream firm in the smartphone industry, provides its patents with its specialized chips used in smartphones with two-part tariffs consisting of royalty and per chip price[4].

Theoretically, using a model of *linear* wholesale pricing between the monopolistic upstream firm and retailers in the presence of network externalities, Choi and Lee (2017) showed that whether the conventional result of double marginalization decreases social surplus depends on the network extenalities, compared to vertical integration. On the other hand, Lee and Choi (2018) compared the integration with separation with two-part tariff under *bilateral duopoly*. In the absence of compatibility, Choi and Lee (2017) and Lee and Choi (2018) found the counter-results, which depends on both the strength of network externalities and the degree of products substitutability under only Bertrand competition. Thus, similarity between previous works (Choi and Lee, 2017; Lee and Choi, 2018) and ours is given by vertically related market with rational expectation. However, the difference between them is that the equivalence between vertical separation in centralized Nash bargaining with a two-part tariff and vertical integration does not hold true always under Bertrand and Cournot competition.

Given these observations of the presence of compatibility and previous works, we introduce network externalites with both two-part tariff and the centralized bargaining in the framework of Choi and Lee (2017) and Lee and Choi (2018)[5]. Note that even though we allow to incorporate the network compatibility into the framework of Choi and Lee (2017) and Lee and Choi (2018), all results they present still hold and do not alter main economic implication. Hence, one issue that remains to be analysed is whether the above results depending on those parameters are robust to the centralized bargaining with two-part tariff in the type of competition: the "equivalence" between vertical separation in centralized Nash bargaining with a two-part tariff and vertical integration as a solution of double marginalization. None of the previous studies have considered a case in which one upstream firm and two retailers interplay between the strength of network

that the users of Amazon's Kindle cannot view e-books purchased on Apple's iTunes.

[4]Qualcomm charges royalties on each mobile phone sold based on its technology in addition to one-time licensing fees from mobile phone manufacturers such as Apple, Samsung, Nokia and LG.

[5]The result that vertical integration may yield lower social welfare than vertical separation also obtained by Choi and Lee (2017) under linear wholesale pricing and Lee and Choi (2018) in a bilateral duopoly with a two-part tariff. These works show that the network effects must be sufficiently strong to cause higher efficiency under vertical separation, while in our paper, the different results including compatibility are achieved under centralized bargaining regardless of the strength of network effects.

externalities with compatibility comparing integration and vertical separation in a two-part tariff with centralized bargaining.

In contrast to conventional wisdom, we find that *regardless* of the strength of network externalities with both degrees of compatibility and product substitutability, industrial profits, social welfare and consumer surplus are always higher under vertical separation in centralized Nash bargaining with a two-part tariff than under integration case. Thus, under either Cournot or Bertrand competition, double marginalization is necessary to implement the efficient outcomes. Consequently, we show that the equivalence between vertical separation under a two-part tariff and vertical integration never holds in markets characterized by network effects under either Cournot or Bertrand competition. However, in the case of full compatibility, double marginalization worsens social welfare. Note that these main results are based on the rational expectations, but not fulfilled expectations.

In this study, we also focus on the role of consumers' expectations in the vertically related market. In a network goods market, the role of consumers' expectations of network size is a critical determinant of market outcomes (Economides, 1996; Hermalin and Katz, 2006; Hoernig, 2012; Katz and Shapiro, 1985; Bhattacharjee and Pal, 2013; Pal, 2015). Adapting the passive (i.e., fulfilled) and responsive (i.e., rational) expectations terminology presented by Hurkens and Lopez (2014). The responsive expectations mean that firms first compete in prices or quantities, then consumers form expectations about network sizes. On the other hand, passive expectations mean that consumers first form expectations about network sizes and firms then compete in prices or quantities. Thus, the difference between responsive and passive expectations lies in consumer time of forming expectations regarding each firm's total sales. In this paper, using the terminology of fulfilled and rational expectations, we mainly consider that consumers' expectations satisfy 'rational expectations' conditions. After this, adopting fulfilled expectation among consumers, we will discuss different economic implication at the end of Section 5.

Note that our assumption about consumers' rational expectation plays an important role in our results under Bertrand and Cournot competition. To justify our assumption, we bring the mobile phone service which is a representative network industry. When subscribing to the mobile phone services, consumers are well-informed about the mobile phone prices before purchasing the mobile phone such as Apple's iPhone and Samsung's Galaxy. Depending on the terms of advertising when launching new version, services or prices provided by mobile phone service providers, consumers choose one provider[6]. For example, there are three major phone service operators in South Korea, SK Telecom, Olleh (KT has stopped using Olleh as its brand name since 2016), and LG U+. If consumers subscribe to one mobile phone service, they usually maintain normally a 2-years contract to offset the lack of subsidies. So, the more consumers bring the higher profits of the operators. Since most consumers buy their mobile phones through the operators, all operators give differentiated subsidies to their consumers by using their distribution channel like retail shops to promote more consumers. Even though the device manufacturers, Apple and Samsung, sell their phones to the mobile operators at an original price, consumers ultimately purchase these the discounted price due to a subsidy of mobile operators.

Borrowing the setting of Choi and Lee (2017) and Lee and Choi (2018), there are three major differences between them and ours. First, we consider both Cournot and Bertrand competition discussing the role of partial or full compatibility vs. full incompatibility. However, they analyzed only under Bertrand competition and do not analyze the difference between the degree of compatibility and imperfect substitutability. Second, Lee and Choi (2018) with bilateral duopoly found that depending on both the strength of network externalities and the degree of products substitutability in absence of compatibility, the merit of vertical separation is altered in view point of the total and consumer welfare and industry profit. By contrast, our results do not depend on them even in the presence of compatibility where the monopolistic upstream firm offers two-part tariffs to retailers. Finally, going beyond Choi and Lee (2017), we consider that whether the equivalence between vertical separation in Nash bargaining with a two-part tariff and vertical integration holds or not in markets characterized by network effects.

The remainder of this paper is organized as follows. In Section 2, we summarize theoretical literature on issues in vertical structure and network externalities. In Section 3, we formulate the basic model. In Section 4, focusing on rational expectations among consumers, we mainly analyze the equilibrium outcomes between vertical integration and separation. In Section 5, including the role of compatibility vs. no compatibility, welfare comparison will be examined between vertical integration and vertical separation, and Section 6 provides our concluding remarks.

[6] Some readers may argue that consumers indeed do not observe the price they pay the operator for the smartphone, but this may be the wholesale price that the operator pays Apple and Samsung.

2. RELATED LITERATURE

There is a large theoretical literature on issues in vertical structure where welfare effects of double margin distortion in input markets. In a seminal paper, Spengler (1950) firstly addressed the double margin distortion. Several studies examine similar issues in vertical control[7]. Telsor (1960), Mathewson and Winter (1984), Bernheim and Whinston (1985), and Carlton and Chevalier (2001) extended the issue from vertical to horizontal externality between retailers. Mathewson and Winter (1984) and Rey and Tirole (1986) look at the vertical restraints facing a single manufacturer who sells to several retailers. Rey and Stiglitz (1995) look at the vertical restraints in a duopolistic market.

More directly related to our study, Bonanno and Vickers (1988) found that vertical separation is more profitable for both manufacturers than vertical integration is if franchise fees are used to extract the retailer's surplus in a duopolistic market. Lin (1988) used a model of zero-one demands and obtains two Nash equilibria: vertical integration by both firms and vertical separation by both firms. Philippe (1994) showed that the manufacturer's decision of whether to vertically integrate or to separate its retailer depends on the degree of product differentiation, if they cannot use franchise fees to extract the retailer's surplus. On the other hand, Li and Shuai (2017) found that vertical separation strengthens competition and increases consumer surplus in a Hotelling model with location-price competition.

As a solution of double marginalization, previous research paid little attention to the equivalence between vertical separation in centralized Nash bargaining with a two-part tariff and vertical integration with network externalities. Since the seminal paper of Katz and Shapiro (1985), many papers have focused on the effect of network externality on market. The progress in information and communication technology led to a proliferation of products that exhibit network externalities due to network goods industries. See (Shyippe, 2001; Birke, 2009). For network externalities, see Economides (1996), Chou and Shy (1993), Hermalin and Katz (2006), Hoernig (2012), Chirco and Scrimitore (2013), Bhattacharjee and Pal (2013), Pal (2015), and so on. Hoernig (2012) showed that firms' owners optimally offer their managers incentive contracts that may induce them to behave more aggressively under Bertrand competition under sufficiently strong network externalities, and vice versa. Toshimitsu (2016) demonstrated that the Cournot equilibrium is more efficient than the Bertrand equilibrium in terms of consumer, producer and total surpluses, if there are sufficient asymmet-

[7] See Motta (2004) for various vertical restraints and vertical mergers.

ric network compatibility effects.

3. THE MODEL

Consider a supply chain consisting of one upstream firm u and two competing retailers i $(i = 1, 2)$. After purchasing inputs from the upstream firm, two competing retailers add some values to the products and sell differentiated network goods to customers. These two networks are either perfectly compatible, perfectly incompatible, or imperfectly compatible to each other. In case these two networks are compatible to each other, utility of consumers of one good increases due to increase in the number of consumers of the other good as well; the extent of such an increase depends on the degree of network compatibility and the strength of network externalities.

Thus, we consider the utility function of the representative consumer[8],

$$U = a(q_i + q_j) - \frac{(q_i^2 + q_j^2 + 2bq_iq_j)}{2} + n\left[(y_i + \phi y_j)q_i + (y_j + \phi y_i)q_j - \frac{(y_i^2 + y_j^2 + 2\phi y_j y_i)}{2}\right] + m; i, j = 1, 2, i \neq j,$$

where a is the intrinsic market size, m denotes the consumption of all other goods, measured in terms of money; q_i denotes the quantity of the final product i; y_i denotes consumers' expectations about final product i's quantity; $b \in (0, 1)$ represents the degree of product differentiation; $\phi \in (0, 1)$ represents the degree of compatibility and $n \in (0, 1)$ measures the strength of the network externalities[9].

Note that the marginal utility of product i increases in y_i and y_j: $\partial^2 U/\partial q_i \partial y_i = n > 0$ and $\partial^2 U/\partial q_i \partial y_j = \phi n > 0$, respectively. This implies that there are pos-

[8]This form of the utility function is a generalization of the utility function considered in several studies including Hoernig (2012), Bhattacharjee and Pal (2013), Pal (2015) and Shrivastavppe (2021). The utility function encompasses the Hoernig (2012)'s utility function as special case in which $b = \phi$. The utility function is the same as in Naskar and Pal (2020) and Shrivastavppe (2021) restrict their analysis by considering two special cases, $b = \phi$ and $\phi = 0$, only. However, Shrivastavppe (2021) extended the model with $b \neq \phi$ and $b, \phi \in (0, 1)$, which implies that the framework considered in Shrivastavppe (2021) is fairly general which allows for a larger parameter space compared to the case of only n.

[9]To analyze the role of compatibility vs. no compatibility, we introduce the degree of compatibility into the model. In this paper, we treat three cases $\phi = 0$ (i.e., completely incompatible), $\phi = 1$ (i.e., completely compatible) and $\phi \in (0, 1)$ (i.e., partially compatible), Thus, we can check the robustness of the main results in presence of compatibility. We will mention those effects of $\phi = 0$ and $\phi = 1$ in subection 5.2.

itive consumption externalities. It is evident that for given consumption bundle (q_i, q_j), utilities reach their highest level, if consumers' expectations are correct (i.e., $y_i = q_i$ and $y_j = q_j$). From the utility function of the representative consumer, we can derive the indirect and direct demand functions for product i as follows[10].

$$p_i = a - q_i - bq_j + n(y_i + \phi y_j),$$
$$q_i = \frac{a(1-b) - p_i + bp_j + n(1-b\phi)y_i - n(b-\phi)y_j}{1-b^2};\ i, j = 1, 2, i \neq j.$$

where p_i and p_j are the prices of products i and j, respectively. For simplicity, retailers require a critical input for production that they purchase from a monopoly upstream firm through two-part tariff contracts involving an up-front fixed-fee f_i and a per unit uniform price w. Upstream firm produces the inputs at a constant marginal cost of production, c. Furthermore, we assume that one unit of input is required to produce one unit of the output.

For the following analysis, we make some important assumption:

Assumption 1. (i) $n > b$, (ii) $1 - b > n$ and $b < \phi n \Leftrightarrow \frac{b}{\phi} < n < 1 \Leftrightarrow b < \phi n < 1$

Assumption 1 (i) implies a stronger network externality in the partial compatibility. Assumption 1 (ii) implies that the own-price effect exceeds the cross-price effect at the fulfilled expectation equilibrium[11]. In other words, the left-hand side measures the degree of product differentiation, which the degree of network externality is lower than that of product differentiation.

We posit a two-stage game. At stage one, if the vertical structure is separated, the upstream firm is involved in a centralized Nash bargaining with two-part tariff involving a fixed fee (f_i) and a wholesale price (w). On the other hand, if it is integrated, this stage is omitted. At stage two, each retailer simultaneously chooses its quantity (q_i, q_j) in order to maximize its profits. If the vertical structure is integrated, the integrated upstream firm sets its quantities (q_i, q_j) in order

[10]To derive direct demand, using a representative consumer's quadratic utility function, its maximization problem is as follows: $\max_{q_i, q_j} V \equiv U - p_i q_i - p_j q_j$. The budget constraint of a representative consumer is $I = p_i q_i + p_j q_j + m, p_m = 1$, where the income I, p_m denotes the price of all other goods, and the prices $p_i, i = 1, 2$ are given. The first order conditions are given by $\frac{\partial V}{\partial q_i} = a - p_i - q_i - bq_j + ny_i + \phi n y_j = 0$, $\frac{\partial V}{\partial q_j} = a - p_j - q_j - bq_i + ny_j + \phi n y_i = 0$. Solving p_i and p_j with symmetry, we can derive the the indirect and direct demand functions for product i.

[11]Note that $|\partial p_i / \partial q_i| > |\partial p_i / \partial q_j|$ implies $1 - n > |b - n\phi|$. For example, if $n > 1/2$, (ii) $n > b$ implies (ii) $1 - b > n$. Also, it is also true that if $1 - b > n$ and $b < \phi n \Leftrightarrow b\phi < n < 1 - n$ in (ii). We appreciate this comment of an anonymous referee.

to maximize its profits. We solve the subgame perfect Nash equilibrium through backward induction.

Before comparing each vertical case, we provide vertical separation where the retailers involve in centralized Nash bargaining with upstream firm to determine the two-part tariff contracts[12]. At stage one, the upstream firm and two retailers determine the terms of the two-part tariff contract by maximizing the following generalized Nash bargaining expression:

$$\max_{f_i,w}\left\{\sum_{i=1}^{2}[(w-c)q_i+f_i]\right\}^{\beta}\left\{\sum_{i=1}^{2}[(p_i-w)q_i-f_i]\right\}^{1-\beta}, \tag{1}$$

where w and $\pi_i=(p_i-w)q_i-f_i$ denote the wholesale price and net profit of the retailers and $\beta\in(0,1)$ (resp. $(1-\beta)$) shows the bargaining power of the upstream firm (resp. retailer). Maximizing Eq. (1) with respect to f_i gives the following:

$$f_i=\frac{1}{2}\left[\beta\sum_{i=1}^{2}(p_i-w)q_i-(1-\beta)\sum_{i=1}^{2}(w-c)q_i\right]. \tag{2}$$

Substituting (2) in (1), we get the maximization problem as

$$\max_{w}\left\{\beta\sum_{i=1}^{2}\left[(p_i-w)q_i+(w-c)q_i\right]\right\}^{\beta}\left\{(1-\beta)\sum_{i=1}^{2}\left[(p_i-w)q_i+(w-c)q_i\right]\right\}^{1-\beta}. \tag{3}$$

Eq. (3) shows that the wholesale price is determined to maximize the industry profit[13].

One might wonder what would happen if the formulation of the supplier's profit is decentralized. While the assumption of decentralized bargaining process is the starting point, it is equally interesting to investigate whether the results alluded above hold when the input price contract constitutes centralized bargaining. The implication of centralized bargaining is justifiable in most continental European countries, such as Germany Hirsch *et al.* (2014). In the context

[12]Note that if we analyze the model with bargaining and discriminatory input price, w_i and w_j between upstream and retailers including two-part tariff contract, we have same results when comparing vertical integration and vertical separation. The detailed computations are available from authors upon request.

[13]While the optimal input price specified in the contract is obtained by maximizing their *joint profits*, the production decision of each downstream firm is made based on independent profit maximization. If this is the case, we have the same result from our setting. The detailed derivations are available from the authors on request.

of strategic input-price determination Calmfors and Driffill (1988) and Danthine and Hunt (1994) argued that collective bargaining is more widely accepted as it internalises various negative externalities.

4. ANALYSIS

Since the monopolistic upstream firm is involved in vertical integration, we can understand that all equilibrium outcomes between Cournot and Bertrand competition have the same value. Here, we provide the case of Cournot competition in vertical integration.

In the case of which the monopolistic upstream firm is involved in a centralized Nash bargaining with two retailers to determine the terms of the two-part tariff contracts, we can understand that all equilibrium outcomes between Cournot and Bertrand competition have the same value except for the wholesale price and fixed fee. Thus, even though we examine both Cournot and Bertrand competition in the vertical separation, we will briefly demonstrate Bertrand competition as short as possible.

4.1. VERTICAL INTEGRATION

We first consider a simple vertical integration. Suppose a firm who produces two differentiated products with a constant marginal cost (c). The integrated firm's maximization problem is defined as follows:

$$\max_{q_i,q_j} \Pi = \sum_{i=1,i\neq j}^{2} (p_i - c)q_i = \sum_{i=1,i\neq j}^{2} [a - q_i - bq_j + n(y_i + \phi y_j) - c]q_i.$$

The integrated firm chooses its quantities in order to maximize its profit. We state the solution to the optimization as two first-order conditions (Eqs. (4-1) and (4-2)) that are to hold under the equilibrium-restrictions of satisfied expectations (Eqs. (4-3) and (4-4)) as follows:

$$R(q_j^{VI}) \equiv q_i(q_j) = \frac{a - c - 2bq_j + n(y_i + \phi y_j)}{2}, \tag{4-1}$$

$$R(q_i^{VI}) \equiv q_j(q_i) = \frac{a - c - 2bq_i + n(y_j + \phi y_i)}{2}, \tag{4-2}$$

$$q_i = y_i, \tag{4-3}$$

$$q_j = y_j, \tag{4-4}$$

where the superscript 'VI' denotes vertical integration. Note that, from the utility function, for any given consumption bundle (q_i, q_j) the representative consumer enjoys the highest utility level if his expectations are correct, i.e., if $q_i = y_i$ and $q_j = y_j$. Following Hoernig (2012), we consider that consumers' expectations satisfy 'rational expectations' conditions. Therefore, we assume that $q_i = y_i$ and $q_j = y_j$ hold true in equilibrium.

Solving Eqs. (4-1)-(4-4) with symmetry, we obtain the equilibrium quantity as follows:

$$q_i^{VI} = \frac{a-c}{2(1+b)-n(1+\phi)}. \tag{5}$$

Finally, we obtain the equilibrium price, profit, consumer surplus, and social welfare as follows:

$$p_i^{VI} = c + \frac{(a-c)(1+b)}{2(1+b)-n(1+\phi)}, \quad \Pi^{VI} = \frac{2(a-c)^2(1+b)}{[2(1+b)-n(1+\phi)]^2}, \tag{6-1}$$

$$CS^{VI} = \frac{(a-c)^2[1+b-n(1+\phi)]}{[2(1+b)-n(1+\phi)]^2}, \quad SW^{VI} = \frac{(a-c)^2[3(1+b)-n(1+\phi)]}{[2(1+b)-n(1+\phi)]^2}. \tag{6-2}$$

By differentiating the above equilibria with respect to network effect, we obtain the following results:

$$\frac{\partial p_i^{VI}}{\partial n} > 0, \frac{\partial q_i^{VI}}{\partial n} > 0, \frac{\partial \Pi^{VI}}{\partial n} > 0, \frac{\partial CS^{VI}}{\partial n} < 0, \frac{\partial SW^{VI}}{\partial n} > 0.$$

Due to network effect of network externalities, the larger network externalities lead to the higher prices, larger quantities, higher profits, and higher social welfare. Note $\frac{\partial CS^{VI}}{\partial n} < 0$. The underlying intuition behind the effect of n on CS is as follows. In the presence of network effects, the strength of network extenalities (n) affects consumers' surplus (CS) through three channels: (a) direct effect (DE) via network size, (b) indirect network size effect (INSE) through consumers' expectation, (c) indirect quantity effect (IDQE) via consumers' expectation. To be more explicit, we can write the change in consumer surplus due to change in its network size, n as follows.

From $CS^{VI}[\mathbf{q}(\mathbf{y}(n), n); \mathbf{y}(n); n]$ under vertical integration where $\mathbf{q}$ and $\mathbf{y}$ denote vectors of final output, price, and network size, respectively, that is $\mathbf{q} =$

(q_i, q_j) and $\mathbf{y} = (y_i, y_j)$, we have

$$\frac{\partial CS^{VI}}{\partial n} = \frac{\partial CS}{\partial \mathbf{q}}\frac{\partial \mathbf{q}}{\partial \mathbf{y}}\frac{\partial \mathbf{y}}{\partial n} + \frac{\partial CS}{\partial \mathbf{y}}\frac{\partial \mathbf{y}}{\partial n} + \frac{\partial CS}{\partial n}$$

$$= \underbrace{-n(y_i+\phi y_j)\underbrace{\frac{\partial \mathbf{q}}{\partial \mathbf{y}}}_{(+)}\underbrace{\frac{\partial \mathbf{y}}{\partial n}}_{(+)}}_{(-):IDQE} + \underbrace{\underbrace{\frac{\partial CS}{\partial \mathbf{y}}}_{(-)}\underbrace{\frac{\partial \mathbf{y}}{\partial n}}_{(+)}}_{(-):INSE} + \underbrace{\frac{\partial CS}{\partial n}}_{(+):DE} \qquad \text{(CS1)}$$

From $\frac{\partial q_i^{VI}}{\partial n} > 0, \frac{\partial y_i^{VI}}{\partial n} > 0$, the IDQE effect of a marginal increase in the value of n from one on CS is negative. Next, we have $\frac{\partial CS}{\partial n} < 0$ from the definition of CS. When there are network effects, an increase in n increases $y_i^{VI} = q_i^{VI}$ ($\frac{\partial y_i^{VI}}{\partial n} > 0$) in equilibrium. Moreover, from $\frac{\partial CS}{\partial y_i} < 0$, we obtain Eq. (CS1)[14], which implies that if INSE and IDQE dominate DE, then we would have $\frac{\partial CS^{VI}}{\partial n} < 0$ under vertical integration.

4.2. COURNOT COMPETITION IN VERTICAL SEPARATION WITH TWO-PART TARIFF

We next turn to centralized bargaining model with two-part tariff in which a monopolistic upstream firm sells its goods to its retailers who sell them under Cournot competition.

At stage two, retailer D_i chooses q_i in order to maximize its profits for given the wholesale price w, and the rival's quantity q_j. Retailer D_i's maximization problem is as follows:

$$\max_{q_i} \pi_i(q_i, q_j; w) = (p_i - w)q_i - f_i = [a - q_i - bq_j + n(y_i + \phi y_j) - w]q_i - f_i.$$

As in the vertical integration, we can state the solution to the optimization problem as two first order conditions (Eqs. (7-1) and (7-2)) that are to hold under the equilibrium-restrictions of satisfied expectations (Eqs. (7-3) and (7-4)) as

[14]To understand INSE, the underlying intuition behind $\frac{\partial CS}{\partial y_i} < 0$ is as follows. Given the equilibrium output q_i, an increase y_i implies that demand function is upward shifting resulting the increased price.

follows:

$$R(q_j^T) \equiv q_i(w, q_j) = \frac{a - w - bq_j + n(y_i + \phi y_j)}{2}, \tag{7-1}$$

$$R(q_i^T) \equiv q_j(w, q_i) = \frac{a - w - bq_i + n(y_j + \phi y_i)}{2}, \tag{7-2}$$

$$q_i = y_i, \tag{7-3}$$

$$q_j = y_j, \tag{7-4}$$

where the superscript 'T' denotes the two-part tariff bargaining contract. From (4-1), (4-2), (7-1), and (7-2), note that given $w = c$, the slope of the reaction function is stiffer under vertical integration than under centralized bargaining. Solving Eqs. (7-1)–(7-4), we obtain the equilibrium quantity in terms of the wholesale price w as follows:

$$q_i(w) = \frac{a - w}{2 + b - (1 + \phi)n}. \tag{8}$$

At stage one, the monopoly upstream firm determines the terms of two-part tariff contract by maximizing the following generalized Nash bargaining

$$\max_w \left\{ \beta \sum_{i=1}^{2} \left[(p_i - w)q_i + (w - c)q_i \right] \right\}^{\beta} \left\{ (1 - \beta) \sum_{i=1}^{2} \left[(p_i - w)q_i + (w - c)q_i \right] \right\}^{1-\beta}. \tag{9}$$

Maximizing Eq. (9) with respect to the wholesale price gives the equilibrium wholesale price and fixed fee as follows[15]:

$$w^T = c - \frac{(a - c)[n(1 + \phi) - b]}{2[1 + b - (1 + \phi)n]}, \tag{10-1}$$

$$f_i^T = \frac{(a - c)^2\{(1 - \beta)[(1 + \phi)n - b] + \beta\}}{4[1 + b - (1 + \phi)n]^2}. \tag{10-2}$$

Noting that From the Assumption 1 (ii), it holds that $\frac{1+b}{1+\phi} > n$, where $\frac{b}{\phi} < \frac{1+b}{1+\phi} \Leftrightarrow \frac{b}{\phi} < 1$. We have $n > \frac{b}{\phi} > \frac{b}{1+\phi}$, then the equilibrium wholesale price is lower than the marginal production cost, c. In this case, monopoly upstream firm wants to make the retailer more aggressive in the market. This is the conventional wisdom

[15]From the Assumption 1(ii), it holds that $\frac{1+b}{1+\phi} > n$, where $\frac{b}{\phi} < \frac{1+b}{1+\phi} \Leftrightarrow \frac{b}{\phi} < 1$. We have $\frac{1+b}{1+\phi} > n > \frac{b}{\phi}$. Given this condition, the equilibrium outcomes hold.

even under $n > 0$ and Cournot competition. However, if $n = 0$, based on Eq. (10-1) we obtain $w^T = c + \frac{b(a-c)}{2(1+b)}$, which implies that the equilibrium input price is *higher* than the marginal production cost, c. In this case (i.e., $n = 0$), monopoly upstream firm wants to make the retailer more defensive in the market. This is the contrast to the result as in Cournot competition in the absence of network externalities.

Finally, we obtain the equilibrium outcomes as follows:

$$q_i^T = \frac{a-c}{2[1+b-n(1+\phi)]}, \quad p_i^T = c + \frac{a-c}{2}, \tag{11-1}$$

$$\pi_i^T = \frac{(a-c)^2(1-\beta)}{4[1+b-(1+\phi)n]}, \quad \Pi^T = \frac{(a-c)^2\beta}{2[1+b-(1+\phi)n]}, \tag{11-2}$$

$$CS^T = \frac{(a-c)^2}{4[1+b-(1+\phi)n]}, \quad SW^T = \frac{3(a-c)^2}{4[1+b-(1+\phi)n]}. \tag{11-3}$$

Note that $q_i^T > 0$ is guaranteed by the Assumption 1. By differentiating the above equilibria with respect to network effect, we obtain the following results:

$$\frac{\partial w^T}{\partial n} < 0, \ \frac{\partial q_i^T}{\partial n} > 0, \ \frac{\partial \pi_i^T}{\partial n} > 0, \ \frac{\partial \Pi^T}{\partial n} > 0, \ \frac{\partial CS^T}{\partial n} > 0, \ \frac{\partial SW^T}{\partial n} > 0.$$

Similar to vertical integration, consumers' surplus is given by

$$CS^T[\mathbf{q}(\mathbf{y}(\mathbf{w}(n)), \mathbf{w}(n)), n); \mathbf{y}(\mathbf{w}(n)); \mathbf{w}(n); n]$$

under vertical separation, we have Here, $\mathbf{q}$, $\mathbf{y}$ and $\mathbf{w}$ denote vectors of final output, price, network size and wholesale prices, respectively, that is $\mathbf{q} = (q_i, q_j)$, $\mathbf{y} = (y_i, y_j)$ and $\mathbf{w} = (w_i, w_j)$. Repeating same process with previous vertical integration, we can also have

$$\frac{\partial CS^T}{\partial n} = \underbrace{-n(y_i + \phi y_j) \underbrace{\frac{\partial \mathbf{q}}{\partial \mathbf{y}}}_{(+)} \underbrace{\frac{\partial \mathbf{y}}{\partial \mathbf{w}}}_{(-)} \underbrace{\frac{\partial \mathbf{w}}{\partial n}}_{(-)}}_{(-):IDQE} + \underbrace{\underbrace{\frac{\partial CS}{\partial \mathbf{y}}}_{(-)} \underbrace{\frac{\partial \mathbf{y}}{\partial \mathbf{w}}}_{(-)} \underbrace{\frac{\partial \mathbf{w}}{\partial n}}_{(-)}}_{(-):INSE} + \underbrace{\underbrace{\frac{\partial CS}{\partial \mathbf{w}}}_{(-)} \underbrace{\frac{\partial \mathbf{w}}{\partial n}}_{(-)}}_{(+):IWE} + \underbrace{\frac{\partial CS}{\partial n}}_{(+):DE}$$

Using $\frac{\partial \mathbf{w}}{\partial \mathbf{y}} > 0$ from Eq. (7-1), with the IDQE, INSE, DE in vertical separation, one network effect is added which is indirect wholesale price effect (IWE) through consumers' expectation about network size. Therefore, if IWE and DE dominate new IDQE with wholesale price and INSE, then we would have $\frac{\partial CS^T}{\partial n} > 0$ under vertical separation.

4.3. BERTRAND COMPETITION IN VERTICAL SEPARATION WITH TWO-PART TARIFF

At stage two, the downstream firm D_i's maximization problem is based on direct demand function. Repeating the same process as in Cournot competition, we can state the solution to the optimization problem as two first order conditions (Eqs. (B_1) and (B_2)) that are to hold under the equilibrium-restrictions of satisfied expectations (Eqs. (B_3) and (B_4)) as follows:

$$p_i(p_j) = \frac{a(1-b)+w+ny_i+\phi ny_j+b[p_j-n(\phi y_i+y_j)]}{2}, \tag{B_1}$$

$$p_j(p_i) = \frac{a(1-b)+w+ny_j+\phi ny_i+b[p_i-n(\phi y_j+y_i)]}{2}, \tag{B_2}$$

$$q_i = y_i, \tag{B_3}$$

$$q_j = y_j, \tag{B_4}$$

Solving Eqs. (B_1)–(B_4) with symmetry, we can obtain the equilibrium prices and outputs in terms of the wholesale price. Given equilibrium outcomes in stage 2, D_i's the profit reduces to $\pi_i^T = \frac{(1-b^2)(a-w)^2}{[2+b-b^2-n(1+\phi)]^2} - f_i$. At stage one, maximizing Eq. (3) in main text subject to the equilibrium outcomes in stage 2 yields the equilibrium wholesale price and fixed fee are as follows:

$$w^{TB} = c + \frac{(a-c)[b(1+b)-n(1+\phi)]}{2[1+b-(1+\phi)n]},$$

$$f_i^{TB} = \frac{(a-c)^2[(1+\phi)(1-\beta)n-(1+b)(b-\beta)]}{4[1+b-(1+\phi)n]^2},$$

where the superscript 'TB' denotes equilibrium outcomes under Bertrand competition in vertical separation. Noting that the term of $[b(1+b)-n(1+\phi)]$ in w^{TB} is guaranteed by the Assumption 1[16], the equilibrium input price is lower than the marginal production cost, c. Using w^{TB} and f_i^{TB}, it is easily check that except for w^{TB} and f_i^{TB}, all equilibrium outcomes between Cournot and Bertrand competition have the same value.

5. RESULTS

In the previous section, we analyzed vertical integration and vertical separation in two-part tariff bargaining contract. In this section, we compare the

[16]From the Assumption 1 (ii), it holds that $\frac{1+b}{1+\phi} > n$, where $\frac{b}{\phi} < \frac{1+b}{1+\phi} \Leftrightarrow \frac{b}{\phi} < 1 \Leftrightarrow b < \phi$. We have $b(1+b)-n(1+\phi) < 0 \Leftrightarrow \frac{b}{n} - \frac{1+\phi}{1+b} < 0$ due to $n > b$ and $\phi > b$.

equilibria between vertical integration and vertical separation in two-part tariff bargaining contract. For simplicity, we set the following assumption to guarantee that all possible variables are positive in equilibrium. Specifically, this assumption takes the following form:

$$\max\left\{0, \frac{n(1+\phi)-b}{2+b-n(1+\phi)}\right\} < \frac{c}{a} < 1. \tag{A}$$

From (6-1) and (11-1), we obtain under either Bertrand or Cournot competition

$$p_i^{VI} - p_i^T = \frac{(a-c)(1+\phi)n}{2[(1+b)-(1+\phi)n]} > 0,$$
$$q_i^T - q_i^{VI} = \frac{(a-c)(1+\phi)n}{2[1+b-n(1+\phi)][2(1+b)-n(1+\phi)]} > 0.$$

Quantities are higher and prices are lower under vertical separation in two-part tariff bargaining than under vertical integration, regardless of the degree of product differentiation and the strength of network externality. Furthermore, the difference of prices (or quantities) depends on the strength of network. The stronger the network externalities are, the larger is the difference between vertical integration prices and vertical separation in two-part tariff bargaining contract prices[17].

From (6-1) and (11-2), we obtain the following results:

$$(\Pi^T + \pi_i^T + \pi_j^T) - \Pi^{VI} = \frac{(a-c)^2(1+\phi)^2 n^2}{2[1+b-(1+\phi)n][2(1+b)-(1+\phi)n]^2} > 0.$$

Furthermore, from (6-2) and (11-2), we obtain the following results:

$$\Pi^T - \Pi^{VI} > 0 \quad \text{if} \quad \beta > \beta^* = \frac{4(1+b)[1+b-(1+\phi)n]}{[2(1+b)-(1+\phi)n]^2}.$$

These findings are summarized in Proposition 1.

Proposition 1: *Suppose Bertrand and Cournot competition. Regardless of the strength of network externalities with compatibility and the degree of product differentiation, industrial profits are larger under vertical separation in centralized Nash bargaining contract than under vertical integration. Furthermore, if*

[17]Differentiating the differences in prices and in quantities with respect to the strength of network externalities, we obtain the following results: $\frac{\partial(p_i^{VI}-p_i^T)}{\partial n} = \frac{(1+b)(a-c)(1+\phi)}{[2(1+b)-n(1+\phi)]^2} > 0$ and $\frac{\partial(q_i^T-q_i^{VI})}{\partial n} = \frac{(1+\phi)[2(1+b)^2-n^2(1-2\phi-\phi^2)]}{2[2(1+b)-n(1+\phi)]^2[1+b-n(1+\phi)]^2} > 0$.

the upstream firm's bargaining power is sufficiently strong, its profit is larger than that of vertical integration.

Proposition 1 is in sharp contrast to the conventional wisdom that monopoly equilibrium is equivalent to the equilibrium of vertical separation in centralized Nash bargaining. It is easy to check it from Eqs. (5), (6-2) and Eq. (11-3), when $n = 0$ under Bertrand and Cournot competition.

The underlying intuition behind Proposition 1 is as follows. Under consumers' rational expectation, they make inferences about expected network size (or expected quantity) from input price. It directly affects their own demand given the strength of network externalities. In other words, rational expectation means that consumers can observe the input price and they response to it. Finally, the upstream firm chooses the wholesale price so as to maximize total profit between upstream firm and retailers. Therefore, from $\frac{\partial \pi_i^T}{\partial n} > 0, \frac{\partial \Pi^T}{\partial n} > 0$, and $\frac{\partial \Pi^{VI}}{\partial n} > 0$, we can easily understand Proposition 1.

Note that under Nash bargaining, the wholesale price is determined to maximize for industrial profits. At stage 1, the upstream firm's maximization problem is equivalent to the following problem:

$$\max_{w} \Pi^T + \pi_i^T + \pi_j^T (\equiv \Pi) = \sum_{i=1}^{2} (p_i - c) q_i, \quad \text{s.t.} \quad \text{Eqs. (7-1) and (7-2).}$$

We can decompose the total effect of input price on industry profits as follows:

$$\frac{d\Pi}{dw} = \underbrace{\frac{\partial \Pi}{\partial q_i}}_{(+)} \underbrace{\frac{\partial q_i}{\partial w}}_{(-)} + \underbrace{\frac{\partial \Pi}{\partial q_j}}_{(+)} \underbrace{\frac{\partial q_j}{\partial q_i}}_{(-)} \underbrace{\frac{\partial q_i}{\partial w}}_{(-)} + \underbrace{\frac{\partial \Pi}{\partial y_i}}_{(+)} \underbrace{\frac{\partial y_i}{\partial q_i}}_{(+)} \underbrace{\frac{\partial q_i}{\partial w}}_{(-)} + \underbrace{\frac{\partial \Pi}{\partial y_j}}_{(+)} \underbrace{\frac{\partial y_j}{\partial q_j}}_{(+)} \underbrace{\frac{\partial q_j}{\partial q_i}}_{(-)} \underbrace{\frac{\partial q_i}{\partial w}}_{(-)}. \quad (12)$$

From the first-term of the RHS of Eq. (12), we get $\frac{\partial \Pi}{\partial q_i} = -w \frac{\partial w}{\partial q_i}$ and $\frac{\partial q_i}{\partial w} < 0$. Therefore, the direct effect of a marginal decreases in w from one on Π is zero. Next, from the second-term of the RHS of Eq. (12), we have $\frac{\partial \Pi}{\partial q_j} > 0$ and $\frac{\partial q_j}{\partial q_i} < 0$ since q_i and q_j are strategic substitutes. Therefore, Π increases with an decrease in w. In the presence of network effect, it is the case of $\frac{\partial q_i}{\partial w} < 0$, which enhances consumers' expectation about retailers i's output, affecting to the third term of RHS of (12) (i.e., $\frac{\partial y_i}{\partial q_i} > 0$) and the fourth term of RHS of (12) (i.e., $\frac{\partial y_j}{\partial q_j} > 0$). Overall, network effects provide an additional incentive to the upstream firm to reduce input price. In turn, it would increase industry profits.

In sum, under vertical integration, the firm maximizes industry profit by setting quantities taking consumers' expectations as given. Under vertical separation in Nash bargaining case, at stage 2, the retailer maximizes its own profit by setting quantities taking consumers' expectations and wholesale price as given. At stage 1, the upstream firm involves in Nash bargaining with the retailer to determine wholesale price which affects consumers' expectation about network size. A lower wholesale price leads to larger expected quantities, which leads to higher joint profits in the vertical separation in centralized Nash bargaining case although the integrated firm's objective is to maximize joint profits.

We turn to compare consumer surplus and social welfare in each of two equilibrium: integration case and vertical separation in centralized Nash bargaining. From Eqs. (6-2), and (11-3), we obtain the following results:

$$CS^T - CS^{VI} = \frac{(a-c)^2(1+\phi)n[4(1+b)-3n(1+\phi)]}{4[1+b-n(1+\phi)][2(1+b)-n(1+\phi)]^2} > 0,$$
$$SW^T - SW^{VI} = \frac{(a-c)^2 n(1+\phi)[4(1+b)-n(1+\phi)]}{4[1+b-n(1+\phi)][2(1+b)-n(1+\phi)]^2} > 0.$$

These findings are summarized in Proposition 2.

Proposition 2: *Suppose Bertrand and Cournot competition. Regardless of the strength of network externalities with compatibility and the degree of product differentiation, social welfare and consumer surplus are always larger under vertical separation in centralized Nash bargaining than in integration case.*

Proposition 2 suggests that since under vertical separation

$$\frac{\partial w^T}{\partial n} = \frac{-(a-c)(1+\phi)}{2[1+b-n(1-\phi n)]^2} < 0 \text{ and } \frac{\partial w^{TB}}{\partial n} = \frac{-(a-c)(1-d^2)(1+\phi)}{2[1+d-(1+\phi)n]^2} < 0\ ,$$

the manufacturer has an incentive to charge below marginal production cost for wholesale prices under vertical separation. From $w^T, w^{TB} < c$ and the result of Proposition 1 in the presence of network externalities, this effect leads to retailers produce more under vertical separation than under vertical integration. As a result, due to the fact of the presence of network externalities and $w^T, w^{TB} < c$, lower prices and higher quantities are always better in consumer surplus and social welfare. Finally, from Proposition 1 and 2, we know that in the presence of network externalities, eparation in centralized bargaining with two-part tariff is more Pareto-efficient than integrated case in term of profits, consumer surplus, and social welfare. Consequently, in our setting under Bertrand and Cournot competition, double marginalization is necessary to implement the efficient outcomes with partial compatibility.

6. DISCUSSION

6.1. FULFILLED EXPECTATIONS

There is no competition in a vertical integration structure even with fulfilled expectations, so it is trivial that the result does not change if profits are maximized with respect to quantities or prices. Furthermore, it is easy to check that all equilibrium outcomes between Cournot and Bertrand competition and also between integration and separation with centralized bargaining have the same value even with fulfilled expectations.

Cournot Competition: We consider Nash bargaining model with two-part tariff when consumers cannot observe wholesale price (i.e., fulfilled expectations) under Cournot competition.

At stage three, in order to maximize its profit for given the input price w, from downstream firm's maximization problem by using response functions, we have equilibrium outputs as follows:

$$q_i = \frac{(a-w)(2-b)+n[y_i(2-b\phi)+y_j(2\phi-b)]}{4-b^2}.$$

At stage two, maximizing Eq. (3) with respect to the wholesale price gives the equilibrium wholesale price and fixed fee as follows:

$$w^F = c - \frac{b[2(a-c)+ny_i(1+\phi)+ny_j(1+\phi n)]}{4(1+b)},$$
$$f_i^F = \frac{[(2-b)(a-w)-n[2(\phi y_i+y_j)-b(y_i+\phi y_j)]]^2}{(4-b^2)^2},$$

where the superscript 'F' denotes the two-part tariff bargaining contract under fulfilled expectations.

In stage one, consumers form fulfilled expectations about the network sizes as $y_i = q_i$ and $y_j = q_j$. Thus, we obtain followings.

$$w^F = c - \frac{b(a-c)}{2(1+b)-n(1+\phi)}, \quad f_i^F = \frac{(a-c)^2[b(1-\phi)-\phi]}{[2(1+b)-n-\phi)]^2}.$$

Using w^F and f_i^F, it is easily check that except for w^F and f_i^F, all equilibrium outcomes under Cournot competition have the same value as with vertical integration.

Bertrand Competition: Similar to previous case with fulfilled expectation, at stage three, in order to maximize its profit for given the wholesale price w, from retailer's maximization problem by using response functions, we have equilibrium prices as follows:

$$p_i = \frac{a(2-b-b^2)+(2+b)w-[b+(2-b^2)\phi]ny_i+[2-b(b+\phi)ny_j]}{4-b^2},$$

At stage two, maximizing Eq. (3) with respect to the wholesale price gives the equilibrium wholesale price s follows:

$$w^{FB} = \frac{2c(2-b)+2ab+bn(1+\phi)(y_i+y_j)}{4},$$

where the superscript 'FB' denotes Bertrand competition with fulfilled expectations. Repeating the same process as in Cournot competition, in stage one, incorporating $y_i = q_i$ and $y_j = q_j$ into w^{FB}, we obtain

$$w^{FB} = c+\frac{(1+b)(a-c)}{2(1+b)-n(1+\phi)}, \quad f_i^{FB} = \frac{(a-c)^2(1+b)(b-\phi)}{2(1+b)-n(1+\phi)]^2}.$$

Using w^{FB} and f_i^{FB}, it is easily check that except for w^{FB} and f_i^{FB}, all equilibrium outcomes under Bertrand competition have the same value as with vertical integration.

In sum, the equilibrium price and quantity can change according to the consumer's expectation timing. If we employ the fulfilled expectation, we obtain the conventional wisdom that the equilibrium under vertical integration is equivalent to the equilibrium under vertical separation in Nash bargaining with the two-part tariff. These findings are summarized in Result 1.

Result 1. *In case of the fulfilled expectations among consumers, the equivalence between vertical separation in centralized Nash bargaining with a two-part tariff and vertical integration holds as a solution of double marginalization.*

6.2. THE ROLE OF FULL COMPATIBILITY VS. NO COMPATIBILITY

We extend our framework to accommodate application compatibility, which enables consumers on the rival retailer (or the i part of integration firm) to interact with content providers on its retailer (or the j part of integration firm). Each firm selects between incompatibility (IC) and compatibility (C) to maximize its profit. Denote by ϕ the following function.

$$\phi = \begin{cases} 1: & \text{both retailers choose compatibility} \\ 0: & \text{both retailers choose incompatibility} \end{cases}$$

Before extending our framework to accommodate application compatibility, we firstly describe the case of 'fulfilled expectations'. There are no differences of equilibrium outcomes between vertical integration and vertical separation with two-part tariff as seen in subsection 6.1. Thus, Result 1 still remains unchanged even with cases of $\phi = 1$ and $\phi = 0$.

Next, we consider the case of 'rational expectations.' Incorporating $\phi = 1$ or $\phi = 0$ into all equilibrium outcomes yields the results of comparisons as follows: Firstly, we have when $\phi = 0$

$$(\Pi^T + \pi_i^T + \pi_j^T) - \Pi^{VI} = \frac{(a-c)^2 n^2}{2(1+b-n)(2+2b-n)^2} > 0,$$

$$CS^T - CS^{VI} = \frac{(a-c)^2(4+4b-3n)n}{4(1+b-n)(2+2b-n)^2} > 0,$$

$$SW^T - SW^{VI} = \frac{(a-c)^2(4+4b-n)n}{4(1+b-n)(2+2b-n)^2} > 0.$$

We summarize these findings in Lemma 1.

Lemma 1. *With full incompatibility $\phi = 0$ and the case of rational expectations, the results of Propositions 1 and 2 still remain unchanged*[18].

Main intuition behind Lemma 1 is still remained as in Propositions 1 and 2.

Next, to see the effect when $\phi = 1$, we need to assume that output of each retailer is positive. We assume the following sufficient condition from Eq. (11-1), which requires that network effect is sufficiently large (see Figure 1).

Assumption 2. $n > n^* \equiv \frac{1+b}{2}$ when $\phi = 1$.

The Assumption 2 enables us to focus only on the case in which both retailers produce regardless of n. When comparing social welfare and consumer surplus between integration and separation in centralized Bargaining with two-part tariff, if $n^{**} \equiv \frac{2(1+b)}{3} > n > n^* \equiv \frac{1+b}{2}$ when $\phi = 1$, then

$$CS^T - CS^{VI} = \frac{(a-c)^2(2+2b-3n)n}{4(1+b-2n)(1+b-n)^2} < 0,$$

and if $n > n^{**} \equiv \frac{2(1+b)}{3}$ when $\phi = 1$, then $CS^T > CS^{VI}$.

[18] Even without Assumption 1, Lemma 1 holds true.

On the other hand, if $n > n^*$ when $\phi = 1$, then

$$(\Pi^T + \pi_i^T + \pi_j^T) - \Pi^{VI} = \frac{(a-c)^2 n^2}{2(1+b-2n)(1+b-n)^2} < 0,$$
$$SW^T - SW^{VI} = \frac{(a-c)^2(4+4b-n)n}{4(1+b-2n)(1+b-n)^2} < 0.$$

With Assumption 2, noting $q_i^k + q_j^k \equiv q^k$ and $p_i^k + p_j^k \equiv p^k$ where $k = VI$ or T, we obtain that when $\phi = 1$ (see Figure 1(c)),

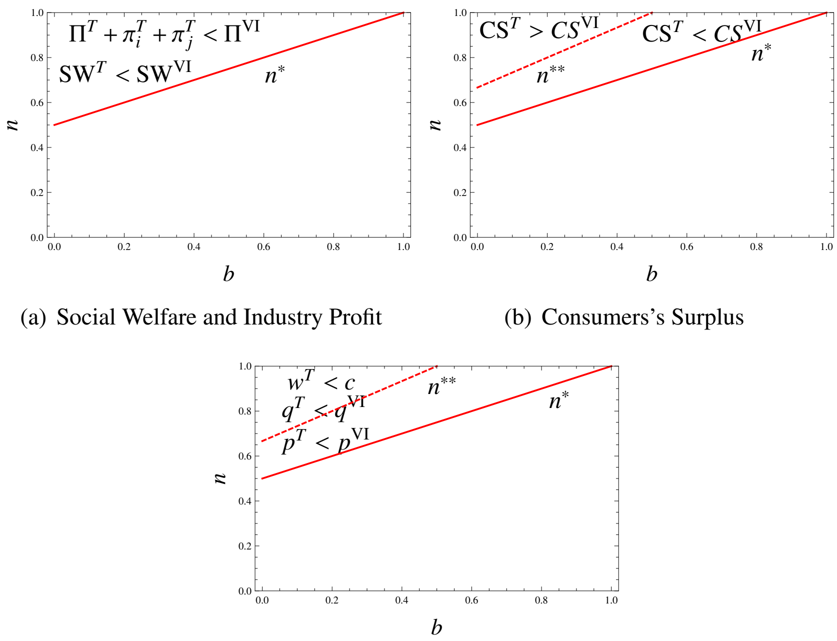
$$q^{VI} - q^T = \frac{-(a-c)n}{2(1+b-2n)(1+b-n)} > 0, \quad p^{VI} - p^T = \frac{(a-c)n}{2(1+b-n)} > 0,$$
$$w^T = c - \frac{(a-c)(2n-b)}{(1+b-2n)} > 0.$$

We summarize these findings in Proposition 3 (see also Figure 1).

Proposition 3. *Under Assumptions 1 and 2 with full compatibility $\phi = 1$ with rational expectations, we obtain*
(i) $q^{VI} > q^T$, $p^{VI} > p^T$ and $w^T < c$.
(ii) the industry profit and social welfare are larger under vertical separation in centralized Bargaining with two-part tariff than under vertical integration.
(iii) if the strength of network effects is intermediate (i.e., $n \in (n^*, n^{**})$), consumers' surplus is larger under vertical integration than under vertical separation in centralized Bargaining with two-part tariff. Otherwise, in the case of $n \in (n^{**}, 1)$, consumers' surplus is larger under vertical separation in centralized Bargaining with two-part tariff than under vertical integration.

Proposition 3 also suggests that the equivalence between vertical separation in centralized bargaining with two-part tariff and vertical integration does not hold in network market with full compatibility. The intuition behind Proposition 3 is as follows. Under vertical separation in centralized bargaining with two-part tariff, when manufacturer charges wholesale prices, there exists a trade-off between network size and downstream competition. If $n > n^* = (1+b)/2$ when $\phi = 1$, then the upstream firm has an incentive to charge below marginal production cost for wholesale prices (i.e., $w^T < c$) since we need to restrict $n > n^* = (1+b)/2$ to get positive output. We call it competition effect.

An increase in output has two effects if $n > n^*$ when $\phi = 1$: competition effect and network size effect. The former is the negative effect of profits but the



(a) Social Welfare and Industry Profit

(b) Consumers's Surplus

(c) Wholesale Price, Output and Final Price

Figure 1: The Choice of Vertical Structure when $\phi = 1$

latter is the positive effect of profits (we call it network effect). If network effect is strong enough, competition effect is overwhelmed by network size effect. Therefore, both profits and outputs are larger under vertical integration than under vertical separation in centralized Bargaining with two-part tariff, which leads to higher social welfare and industry profit under i vertical integration than under vertical separation in centralized Bargaining with two-part tariff (see Figure 1(a)).

Consider the comparison of consumers' surplus. Even though the manufacturer has an incentive to charge below marginal production cost for wholesale prices in the case of $n \in (n^{**}, 1)$, both final outputs and prices under separation in centralized Bargaining with two-part tariff are smaller than under vertical integration (see Figure 1(c)). Thus, when comparing consumer surplus in the case of $n \in (n^*, n^{**})$, the network size effect dominates competition effect so that consumers' surplus under vertical separation in centralized Bargaining with two-part tariff is smaller than under vertical integration. This leads to the result, $CS^T < CS^{VI}$ in the case of $n \in (n^*, n^{**})$. However, in the case of $n \in (n^{**}, 1)$, the competition effect dominates the network size effect so that $CS^T > CS^{VI}$. Hence, we arrive at Proposition 3[19].

7. CONCLUDING REMARKS

Our results contrast to the conventional wisdom in a vertically related market in the absence of network externalities with compatibility. In the presence of network externalities with compatibility, this study compares efficiency between vertical integration and vertical separation with a non-linear contract in centralized Nash bargaining under Cournot and Bertrand competition. In contrast to conventional wisdom, (i) we show that regardless of the strength of network externalities with compatibility, social welfare, consumers' and producers' surpluses are always higher under vertical separation in centralized Nash bargaining contract than under vertical integration; (ii) in the case of full compatibility, the industry profit and social welfare are smaller under vertical separation in centralized Nash bargaining with a two-part tariff than under vertical integration.

As a solution of double marginalization the equivalence between vertical separation under a two-part tariff and vertical integration does not hold in network market with compatibility. Thus, under either Cournot or Bertrand competition, double marginalization is necessary to implement the efficient outcomes from the firms' viewpoint, except for which in the case of full compatibility, double marginalization worsens social welfare.

We conclude by discussing the limitations. We focused on the linear demand function in a vertical structure. For further research, it will be interesting to investigate whether our results will hold with non-linear demand as well. Another worthy extension examines whether our results are robust or not when incorporating the choice of endogenous vertical structure with network externalities with compatibility into a model. The extension of our model in these directions remains an agenda for future research.

[19]Readers may consider that one firm chooses compatibility and the other firm chooses incompatibility. It is well-known that the durable goods monopolists tend to make its goods less compatible as a planned obsolescence strategy in the presence of network effect under the time inconsistency problem. A few papers treated asymmetric compatibility between backward and "forward" compatibility. See, for example, (Lee, 2006; Lee and Niem, 2010). Lee and Niem (2010) analyzed the possibility of the commitment to forward compatibility is profitable to the monopolist, depending upon the degree of technological progress and network effects. For asymmetric compatibility between backward and forward compatibility in the vertically related market, these analyses are beyond the scope of this study, however, those will be future research agenda.

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